Hidden Safety Net of Underutilized Supplemental Insurance in US Agriculture

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Abstract

Many U.S. farmers, growers, and ranchers depend on Federally subsidized crop insurance to help manage production risks, yet even the most comprehensive policies only trigger indemnities after 15% losses. Supplemental insurance was introduced to address this gap but remains underutilized. Using 958,658 observations of sub-county aggregated insurance transactions and applying recent calibration and simulation methods, our findings indicate that low participation in supplemental coverage leaves substantial benefits untapped. While basic insurance provides a foundation, integrating supplemental policies significantly improves downside risk reduction and income transfer. Although these enhancements involve higher premiums, a benefit-per-premium analysis still supports broader adoption of supplemental coverages.

Keywords: crop insurance; supplemental coverage; subsidies; insurance utilization

JEL codes: Q12, Q14, Q18, G22, R52

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1. Introduction

Agriculture is a foundational pillar of many global economies, significantly influencing employment, economic output, and national food security. Despite its importance, farmers encounter a wide array of challenges, including volatile market prices, shifts in consumer preferences, unpredictable weather, and crop diseases. Under these circumstances, robust risk management tools are crucial to maintaining agricultural productivity, profitability, and viability (Kim, Yu and Pendell 2019; Gaku and Tsiboe 2024). Among these tools, government-subsidized programs such as agricultural insurance is widely used globally, providing financial relief in the face of unforeseen losses (Baldwin, Williams, Tsiboe, et al. 2023; Mahul and Stutley 2010; Smith and Glauber 2012; Belasco 2020; Turner and Tsiboe 2022; Tsiboe and Turner 2023; Baldwin, Williams, Sichko, et al. 2023; Turner et al. 2023). Traditional agricultural insurance policies, such as yield or revenue protection for a single commodity, have historically offered a safety net for farmers. Yet, these policies often fall short of covering the full spectrum of financial risks present in agriculture. For instance, even the most comprehensive policies do not trigger payments until losses exceed 15%. This coverage gap is particularly impactful in the U.S., where most producers opt for policies with coverage levels ranging from 65-75%, exposing them to significant financial vulnerability in adverse years.[1]

[1]Recent reports from the USDA, Economic Research Service (ERS) have provided detailed analyses of agricultural risk management programs (Turner et al. 2023; McFadden and Hoppe 2017; Hrozencik, Perez-Quesada and Bocinsky 2024), as well as broader insights into annual agricultural risk management policy developments (Baldwin, Williams, Tsiboe, et al. 2023; Baldwin, Williams, Sichko, et al. 2023; Baldwin, Turner and Tsiboe 2024).

Starting in 2014, U.S. agricultural policy introduced area-based supplemental policies aimed at bolstering farmers against financial losses by covering a portion of the deductible not addressed by standard policies (Turner et al. 2023). These supplemental plans are designed to enhance a farmer's individual crop insurance by adding county-level coverage, thus strengthening the overall risk management framework. Despite the potential advantages of these policies in mitigating risk (Gaku and Tsiboe 2024; Tsay and Paulson 2024), their adoption remains surprisingly low (Paulson et al. 2022) – just about 5% of total annual net acres insured with supplemental protection availability from 2015-23. This underutilization highlights program design issues such as basis risk (Tsay and Paulson 2024; Tsiboe, Tack and Yu 2023), structural obstacles such as linkage to an underlying traditional insurance policy, and eligibility linkages to other Federal programs (Turner et al. 2023).

This study aims to estimate whether supplemental agricultural insurance coverage offers significant and economically meaningful opportunities for incremental risk management gains amidst a broad array of existing insurance programs. Since their introduction in the 2014 Farm Bill, supplemental agricultural insurance coverages have been maintained and expanded across various commodities and types of supplemental coverage. Given their low participation rates, this research provides insights that are instrumental in guiding ongoing modifications for future agricultural policy. Furthermore, the findings of this study will assist extension efforts aimed at assisting farmers in making informed risk management decisions in the context of current programs.

We integrate a public dataset of Federal Crop Insurance Program (FCIP) insurance pool-level observations (which we define as agents) with recent calibration methods (Tsiboe, Turner and Yu

2024) to estimate end-of-season yield data for 958,658 observations.[2] These observations cover producers of corn, soybeans, wheat, cotton, sorghum, rice, canola, dry peas, barley, sunflowers, peanuts, dry beans, oats, and popcorn from 2015-23. We then use these calibrated yields as a basis for revenue simulation, applying the same methods currently used in the FCIP. Revenue simulations were performed for each agent, considering both 2015-23 actual observed traditional policy choices and the observed utilization rates of supplemental agricultural insurance coverage, particularly focusing on Supplemental Coverage Option [SCO] and Enhanced Coverage Option [ECO] - the two most patronized supplemental plans. We explored the financial outcomes under various alternative scenarios of SCO and ECO utilization rates, in conjunction with the actual observed traditional policy choices. Finally, relative to the 2015-23 status quo, we use the simulated outcomes to estimate the marginal revenue, and reductions in revenue variability associated with the alternative scenarios of SCO and ECO utilization rates.

The simulation results highlight the potential significant role of SCO and ECO in reducing financial risks for U.S farmers during the 2015-23 crop years. Compared to the existing policy elections in 2015-23, standalone basic insurance policies (Actual Production History [APH], Yield Protection [YP], Revenue Protection [RP], or RP with Harvest Price exclusion [RP-HPE] alone) show limited effectiveness in reducing risk and transferring income, indicating that the current rates of SCO and ECO usage do not fully capitalize on the potential additional risk reduction and income transfer benefits of these policies. By fully integrating SCO and ECO, significant enhancements are achieved in risk reduction and income metrics, with a basic policy + SCO +

[2] An insurance pool represents a sub-county level group of producers that share common characteristics and consequently are treated the same for purposes of setting crop insurance premium rates.

ECO combination notably increasing both downside risk reduction and income transfer. However, the enhanced coverage from layering a traditional insurance policy with a supplemental plan also results in higher premium rates and reduced subsidies, with the basic policy + ECO combo seeing the highest increase in paid premium rates (i.e., the subsidized actuarially fair premium rate) among the options.

Heterogeneity analysis reveals that some crops—like rice, barley, popcorn, peanuts, and soybeans—exhibit the greatest reduction in revenue risk for a relatively modest increase in insurance costs, making stacking a basic policy with a supplemental plan especially attractive. Others, including sorghum, oats, dry peas, and dry beans, still exhibit good protection but at a higher extra cost. Meanwhile, canola, wheat, corn, sunflowers, and cotton exhibit less risk reduction and come with higher premiums. The impact by crop also has a pronounced geographical distribution by state, and considerable variation was also observed by basic policy characteristics (insurance plan, coverage level, and unit structure). Overall, these variations suggests that a one-size-fits-all approach to increasing supplemental enrolment is not optimal.

Our study advances the literature on the U.S. farm safety net in several keyways. Particularly, we use a nationally representative dataset spanning 14 crops that collectively account for about 84% of the total non-livestock liability within the FCIP from 2015-23. This contrasts with most existing research on crop insurance which typically focuses on a small number of crops within limited geographic areas, often relying on small samples (Barnett et al. 2005; Deng, Barnett and Vedenov 2007; Du, Feng and Hennessy 2017; Miranda 1991; Smith, Chouinard and Baquet 1994). Although these prior studies also employ agent-based models and yield and price simulations—whether univariate or multivariate—their methodologies vary significantly. Some rely on a single, oversimplified agent representing all producers of a given crop, while others use more nuanced, county-level heterogeneous agents. Attempts at finer granularity using SOBTPU (aggregate experience for groups of producers who are similarly defined by their contract choice, the insurance pool they selected, and the crop year) or farm-level (Gaku and Tsiboe 2024) data have been made, but most analyses still depend on county-level mean yields and variances. By defining our agents at the SOBTPU level, our study reduces the potential aggregation bias inherent in single-agent or county-level approaches.

Furthermore, our analysis is the first to examine the gaps in the U.S. farm safety net arising from underutilization of the relatively new supplemental policies, offering timely and valuable insights into their design for future farm policy debates. To the best of our knowledge, only Tsay and Paulson (2024), which focuses on non-irrigated corn and soybeans in 17 states, and Gaku and Tsiboe (2024), which examines corn, wheat, soybeans, and sorghum in Kansas, provide a similar perspective. However, unlike our work, neither study addresses the missed risk mitigation and income transfer opportunities that result from low participation in these programs.

The remainder of this paper is organized as follows. Section 2 describes the data sources and details the construction of key variables for the analysis. Section 3 provides background information, examines the offering of supplemental coverage and explores participation levels from 2015-23. Section 4 outlines the design of our counterfactual simulation. Section 5 presents the empirical findings and discusses the results, and Section 6 concludes the study.

2. Data and Variable Construction

Our analysis leverages data drawn from the most detailed FCIP summary of business known as "Summary of Business by Type, Practice, Unit Structure" or "SOBTPU." Each SOBTPU entry aggregates loss experience for groups of producers who are similarly defined by their contract choice (i), the insurance pool they selected (j), and the crop year (t). These contract choices are identified by specific combinations of insurance plan (e.g., APH, RP, etc..), coverage level, and unit structure (e.g., Optional unit [OU], Enterprise unit [EU], etc..). Insurance pools represent the most granular level of rate making within the FCIP and are distinguished by unique combinations of county, crop, crop type (e.g., corn as grain or silage), and production practice (e.g., irrigated, organic). We extract policy rating parameters and commodity prices (projected and harvest) from the RMA's Actuarial Data Master (ADM). Finally, each SOBTPU entry's end of season yield (i.e. an approximation of the mean actual end of season yields of those producers whose experiences constitute that entry), approved yield, and rate yield are calibrated using methods summarized in Appendix Note S1 (Tsiboe et al. 2024).

Our study focuses on data from 2015-23 for 46 crops across 2177 counties, encompassing 12132 crop/county programs where SCO and ECO offerings were available.[3] Table 1 presents the descriptive statistics of our dataset. During this period, the annual net insured area averaged 230.39 million acres with a total liability of $106.22 billion, and the program collected premiums totaling $10.2 billion annually. Additionally, it paid out $7.89 billion in indemnities to producers each year. Corn, soybeans, wheat, cotton, sorghum, and rice comprised most of this business, accounting respectively for 161.22 million acres ($93.98 billion), 150.35 million acres ($59.87 billion), 77.2 million acres ($15.48 billion), 22.76 million acres ($9.83 billion), 10.11 million acres ($2.02 billion), and 5.28 million acres ($3.83 billion) of the total annual net insured area and liability.

[3] The crops included all pasture, rangeland, and forage (including seeding), almonds, apples, barley, blueberries, buckwheat, canola, corn, cotton, cranberries, cucumbers, dry beans, dry peas, flax, grapefruit, grapes, green peas, lemons, mandarins/tangerines, millet, mustard, oats, onions, oranges, peaches, peanuts, popcorn, potatoes, processing beans, prunes, pumpkins, rice, rye, safflower, sesame, sorghum, soybeans, sugar beets, sugarcane, sunflowers, sweet corn, tangelos, tobacco, tomatoes, walnuts, and wheat.

These crops also led in all other metrics listed in Table 1. The cumulative loss ratio across all crops was 0.77 but varied among the six major crops, ranging from 0.56 for soybeans to 2.13 for rice. The sample represents 84.21% of the total non-livestock liability within the FCIP from 2015-23. See Table S1 in the online appendix for the book of business summary of other crops not shown on Table 1.

3. Supplemental Coverage Offering and Participation

The FCIP offers a range of crop insurance products that can be classified along several dimensions. However, for the purposes of this study we touch base on only two. Traditional or basic policies which form the bulk of the FCIP's book of business ensure a single commodity when the protected outcome (yield, revenue, price, or margins) fall below a guaranteed level (usually 50-95% of expected). In addition to the traditional crop insurance policies, several endorsements and special provisions are available, which are typically characterized as supplemental coverage that are "stacked" with an underlying traditional policy to achieve a greater level of protection or mitigate a specific risk.[4] Another important distinction, and perhaps the most *controversial* from a program planning perspective, is the method by which policies are rated (priced) and payments are triggered for producers: rating and indemnification based on actual on-farm observed outcomes versus those based on outcomes not tied directly to the farm (e.g., county yield/revenue or precipitation). Here we refer to these as "Individual-based" and "Area or Index-based", respectively.[5] While basic

[4] These endorsements were designed to add-on to underlying individual protection, although a few function as a standalone insurance policy. These endorsements are intended to provide protection against "shallow losses", or those losses not triggered by traditional crop insurance plans (i.e., losses triggered at greater than 85% of insurable revenue subject to a payment limit).

[5] While Individual-based policies are often quite large, enjoy broad producer/political support, and will likely remain relevant going forward, the global importance and range of Index insurance

policies are either Individual-based (e.g., YP and RP) or Index-based (e.g., Pasture, Rangeland, Forage Insurance Program [PRF] and Area Risk Protection Insurance [ARPI]), all supplemental policies are index based.

Federal crop insurance designed to provide area yield protection is not a novel concept despite the lack of participation in both contemporary traditional and supplemental area-based plans of crop insurance. The Federal Crop Insurance Act of 1938 established the Federal Crop Insurance Corporation and introduced farm-level yield insurance for wheat, but the small samples of farm-level data were only adequate for determining the mean and not the variability of yields. Thus, in 1946, all crops were insured under countywide rates (Kramer 1983). However, in 1977 the Government Accountability Office released a report which called for the need for farm-level yield protection, and the Federal Crop Insurance Act of 1980 (P.L. 96-365) was passed shortly after which provided for farm-level protection. Area-based policies began to resurface in the 1990 farm bill discussion (Miranda 1991), but individual policies continued to dominate insured acreage. As of 2024, six supplemental endorsements were available in the FCIP including the Supplemental Coverage Option (SCO), the Enhanced Coverage Option (ECO), the Stacked Income Protection Plan (STAX), the Margin Protection (MP) plan, the Hurricane Insurance Protection-Wind Index (HIP-WI) plan, and the Post-Application Coverage Endorsement (PACE). In this study we focus on the two most patronized supplemental endorsements (SCO and ECO) and how they are used in conjunction with APH, YP, RP or RP-HPE individual level insurance plans.

products have grown considerably in both high- and low-income countries largely in response to the large administrative (and/or transaction) costs of the former. Tack and Yu (2021) provide a recent overview of this literature.

The SCO was first made available for the 2015 crop year after being authorized in the 2014 farm bill. The SCO provides additional coverage for a portion of the producer's underlying individual insurance deductible. [6] There is only one coverage level available for SCO at 86% with a maximum payment rate equal to the difference between 86% and the coverage level of the underlying individual policy. For example, if the underlying policy had a 75% coverage level, the maximum payment rate for SCO is 11% of insurable revenue or yield. Further, SCO liability is a function of the underlying individual plan of insurance (i.e., APH, YP, RP or RP-HPE). For example, the SCO liability of a producer with RP/RP-HPE [YP/APH] crop insurance at the 75% coverage level is 11% of the product of 75% × approved yield (tied to the on-farm production history) × RMA projected price [× the price election share].

The ECO, introduced in the 2018 farm bill, contains coverage levels of 90% (ECO90) and 95% (ECO95) of insurable revenue, and, like SCO, is subject to a payment limit which is the difference between either 90% or 95% and 86%. This feature allows ECO to be purchased with SCO by stacking coverage bands (see Figure 1). ECO is also like SCO in that the liability is based on the same yield and price variables used to determine liability for underlying individual plans. Importantly, a producer must purchase an underlying individual plan of coverage to be eligible to enroll in either SCO or ECO. A producer does not need to be enrolled in SCO to purchase ECO, and enrollment in both at the same time is allowed. From 2015-24, the Federal Government

[6] We define individual insurance to be one with liability based on an APH farm-level yield history. Two primary examples of individual insurance include Yield Protection (YP) and Revenue Protection (RP) crop insurance.

subsidized 65% of the SCO premium and for the case of ECO 51% for YP/APH and 44% for RP/RP-HPE.[7]

Figure 2 illustrates that since their introduction, the SCO and ECO are available for purchase across nearly all eligible commodity/county programs. Eligibility for SCO and ECO is determined by whether the commodity/county program offers an individual-based basic insurance policy – i.e., APH, YP, RP, or RP-HPE. As of 2023, out of 20607 eligible county crop programs, 15804 (76.69%) offered SCO and 14194 (68.88%) offered ECO. Specifically for the 89 commodities eligible in 2023, 56 (62.92%) provided SCO, while only 33 (37.08%) had ECO available. Despite the availability of individual-based basic policies in Hawaii and some areas of Alaska, neither SCO nor ECO are available to producers in these states as of 2023. However, both options have been consistently accessible from 2015 to 2023 in all eligible counties for cotton, 98% for corn and soybeans, 92% for wheat, and 91% for rice (see Figure 3).

Despite their widespread availability, usage of SCO and ECO is surprisingly minimal. Particularly, Table 1 shows that of the 230.39 million acres with SCO/ECO availability that were annually enrolled in the FCIP from 2015-23, only 10.74 million acres (i.e., 4.66% of the total) were enrolled in a supplemental program. The portion of insured eligible acres annually enrolled in SCO [ECO] in 2023 for corn, soybeans, wheat, cotton, sorghum, and rice, were 7.16% [6.26%], 6.06% [4.89%], 8.78% [5.32%], 2.25% [0.63%], 6.03% [3.91%], and 10.61% [4.32%], respectively. Figure 3 shows that while SCO adoption declined by 15.85 percentage points among rice producers from 2015-23, corn, soybeans, sorghum, wheat, and cotton experienced growth estimated at 6.79, 5.63,

[7] Starting with the 2025 crop year, premium support for ECO increased to the same level as SCO (i.e., 65%).

3.17, 2.91, and 2.14 percentage points, respectively. Aside from these major crops, notable exceptions of SCO adoption that is more than 5% of eligible acres from 2015-23 include canola (19.15), dry peas (5.13), barley (5.01), peanuts (5.39), potatoes (5.09), flax (5.94), tobacco (20.37), mustard (20.14), onions (9.16), blueberries (13.69), peaches (17.61), and buckwheat (8.98). On the contrary, sugar beets, millet, grapes, oranges, sesame, mandarins/tangerines, lemons, pumpkins, grapefruit, and tangelos recorded SCO adoption rates of less than 1% of eligible acres from 2015-23 (see Table S2 in the online appendix).

While there has been an increase in participation in these supplemental coverages since their inception, the increase has been marginal with most counties only enrolling in around 4-5% of insured acreage (Figure 2). Most of the increases in participation occur in regions where leading principal crops are grown such as the Heartland, the Northern Great Plains, the Mississippi Portal, and the western Prairie Gateway.[8] Further, there appears to have been a slower uptake of SCO relative to its inception year compared to the uptake of ECO at 95% (ECO95) in its inception year. This highlights the slow adoption of supplemental coverages initially with SCO followed by a greater likelihood of adoption of newer supplemental coverages since producers were more familiar with the risk protection offered. It is likely that the producers who were already enrolled in SCO added ECO95 to their risk management portfolio which also explains why ECO95 had a relatively high percentage of uptake in its inception year.

This work addresses the perceived lack of participation in supplemental coverages. While adding SCO and ECO to a producer's risk management portfolio increase the level of expected revenue

[8] We define regions based on Farm Resource Regions defined by the USDA, Economic Research Service.

guaranteed, it comes at a cost. Both options are offered as endorsements which implies a producer must have an underlying APH, YP, RP, or RP-HPE policy which also comes at a premium cost. In some instances, producer premiums double. For example, according to the 2024 USDA-RMA Cost Estimator, it costs $16.00 per acre for a producer in Craighead County, Arkansas to insure their soybeans with RP at 75%. If the same producer wanted to add SCO and ECO-95, it costs an additional $4.00 per acre and $15.00 per acre, respectively, increasing the total cost of risk protection by 119%. Further, a producer is not eligible to insure acreage under SCO that is enrolled in the Agriculture Risk Coverage program authorized in the farm bill which also impacts their decision to enroll.

4. Counterfactual Simulation Design

In this section, we outline the simulation design used to quantify missed opportunities in risk reduction and revenue transfer due to low participation in supplemental protection, as discussed previously. The design comprises two main parts. Initially, we counterfactually modify the SOBTPU to reflect incremental changes in the adoption of supplemental plans. Subsequently, we calculate the associated changes in risk reduction efficiency, out-of-pocket cost to producers, and Federal cost resulting from these counterfactual incremental changes.

Our counterfactual simulation design employs the concept of a representative agent, henceforth referred to as an 'agent', which corresponds to the SOBTPU entries associated with continuously rated insurance plans (YP, APH, RP, or RP-HPE), summarized by summing outcomes by crop year, county, crop, crop type, production practice, unit structure, insurance plan, and coverage level. On the contrary, the calibrated yields for each SOBTPU entry described in Appendix Note S1 were summarized for each agent by taking a weighted average by area insured. Given that our calibrated yields extend only through 2023, this section of the analysis is confined to the period from 2015-23. Furthermore, we were only able to calibrate yields for corn, soybeans, wheat, cotton, sorghum, rice, canola, dry peas, barley, sunflowers, peanuts, dry beans, oats, and popcorn. Thus, the simulations are only limited to these crops.

The lower part of Table 1 presents selected descriptive statistics for our sample of agents, totaling 958,658 across all crops. Among the six major crops, the number of agents is as follows: corn with 318,974 agents, soybeans with 290,004, wheat with 166,986, cotton with 66,036, sorghum with 33,839, and rice with 12,906. The most utilized basic insurance plan among these agents is RP, featuring a weighted average coverage level of 75% and an average insured area of 1827 acres per agent. On average, these agents pay a premium of 12 cents per dollar of liability and receive a subsidy of 63 cents per dollar of premium for the basic policy. The agents included in our simulations represent 79.84% of the total liability of the 13824 crop/county programs where SCO and ECO offerings were available from 2015-23. Among the six major crops, the simulation representation was highest for corn at 47.74%, followed by wheat at 44.03%, cotton at 42.08%, soybeans at 41.05%, rice at 37.46%, and sorghum at 37.13%.

The baseline (status quo) adoption rates for the SCO for each agent are determined by their specific crop year, county, crop, crop type, practice type designation, underlying insurance plan, and coverage level. For example, an agent with a 2022 crop year designation under the YP plan with a 70% coverage level for corn in Adam County, Illinois, will have their SCO adoption rate calculated as the ratio of the acres endorsed for SCO-YP at 70% to the total insured acres for YP at 70% for corn in that county during 2022. Since the ECO plan does not depend on the coverage level of the underlying basic policy like SCO does, we adapted our approach to calculate adoption rates without considering coverage levels, resulting in two separate adoption rates: one for ECO95 and another for ECO90. Across all the agents in the analysis, these baseline values average 2.26%, 0.08%, and 0.72% for SCO, ECO90, and ECO95, respectively.

For each agent, our objective is to compute the counterfactual scenario in which the agent selected different SCO and ECO participation rates, while keeping other attributes constant. The incremental changes in supplemental plan adoption analyzed in this study are detailed in Table 2.

Since participation for the underlying basic policy remains constant in each scenario, the liabilities (L_{ijt}), premiums (P_{ijt}), and subsidies (S_{ijt}) for these policies are maintained at their recorded values in the SOBTPU for each agent. For supplemental plans, loss experience outcomes are recalculated according to procedures specified in FCIP Appendix III/M-13 Handbook, given the incremental changes in supplemental plan adoption in each scenario. Given that end of season yields (y_{ijt}) and prices (p_{ijt}) - and by extension indemnities (I_{ijt}) - are stochastic, we simulate 500 draws of these outcomes per agent. Particularly we applied the same simulation methods – and parameters retrieved from the ADM - that RMA uses to simulate revenue streams for the purposes of assigning additional premium rate loads for revenue protection policies (Risk Management Agency [RMA] 2009; Coble et al. 2010).[9] In these simulations, we calculated the "lookup rate" using the formulars described in the M-13 Handbook given the relevant ADM parameters and calibrated approved yield. We replaced the "Approved Yield" with the mean of calibrated end-of-season yield and the rate yield when calculating the "Adjusted Mean Quantity" and "Adjusted Standard Deviation Quantity" which are used in the yield simulations. Price simulations follow

[9] Also see FCIP Appendix III/M-13 Handbook, particularly the file "P11_1 - Plan 01 02 and 03 Premium Calculation 06.30.2022", Section 5: Revenue Coverage Add on Rates (Applicable only for Plans 02 and 03), on pages 16 to 19. The 2023 crop year version is found here https://www.rma.usda.gov/media/12527.

the exact process outlined in the M-13 Handbook given the relevant parameters from the ADM. These price and yield simulations are done separately for each agent in the analysis. Thus, to approximate the insurance contract harvest price for the analysis, we average the i^{th} end-of-season price draw out of the 500 across all agents to get our 500 draw of insurance contract harvest price for the simulation. A similar approach is used for the case of county yields (which are used to determine SCO and ECO payment factors), where for a given county, the final yield for each iteration is taken as the acre weighted average mean of all the agents in that county.

Given the counterfactual calculations (indicated by ~) for policy out-of-pocket cost ($\tilde{P}_{ijt}^{a} - \tilde{S}_{ijt}^{a}$) and indemnities ($\tilde{I}_{ijt}^{a}$), the total end of season net revenue associated with a given scenario (a) for each agent is calculated for each of the 500 draws, subscripted by d, of yield and price as $\tilde{\pi}_{ijtd}^{a} = \tilde{y}_{ijtd} \cdot \tilde{p}_{ijtd} + \tilde{I}_{ijtd}^{a} - \tilde{Q}_{ijt}^{a}$. These are then compared along two dimensions: (1) direct revenue enhancement and (2) revenue variability reduction.

We employ two principal indicators to evaluate all scenarios: relative mean revenue and revenue variability. Relative mean revenue, the "Revenue Transfer Index" (RTI), is determined by averaging the revenue for each agent across the 500 simulations ($\bar{\bar{\pi}}_{ijt}^{a} = \sum_{d=1}^{500} \tilde{\pi}_{ijtd}^{a}$), then dividing this by the average revenue without any crop insurance (i.e., $\bar{\bar{\pi}}_{ijt}^{0} = \sum_{d=1}^{500} \tilde{y}_{ijtd} \cdot \tilde{p}_{ijtd}$). This ratio, $RTS_{ijt}^{a} = \bar{\bar{\pi}}_{ijt}^{a} / \bar{\bar{\pi}}_{ijt}^{0}$, provides insights into the effectiveness of the FCIP in enhancing revenue under various alternative scenarios. For revenue variability, we analyze fluctuations in each agent's revenue across all 500 simulations, utilizing the Coefficient of Variation (CV) to measure overall risk, and Normalized Lower Relative Partial Moments (N-LRPM) and Normalized Lower Absolute Partial Moments (N-LAPM) for measuring absolute and relative downside risk, respectively.[10] These metrics are calculated relatively, comparing scenarios with and without the insurance to formulate a "Variability Reduction Index" (VRI). Subsequently the revenue transfer potential and the risk reduction potential in percentage terms are calculated as $\left(RTS_{ijt}^{a}-1\right)\times 100\%$ and $\left(VRI_{ijt}^{a}-1\right)\times 100\%$, respectively.

For each agent, the aggregate variables that capture the cost of coverage, including the actuarially fair premium per dollar of liability in cents, the premium subsidy percentage, and premium paid per dollar of liability in cents were also calculated as $100\times\sum_{d=1}^{500}\frac{\tilde{P}_{ijtd}^{a}}{\tilde{L}_{ijtd}^{a}}$, $\bar{\tilde{S}}_{ijt}^{a}=100\times\sum_{d=1}^{500}\frac{\tilde{S}_{ijtd}^{a}}{\tilde{P}_{ijtd}^{a}}$, and$100\times\sum_{d=1}^{500}\frac{\tilde{P}_{ijt}^{a}-\tilde{S}_{ijt}^{a}}{\tilde{L}_{ijtd}^{a}}$, respectively, where $\tilde{L}_{ijtd}^{a}$ is the total simulated liability (basic plus supplemental) of that agent's counterfactual. To synthesize our findings, we average all the outcomes for each scenario across all the agents between the 5th and 95th percentiles to derive an overall measure of a scenario's impact on revenue levels and stability.

Standard errors for each metric are calculated using the jackknife method, where the metrics are recalculated iteratively, each time excluding one state. The standard deviation of these recalculated metrics across iterations is then taken as the standard error.

Before presenting the results, it is crucial to acknowledge that our study operates under the empirical assumption that stochastic outcomes, such as yield, price, or indemnities, are predominantly influenced by uncontrollable factors such as weather, rather than by farmers' decisions. This minimizes the relevance of moral hazard and adverse selection in our analysis. Although subsidies have mitigated adverse selection (Tsiboe and Turner 2023; Coble and Barnett

[10] The CV is calculated using conventional formulae; N-LAPM and N-LRPM are calculated using formulation provided in (Antle 2010).

2013; Just, Calvin and Quiggin 1999; Glauber 2013; Glauber 2004), the issue of moral hazard, particularly concerning input use, continues to be debated (Smith and Goodwin 2017; Horowitz and Lichtenberg 1993; Yu and Hendricks 2020). However, according to the literature, the impact of moral hazard on yields appears minimal, largely because yields are primarily affected by climatic events (Coble et al. 1997; Babcock and Hennessy 1996; Quiggin, Karagiannis and Stanton 1993; Mieno, Walters and Fulginiti 2018). In the FCIP, weather-related factors, specifically drought and temperature (accounting for 42% of claims) and excess moisture (28% of claims), have predominated in insurance claims since 2000. Nonetheless, ensuring an unbiased comparison of scenarios requires that an agent's behavior remains consistent under the baseline and all alternative scenarios. We maintain this consistency by keeping the yields and prices constant for a given agent across all scenarios.

5. Results and Discussions

5.1 Establishing the baseline

Table 3 presents a compelling view into the effectiveness of integrating basic crop insurance policies (APH, YP, RP, and RP-HPE) with supplemental protection (SCO and ECO) over the period from 2015 to 2023. The data reveals a significant boost in revenue transfer potential under baseline conditions, with the observed stacking rate generating approximately 27.9% more revenue than scenarios lacking any crop insurance. This increase primarily originates from the subsidized portions of insurance premiums and indemnity payments that cover losses. Moreover, the baseline highlights a substantial reduction in revenue variability. Specifically, the overall risk associated with revenue fluctuations decreased by nearly 49.05% when compared to instances without insurance coverage. The baseline scenario shows a remarkable decrease in both relative and absolute downside risks by 83.6% and 80.98%, respectively. The cost for this level of security? An actuarially fair premium rate of just 12.34 cents per dollar of liability, 63.67% of which is subsidized by the federal government, leaving farmers to pay merely 4.35 cents out of pocket.

Figure S1 further enriches our understanding by pinpointing cotton as the crop with the highest downside revenue risk reduction rate at 88.47%, closely followed by corn (85.91%), canola (83.41%), wheat (82.42%), sorghum (79.78%), dry peas (78.96%), dry beans (78.34%), sunflowers (78.01%), soybeans (77.31%), peanuts (74.67%), barley (74.03%), oats (73.28%), rice (71.06%), and popcorn (68.68%). The geographical distribution of these crops along downside risk reduction potential, also in Figure S1, showcases states (major crop in that state) like Arizona (cotton), Iowa (corn), Indiana (soybeans), Minnesota (corn), and Illinois (corn) as leaders in downside revenue risk reduction, with rates exceeding 86%. Conversely, states such as Arkansas (soybeans), California (almonds), Vermont (corn), Louisiana (soybeans), and West Virginia (corn) are identified as having the lowest risk reduction rates, ranging less than 71%. Comparing Figure S1 to S2 and S3 indicates that the programs which offer high downside revenue risk reduction also tend to involve higher revenue transfers and greater out-of-pocket costs for producers.

These baseline figures underscore the vital role of crop insurance in protecting American farmers from 2015 to 2023. This protective impact is corroborated by recent research, highlighting the efficacy of crop insurance in reducing financial risks for farmers. For instance, producers of corn, wheat, soybeans, and sorghum in Kansas who incorporated FCIP products into their risk management strategies experienced notable reductions in profit risk compared to those without crop insurance (Gaku and Tsiboe 2024). Furthermore, another study revealed that SCO contributed to additional risk mitigation for producers of non-irrigated corn and soybeans across 17 states (Tsay and Paulson 2024).

5.2 Effects of Increasing Participation in Supplemental Protection

Our counterfactual analysis begins by simulating a standalone basic policy, meaning that agents do not incorporate supplemental protection into their coverage. We then explore scenarios in which basic policies are fully stacked with supplemental protection (100% each for SCO and ECO conditional on availability)—indicating that all acres insured under the basic policy also receive a specified supplemental coverage combination. Throughout these simulations, current subsidy and coverage parameters are maintained. Compared to baseline conditions, these scenarios reveal substantial variations in relative revenue indices and aggregate coverage costs. The results of these alternative scenarios are presented as percentage changes from the baseline in Table 3 (columns 2–7).

Compared to the existing 2015 to 2023 benchmark, the basic policy alone has a negligible effect on risk mitigation and revenue transfer. Specifically, the policy's capability to reduce relative [absolute] downside risk is marginally diminished by approximately 0.28 [0.31] percent from the baseline, while the potential for revenue transfer is reduced by 1.27 percent. These findings suggest that merely purchasing a basic policy without fully stacking with a supplemental plan fails to exploit the full benefits of risk reduction and income transfer available to producers during this period. Fully integrating the SCO with the basic policy substantially boosts revenue metrics, with relative [absolute] downside risk reduction and revenue transfer improving by 10.16 [10.79] and 87.36 percent, respectively, compared to baseline levels. Moreover, the addition of ECO at a 95% coverage level significantly amplifies improvements across all metrics. The combination of Basic + ECO95 enhances both relative and absolute measures of downside risk reduction by 4.3 and 4.77 percent, respectively, and increases revenue transfer by 33.01 percent above the baseline. The most comprehensive benefits are observed when SCO and ECO95 are synergistically stacked with basic policies, delivering the highest increments in downside risk reduction (10.6 and 11.33 percent), overall risk alleviation (24.49 percent), and revenue transfer (98.89 percent). These results underscore that multi-layered insurance options offer the most effective safeguard against a wide array of agricultural risks, providing substantial protective measures that exceed those of standalone policies.

While enhanced participation in SCO and ECO is correlated with improvements in risk reduction and revenue transfer, it also leads to higher aggregate actuarially fair premium rates and reduced aggregate subsidy rates, resulting in increased aggregate premium paid rates. Notably, the combination Basic + ECO95 exhibits the highest increase in the premium rate faced by producers, at 91.66%, stemming from a 48.57% increase in the actuarially fair premium rate and a 10.83% reduction in the subsidy rate. In terms of the premium rate paid, Basic + ECO95 is followed by Basic + SCO + ECO95 (62.79%), Basic + SCO + ECO90 (46.7%), Basic + SCO (35.78%), Basic + ECO90 (34.18%), and Basic only (-2.34%).

5.3 Robustness checks

To ensure our main findings (shown in Table 3) remain robust under different conditions, we conducted some checks. First, we revisited our baseline choice of 2015–23. While SCO was broadly available throughout this window, ECO only became accessible in 2021. To see if this rollout affected our results, we re-ran our simulations for 2021–23, when both SCO and ECO were fully in play. As shown in Table S4, the results align closely with the broader 2015–23 findings, reinforcing the robustness of our preferred baseline. Second, we recognized that intense within-year weather events—particularly in major crop regions— potentially overshadows the potential risk reduction and revenue benefits of stacking basic policies with supplemental plans. To test this, we isolated each crop year from 2015 to 2023. In every single year, the results are consistent with the study's main findings (see Figure S4).

5.4 Heterogeneous Outcomes in Full Participation

By consolidating all counterfactual outcomes into a single measure, the program-level analysis shows that stacking a basic policy with supplemental coverage consistently boosts revenue transfer and reduces risk—albeit at a higher out-of-pocket cost for producers. Yet these top-level figures conceal substantial variation across different contexts. To shed light on these nuances, this subsection summarizes the results by various observable characteristics (crop, state, and basic policy characteristics), focusing specifically on scenarios with full participation in Basic + SCO + ECO95 (the most comprehensive option).

When it comes to balancing risk reduction and cost, not all crops are created equal. As shown in Figure 4 (Panel Crop), three distinct categories emerge. First, rice, barley, popcorn, peanuts, and soybeans deliver substantial downside risk reduction—ranging from 17.94 to 74.28 percent improvement over the baseline—at marginal costs of 24.58 to 74.28 percent above baseline. For these crops, the ratio of downside revenue risk reduction to increased out-of-pocket cost (i.e., elasticity) stands at 0.75, 0.73, 0.43, 0.41, and 0.33, respectively. These relatively high elasticities make stacking a basic insurance policy with a supplemental plan particularly appealing for producers of rice, barley, popcorn, peanuts, and soybeans.

The next group consisting of sorghum, oats, dry peas, and dry beans also show considerable improvements in downside risk reduction (above 9.08 percent) but require additional premiums ranging from 30.43 to 62.48 percent above the baseline. Although these crops still benefit significantly from fully stacking basic insurance with a supplemental plan, the higher premium costs make this option relatively pricier compared to the first group. The final group consisting of canola, wheat, corn, sunflowers, and cotton provide only modest risk reduction (below 12.05 percent of the baseline), with marginal costs spanning 33.23 to 71.08 percent above baseline. This lower level of protection, combined with relatively high additional costs, makes stacking policies less appealing for producers seeking strong coverage without substantially increasing their expenses.

Similarly, Figure 5 narrows in more closely on the spatial variation in the ratio of downside revenue risk reduction to increased out-of-pocket cost by crop. Barley and Rice were the two commodities with the largest ratio at 0.73 and 0.75 respectively. This is followed by a cluster of commodities with a ratio between 0.2 and 0.5, including popcorn (0.43), peanuts (0.41), soybeans (0.33), sorghum (0.3), oats (0.29), dry peas (0.28), dry beans (0.24), canola (0.22). Commodities with the lowest ratio were wheat (0.19), corn (0.17), sunflowers (0.16), and cotton (0.13). Two major commodities, corn and cotton, had the lowest ratio in the largest production regions, the Midwest and Southern Plains for corn and cotton respectively. Lower protection combined with larger regional risks under changing climate conditions (e.g. frequency of drought for Texas cotton) discourage the use of stacked supplemental coverage.

Next, we explore heterogeneity along three insurance unit structure choices. Optional units (OU) insure each section of land separately. Enterprise units (EU) allow producers to cluster all their insurable acres of a single crop and management practice within a county under a single insurable unit. Starting in 2019, a farm that crosses county lines can cluster multi-county acreages into a single EU. Producers selecting to use EU reduce producer premiums due to higher subsidy rates at different levels of coverage. Risk Management Agency premium subsidies for MPCI 50% to 70% coverage levels are 80% followed by coverage levels (subsidy rates) of 75% (77%), 80%

(68%) and 85% (53%). EU are being utilized more over time, while trends in OU and basic units are declining (Zulauf et al. 2023). Basic units (BU) allow a producer to insure by a share of production, not by land unit but is beneficial when some sections have greater loss potential in bad years.

As shown in Figure 4 (Panel Unit Structure), both EU and OU offer marginal benefits from downside risk reduction and the ratio of downside risk reduction to out-of-pocket cost, but basic units did not vary significantly from the baseline. Out-of-pocket cost per dollar of liability from stacking supplemental plans are higher for EU, OU and BU relative to the baseline. While the greatest increase is associated with EU, the MPCI subsidy levels for EU are also the highest and therefore most affordable in the baseline. Further, it is worth noting that while purchasing an underlying MPCI policy is required to participate in ECO, the ECO producer premium is not a function of the underlying MPCI coverage choice. Thus, the producer premium for SCO is driving this finding since only the purchased liability for SCO will change with the underlying MPCI coverage choice.

Producers also decide in each year whether their crop insurance will protect against large declines in yield alone or in revenue (yield and price). Figure 4 (Panel Insurance Plan) offers insights into the impact of supplemental coverage when underlying baseline policies are based on RP or YP. The RP is the most common plan selected across major commodities. Relative to the baseline, stacking supplemental options onto RP and RP-HPE offer moderate reductions in the downside revenue risk potential. However, RP and RPHPE did increase the producer premiums per dollar of liability with the largest increases associated with RPHPE. The YP/APH policies that insure against yield losses did not significantly change the downside revenue risk reduction, but did increase premiums per dollar of liability relative to the baseline.

Finally, Figure 4 (Panel Coverage Level) offers insights into the impact of supplemental coverage options under different levels of underlying coverage. As shown in Figure 1, underlying coverage goes up to the 85% coverage level. So, it is unsurprising that as coverage levels in the underlying policy decline and more risk is covered by the supplemental policies, the risk reduction potential increases.

6. Conclusion

Producers face a wide range of risks including market volatility and extreme weather events, challenging farm level risk management. Federally subsidized crop insurance offering yield or revenue protection has become a key risk management tool for producers. Yet, the most comprehensive crop insurance policies do not trigger payments until losses exceed 15%. Starting in 2014, U.S. agricultural policy introduced supplemental insurance policies to bolster the overall risk management framework by adding county-level protections that covers the deductibles not addressed by standard policies. Despite their potential benefits, adoption for these supplemental policies has remained low.

This study underscores the significant potential of supplemental agricultural insurance policies—namely the Supplemental Coverage Option (SCO) and Enhanced Coverage Option (ECO)—to mitigate financial risks for U.S. farmers. Particularly the study has found that while standalone basic insurance policies (APH, YP, RP, or RP-HPE) provide a foundational level of protection, fully integrating SCO and ECO yields substantial improvements in downside risk reduction and income transfer. Although these increases come at the cost of higher premiums, when evaluated based on benefit per unit of premium results still favor higher supplemental coverage adoption.

Despite these trade-offs, several crops—such as rice, barley, popcorn, peanuts, and soybeans—demonstrate notable reductions in revenue variability for relatively modest added costs, indicating they are potentially well-suited for fully integrating supplemental coverage. By contrast, canola, wheat, corn, sunflowers, and cotton show more moderate risk-reduction benefits with higher premiums. This heterogeneity indicates that a uniform strategy for increasing supplemental coverage enrollment does not align with every producer's needs. Instead, tailoring supplemental coverage usage to each producer's unique cost tolerance and risk profile help ensure that the additional premiums yield proportional risk reductions, thereby maximizing efficiency and farmer benefits.

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Tables and Figure

Table 1: Summary statistics of study data for major crops from 2015 to 2023

	All crops and counties with SCO/ECO availability	Corn counties with SCO/ECO availability	Soybeans counties with SCO/ECO availability	Wheat counties with SCO/ECO availability	Cotton counties with SCO/ECO availability	Sorghum counties with SCO/ECO availability	Rice counties with SCO/ECO availability
Book of business:							
Total annual policies with premium (1,000)	1036.20 (25.85)	745.80 (18.71)	710.49 (19.04)	289.95 (26.77)	82.45 (7.00)	66.83 (10.86)	18.39 (1.14)
Total annual units with premium (1,000)	2097.45 (65.42)	1385.83 (63.17)	1356.41 (60.39)	688.05 (83.64)	222.34 (27.09)	127.72 (22.37)	42.45 (3.10)
Total annual net acres insured (million)	230.39 (7.95)	161.22 (7.20)	150.35 (6.48)	77.20 (5.11)	22.76 (3.43)	10.11 (1.68)	5.28 (0.39)
Total annual companion/endorsed acres (million)	10.74 (10.28)	7.81 (8.53)	5.48 (6.59)	4.34 (3.25)	0.85 (0.99)	0.42 (0.32)	0.62 (0.24)
Total annual liability (billion $)	106.22 (27.54)	93.98 (24.29)	59.87 (16.23)	15.48 (4.19)	9.83 (2.74)	2.02 (0.68)	3.83 (1.23)
Total annual premium (billion $)	10.20 (2.89)	8.30 (2.39)	4.97 (1.44)	2.46 (0.87)	1.85 (0.59)	0.44 (0.15)	0.23 (0.10)
Total annual subsidy (billion $)	6.49 (1.87)	5.22 (1.54)	3.15 (0.92)	1.57 (0.56)	1.27 (0.42)	0.28 (0.10)	0.15 (0.06)
Total annual indemnity (billion $)	7.89 (4.25)	5.12 (3.10)	2.77 (1.39)	2.29 (1.42)	2.43 (1.78)	0.38 (0.44)	0.50 (0.31)
Cumulative loss ratio	0.77	0.62	0.56	0.93	1.31	0.86	2.13
Annual share of non-livestock liability (%)	84.21	74.51	47.46	12.27	7.80	1.60	3.03
Agent characteristics:							
Output unit	-	Bushel	Bushel	Bushel	Pound	Bushel	Pound
Basic policy unit structure [mode]	EU/WU	EU/WU	EU/WU	OU	EU/WU	EU/WU	EU/WU
Basic policy insurance plan [mode]	RP	RP	RP	RP	RP	RP	YP
Basic policy average coverage level	0.75 (0.07)	0.77 (0.07)	0.76 (0.08)	0.72 (0.06)	0.68 (0.07)	0.70 (0.06)	0.68 (0.11)
Basic policy net insured area (1,000 acres)	1.83 (5.69)	2.14 (6.51)	1.97 (5.85)	1.78 (5.85)	1.28 (3.70)	1.04 (2.54)	1.26 (2.33)
Basic policy liability ($/acre)	409.41 (1215.83)	531.81 (1066.97)	363.14 (773.74)	231.49 (588.02)	543.30 (3364.96)	197.82 (172.55)	834.03 (1773.14)
Basic policy premium per dollar of liability	0.12 (0.10)	0.11 (0.08)	0.10 (0.07)	0.16 (0.10)	0.20 (0.16)	0.23 (0.13)	0.07 (0.05)
Basic policy subsidy per dollar of premium	0.63 (0.12)	0.63 (0.12)	0.63 (0.12)	0.63 (0.11)	0.66 (0.10)	0.63 (0.09)	0.63 (0.13)
SCO adoption rate (% of net insured area)	2.26 (10.34)	2.15 (9.46)	1.33 (7.27)	2.76 (11.17)	3.35 (14.05)	2.32 (10.03)	12.09 (27.30)
ECO90 adoption rate (% of net insured area)	0.08 (1.09)	0.13 (1.35)	0.09 (1.09)	0.03 (0.62)	0.01 (0.33)	0.01 (0.77)	0.03 (1.54)
ECO95 adoption rate (% of net insured area)	0.72 (4.25)	0.99 (4.71)	0.60 (3.62)	0.67 (4.40)	0.20 (2.94)	0.26 (2.11)	0.52 (4.83)
Projected price ($/output unit)	7.87 (4.65)	6.01 (0.89)	13.67 (2.19)	7.98 (1.82)	0.54 (0.07)	5.34 (1.15)	0.15 (0.04)
Calibrated approved yield (output unit/acre)	415.89 (1471.93)	155.97 (48.05)	44.58 (12.35)	49.30 (21.87)	1443.75 (629.54)	66.86 (25.85)	7793.22 (8215.07)
Calibrated rate yield (output unit/acre)	300.52 (864.65)	114.06 (50.03)	35.45 (11.66)	39.68 (18.32)	856.96 (574.93)	54.14 (23.72)	4937.94 (2476.33)
Calibrated final yield (output unit/acre)	356.64 (1151.90)	150.09 (80.98)	44.05 (23.53)	47.70 (34.53)	1126.68 (911.36)	58.37 (40.88)	6034.03 (5058.06)
Number of agents	958,658	318,974	290,004	166,986	66,036	33,839	12,906
Liability shares of crop/county with SCO/ECO (%)	79.84	47.74	41.05	44.03	42.08	37.13	37.46

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

Table 2: Counterfactual simulation definitions

	Scenario parameters								
	Coverage level (%)			Subsidy rate (%)			Participation as a percent of basic insurance insured		
	SCO	**ECO90**	**ECO95**	**SCO**	**ECO90**	**ECO95**	**SCO**	**ECO90**	**ECO95**
Baseline	86	90	95	65	YP=51 & RP = 44		Current (2016 to 2022) levels		
Full participation of specified combination at current subsidy and coverage levels									
Basic only	86	90	95	65	YP=51 & RP = 44		0	0	0
Basic + SCO							100	0	0
Basic + ECO90							0	100	0
Basic + ECO95							0	0	100
Basic + SCO + ECO95							100	100	0
Basic + SCO + ECO90							100	0	100
Basic only + incremental participation of SCO at current subsidy and coverage levels									
Basic only + 1% SCO	86	90	95	65	YP=51 & RP = 44		1	0	0
Basic only + 5% SCO							5	0	0
Basic only + 10% SCO							10	0	0
Basic only + 15% SCO							15	0	0
Basic only + 20% SCO							20	0	0
Basic only + 25% SCO							25	0	0
Basic only + 50% SCO							50	0	0
Basic only + 100% SCO							100	0	0

Table 3: Impact of increased supplemental agricultural insurance coverage adoption from 2015 to 2023

	Baseline scenario	Alternative scenarios of full participation of specified combination at current subsidy and coverage levels					
		Basic only	Basic + SCO	Basic + ECO90	Basic + ECO95	Basic + SCO + ECO90	Basic + SCO + ECO95
		Expressed percentage changes over baseline					
Revenue transfer potential relative to no insurance (%)	27.897*** (0.328)	-1.271*** (0.038)	87.362*** (3.465)	13.864*** (0.758)	33.010*** (1.613)	92.642*** (3.579)	98.889*** (3.822)
Overall risk reduction potential relative to no insurance (%)	49.047*** (0.164)	-0.677*** (0.022)	21.893*** (0.389)	4.819*** (0.096)	11.371*** (0.197)	23.148** (0.406)	24.491** (0.428)
Relative downside risk reduction potential relative to no insurance (%)	83.596*** (0.113)	-0.276*** (0.010)	10.163*** (4.440)	1.978*** (0.113)	4.296*** (0.259)	10.425*** (4.469)	10.602*** (4.529)
Absolute downside risk reduction potential relative to no insurance (%)	80.975*** (0.122)	-0.310*** (0.011)	10.785** (3.900)	2.185*** (0.103)	4.775*** (0.236)	11.093** (3.922)	11.329** (3.978)
Actuarially fair premium per dollar of liability (cents)	12.338*** (0.151)	-1.632*** (0.042)	29.304*** (0.266)	17.246*** (0.246)	48.571*** (0.662)	35.038*** (0.319)	43.791*** (0.577)
Premium subsidy rate (%)	63.671*** (0.145)	0.246*** (0.008)	0.268*** (0.064)	-5.539*** (0.097)	-10.828*** (0.214)	-0.825*** (0.408)	-1.931*** (0.835)
Premium paid per dollar of liability (cents)	4.351*** (0.047)	-2.343*** (0.055)	35.779*** (0.632)	34.185*** (0.411)	91.658*** (1.037)	46.700*** (0.847)	62.793*** (2.954)
		Risk reduction potential change per change in in premium paid (%)					
Overall risk	-	0.289*** (0.008)	0.612*** (0.013)	0.141*** (0.002)	0.124*** (0.002)	0.496*** (0.013)	0.390*** (0.023)
Relative downside	-	0.118*** (0.004)	0.284*** (0.123)	0.058*** (0.003)	0.047*** (0.003)	0.223*** (0.097)	0.169*** (0.076)
Absolute downside	-	0.132*** (0.004)	0.301** (0.108)	0.064*** (0.003)	0.052*** (0.003)	0.238** (0.085)	0.180** (0.067)

Source: Simulated by authors using data from USDA, RMA

Figure 1: Illustration of supplemental coverage combined with an underlying individual policy at 75% coverage level

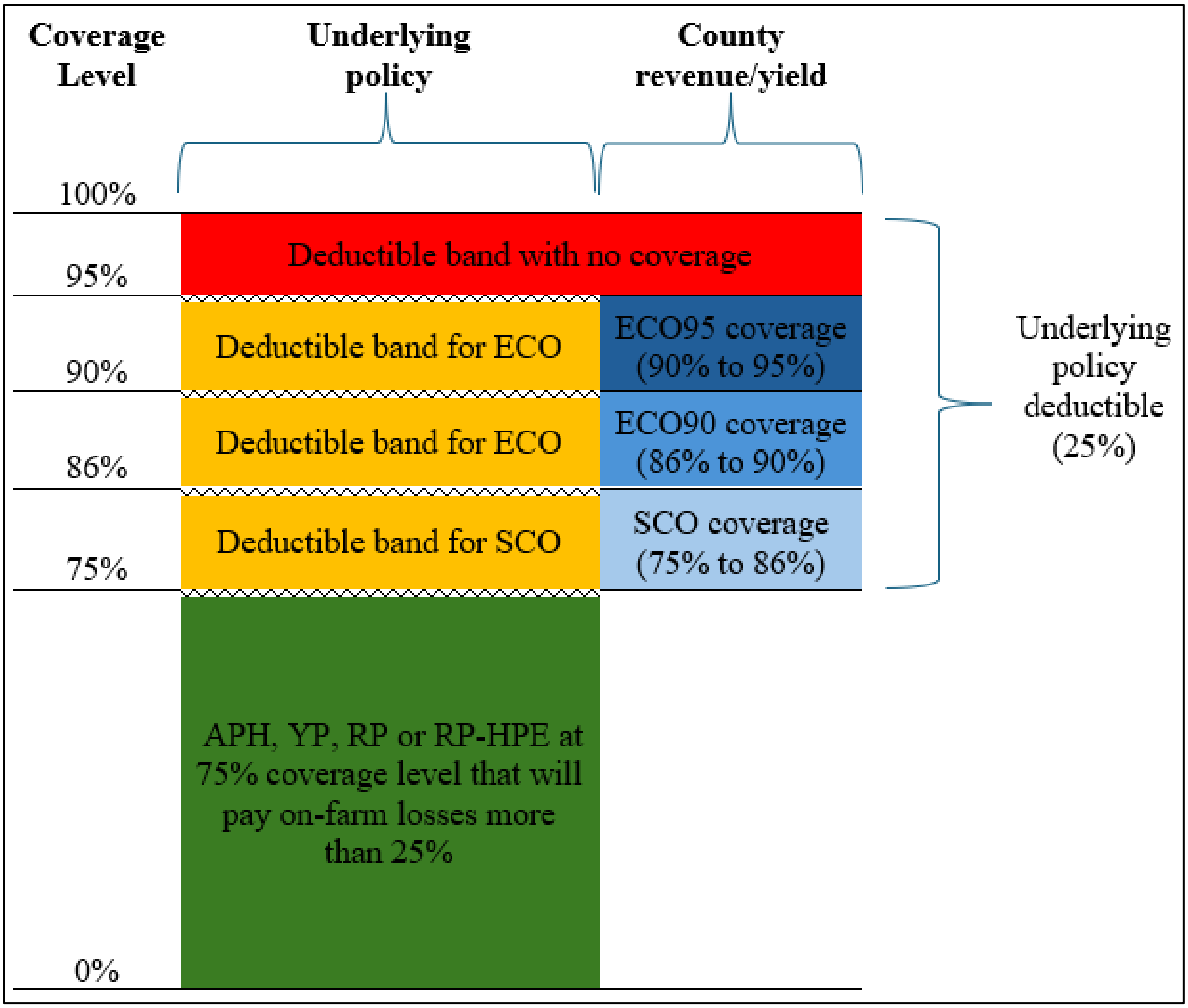


Figure 2: Supplemental coverage offering and adoption in the U.S. Federal Crop Insurance Program from 2015 to 2023

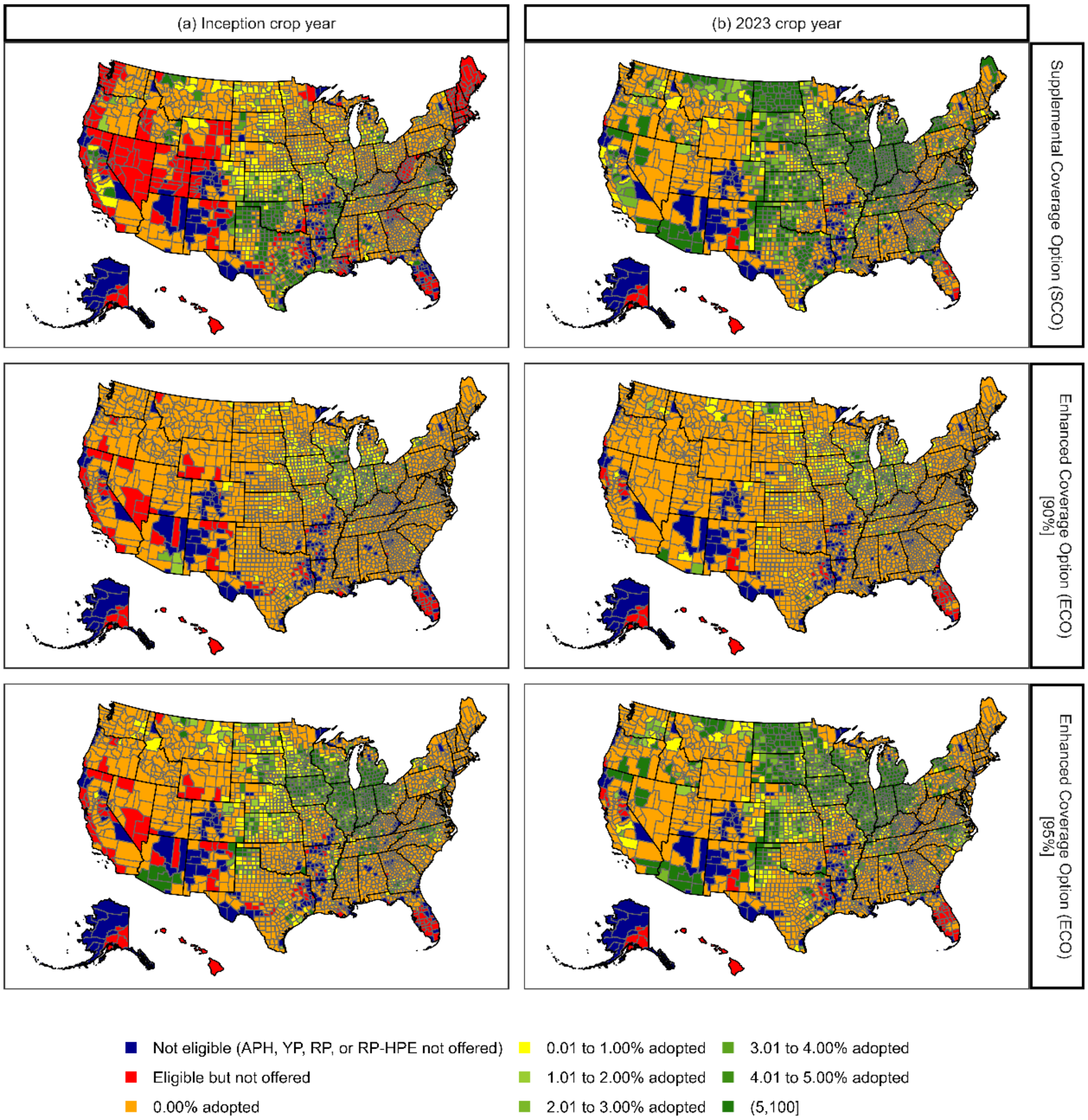


Figure 3: Supplemental coverage availability and usage by commodity from 2015 to 2023

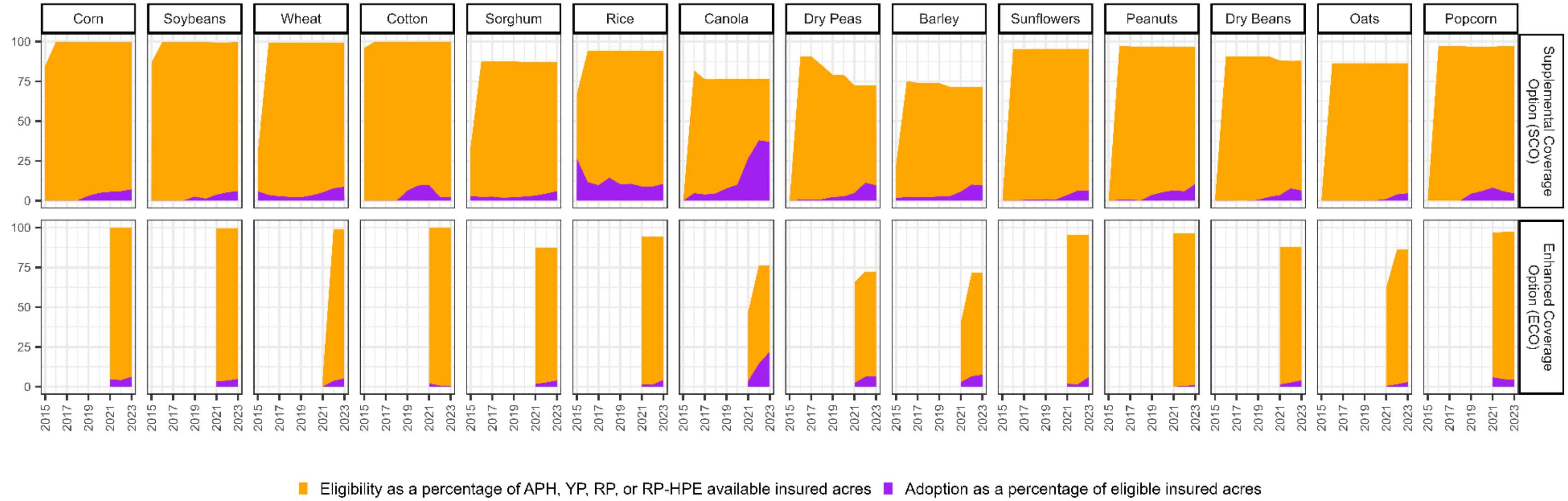


Figure 4: Impact of increased supplemental agricultural insurance coverage adoption by crop and basic policy characteristics from 2015 to 2023

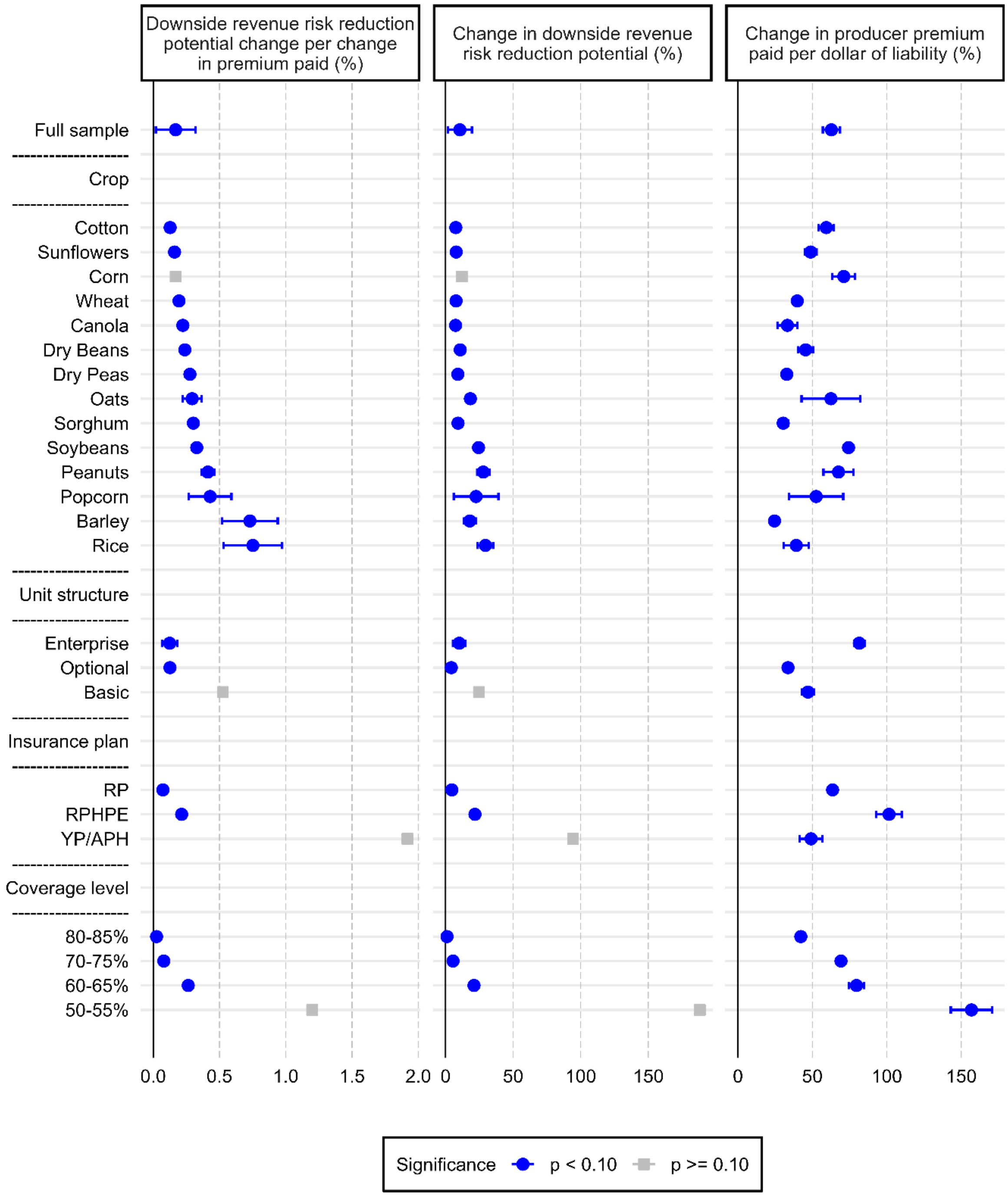
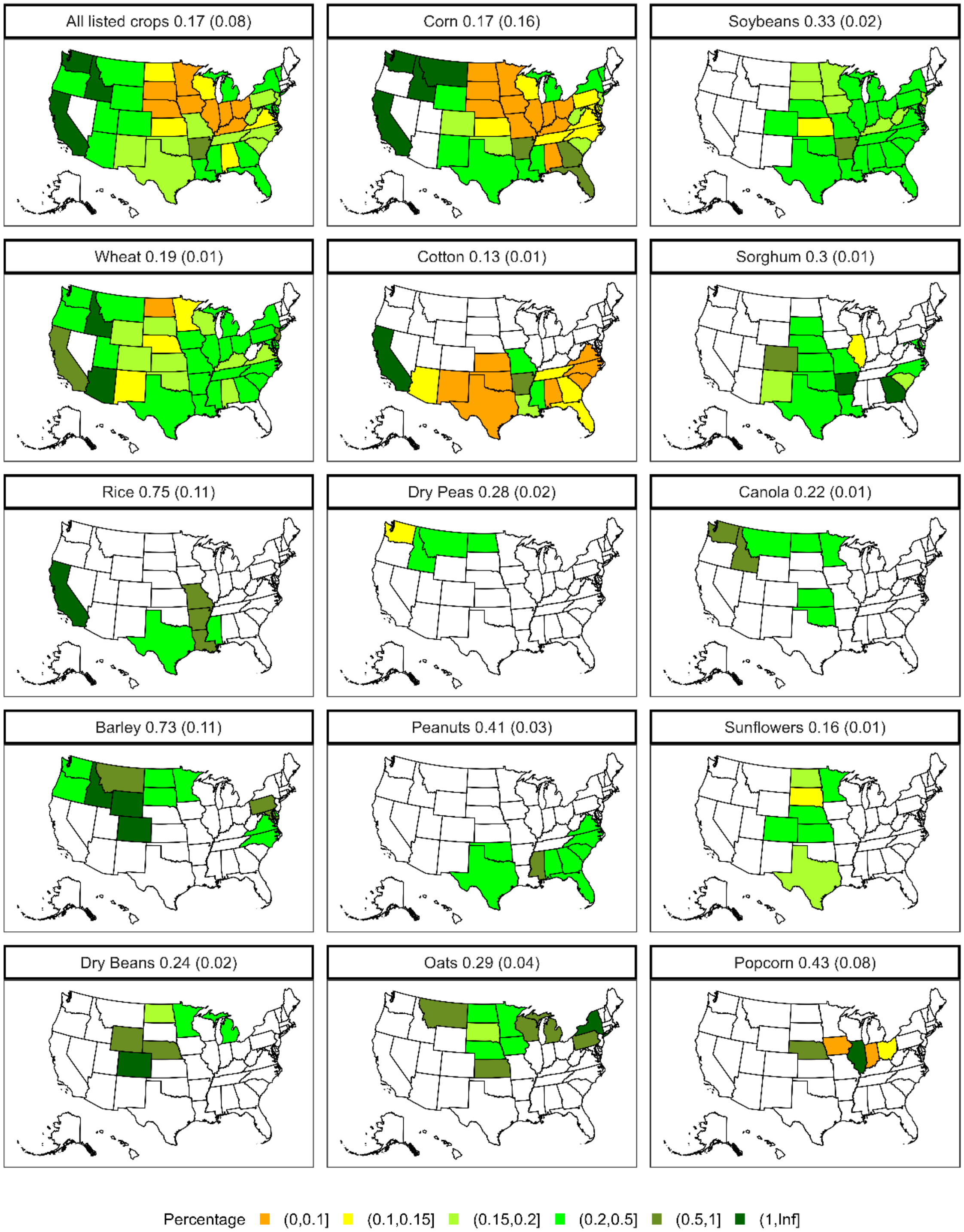


Figure 5: Downside revenue risk reduction potential change per change in premium paid (%) by state from 2015 to 2023



Appendix

Note S1: The Relationship between Yields, Premium Rates, and Indemnity Payments

The summary provided here draws heavily from detailed descriptions contained in (Tsiboe et al. 2024). The objective here is to provide a condensed summary of the relevant information from underlying stud, at a level of detail that will allow the reader to understand the calibration process. Given that objective, the structure, and wording of this note closely follows that of relevant section of the underlying document. To improve the readability of this chapter we do not repeatedly cite the document in the conventional manner. Therefore, this note is not represented as original work that does not draw heavily from another source.

For a particular commodity that has been chosen for cultivation, producers can protect expected crop yield ($\ddot{y}_t$) and expected price ($\bar{p}_t$) at a coverage level of θ_t via a crop insurance contract with a respective guarantee of $\theta_t \ddot{y}_t \bar{p}_t$. The majority of FCIP policies define the cost of crop insurance coverage as the product of the guarantee and a premium rate determined using an actuarial tool referred to as the continuous rating formula (CRF) (Milliman & Robertson 2000; Risk Management Agency [RMA] 2000; Risk Management Agency [RMA] 2009). The CRF is designed such that premium rates are tied to the risk profile of the producer, and is of the form:

$$\tau_t = \left[\alpha_t (\bar{y}_t / \bar{R}_t)^{\beta_t} + \delta_t\right] \vartheta(\theta_t) \rho(u_t) \tag{S1}$$

where α_t, δ_t, β_t, and $\bar{R}_t$ respectively represent the reference rate, catastrophic fixed loading factor, rating exponent, and the reference yield for the insurance pool the insured selects. The variable $\bar{y}_t$, also known as the rate yield, captures the risk inherent in the producer's historic production experience. The variable u_t is the insurance unit election for the policy which captures the level of risk aggregation of the producer which can broadly be either an optional unit (OU), basic unit (BU), or enterprise unit (EU). The continuous rating formula first adjusts the reference rate based on the rate multiplier curve expressed by $(\bar{y}_t / \bar{R}_t)^{\beta_t}$ which is decreasing in the relative productivity of the producer seeking insurance. The resulting initial rate represented by $\alpha_t (\bar{y}_t / \bar{R}_t)^{\beta_t} + \delta_t$ is then further adjusted based on the functions $\vartheta(\theta_t)$ and $\rho(u_t)$ which independently take on unique values based on the producer's coverage level and insurance unit elections to get the final premium rate (τ_t).

The methods being proposed by this study to calibrate yields are centered around the formular used for indemnification and the relationship between variables that enter the CRF and how they are related over sequential crop years. Although several broad types of insurance policies are available within the FCIP, for simplicity in demonstrating how the yields are calibrated, focus is given to individual-level yield protection policies meaning price is set equal to unity. However, with the appropriate adjustments to insurance outcomes, yield from revenue-based policies rated via CRF can also be calibrated.

Focusing on per acre outcomes in output terms, the framework recognizes that the end of season yield (y_t) for a given insured is:

$$y_t = \begin{cases} I_t > 0 & \theta_t \ddot{y}_t - I_t \\ I_t = 0 & \theta_t \ddot{y}_t + \Delta y_t \end{cases} \qquad \Delta y_t \geq 0 \tag{S2}$$

Where the yield guarantee ($\theta_t \ddot{y}_t$) for the insurance contract is given by the product of approved yield ($\ddot{y}_t$) and choice of coverage (θ_t). Equation (S2) shows that the end of season yield is centered around the yield guarantee such that for the case where an indemnity is paid ($I_t > 0$), the end of season yield equates to the guarantee minus the amount of the paid indemnity also in per acre terms. When no indemnities are paid ($I_t = 0$), Equation (S2) implies that the observed yield was greater or equal to the yield guarantee by some marginal yield (Δy_t). In what follows, a framework is presented for approximating the unknown marginal yield (Δy_t) by using the CRF and information from the current and previous crop years.

For any given crop year, the rate yield ($\bar{y}_t$) can be thought of as the one key variable in the continuous rating formula that holds all the historic yield information for the producer seeking insurance. Thus, year-to-year changes in the rate yield for a given insured can be attributed to the new information brought in by the most recent entry in the insured's APH. Since at this point the focus is to calibrate yields for non-indemnified contracts (indemnified contracts already indirectly reveal yield information via the size of the indemnity), the rate yield for the current crop year can be related to rate yield of the previous crop year and the observed yield as:

$$\bar{y}_t = (n_{t-1}\bar{y}_{t-1} - I[n_{t-1} = 10]y_o + y_t)/n_t =$$

$$(n_{t-1}\bar{y}_{t-1} - I[n_{t-1} = 10]y_o + \theta_t \ddot{y}_t + \Delta y_t)/n_t \tag{S3}$$

Where n_t is the number of observed yield entries in the APH used in calculating $\bar{y}_t$; $I[\cdot]$ is an indicator function if there are ten recorded yields in the APH; and y_o is the oldest entry in the APH. Equation (S3) indicates that if the previous and current years' APH is observed, and the number of years' worth of data that are being used to calculate the current APH is known (represented by n_t and n_{t-1}), then the yield for the current year can be precisely derived based on the change in APH from the previous year to the present. Essentially, Equation (S3) indicates that the problem of identifying current yield information is akin to solving for a single missing value when the mean and number of observations is known. For example, observing a set {2, 3,?} with a known mean of 3, it is easy to work out that the missing value is 4. Further, the non-missing observations in the set do not need to be observed individually. Rather, the sum of the non-missing observations is all that is needed to derive the missing observation if the total number of observations in the set is known. For Equation (S3), this means the values of n_t and n_{t-1} must be known to calibrate the current year's yield (y_t).

In practice, values for n_t and n_{t-1} are not publicly available for individual or insurance pool level observations meaning values for each need to be selected in a way that will minimize any resulting error in the derived yields. One method for doing this is to plug Equation (S3) into the continuous rating formula to create an optimization problem, defined by Equation (S4), that minimizes the squared difference between the observed premium per dollar of liability (i.e., total premiums divided by liability) for time t, ($\check{\tau}_t$), and the premium rate for time t as calculated directly using the continuous rating formula.

$$\min_{\Delta y_{t-1}, n_t, n_{t-1}} \left[\check{\tau}_t - \left(\alpha_t \left[\frac{n_{t-1}\bar{y}_{t-1} + \theta_{t-1}\ddot{y}_{t-1} + \Delta y_{t-1}}{n_t \bar{R}_t}\right]^{\beta_t} - \delta_t\right) \vartheta(\theta_t)\rho(u_t)\right]^2$$
(S4)

s.t: $n_{t-1} \in [2,10]$, $n_t \in [n_{t-1}, 10]$, $\Delta y_{t-1} \in [0, 2\ddot{y}_{t-1} - \theta_{t-1}\ddot{y}_{t-1}]$

In the optimization process, we explore all n_{t-1} and n_t combinations within their defined limits. n_{t-1} varies from 2 to 10, and n_t, always greater or equal to n_{t-1}, ranges from n_{t-1}'s current value to 10. For each insurance pool and n_{t-1}, n_t pair, we set Δy_{t-1}'s bounds based on the pool's approved yield ($\ddot{y}_t$) and chosen coverage level (θ_t), from a minimum of 0 to a maximum of $2\ddot{y}_{t-1}$ minus the guaranteed yield ($\theta_{t-1}\ddot{y}_{t-1}$). We then determine the Δy_{t-1} within this range that minimizes our optimization function (Equation [S4]) for the given n_{t-1}, n_t, and other parameters, recording the minimal function value and corresponding n_{t-1}, n_t, and Δy_{t-1}. We repeat this for all feasible n_{t-1}, n_t, and Δy_{t-1} combinations, retaining the set with the lowest function value as the optimal solution for each pool. The intuition behind this methodology is that by varying n_t and n_{t-1}, we can solve for the remaining variable, the marginal yield Δy_{t-1}. The optimal solution is the n_t, n_{t-1}, and Δy_{t-1} trio that yields a premium rate, via the CRF, closest to the premium per liability dollar observed. This strategy relies on the fact that year to year APH values tend to be very stable over time meaning the derived yields are not very sensitive to the choice of n_t, and n_{t-1}.

Putting everything together, the observed yield for the current crop year can be calculated as:

$$y_t = \begin{cases} I_t^y > 0 & \theta_t \ddot{y}_t - I_t^y \\ I_t^y = 0 & n_{t+1}\bar{R}_{t+1}\left[\frac{(\check{\tau}_{t+1}/\vartheta(\cdot)\rho(\cdot)) - \delta_{t+1}}{\alpha_{t+1}}\right]^{\frac{1}{\beta_{t+1}}} - n_t \bar{y}_t \end{cases} \quad \text{(S5)}$$

The underlying study validated this calibration method by applying the proposed procedure to a dataset for which actual yields are observed. They found the calibrated yields to be sufficiently accurate to replace observed yields and produce regression relationships that are comparable to those inherent in actual observed yields.

In the present study, we used the proposed procedure to calibrate yields for aggregate level crop insurance outcomes made available by RMA's summary of business aggregated by county, crop, crop type, production practice, insurance plan, coverage level, and insurance unit ("SOBTPU" for short). In the calibration we linked each SOBTPU entry to policy level continuous rating parameters and commodity prices also available from RMA's Actuarial Data Master (ADM). After this linkage, all but T_t was determined via several FCIP related actuarial relationships outlined in the underlying study.

The representative approved yield ($\ddot{y}_{i,t}$), rate yield ($\bar{y}_{i,t}$), and indemnity in yield terms (I_t^y) for a pool were calculated as

$$\ddot{y}_{i,t} = L_{i,t}\left[\theta_{i,t} \times A_{i,t} \times p_{i,t}\right]^{-1} \quad \text{(S6)}$$

$$\bar{y}_{i,t} = \min\left\{\bar{R}_{i,t}\left[\left(\tau_{i,t} - \delta_{i,t}\right)\frac{1}{\alpha_{i,t}}\right]^{\frac{1}{\beta_{i,t}}}, \ddot{y}_{i,t}\right\} \tag{S7}$$

$$I_{i,t}^{y} = I_{i,t}\left[A_{i,t} \times p_{i,t}\right]^{-1} \tag{S8}$$

where $A_{i,t}$, $I_{i,t}$, and $p_{i,t}$ are total insured acres, total indemnity, and projected price, respectively.

Applying the methods to the SOBTPU produced over two million historical insurance-pool-level yield observations, covering 68 different crops across the entire US farming sector for the period of 2011 to 2021. We use these calibrated yields in our counterfactual simulations.

Figure S1: Baseline percentage reduction in downside risk relative to no insurance from 2015 to 2023

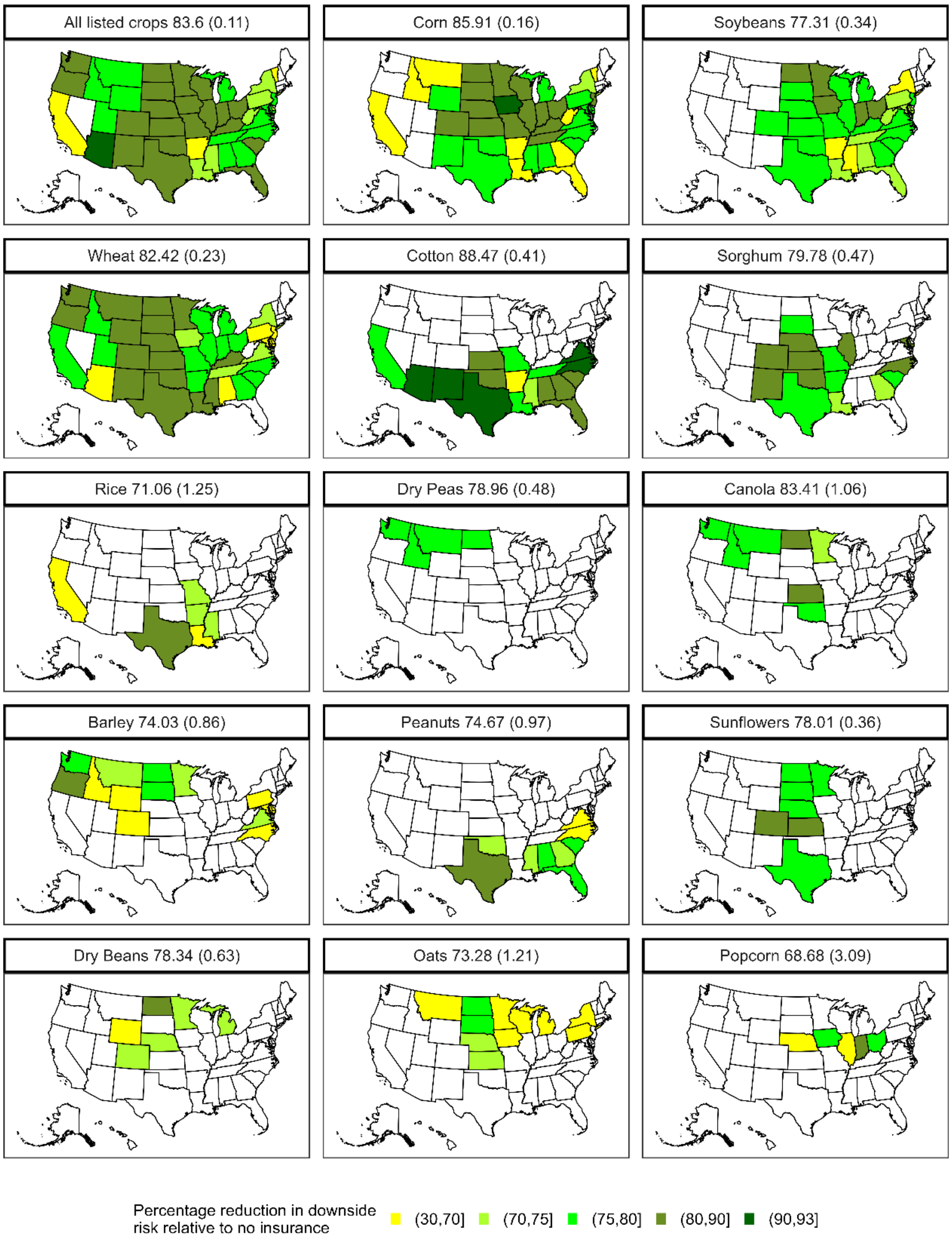


Figure S2: Baseline percentage increase in revenue relative to no insurance from 2015 to 2023

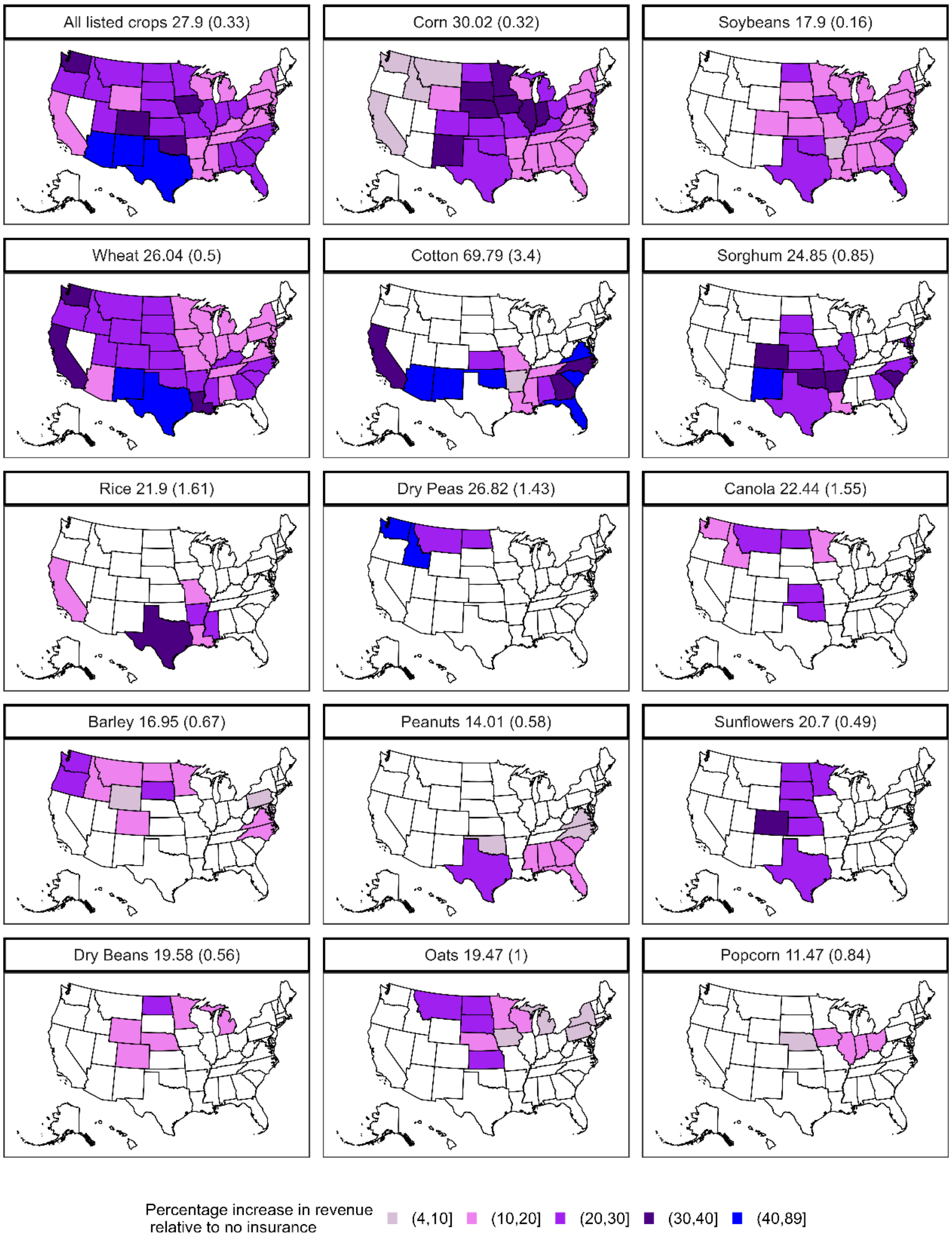


Figure S3: Baseline aggregate premium rate paid in cents from 2015 to 2023

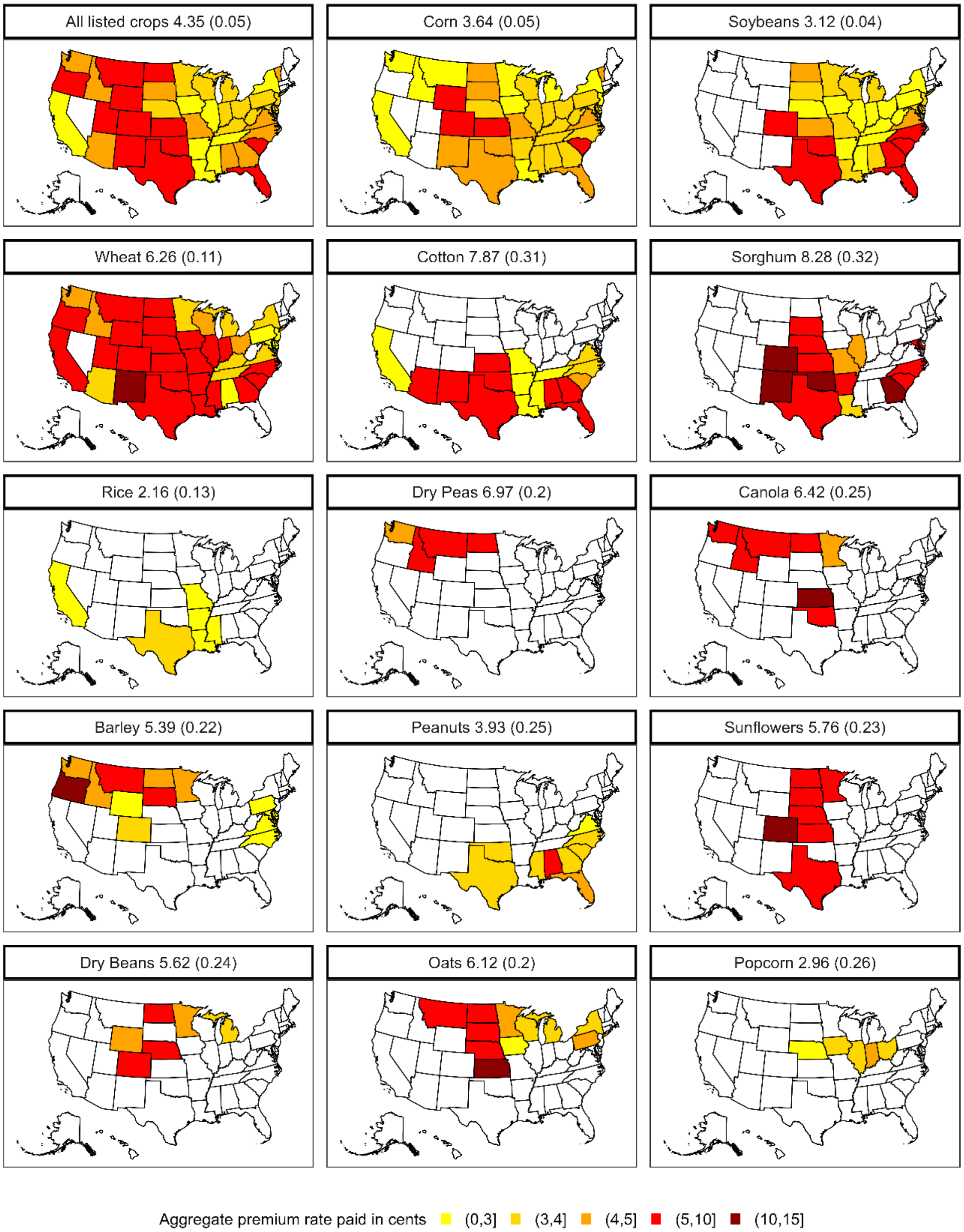


Figure S4: Impact of increased supplemental agricultural insurance coverage adoption by crop year

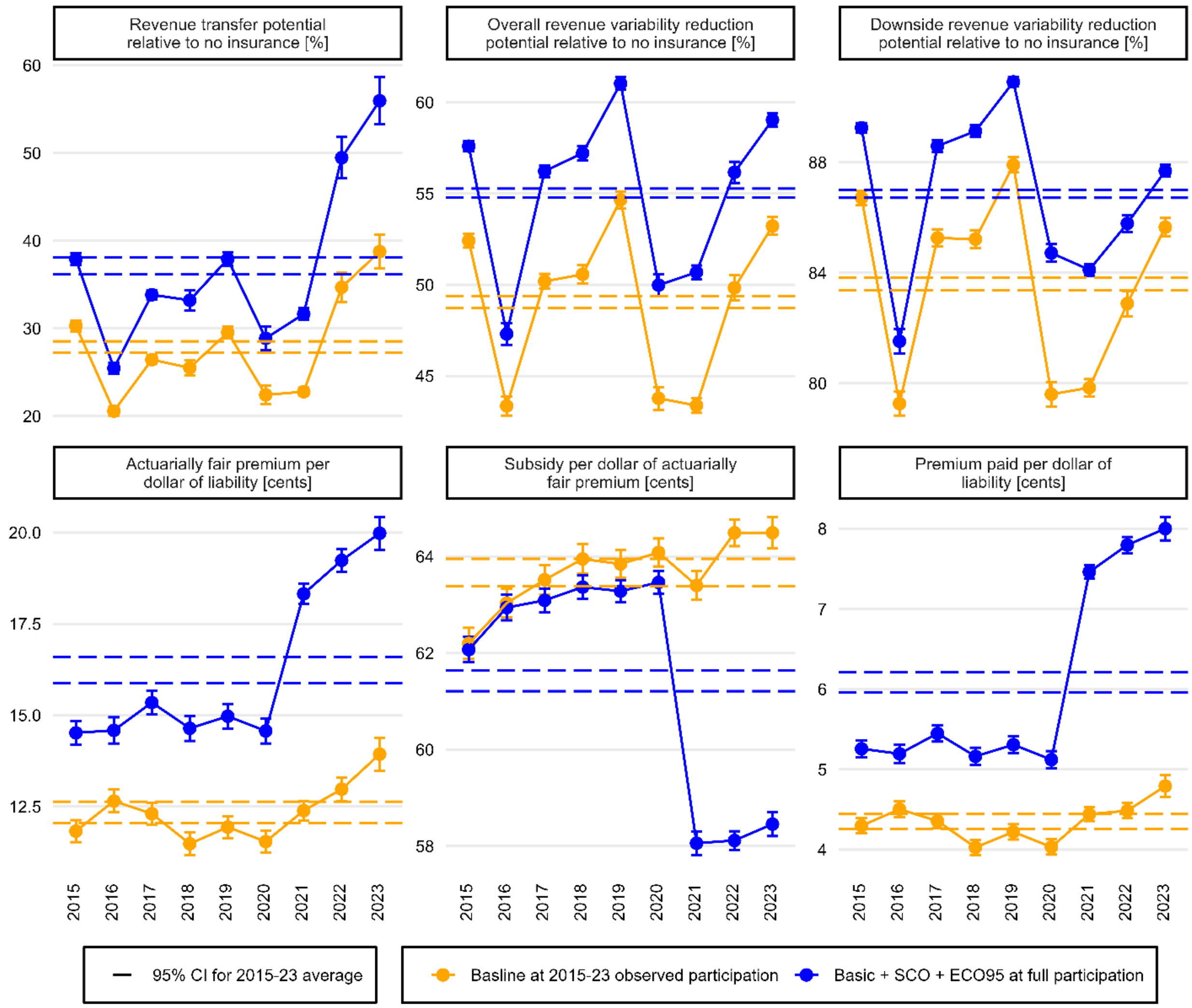


Figure S5: Income transfer potential impacts of increased supplemental and enhanced coverage adoption by state from 2015 to 2023

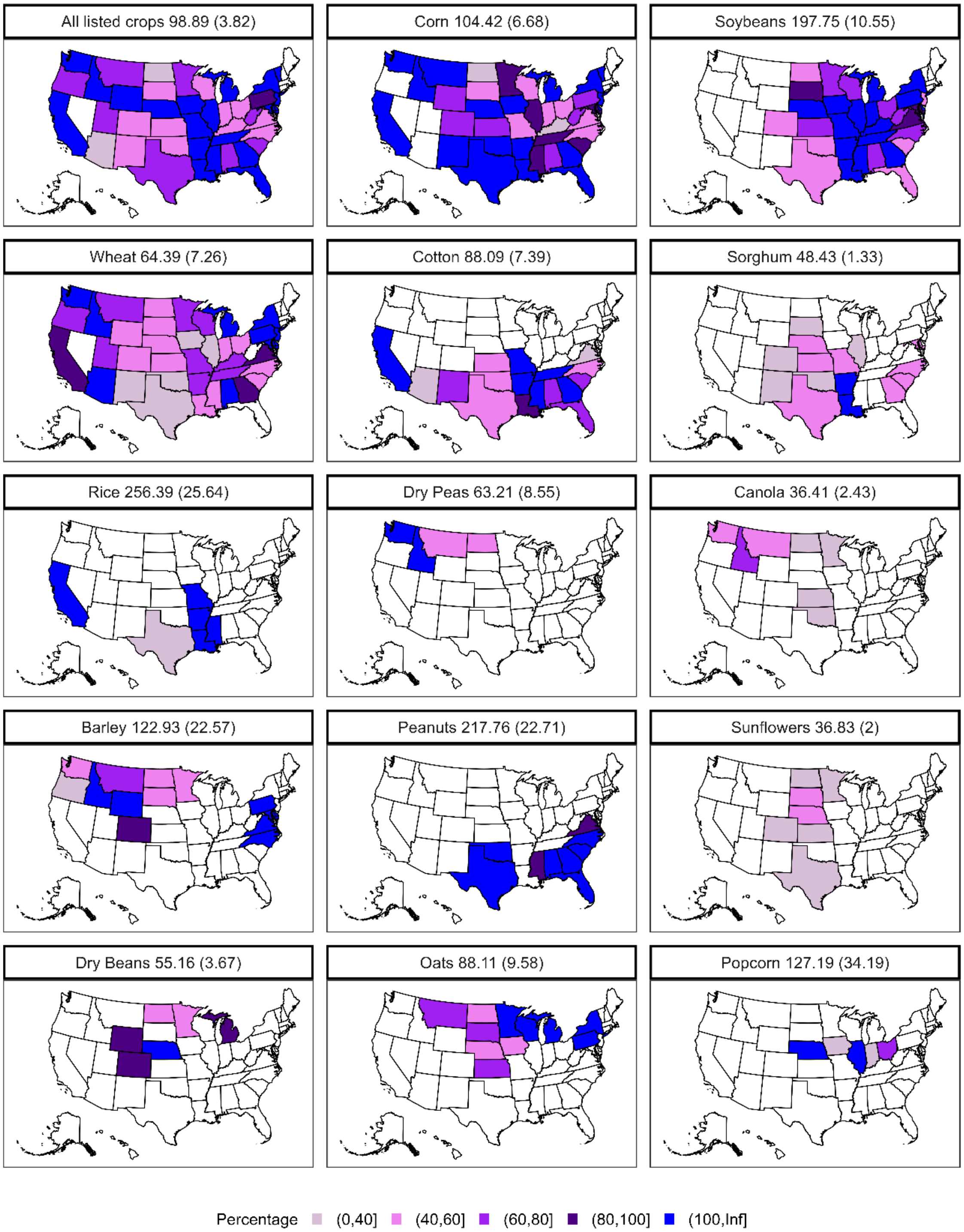


Figure S6: Farmer paid premium per dollar of liability impacts of increased supplemental and enhanced coverage adoption by state from 2015 to 2023

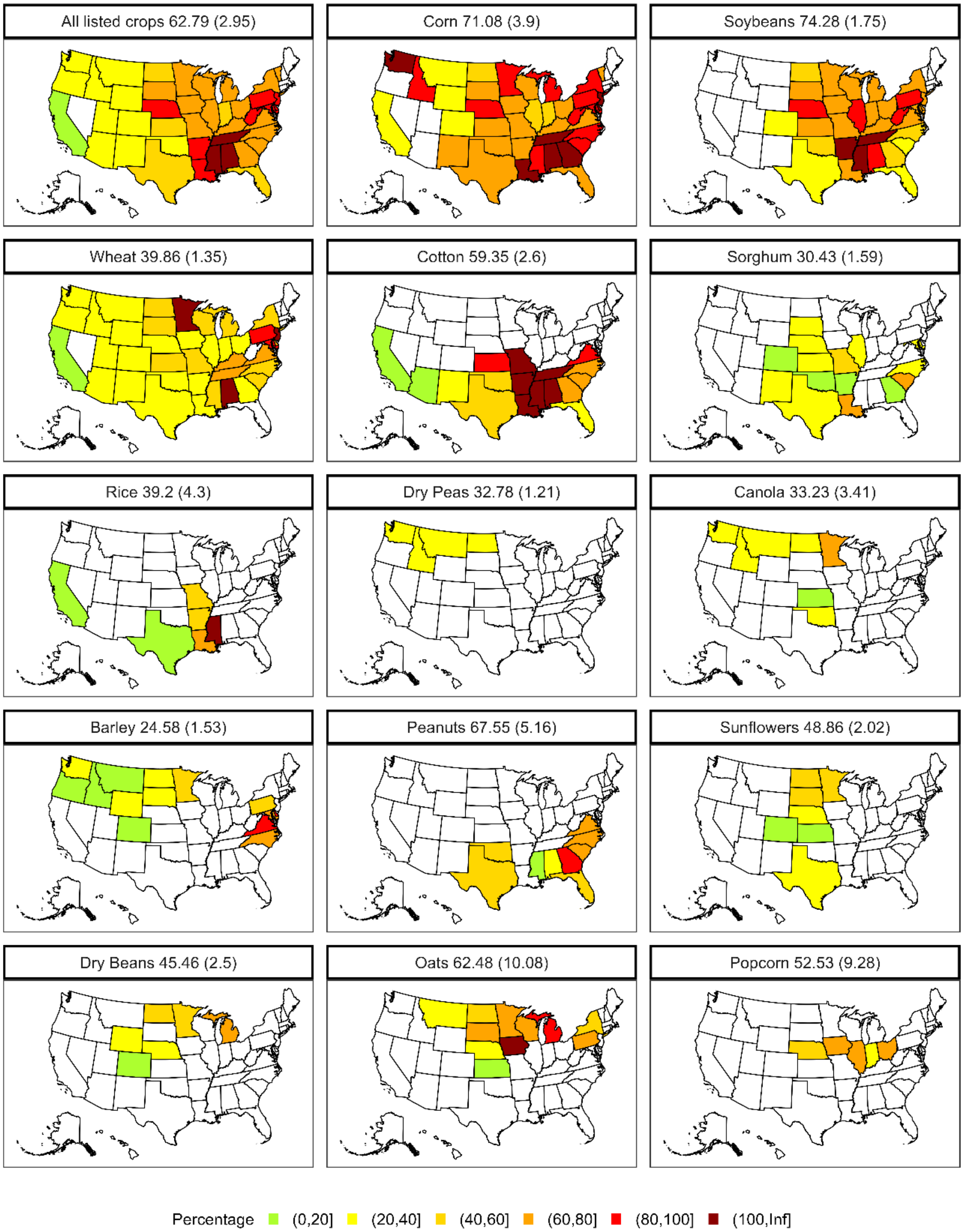


Table S1: Federal crop insurance program book of business for crops and counties with SCO/ECO availability from 2015 to 2023

Commodity	Total annual policies with premium (1,000)	Total annual units with premium (1,000)	Total annual net acres insured (1,000)	Total annual companion/ endorsed acres (1,000)	Total annual liability (million $)	Total annual premium (million $)	Total annual Subsidy (million $)	Total annual Indemnity (million $)	Cumulative loss ratio	Annual share of non-livestock liability (%)
Dry Peas	10.90 (1.80)	24.67 (5.64)	4008.88 (691.74)	219.21 (250.88)	762.85 (197.29)	138.76 (36.02)	87.06 (23.01)	169.04 (116.01)	1.22	98.30
Canola	13.66 (2.82)	30.15 (8.66)	3995.07 (528.50)	955.61 (1099.18)	1101.60 (526.15)	208.75 (95.64)	139.66 (64.37)	140.63 (102.08)	0.67	98.71
Barley	14.24 (1.83)	27.23 (4.51)	3761.56 (592.10)	230.45 (256.56)	849.20 (296.56)	109.31 (41.10)	69.81 (27.07)	88.40 (58.01)	0.81	97.34
Peanuts	15.73 (1.00)	47.57 (3.81)	2773.08 (238.21)	119.39 (112.22)	1675.06 (390.45)	155.57 (45.36)	94.09 (28.12)	194.92 (108.26)	1.25	90.72
Sunflowers	8.29 (1.15)	13.72 (2.15)	2665.03 (387.31)	95.89 (119.67)	670.11 (284.48)	127.73 (54.49)	89.62 (39.42)	79.12 (36.17)	0.62	99.38
Dry Beans	10.40 (1.09)	24.22 (3.06)	2449.16 (346.30)	84.95 (101.22)	1092.78 (260.64)	156.16 (40.24)	98.53 (26.45)	135.79 (82.61)	0.87	97.08
Pasture/Rangeland/Forage	6.47 (1.20)	12.98 (1.75)	1882.19 (223.32)	34.95 (47.68)	305.55 (76.37)	36.60 (11.85)	24.90 (6.89)	38.89 (18.37)	1.06	9.54
Sugar Beets	5.68 (0.15)	13.40 (0.39)	1020.07 (37.85)	8.45 (6.99)	1039.12 (174.81)	58.76 (12.66)	32.46 (7.16)	48.17 (51.69)	0.82	98.01
Oats	10.06 (0.68)	15.96 (1.39)	878.70 (86.52)	17.46 (26.72)	115.51 (44.67)	20.09 (7.89)	12.29 (5.19)	21.87 (13.43)	1.09	95.90
Almonds	4.36 (0.39)	7.55 (1.00)	860.90 (90.67)	6.06 (7.40)	2586.48 (533.57)	83.85 (26.13)	49.46 (15.70)	114.99 (146.08)	1.37	99.96
Sugarcane	0.68 (0.02)	4.33 (0.65)	753.76 (24.84)	10.00 (2.86)	359.98 (80.49)	6.57 (1.72)	4.60 (1.21)	5.69 (7.93)	0.87	85.18
Potatoes	1.42 (0.06)	4.62 (0.38)	654.17 (22.21)	17.35 (16.44)	1112.77 (257.87)	72.12 (9.27)	45.05 (5.33)	62.54 (23.27)	0.87	85.00
Grapes	5.09 (0.17)	17.41 (1.69)	546.83 (12.62)	1.14 (0.87)	1811.71 (347.19)	64.78 (21.15)	38.48 (10.86)	106.94 (101.72)	1.65	98.55
Millet	2.03 (0.29)	5.01 (0.87)	443.25 (103.67)	2.87 (3.88)	44.53 (25.65)	10.36 (6.16)	6.15 (3.64)	10.90 (12.21)	1.05	99.73
Popcorn	1.72 (0.08)	3.22 (0.17)	351.45 (23.37)	19.83 (19.29)	250.33 (68.33)	17.14 (4.65)	9.67 (2.80)	8.93 (6.24)	0.52	83.79
Flax	1.13 (0.26)	2.41 (0.60)	259.29 (60.68)	18.87 (25.59)	40.16 (11.93)	7.55 (3.07)	4.46 (1.81)	9.85 (6.66)	1.30	98.92
Tobacco	5.56 (0.71)	17.56 (1.81)	229.01 (49.80)	62.20 (46.79)	787.12 (121.65)	99.70 (7.12)	57.14 (3.99)	188.50 (59.49)	1.89	139.68
Tomatoes	0.52 (0.05)	2.56 (0.17)	231.50 (16.17)	11.48 (3.48)	633.96 (226.27)	13.95 (6.63)	7.72 (2.78)	16.06 (15.35)	1.15	97.92
Apples	2.19 (0.05)	7.19 (1.19)	213.69 (6.73)	3.54 (3.91)	1458.02 (304.40)	109.60 (16.54)	71.85 (9.35)	102.55 (35.26)	0.94	95.41
Sweet Corn	1.31 (0.15)	2.25 (0.13)	192.91 (4.36)	3.60 (3.43)	104.43 (24.86)	5.39 (1.56)	2.90 (0.85)	5.98 (1.03)	1.11	98.14
Walnuts	1.40 (0.07)	2.03 (0.21)	183.90 (23.02)	1.41 (0.81)	287.20 (44.59)	5.70 (1.06)	3.64 (0.68)	5.57 (4.67)	0.98	99.46
Oranges	1.59 (0.08)	3.22 (0.10)	125.05 (3.20)	0.41 (0.27)	353.18 (58.81)	20.72 (2.01)	12.95 (1.24)	9.36 (7.64)	0.45	44.94
Green Peas	1.02 (0.08)	1.62 (0.08)	119.89 (6.05)	1.52 (1.50)	63.82 (11.51)	8.16 (2.03)	4.43 (1.13)	9.78 (2.35)	1.20	97.73
Safflower	0.28 (0.03)	0.56 (0.03)	100.15 (7.76)	1.05 (1.46)	11.23 (1.79)	1.91 (0.38)	1.30 (0.27)	1.75 (0.84)	0.92	99.52
Mustard	0.19 (0.11)	0.43 (0.32)	77.77 (56.66)	11.63 (19.34)	16.10 (19.72)	4.24 (5.10)	2.53 (3.01)	5.90 (9.17)	1.39	84.18
Onions	0.49 (0.06)	1.49 (0.18)	80.79 (10.28)	5.42 (2.24)	185.99 (11.13)	30.83 (6.99)	19.65 (4.35)	26.71 (8.13)	0.87	85.64
Processing Beans	0.42 (0.02)	1.18 (0.07)	73.93 (3.43)	2.99 (2.74)	39.90 (4.30)	4.16 (0.59)	2.40 (0.32)	4.21 (0.90)	1.01	80.62
Blueberries	0.84 (0.08)	1.42 (0.28)	55.09 (4.52)	7.07 (4.99)	258.08 (70.79)	22.10 (9.42)	14.05 (5.62)	37.30 (18.46)	1.69	78.48
Rye	0.33 (0.12)	0.65 (0.28)	53.92 (22.11)	0.89 (2.25)	7.04 (4.49)	1.41 (1.06)	0.85 (0.63)	1.63 (1.73)	1.15	81.86
Mandarins/Tangerines	0.67 (0.08)	1.07 (0.16)	52.41 (5.87)	0.03 (0.04)	333.38 (46.86)	22.79 (1.19)	14.77 (0.91)	16.70 (19.97)	0.73	96.86
Sesame	0.22 (0.14)	0.51 (0.37)	39.26 (27.69)	0.03 (0.09)	5.06 (3.20)	1.49 (0.97)	0.91 (0.59)	1.78 (1.79)	1.19	78.76
Lemons	0.68 (0.03)	0.82 (0.05)	35.62 (2.70)	0.09 (0.01)	169.24 (33.73)	9.19 (1.15)	5.81 (0.77)	3.43 (3.09)	0.37	82.85
Prunes	0.45 (0.07)	0.60 (0.10)	34.97 (4.52)	0.90 (0.43)	85.32 (19.26)	19.28 (3.84)	11.83 (2.31)	17.07 (16.74)	0.89	100.00
Peaches	0.43 (0.02)	0.89 (0.07)	16.06 (0.86)	1.55 (1.58)	53.15 (11.62)	15.15 (3.94)	9.48 (2.38)	14.18 (10.17)	0.94	50.56
Cranberries	0.38 (0.00)	0.51 (0.00)	24.51 (0.00)	0.84 (0.00)	141.33 (0.00)	3.80 (0.00)	2.06 (0.00)	2.57 (0.00)	0.68	83.71
Buckwheat	0.05 (0.03)	0.16 (0.09)	10.87 (5.14)	0.98 (1.38)	2.20 (1.47)	0.49 (0.31)	0.30 (0.19)	0.42 (0.47)	0.86	77.24
Cucumbers	0.05 (0.00)	0.19 (0.02)	11.18 (0.82)	0.15 (0.18)	8.92 (1.19)	0.54 (0.07)	0.31 (0.04)	0.52 (0.18)	0.96	43.16
Cultivated Wild Rice	0.04 (0.00)	0.07 (0.01)	13.57 (1.52)	0.00 (0.00)	9.87 (3.40)	0.64 (0.21)	0.38 (0.13)	0.49 (0.32)	0.77	53.90
Mint	0.03 (0.01)	0.07 (0.01)	5.44 (0.67)	0.00 (0.00)	5.60 (1.20)	0.13 (0.04)	0.08 (0.02)	0.29 (0.29)	2.18	37.32
Pumpkins	0.11 (0.02)	0.18 (0.03)	8.67 (1.27)	0.02 (0.03)	6.53 (1.48)	0.63 (0.30)	0.32 (0.15)	0.65 (0.42)	1.03	98.66
Grapefruit	0.20 (0.01)	0.25 (0.01)	5.78 (0.53)	0.00 (0.00)	13.80 (3.51)	0.62 (0.20)	0.39 (0.12)	0.37 (0.34)	0.60	18.62
Tangelos	0.17 (0.02)	0.20 (0.02)	4.32 (0.68)	0.02 (0.03)	16.32 (1.95)	0.96 (0.25)	0.60 (0.16)	0.39 (0.43)	0.41	82.99

Table S2: Supplemental coverage availability and usage by commodity from 2015 to 2023

Commodity	Insured area in million acres	APH, YP, RP, or RP-HPE availability as a percentage of insured acres	Eligibility as a percentage of APH, YP, RP, or RP-HPE available insured acres		Adoption as a percentage of eligible insured acres	
			SCO	ECO	SCO	ECO
All Commodities	2,275.490	99.688	98.918	39.107	3.604	4.943
Corn*	795.774	99.994	99.958	41.136	3.296	5.727
Soybeans*	746.583	99.978	99.892	41.632	2.479	4.509
Wheat*	378.785	99.999	99.113	31.441	4.989	4.670
Cotton*	107.668	99.853	99.807	40.567	3.439	1.021
Rice*	24.041	100.000	99.713	42.577	14.054	9.087
Canola*	20.364	99.432	91.581	45.674	19.151	16.893
Dry Peas*	19.712	99.907	91.121	37.679	5.131	6.664
Barley*	17.413	99.912	98.647	39.105	5.005	6.746
Peanuts*	13.625	99.488	88.975	41.550	5.395	1.332
Sunflowers*	12.936	99.851	87.041	36.029	2.582	3.214
Dry Beans*	12.484	99.690	88.594	39.386	3.967	6.204
Oats*	4.211	99.918	87.848	41.923	1.929	2.406
Popcorn*	1.738	99.354	89.458	40.351	3.748	4.969
Sorghum*	50.035	99.967	99.066	43.360	3.524	2.968
Pasture	10.221	99.835	89.249	35.536	2.268	4.188
Sugar Beets	10.147	99.998	89.266	41.048	0.642	0.420
Almonds	6.172	100.000	92.764	0.000	1.354	0.000
Millet	4.212	99.963	91.712	48.486	0.842	0.188
Grapes	3.656	99.979	90.004	0.000	0.380	0.000
Potatoes	3.503	99.490	85.262	0.000	5.085	0.000
Sugarcane	2.699	99.962	95.911	43.730	3.315	0.000
Flax	2.615	99.934	83.615	32.391	5.942	6.160
Tobacco	2.302	99.905	86.950	32.720	20.369	18.344
Tomatoes	2.203	100.000	87.373	0.000	5.000	0.000
Sweet Corn	1.843	99.964	89.847	0.000	2.094	0.000
Apples	1.525	100.000	89.794	0.000	3.524	0.000
Oranges	1.262	90.931	74.007	0.000	0.351	0.000
Green Peas	1.157	99.660	89.224	0.000	1.594	0.000
Walnuts	0.905	100.000	95.100	0.000	1.660	0.000
Mustard	0.819	98.008	90.806	0.000	20.142	0.000
Processing Beans	0.772	99.979	81.237	0.000	4.717	0.000
Safflower	0.610	100.000	89.759	41.863	1.325	1.514
Rye	0.513	96.786	88.761	43.026	1.815	0.154
Onions	0.484	99.888	88.068	0.000	9.156	0.000
Sesame	0.470	99.229	74.759	23.503	0.074	0.000
Mandarins/Tangerines	0.389	92.806	91.062	0.000	0.077	0.000
Blueberries	0.340	99.949	93.794	0.000	13.690	0.000
Prunes	0.284	100.000	86.616	0.000	3.205	0.000
Lemons	0.272	91.573	90.487	0.000	0.298	0.000
Cranberries	0.206	100.000	21.133	0.000	2.828	0.000
Peaches	0.190	99.954	89.362	0.000	17.615	0.000
Cucumbers	0.172	100.000	53.319	0.000	1.612	0.000
Buckwheat	0.119	100.000	82.202	53.050	8.977	0.915
Pumpkins	0.084	100.000	90.796	0.000	0.207	0.000
Grapefruit	0.061	91.689	67.082	0.000	0.090	0.000

* Indicates commodities in the simulations

Table S3: Summary statistics of study data for minor crops from 2015 to 2023

	Canola counties with SCO/ECO availability	**Dry Peas counties with SCO/ECO availability**	**Barley counties with SCO/ECO availability**	**Sunflowers counties with SCO/ECO availability**
Output unit	Pound	Pound	Bushel	Pound
Basic policy unit structure [mode]	EU/WU	OU	OU	EU/WU
Basic policy insurance plan [mode]	RP	RP	YP	RP
Basic policy average coverage level	0.72 (0.05)	0.71 (0.07)	0.73 (0.06)	0.71 (0.05)
Basic policy net insured area (1,000 acres)	2.38 (7.02)	1.26 (2.21)	0.75 (1.60)	1.21 (2.55)
Basic policy liability ($/acre)	227.68 (159.43)	194.74 (134.08)	238.81 (420.69)	227.16 (167.78)
Basic policy premium per dollar of liability	0.19 (0.08)	0.17 (0.08)	0.15 (0.08)	0.21 (0.09)
Basic policy subsidy per dollar of premium	0.63 (0.11)	0.62 (0.11)	0.63 (0.11)	0.65 (0.10)
SCO adoption rate (% of net insured area)	6.15 (17.37)	2.69 (12.47)	1.58 (9.16)	1.96 (10.44)
ECO90 adoption rate (% of net insured area)	0.10 (0.79)	0.01 (0.48)	0.02 (0.31)	0.01 (0.20)
ECO95 adoption rate (% of net insured area)	2.41 (8.84)	1.15 (6.45)	0.85 (5.59)	0.88 (5.56)
Projected price ($/output unit)	0.20 (0.05)	0.20 (0.08)	5.28 (1.40)	0.27 (0.08)
Calibrated approved yield (output unit/acre)	1501.90 (441.84)	1521.46 (565.15)	70.49 (66.94)	1399.79 (409.21)
Calibrated rate yield (output unit/acre)	1287.60 (462.02)	1199.79 (680.56)	57.58 (27.00)	1195.97 (475.64)
Calibrated final yield (output unit/acre)	1334.83 (748.38)	1301.55 (866.47)	65.09 (63.36)	1274.73 (765.99)
Number of agents	6,281	10,314	17,174	7,288
Liability shares of crop/county with SCO/ECO (%)	45.29	41.82	42.07	42.30
	Peanuts counties with SCO/ECO availability	**Dry Beans counties with SCO/ECO availability**	**Oats counties with SCO/ECO availability**	**Popcorn counties with SCO/ECO availability**
Output unit	Pound	Pound	Bushel	Pound
Basic policy unit structure [mode]	OU	OU	EU/WU	OU
Basic policy insurance plan [mode]	YP	RP	RP	RP
Basic policy average coverage level	0.69 (0.07)	0.72 (0.05)	0.70 (0.08)	0.75 (0.08)
Basic policy net insured area (1,000 acres)	0.43 (0.68)	0.82 (1.68)	0.19 (0.42)	0.41 (0.67)
Basic policy liability ($/acre)	618.59 (778.79)	471.24 (249.15)	221.47 (136.71)	682.70 (290.10)
Basic policy premium per dollar of liability	0.09 (0.06)	0.14 (0.08)	0.16 (0.09)	0.07 (0.04)
Basic policy subsidy per dollar of premium	0.63 (0.09)	0.63 (0.10)	0.62 (0.11)	0.57 (0.11)
SCO adoption rate (% of net insured area)	3.06 (13.25)	1.71 (9.40)	1.64 (10.18)	2.13 (11.77)
ECO90 adoption rate (% of net insured area)	0.00 (0.00)	0.08 (2.04)	0.08 (2.58)	0.28 (3.92)
ECO95 adoption rate (% of net insured area)	0.11 (2.13)	0.74 (4.42)	1.14 (6.28)	1.10 (7.63)
Projected price ($/output unit)	0.22 (0.03)	0.35 (0.07)	5.57 (0.01)	0.22 (0.04)
Calibrated approved yield (output unit/acre)	3801.77 (945.66)	1985.45 (492.92)	77.20 (24.52)	4608.64 (945.04)
Calibrated rate yield (output unit/acre)	3408.75 (999.77)	1706.39 (616.55)	72.35 (24.57)	3937.21 (1342.73)
Calibrated final yield (output unit/acre)	3456.38 (2039.93)	1894.29 (1055.82)	79.70 (52.37)	4878.23 (2200.99)
Number of agents	18,029	7,048	1,519	2,260
Liability shares of crop/county with SCO/ECO (%)	35.95	29.09	7.10	32.48

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

Table S4: Impact of increased supplemental agricultural insurance coverage adoption from 2015 to 2023

	Baseline scenario	Alternative scenarios of full participation of specified combination at current subsidy and coverage levels					
		Basic only	Basic + SCO	Basic + ECO90	Basic + ECO95	Basic + SCO + ECO90	Basic + SCO + ECO95
		Expressed percentage changes over baseline					
Revenue transfer potential relative to no insurance (%)	32.082*** (0.587)	-2.630*** (0.077)	65.941*** (3.376)	13.864*** (0.758)	33.010*** (1.613)	81.779*** (4.052)	100.522*** (5.205)
Overall risk reduction potential relative to no insurance (%)	48.815*** (0.199)	-1.343*** (0.043)	18.948*** (0.397)	4.819*** (0.096)	11.371*** (0.197)	22.714*** (0.451)	26.741*** (0.537)
Relative downside risk reduction potential relative to no insurance (%)	82.795*** (0.139)	-0.513*** (0.016)	7.011*** (0.308)	1.978*** (0.113)	4.296*** (0.259)	7.796*** (0.397)	8.329*** (0.514)
Absolute downside risk reduction potential relative to no insurance (%)	80.162*** (0.149)	-0.582*** (0.018)	7.764*** (0.295)	2.185*** (0.103)	4.775*** (0.236)	8.687*** (0.366)	9.394*** (0.479)
Actuarially fair premium per dollar of liability (cents)	13.100*** (0.166)	-3.901*** (0.102)	23.626*** (0.254)	17.246*** (0.246)	48.571*** (0.662)	40.828*** (0.409)	67.086*** (0.739)
Premium subsidy rate (%)	64.131*** (0.142)	0.773*** (0.024)	0.429*** (0.108)	-5.539*** (0.097)	-10.828*** (0.214)	-3.943*** (0.115)	-8.368*** (0.210)
Premium paid per dollar of liability (cents)	4.573*** (0.052)	-5.818*** (0.140)	28.455*** (0.570)	34.185*** (0.411)	91.658*** (1.037)	61.217*** (0.603)	109.499*** (1.116)
		Risk reduction potential change per change in in premium paid (%)					
Overall risk	-	0.231*** (0.006)	0.666*** (0.015)	0.141*** (0.002)	0.124*** (0.002)	0.371*** (0.007)	0.244*** (0.005)
Relative downside	-	0.088*** (0.003)	0.246*** (0.011)	0.058*** (0.003)	0.047*** (0.003)	0.127*** (0.007)	0.076*** (0.005)
Absolute downside	-	0.100*** (0.003)	0.273*** (0.010)	0.064*** (0.003)	0.052*** (0.003)	0.142*** (0.006)	0.086*** (0.005)

Source: Simulated by authors using data from USDA, RMA