Risk Reduction Impacts of Crop Insurance in the United States

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Abstract

The Federal Crop Insurance Program (FCIP) offers insurance policies that reduce risk of declining farm revenues by increasing mean revenue, decreasing revenue variability, or some combination of both. Using historic data from the FCIP, this paper estimates the effect that different insurance policies have on mean revenue and revenue variability and to what degree indemnity payments are converted into reduced revenue variability. The results suggest that on average, a 1 percent increase in revenue results in a 2.25% reduction in inter-crop-year revenue variability. Most of this effect is found to be attributed to individual revenue and yield protection plans, which are the most participated in insurance plans and generally produce simultaneous increases in mean revenue and decreases in revenue variability.

Keywords: crop insurance; basis risk; risk mitigation; farm safety net.

JEL codes: Q12, Q18, Q14

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Introduction

Agricultural producers face various sources of risk in their operations, including production, price, financial, and political risk. Producers employ a variety of strategies to mitigate or cope with the impacts of these risks including savings, irrigation, on-farm diversification, hedging with futures contracts, and engaging in off-farm employment. Government-supported Federal risk management programs often play a role in producers' risk management strategies (Gaku and Tsiboe 2024; Turner et al. 2023; Tsiboe 2024a).[i] The most prominent component of the U.S. farm safety net in terms of government support is the Federal Crop Insurance Program (FCIP). Expenditures on premium subsidies for the FCIP increased nine-fold from 2000 to 2022, accounting for nearly a third of the total budgetary support to producers in 2022 (OECD 2023).

Rising government outlays for premium subsidies have made the FCIP a program of interest among think tanks (Melear and Theodorou 2023), interest groups (Hackett 2023; O'Connor and Bryant 2017; Schechinger 2023), and policy makers (Government Accountability Office 2023) who advocate for lowering government spending on agricultural support. The Congressional Budget Office also routinely provides potential scenarios for reducing FCIP costs (Congressional Budget Office 2017; 2022). At the same time, crop insurance remains a popular program amongst producers (Tsiboe 2024b), who indicate that the program is vital to their need to mitigate against production and revenue risk (Michelle R Hemler et al. 2020). Accordingly, efforts to substantially reduce support for FCIP are likely to face opposition from some groups. However, balancing these two priorities may be possible, given that the effects of reducing FCIP budgetary expenditures are likely to vary depending on which of the many crop insurance policies offered by the FCIP are affected.

This paper examines the potential to reduce revenue risk, measured by year-to-year revenue variability, among 51 distinct policy options formed by combining nine insurance plans and ten coverage levels available under the FCIP at the time of writing.[ii] Using methods developed by Tsiboe, Turner, and Yu (2024), the study first calibrates end-of-season implied yields for 798,446 representative producers (defined by an insurance pool) that cultivated soybeans, sorghum, wheat, dry beans, corn, cotton, barley, peanuts, dry peas, rice, and canola from 2011 through 2022. These implied yields are then used to establish baseline (no-insurance) farm revenues for each producer. Next, alternative revenue scenarios are computed to account for variations in both direct (indemnity payments) and indirect (premium subsidies) income transfers, net of insurance costs, across available policy options. Finally, these insurance-based revenue scenarios are used to generate standardized measures that estimate each policy option's impact on mean revenue and revenue variability relative to the no-insurance baseline.

Our estimates suggest that revenue (RP and RP-HPE) and yield (YP and APH) protection plans that are based on the actual production experience of producers generally produce simultaneous increases in mean income and reductions in revenue variability relative to a baseline of no insurance. Specifically, for each additional one percent increase in income transferred via the crop insurance policy, inter-crop-year revenue variability declines by more than two percent. In contrast, results suggest that area yield and revenue protection plans (AY, AR, and AR-HPE) that are based on the collective production experience of all producers in each county tend to reduce mean revenue and increase revenue variability. This outcome is potentially due to the basis risk associated with these products – i.e., the discrepancy between county-level and farm-level outcomes (Tsiboe, Tack, and Yu 2023). Finally, margin protection plans (MP and MP-HPE), also based on the collective production experience of all producers in each county, tend to increase mean revenue, but simultaneously increase revenue variability.

This analysis contributes to the literature by offering several improvements over similar existing studies. First, the study is based on a period (2011-2022) that focuses on the FCIP under contemporary insurance plan offerings which make the results of this study uniquely relevant in the context of the modern policy environment. The Risk Management Agency (RMA) introduced new crop insurance plans in crop year 2011, referred to as COMBO products (Coble et al. 2010), which have come to represent the majority of FCIP insured liabilities. Many studies that estimate the performance of alternative FCIP policies predate the introduction of these COMBO products (Carriker et al. 1991; Miranda 1991; Smith, Chouinard, and Baquet 1994; Deng, Barnett, and Vedenov 2007; Barnett et al. 2005) making it unclear if the results of these studies are generalizable to the current crop insurance landscape.

Second, this analysis is based on a nationally representative dataset encompassing 9 currently available insurance plans and 11 major crops which together capture 87% of the FCIP's non- livestock insured liabilities from 2011-2022. This contrasts with existing analyses of crop insurance plans which tend to be limited in scope; typically analyzing several crops within a relatively small geography, often on small samples. Du, Feng, and Hennessy (2017) analyze the decision to select between competing insurance contracts from an expected utility perspective using 997 county level observations from 2009 consisting of corn and soybean producers in 12 states. Miranda (1991) focuses on 102 soybean producers in Western Kentucky to compare the risk reduction potential of area vs individual yield policies. Smith, Chouinard, and Baquet (1994) use data from 123 Montana wheat producers to compare area plans to individual yield protection. Deng, Barnett, and Vedenov (2007) analyze a sample consisting of cotton and soybean producers in Georgia and South Carolina which they use to compare multi-peril crop insurance (MCPI) to the group risk protection plan (GRP). Barnett et al. (2005) also compare the performance of MCPI to a GRP but focus on corn and sugar beet farms in 12 states. Several extension materials, including online crop insurance decision tools also provide estimations of crop insurance policy performance, however, these tend to be focused on a limited number of crops or insurance plans that are relevant to the region being served by the extension service.

The remainder of this paper is structured as follows. The next section provides an overview of insurance policies offered within the FCIP and discusses the aspects of those policies that are relevant to this study. Details on the data sources used and the properties of the final sample are then discussed. Next, the details of the methods underlying the simulation analysis are presented. The penultimate section presents results from the simulation analysis followed by conclusions.

Background on U.S. Federal Crop Insurance Policies

The crop insurance title of the Farm Bill is implemented via the FCIP which was first authorized in the Agricultural Adjustment Act of 1938 (P.L. 75-430) as part of the response to the Great Depression and Dust Bowl. The Federal Crop Insurance Corporation (FCIC), which is a wholly owned government corporation, administers the FCIP via the United States Department of Agriculture's (USDA) Risk Management Agency (RMA). The FCIP is implemented as a public-private-partnership where private insurance companies (referred to as Approved Insurance Providers [AIPs]) sell and service the policies. The federal government subsidizes farmers' premium rates and AIP underwriting gains in addition to providing financial support to cover administrative and operating (A&O) costs.

The FCIP provides a variety of crop insurance plans that are either priced and indemnified based on the actual experience of the purchaser (referred to as Actual Production History [APH] plans) or an area or group-based index (colloquially referred to as area or index plans) which may or may not reflect the on-farm loss experience of the producer (Risk Management Agency [RMA] 2023). Within the FCIP, insurance plans are categorized in two ways: those that serve as a primary insurance policy (referred to as a basic provision) and those that act as supplemental policies to a basic provision policy. These supplemental policies provide additional protection to a policy above the level offered by the underlying policy alone. Figure 1 provides an overview of the insurance plans available under the FCIP basic provisions since 1989.

Regardless of the insurance plan, a producer will only receive an indemnity payment when realized outcomes fall below a guaranteed value. This guarantee is broadly based on the product of a producer's expected crop yield ($\ddot{y}_t$), the expected commodity price ($\bar{p}_t$), and coverage level θ_t (i.e., $\theta_t \ddot{y}_t \bar{p}_t$). For both APH and area-based contracts, the cost of crop insurance coverage is given by the product of the guarantee and a premium rate. For area-based contracts, the premium rate is regionally determined as an actuarial aggregation of historic lost cost ratios. Alternatively, premium rates for APH-based insurance contracts are determined via the continuous rating formula (Risk Management Agency [RMA] 2000; Tsiboe and Tack 2022; Tsiboe and Turner 2023a; 2023b; Turner et al. 2024). In the FCIP, the actuarily fair premium rate, $\tau(\theta_t, u_t, \bar{y}_t; \boldsymbol{\omega}_t)$, faced by the producer is further subsidized at a rate, $S(\theta_t, u_t)$, which varies by the producer's choice of insurance plan, coverage level (θ_t), and insurance unit (u_t). Thus, the producer's out of pocket cost (or their "paid premium rate") is given by $\big(1 - S(\theta_t, u_t)\big)\tau(\theta_t, u_t, \bar{y}_t; \boldsymbol{\omega}_t)$, where $\boldsymbol{\omega}_t$ is the policy parameter space of the insurance pool the insured selects.

Ultimately, the properties of a chosen crop insurance contract influence a producer's accounting profit which is represented as:

$$\pi_t = \mathrm{A}_t(E[p_t y_t] + E[I(y_t p_t)] - [1 - S(.)]\tau(.)\theta_t \ddot{y}_t \bar{p}_t) - C(\mathrm{A}_t) \tag{1}$$

Where A_t represents the area planted, $E[p_t y_t]$ represents the producer's per acre crop value and is an expectation over the product of the stochastic non-negative yield of the crop, y_t, and its market price, p_t, and $E[I(y_t p_t)]$ represents the per acre indemnity paid out by the chosen crop insurance contract. The per acre cost of the insurance policy is represented by the term $[1 - S(.)]\tau(.)\theta_t \ddot{y}_t \bar{p}_t$ while $C(\mathrm{A}_t)$ captures costs associated with planting and harvesting the chosen production acreage. As is indicated in Equation (1), the effectiveness of a given insurance policy, in terms of preserving farm income, is ultimately an empirical question concerning the historical relationship between the indemnity payments issued by a policy relative to the cost of the insurance policy.

Data

Data for the analysis are from the RMA summary of business reports for crop years 2011-2022 aggregated by county, crop, crop type, production practice, insurance plan, coverage level, and insurance unit (referred to as "Summary of Business" by "Type, Practice, Unit Structure" and abbreviated as "SOBTPU"). The methodology developed by Tsiboe, Turner, and Yu (2024) requires that the insurance pool for which yields are being calibrated be one that is associated with an insurance policy that is priced using continuous rating. Consequently, the sample is drawn from entries in the SOBTPU that represent insurance pools associated with the YP, APH, RP, and RP-HPE insurance plans. We follow the practice employed by RMA of adjusting gross revenue protection policies to be equivalent to their corresponding yield protection policies by following the procedures outlined in (Coble et al. 2010). Insurance pools with less than four years of available data are dropped from the analysis. Policy rating parameters and insurance policy commodity prices (projected and harvest) are retrieved from RMA's Actuarial Data Master (ADM) and price addendums. End of season state level marketing average prices are retrieved from the USDA National Agricultural Statistics Service (NASS) Quick Stats and then merged to the insurance pool level data. Missing marketing average prices from Quick Stats are approximated with harvest prices from the ADM.

The final dataset consists of 1,041,557 FCIP observations with 190,814 unique insurance pools across producers of soybeans, sorghum, wheat, dry beans, corn, cotton, barley, peanuts, dry peas, rice, and canola. The final dataset represents 51% of total insured acreage, 52% of insured liabilities, 51% of premiums, 53% of issued subsidies, and 43% of indemnities among the 11 commodities analyzed from 2011-2022. Table 1 shows the descriptive statistics of all variables used in this study across all the insurance pools. Although the summary statistics reported in table 1 are representative of the sample, they do obfuscate variation in some metrics which change systematically with the properties of the insurance pool. This is particularly relevant for per acre liabilities, premiums, subsidies, and indemnities which vary by crop, insurance plan, unit structure, and coverage level which are all used to define the insurance pool.

Tables S2-S5 in the appendix report means and standard deviations for insurance metrics broken down by three major crops (corn, soybeans, and wheat), three of the major insurance plans that utilize continuous rating (YP, RP, and RPHPE), the three most frequently selected unit structures (EU, OU, and BU), and coverage levels from 50%-85%. Tables S2-S5 demonstrate several trends in how these metrics vary by insurance pool type. Among insurance plans, premiums, liabilities, subsidies, and indemnities are higher on a per acre basis for insurance plans that offer more protection (i.e. RP plans have more liabilities per acre than YP plans since RP covers both yield declines and price risk). The same is true as coverage levels increase since at higher coverage levels, less of the risk is being subsumed by the producer. Finally, insurance pools defined by enterprise unit structures have similar liabilities per acre compared to basic or optional units but typically have lower per acre premiums and lower indemnities per acre. This is because enterprise units require all acreage operated by a producer for a single crop in the producer's county to be insured under one policy. This provides geographical diversification which justifies a lower premium rate that is commensurate with the lower probability of a loss surpassing the policy's deductible.

Counterfactual Analysis

As alluded to previously, the empirical analysis compares the historical relationship between income transfers (i.e. indemnity payments) and the cost of insurance for each insurance policy to assess the degree to which indemnity payments result in reduced revenue variance. Generally, this is achieved by taking each insurance policy and counterfactually calculating the outcomes if all producers in the sample that had access to a given policy had purchased it.

To do so, the analysis utilizes the concept of a representative agent (hereafter referred to as an "agent") which serves as an aggregation of a group of similar producers into a single observational unit. In the analysis, agents are defined by the aggregation level of the SOBTPU described in the data section. This definition of an agent implies that even though each observational unit represents multiple producers, all producers in that SOBTPU observational unit had access to the same crop insurance policy options, produced the same crop, followed similar production practices, purchased the same insurance policy, and faced the same crop insurance premium rating parameters.

The key conditional outcomes for determining the change in each agent's income that is directly attributable to holding an insurance policy (relative to being uninsured) are the end of season yields and prices associated with FCIP crop insurance choices. While the prices each agent faces are publicly available (as described in the previous section), end of season yields are not. To obtain pseudo-yield data at the same level as the observational units, the methodology proposed by Tsiboe, Turner, and Yu (2024) is used which utilizes the deterministic relationship between changes in pool level yields and observed year to year variation in crop insurance rating parameters.

For each agent, the goal is to calculate the counterfactual state of the world had the agent chosen a different insurance policy, holding other aspects of the agent fixed. This approach allows an assessment of which policy would have historically been most effective at increasing farm revenue and/or reducing revenue variance. The policy alternatives for each agent, which are conditional on the agent's county, are defined as the unique combinations of nine insurance plans (YP, APH, RP, RP-HPE, AY, AR, AR-HPE, MP, and MP-HPE), twelve coverage levels (50-95% in 5% increment where applicable), and a set of rating parameters ($\tilde{\boldsymbol{\omega}}_t$), which includes the rating parameters for the continuous rating formula, price volatility factors, and base rates for area plans (i.e., AY, AR, AR-HPE, MP, and MP-HPE). Although there are a number of other crop insurance plans in the FCIP that are available but not included in this analysis, the omitted plans are generally characterized by low sales volume (as measured by insured liabilities) or are only participated in by single commodities. Table S6 in the appendix reports the top 3 commodities (in terms of 2022 insured liabilities) for each insurance plan reported in figure 1 and table S1.

For a given pool (i), policy (j), and crop year (t), the following per acre counterfactual calculations is used:

$$\tilde{P}_{i,j,t} = \tilde{\tau}_{i,j,t} \cdot \ddot{y}_{i,t} \cdot \tilde{\theta}_{i,j,t} \cdot \bar{p}_{j,t} \tag{2}$$

$$\tilde{\pi}_{i,j,t} = y_{i,t} \cdot p_{j,t} + \tilde{I}_{i,j,t} - [1 - \tilde{S}_{i.t}]\tilde{P}_{i,j,t} \tag{3}$$

where all variables are as previously described with the key difference being that the ascent ~ indicates the variables' policy-specific counterfactual analogs. The premium rates ($\tilde{\tau}_{i,j,t}$) for area and margin plans (i.e., AY, AR, AR-HPE, MP, and MP-HPE) are based on base rates set by RMA which change by coverage level and price volatility factors, and are available from the ADM. For the individual level plans (YP/APH, AR, and AR-HPE) we use the continuous rating formula and the drawn rating parameter combinations. Given their respective rating parameters and approved yields, $\ddot{y}_{i,t}$, and rate yields, $\bar{y}_{i,t}$, where applicable, the premium rate for each counterfactual is calculated as outlined in the FCIP Appendix III/M-13 Handbooks.

The individual level plans are available for all three types of insurance units (OU, BU, and EU); however, the area and margin plans are sold at only the OU level. Since we do not know if insurance unit designation in the SOBTPU is a matter of eligibility or simply a choice, for the case of the individual level plans, we fix the value that would have been generated by the unit residual function ($\rho(\cdot)$) in the CRF at the mean for the observed data used for the yield calibration. In contrast, the rate residual factor ($\vartheta(\cdot)$) is based on the associated coverage level ($\tilde{\theta}_{i,j,t}$) for the counterfactual policy given values from the ADM. It follows that because the insurance unit is held constant, the subsidy rate ($\tilde{S}_{i.t}$) is driven by the associated coverage level ($\tilde{\theta}_{i,j,t}$) for the counterfactual policy given values from the ADM. Finally, end of season prices ($p_{j,t}$) are set equal to the marketing year average price as a proxy for cash prices which are unobservable. The indemnity ($\tilde{I}_{i,j,t}$) for each type of insurance plan is calculated using projected and harvest prices where appropriate as outlined in the FCIP Appendix III/M-13 Handbooks.

In total over 24 million insurance pool level policy counterfactuals were calculated in which each of the 799,229 agents had between 1 and 27 potential policy alternatives formed from the unique combination of eight insurance plans, ten coverage levels, unique rating parameter combinations ($\tilde{\boldsymbol{\omega}}_t$), and twelve crop years (2011-2022). To assess the diagnostics performance of the counterfactual calculations a "counterfactual" outcome for the insurance policy that was selected by each agent is calculated as the "baseline scenario". This outcome is compared to the observed outcomes in the summary of business for each agent under the premise that the process used to generate counterfactuals mimics observed reality before it is deemed a credible way to generate plausible counterfactuals which do not have actual observed analogs. The diagnostics from this exercise are presented in figure S1 and demonstrate that under the baseline scenario, the total liability, total premium, subsidy amount, and loss ratios from 2011-2022 align with the actual observed values for the same period based on the SOBTPU experience, from which the calibrated yields are derived.

Risk Reduction Analysis

Although a definition of risk is not universally accepted, most definitions of risk incorporate the frequency for which an adverse outcome occurs, the variability in outcomes (i.e., a lack of stability), or some combination of both (Hardaker 2000; Society for Risk Analysis 2018). For this analysis a composite index of both mean income and revenue variability is used in which both a revenue variability decrease, and a mean revenue increase is required for a policy to "reduce risk". Total revenue variation (i.e., the coefficient of variation [CV] of revenue) is used as the measure of variability. A "Variability Reduction Score" (VRS), which is the ratio of the revenue fluctuation under the policy to the revenue fluctuation if no insurance was purchased by the producer, is then determined. A VRS below one signifies the extent to which a policy mitigates variation in revenue across crop years. The "Income Transfer Score" (ITS) designates the ability of a policy to directly transfer income to cover losses. The ITS is calculated as the ratio of the expected revenue under the policy to the expected revenue had the producer opted for no insurance.

To gauge the risk reduction potential of FCIP policy alternatives, the "Risk Reduction Efficiency Ratio" (RRER), is calculated as:

$$RRER_j = -I\left(VRS_j < 1\right) I\left(ITS_j > 1\right) \left(\frac{VRS_j - 1}{ITS_j - 1}\right) \tag{4}$$

where $I(.)$ is an indicator function which takes on the value of unity if the condition in the parentheses is met. The RRER range from zero to positive infinity and serves as an indicator of a policy's efficiency in transferring income to producers to reduce revenue volatility across crop years, with the magnitude signifying the extent of the reduction. Therefore, when comparing two policies, if $RRER_A > RRER_B$, policy A is more efficient in mitigating risks than policy B. Another way to interpret the RRER is that it deflates the measure of reduced revenue variability commensurate with how much income was required to achieve the reduction in variability. For example, an insurance policy that provides an indemnity payment of $1 billion every year with certainty would greatly reduce revenue variation by reducing the actual variation in earned revenue to a very small portion of total revenue, but this policy would receive a very low RRER since the $1 billion payment would be factored into the denominator of the RRER. Intuitively, the construction of the RRER is designed to capture the effect of income transfers conditional on the transfers being inversely correlated with crop revenue. This definition means that an insurance policy with a higher RRER will unambiguously improve a producer’s welfare (relative to being uninsured) assuming that the producer is not risk loving.

For a particular policy designation (or producer group), the representative producer RRERs are averaged across the respective sample counterfactuals that lie within the range of their respective sample's 0.5^{th} and 99.5^{th} percentile to derive an aggregate RRER for that policy designation (or producer group). Lastly, standard errors for the RRER are computed via the bootstrapping method where the measures are repeatedly calculated in 100 repeated samples by drawing crop years from the analysis on each iteration. A similar aggregation for both the VRS and ITS is employed and reported.

Results

The program-level analysis (i.e., all counterfactual outcomes grouped into a single metric) reveals that the FCIP holds a mean variability reduction score of 0.94 and a mean income transfer score of 1.03. In other words, on average, purchasing an FCIP insurance policy is associated with approximately 6% less revenue variability and 3% higher revenue relative to being uninsured. For about 51% of the agents in the analysis, the FCIP reduced their inter-crop-year revenue variability. For 45% of agents, revenue was higher with the income transfer associated with the crop insurance policy (relative to no insurance).[iii] These numbers resulted in a program level RRER of 2.25, indicating that a 1% increase in revenue (supplied by indemnities and premium subsidies net the cost of insurance) relative to the baseline of no insurance results in a 2.25% reduction in inter-crop-year revenue variability.

These broad characterizations, however, mask the extensive variation in the risk reduction potential of different types of insurance policies. Figure 2 depicts measures of policy performance including the mean VRS and ITS (separately displayed). Although there is variation in the measures of risk reduction performance, there are clear groupings by type of policy within figure 2. Yield and revenue protection policies (YP, APH, RP, and RPHPE) that are based on the actual production experience of producers all have income transfer scores and variability reduction scores that suggest reduced revenue variability with simultaneous increased mean revenue. Additionally, policies within this group are generally ordered by coverage level with higher coverage levels being associated with effects that are greater in magnitude. In contrast to these producer experience-based yield and revenue plans, VRS and ITS scores for area-based plans for yield and revenue protection (AR, AY, and ARHPE) suggest increases in revenue variability and decreases in mean revenue relative to no insurance. Finally, margin protection plans (MP and MPHPE) have VRS and ITS scores that are both above 1 indicating higher mean revenue and higher revenue variability relative to no insurance. In the context of figure 2, it is worth reiterating some of the properties of the different classes of insurance plans. Both margin protection plans (MP and MPHPE) and area-based plans (AR, AY, and ARHPE) define indemnity triggers using county-level indices. In the case of margin protection plans, these indices capture estimated county level average revenues and input costs whereas area-based plans capture average yields and revenues only. In both cases, the indemnity triggers are defined such that they are not directly coupled to on-farm outcomes, meaning the lack or correlation between these plans and on farm revenues (as evidenced by higher VRS scores in figure 2) are not surprising.

Heterogeneity in Results

Although the aggregate level RRER, VTS, and ITS provide some insight into the risk reduction properties of FCIP insurance plans at the program level, these measures mask heterogeneity in the risk reduction properties of the insurance plans. This section provides additional reporting of results decomposed by the commodity being produced and geographic location.

Plots that report ITS and VTS separately (as was done in figure 2) are reported separately for the major commodities in figure S2 (in the appendix). The results presented in figure S2 are generally qualitatively equivalent to those reported in figure 2. Insurance plans based on on-farm experience (YP, APH, RP, and RPHPE) are represented in the upper left quadrant indicating higher revenue and lower revenue variation compared to being uninsured. One exception to this is the case of peanuts, where some lower coverage level on-farm yield and revenue protection plans show lower mean revenue relative to the baseline of no-insurance. Margin protection plans, when available, exists in the upper right quadrant (higher mean revenue and revenue variability) except for wheat which has all margin plans indicating VTS above one (higher revenue variability) but with some plans indicating lower mean revenue relative to baseline. Area plans, among both corn, soybeans, and rice are depicted in the lower right quadrant (lower revenue, increased revenue variability) which is consistent with the pooled results. However, area plans for other crops are not consistent with the pooled results—specifically, area plans are depicted in the upper left quadrant for cotton, upper right quadrant for sorghum, and split between the upper and lower right quadrants for wheat.

Taking the VTS and ITS scores and combining them into a RRER (as defined in the previous section) produces a unidimensional measure that allows for easier comparison of insurance plans across different commodities. Figure 3 reports RRERs for all commodities (pooled) in addition to separate RRERs for each commodity in the dataset. Among all commodities, the plans with the highest RRER are RPHPE-85%, YP/APH-85%, and RP-85% which are indicated by the blue, green, and red estimates in the first column. However, these plans do not universally have the highest RRERs for each commodity reported in figure 3. RRERs for dry peas, for example, indicate RP-70% being the most efficient at reducing risk (as indicated by the blue estimate in the dry peas column). In general, regardless of commodity, on-farm yield and revenue-based plans with high coverage levels (70% or higher) tend to be the highest ranked, indicating significant reductions in revenue variability and increase in mean revenue relative to no insurance.

Figure 3 also indicates for each commodity which plan had highest insured acreage from 2011-2022 (indicated by ✡) among the analyzed plans. For every commodity, the plan with the most participation was either RP-75% or RP-70%. Dry peas were the only commodity for which either of these plans ranked highest in terms of the plans' RRER. However, for every commodity, the most participated in plan also had confidence intervals that overlapped with those of the highest RRER plan, indicating that participation tends to be concentrated in the group of insurance plans with the highest RRERs. Analogous figures to figure 3 are reported in the appendix that depict RRERs separately computed by irrigation status (figure S4), organic certification (figure S5), and unit structure (figure S6), all of which produce an ordering of insurance plans that is qualitatively equivalent to the ordering in the "All" column of figure 3.

We next analyze spatial heterogeneity, first by producing state-level analogs to figure 2 (see figure S3). Although the risk reduction properties of the different insurance plans vary by state, much of this variation is likely explained by the predominant commodities being produced in the state. For example, the panels for Virginia and Georgia (which are both major peanut producers) in figure S3 mimic the patterns exhibited in figure S2 for peanuts. Similarly, Iowa, Indiana, and Illinois, which are important corn and soybean-producing states, have patterns depicted in figure S3 that match the patterns for corn and soybeans in figure S2.

As a final measure of spatial heterogeneity, for each state and crop, we calculate the difference between the highest RRER and the RRER of the insurance plan with the most insured acreage. This difference captures how much revenue variability would have decreased by switching to the insurance plan with the highest RRER relative to the most frequently purchased policy. In other words, this difference identifies if there were other policies (besides the most frequently purchased) that had a stronger negative correlation between indemnity payments and mean farm revenue over the period analyzed. These differences are reported in figure 4. The average difference among all crops ("All" in figure 4) was 0.64, indicating that on average switching from the most frequently purchased policy to the policy with the highest RRER would result in an additional 0.64% reduction in revenue variability (relative to the most participated in policy) from each 1% increase in indemnity payments. Crop-specific calculations in the remaining panels in figure 4 indicate relatively large differences in RRER among some crops like sorghum (1.89), peanuts (1.78), and barley (1.12). Cotton also has a relatively large average difference between the most frequently purchased plan and the plan with the highest RRER, but with notable variation by state, which renders the average difference of 1.11 statistically insignificant. Wheat and corn have RRER differences of 0.99 and 0.91, respectively. Soybeans and dry beans have similar differences (0.83 and 0.94) but lack statistical significance due to the large variation across space. Finally, canola, rice, and dry peas all have RRER differences below 0.5, all of which lack statistical significance.

Discussion and Conclusion

This analysis estimates how efficient existing crop insurance plans are at reducing risk as measured by the magnitude of the direct income transfers (that occur via crop insurance indemnity payments, provision of premium subsidies, and net the cost of insurance) needed to achieve a given level of revenue variance reduction (i.e., how correlated the income transfer are with crop revenue). Simulated outcomes for each policy alternative are created for the same insurance pool, which are then used to estimate and rank each policy based on mean revenue and revenue variability relative to a baseline of being uninsured. The findings indicate that on-farm revenue plans (RP and RP-HPE) and on-farm yield protection plans (YP/APH) generally provide the most effective risk reduction in terms of providing simultaneous reductions in revenue variability and increase in mean revenue. On average, a one percent increase in funds transferred to producers under these policies to cover losses results in a greater than two percent reduction in inter-crop-year revenue variability. Results for county-level area plans (AY, AR, and AR-HPE) tend to reduce mean revenue and increase revenue variability. Finally, margin protection plans (MP and MP-HPE) are shown to produce the largest increases in mean revenues, but at the same time also result in higher revenue variability.

As expected, participation trends generally mirror the ranking of risk reduction efficiency measures, with most insured acres under revenue and yield protection policies, while area plans, and margin protection plans have generally low participation rates. This suggests that producers may be aware of the relative efficiency by which different plans reduce risk even if an explicit measure of efficiency is not considered in their purchasing decisions. A potential determinant in the observed low uptake of index and area-based plans may be the basis risk associated with these policies and the resulting "compound lottery" created by this type of product design.

While this study rigorously employs a comprehensive counterfactual analysis of the FCIP to estimate the efficacy of policy offerings, several caveats warrant attention. First the empirical methods rest on the fact that outcomes that influence farm incomes, such as yields and price, are stochastic and independent of the producer's insurance decisions (i.e., no adverse selection or moral hazard). Additionally, results are based on a period that captures the FCIP's current policy offerings (2011-2022). Although this period is the most relevant from a public policy perspective, our results are externally valid only to the extent that FCIP participation patterns, weather patterns, and public policy are similar in the future. Another consideration when interpreting the results is the reliance on aggregated data from various producers. Future research could improve on this analysis and eliminate the potential for aggregation bias by utilizing farm-level data. However, to date, no farm-level data set has been made available to researchers that covers the temporal and spatial scope of RMA's summary of business. It is not obvious that use of existing farm level data sets for similar analysis is superior given that their increased granularity comes at the expense of a more limited scope (in terms of spatial reach and number of commodities covered).

Finally, although the results presented here provide insights into how cost efficient FCIP policies are with respect to reducing risk, they do not provide an exhaustive analysis of the FCIP as it relates to government expenditures. The specific costs to the government for each FCIP policy are influenced by variations in: (A) total premiums, (B) premium subsidies to producers, (C) indemnities, (D) program delivery costs, and (E) reinsurance (netting underwriting losses against gains). Costs D and E are omitted from this analysis since they are not conditional on the income transfers that are the focus of this study's analysis. Specifically, program delivery costs are primarily a function of participation and plan availability whereas reinsurance costs are a function of decisions made by Approved Insurance Providers (AIPs). Given that this study's research design is based on holding participation fixed in each simulation to highlight variation in plan performance irrespective of decisions made by any market participants (AIPS or producers), cost items D and E are not relevant to this analysis but may be important considerations for some policy discussions.

Despite these constraints, this research sheds light on the ranking of the full menu of alternative crop insurance policies in terms of their ability to transfer funds at sufficient magnitudes and with correct timing to reduce inter-year revenue variability. This ultimately contributes to the collective understanding of how cost-efficient various types of farm support programs are and provides information that is likely to be relevant in policy discussions related to the future of the U.S. farm safety net.

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Tables

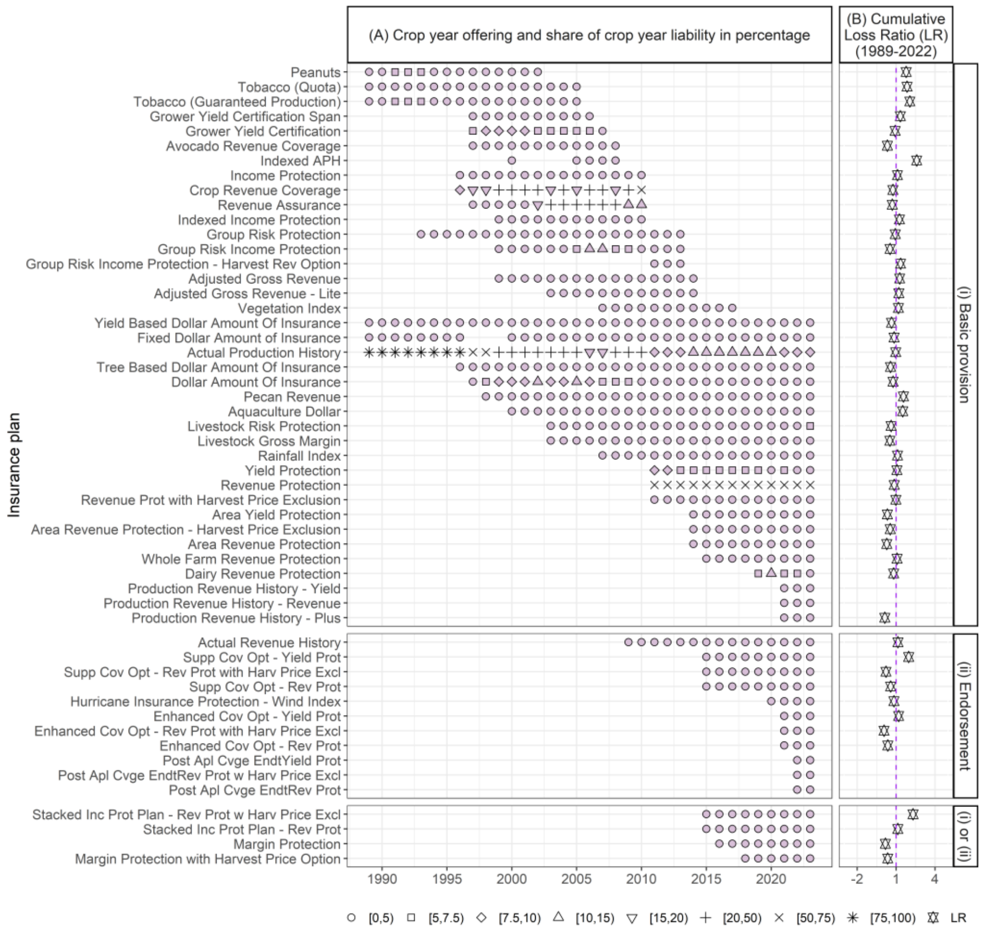
Table 1: Means and standard deviations of US Federal crop insurance pools, 2011-22

	Mean (Standard Deviation)
Summary of business variables	
Number of insurance pools	190,814
Number of observations	1,041,557
Net insured area (acres)	1499.936 (5141.724)
Total insured liability ($/acre)	224.621 (545.768)
Total premium ($/acre)	20.144 (38.829)
Total premium subsidy ($/acre)	12.713 (18.776)
Total indemnity ($/acre)	14.941 (40.181)
Premium per dollar of liability	0.105 (0.085)
Subsidy per dollar of premium	0.665 (0.139)
Loss cost ratio	0.082 (0.198)
Loss ratio	0.725 (2.320)

Note: Author compilation based on data and policy information from USDA Risk Management Agency (RMA).

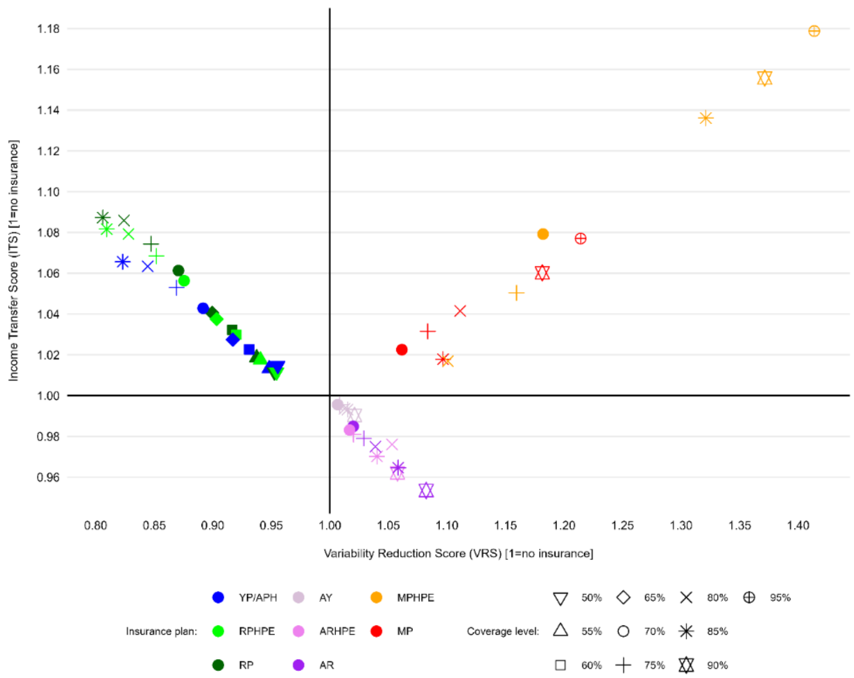
Figures

Figure 1: Historic overview of U.S. Federal crop insurance plan offerings, participation, and actuarial performance



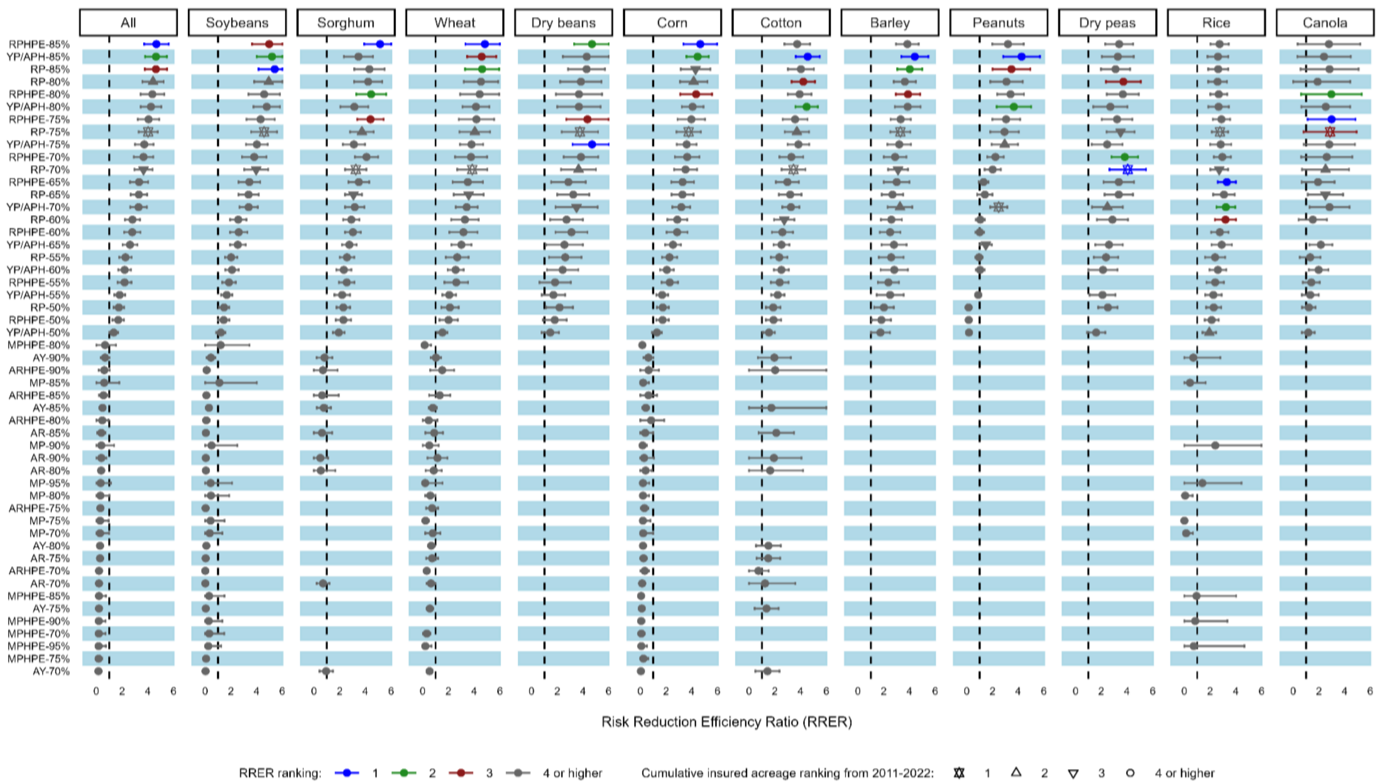
Notes: This table presents currently available crop insurance plans in the FCIP basic provisions. Highlighted rows represent insurance plans analyzed in this study. Cumulative loss ratios are calculated as the sum of indemnities divided by the sum of total premiums for the entirety of the insurance plans availability. For plans that are currently available, cumulative loss ratios are calculated using data from the plan's first year of availability through the 2022 crop year. For columns reporting liabilities, the percentage in parenthesis indicates what share of total FCIP liabilities was represented by the insurance plan for that crop year.

Figure 2: Revenue transfer and variability reduction among U.S. Federal crop insurance policy alternatives, 2011-22



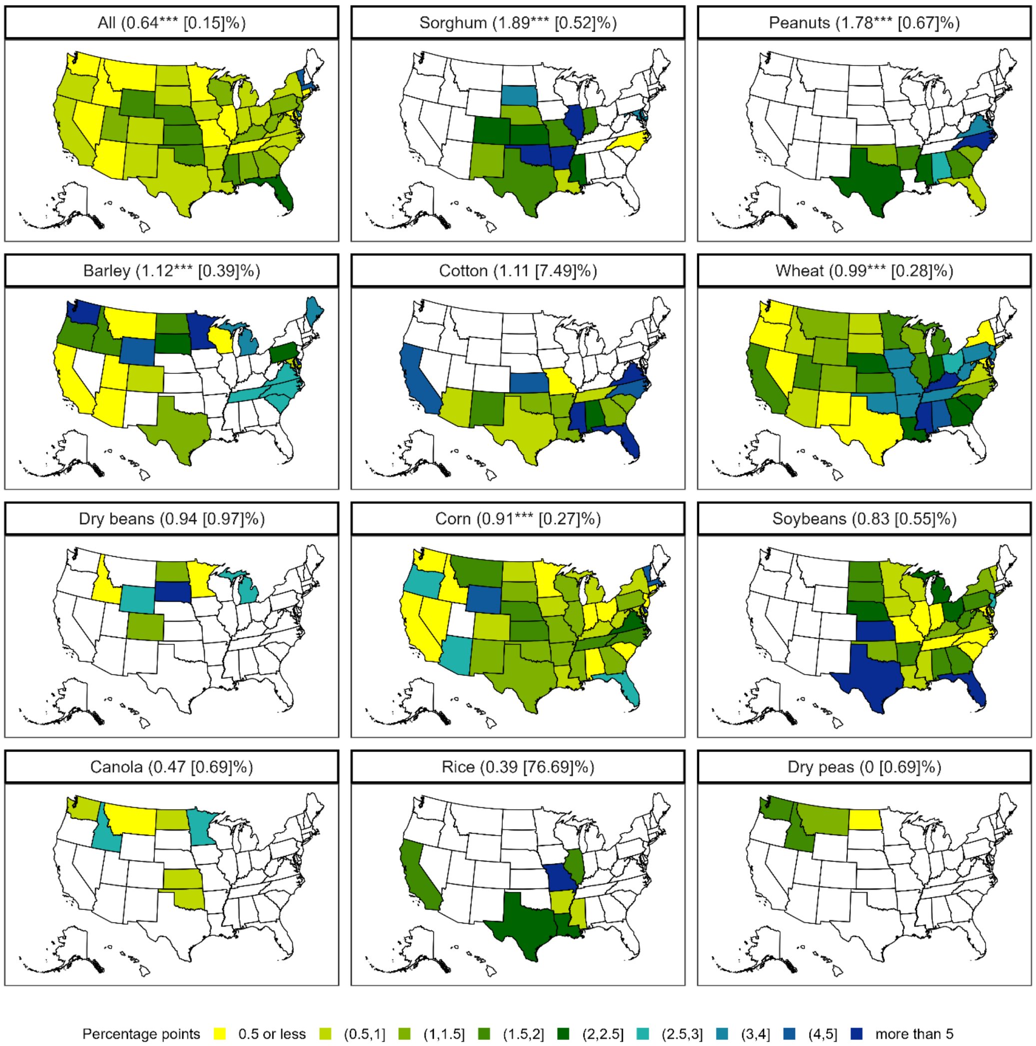
Each point in the figure represents the relative revenue outcomes for the corresponding insurance plan and coverage level combination. The "Income Transfer Score" (ITS) estimates mean revenue changes by first averaging each agent's simulated revenues across all years, then dividing by the average revenue obtained without crop insurance. A higher ITS thus indicates a greater revenue benefit from the FCIP. To measure revenue variability, we use the coefficient of variation, calculated with and without crop insurance, and express the results as a "Variability Reduction Index" (VRI). A lower VRI signifies a greater reduction in revenue risk. Taken together, ITS and VRI provide insights into the FCIP's effectiveness in enhancing and stabilizing revenue under different policy alternatives.

Figure 3: Risk reduction efficiency conditional on insurance pool commodity, 2011-22



The RRER range from zero to positive infinity and serves as an indicator of a policy's efficiency in transferring income to producers to reduce revenue volatility across crop years, with the magnitude signifying the extent of the reduction. Therefore, when comparing two policies, if $RRER_A > RRER_B$, policy A is more efficient in mitigating risks than policy B. The figure shows the relationship between the ranking of RRER from the best (1) to the worst (4 or higher) and the most patronized policy by commodity.

Figure 4: Potential risk reduction efficiency by switching from most patronized policy to the most efficient conditional on crop and state, 2011-22



The RRER range from zero to positive infinity and serves as an indicator of a policy's efficiency in transferring income to producers to reduce revenue volatility across crop years, with the magnitude signifying the extent of the reduction. Therefore, when comparing two policies, if $RRER_A > RRER_B$, policy A is more efficient in mitigating risks than policy B. The figure shows the gain in RRER by moving from the most patronized policy to the policy with the best RRER as determined by the analysis.

Endnotes

[i] Recent Federal reports provide in-depth descriptions of risk management programs available to producers (Turner et al. 2023; McFadden and Hoppe 2017; Hrozencik, Perez-Quesada, and Bocinsky 2024; Baldwin, Turner, and Tsiboe 2024; Turner and Tsiboe 2024) or more broadly examined annual agricultural policy developments (Baldwin, Williams, Tsiboe, et al. 2023; Baldwin, Williams, Sichko, et al. 2023; Baldwin, Turner, and Tsiboe 2024).

[ii] These alternative insurance policies defined by the unique combinations of nine distinct insurance plans (Yield Protection [YP], Actual Production History [APH], Revenue Protection [RP], RP with Harvest Price Exclusion [RP-HPE], Area Yield Protection [AY], Area Revenue Protection [AR], AR-HPE, Margin Protection [MP], and MP-HPE) and ten different coverage level elections (add-on coverage from 50-95% in 5% increments, where applicable). Policies with a Harvest Price Exclusion clause (HPE) base the insurance guarantee on projected price and do not readjust the insurance guarantee in cases where the harvest price is higher than the projected price.

[iii] The term “income transfer” refers to the net exchange of dollars (i.e., indemnity payments received net of any premiums paid).