Actuarial Updates Cut Taxpayer Cost in Subsidized Agricultural Insurance Programs

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Abstract

The substantial fiscal commitment of government-subsidized agricultural insurance highlights its critical role in supporting farmers, yet it also reveals the program's financial vulnerability amid debates over fiscal cuts aimed at easing pressure on the public purse. Central to these debates is the need for actuarially sound premium rates. This study, which analyzes more than three million observations across 49 commodities from 2001 to 2024 in the United States context, examines how innovations in ratemaking affect taxpayer obligations. The findings indicate that updating the parameters used to calculate crop insurance costs for farmers can significantly reduce taxpayer expenses. Updating all the ratemaking parameters together saves about 6% annually, however, targeting just one component—such as the reference yields—can yield annual savings of up to 14%. Although most states benefit from these updates, precise ratemaking falls short in a few cases. Overall, the results highlight the complexities of setting premium rates that are both actuarially and fiscally sound, suggesting that smarter, targeted updates could improve the efficiency of the program and alleviate the financial burden on taxpayers.

Keywords: crop insurance; premium rate; subsidies; actuarial science; fiscal responsibility; cost cuts, taxpayer savings

JEL codes: Q14, Q17, Q18, G22, H72

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1. Introduction

Agricultural producers have sought ways to manage risk and reduce volatility inherent in their operations, however, many supplement their private risk management action with government-subsidized programs such as agricultural insurance (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).[1] These programs also promote and sustain agricultural productivity, rural development (Azzam, Walters and Kaus 2021; Lee 2021), and food security (Savary et al. 2012; Lusk 2017). Collectively, these benefits contribute to overall macroeconomic stability. While the substantial fiscal commitment of government-subsidized agricultural insurance (Joseph Glauber et al. 2021; Mahul and Stutley 2010; U.S. Government Accountability Office [U.S. GAO] 2023; United States Government Accountability Office [GAO] 2014) emphasizes its crucial function in backing farmers, it also spotlights its financial vulnerability amid discussions in both political and academic circles. These perennial discussions focuses on the possibility of achieving cost savings by reducing the subsidies that support such programs (Congressional Budget Office [CBO] 2017; Lusk 2017; Hackett 2023; Melear and Theodorou 2023; Government Accountability Office 2023). However, cutting back on subsidies potentially leads to lower participation rates among producers (Congressional Budget Office [CBO] 2017), underscoring the delicate balance between cost management and maintaining farmer support.

[1] As of 2007, about half of all countries had some sort of agricultural insurance (Mahul and Stutley 2010).

One of the longest-standing and largest government subsidized agricultural insurance is the U.S. Federal Crop Insurance Program (FCIP) (Baldwin, Williams, Tsiboe, et al. 2023; Baldwin, Williams, Sichko, et al. 2023; Turner and Tsiboe 2022; Turner et al. 2023; Baldwin, Turner and Tsiboe 2024). Since its inception in the 1930s, the FCIP has grown to insure approximately 540 million acres and $208 billion in production value across over 140 commodities as of the 2023 crop year.[2] Through this program, the U.S Federal Government subsidized 61% [$10.43 billion] of the insurance premiums for producers annually from 2001 to 2023 and allocated over $1.85 billion each year to Approved Insurance Providers (AIPs) through a public-private partnership, ensuring the program's delivery to agricultural producers. The net total cost (i.e., taxpayer obligations) of the FCIP averaged $9.10 billion annually during this period, with an annual real growth rate of 8%.

Central to the fiscal integrity of government subsidized agricultural insurance is the necessity of establishing premiums that are actuarially sound. Actuarially sound premiums must align closely with the true risk of crop loss, reflected in a loss ratio (LR), the quotient of indemnities to premiums, of exactly 1.0, ensuring that premiums are neither overpriced nor insufficient. In the U.S. context, the Federal Crop Insurance Act, particularly under Section 508(d), mandates that the Risk Management Agency (RMA), which oversees the FCIP, not only sets premiums to cover expected indemnities but also incorporates a reasonable disaster reserve into the rating systems to manage unforeseen large-scale losses. This dual requirement underscores the RMA's role in balancing financial sustainability with risk management, ensuring the program's ability to respond to both typical and catastrophic agricultural risks.

[2] All dollars are in 2023 real terms.

This study aims to evaluate how actuarial innovations—specifically, annual updates to agricultural insurance rating parameters—contribute to the program's fiscal integrity. Focusing on the FCIP, the research employs a counterfactual simulation approach to estimate what loss outcomes would have been if the rating parameters had not been updated in a given crop year. In this method, the impacts of these innovations are determined by comparing the hypothetical outcomes under a "no update" scenario with the actual outcomes observed after the updates. A key element of the simulation is a "roll-back" approach, where the current year's actuarial data is replaced with that of the previous year and premiums are recalculated based on the actual loss outcomes. This technique, combined with adjustments in crop insurance demand that respond to changes in premium rates, captures not only the static fiscal impacts but also the dynamic behavior of market participants. The simulation was retrospectively applied to the RMA's summary of business and actuarial data master from 2001 to 2024.

The results show that updating rating parameters reduced the FCIP's financial burden on taxpayers by about 6% each year from 2002 to 2024 from a baseline of $7.57 billion. This means that by pricing insurance products in an actuarial sound manner, the program is nudged closer to fiscal soundness. When targeted changes to specific components of the actuarial data master are considered, even larger savings are possible. For example, updating only the reference rate, fixed rate, rating exponent, or reference yield results in cost reductions of 8%, 10%, 11%, and 14%, respectively. Although most years showed consistent cost reductions, there were exceptions in 2002, 2012, and 2024, when these actuarial updates did not fully relieve the fiscal burden. At the state level, the savings varied according to each state's agricultural setting, risk, and the size of its crop insurance footprint. States with larger areas enrolled in the program, like Illinois, Iowa, Indiana, Minnesota, and Missouri, generally have more data to set rates accurately, leading to better savings. In contrast, states with smaller or more volatile agricultural settings, such as Alaska and New Hampshire, did not experience significant cost reductions from these updates, while a few states, including Florida, Texas, and Vermont, even showed modest positive net costs.

This study makes three key contributions worth highlighting. First, the study advances FCIP ratemaking literature by offering new insights into actuarial updates (mainly driven by the inflow of new information) an often-overlooked area. Extensive research has explored various strategies to enhance the actuarial performance of the FCIP including reform to its ratemaking methodology (Park, Brorsen and Harri 2019; Goodwin and Hungerford 2015; Woodard, Sherrick and Schnitkey 2011; Ramirez, Carpio and Rejesus 2011; Skees and Reed 1986; Goodwin 1994; Carriquiry, Babcock and Hart 2008), technology-induced yield trends (Adhikari, Knight and Belasco 2012; Seo et al. 2017), heteroscedastic yields (Harri et al. 2011; Annan et al. 2014), and the accommodation of extra sources of information (soil and weather) to improve rates (Tsiboe and Tack 2022; Woodard and Verteramo-Chiu 2017; Liu and Ramsey 2023; Rejesus et al. 2015). Yet, how these modifications translate to improve the fiscal integrity of the FCIP's remains largely unaddressed. This study enhances the understanding of this linkage by using a simple but robust method that utilizes the timing of lagged rating adjustments, informed by historical loss experiences. This approach effectively highlights the directional impact of these adjustments on the fiscal landscape of the FCIP. The methodology not only broadens the comprehension of these matters but also emphasizes the critical importance of rating adjustments vis-à-vis the proposed overhaul of the current FCIP ratemaking methods.

Secondly, government publications on the costs of the FCIP range from very simple to highly complex, often leading to misunderstandings about key cost components. For instance, payments made to AIPs—the companies responsible for delivering the program—are frequently misinterpreted, as are items related to how underwriting gains and losses are shared between the government and the companies. In many cases, the government's share of underwriting gains and losses is scarcely presented, compounding confusion. Such ambiguities can lead to misconceptions regarding the overall costs and benefits of the program for producers, taxpayers, and the companies involved. This paper helps alleviate some of this confusion by providing consolidated, intuitive descriptions of the key fiscal elements of the FCIP, thereby offering a more complete and transparent understanding of its fiscal landscape.

Finally, this study leverages granular data, breaking down observations into insurance pools within each county to minimize aggregation bias and ensure similar units are analyzed together. It expands on previous research by including a diverse set of 49 commodities and seven insurance plans, covering approximately 82% of the FCIP's liability and 71% of the acreage insured from 2001-2024. This detailed approach enhances the understanding of actuarial adjustments and the complex interdependence influencing policy in the FCIP.

The remainder of the paper is structured as follows. Section 2 provides background information for understanding the linkage between actuarial adjustments and the FCIP's fiscal landscape over the study period. Section 3 detail the construction of data and variables used in the analyses. Section 4 describes the simulation methodology employed to estimate the impacts of rate updates. Following this, Section 5 presents the results and discusses the heterogeneity in outcomes with Section 6 providing the conclusions.

2. Fiscal Landscape and Actuarial Updates in US Agricultural Insurance

2.1 FCIP overview and background

The Federal Crop Insurance Program (FCIP) provides risk management for most U.S. crops, protecting against financial losses from adverse conditions. Created in 1938 in response to the Great Depression and a struggling private insurance market, it initially covered only wheat. After soaring disaster payments and low participation in the 1970s, Congress passed the Federal Crop Insurance Act of 1980 to expand coverage, introduce premium subsidies, and involve private insurers. Subsequent legislation further broadened options, boosted subsidies, and integrated the FCIP with other USDA programs, firmly establishing it as a cornerstone in the U.S. agricultural farm safety net.

The government entities in the FCIP's public-private partnership are USDA's Federal Crop Insurance Corporation (FCIC) and the Risk Management Agency (RMA); private entities are Approved Insurance Providers (AIPs) (see Figure 1).[3] The FCIP is governed by the FCIC Board and managed by RMA, offering innovative crop insurance for multiple perils. AIPs sell and service FCIC-approved policies nationwide, while RMA approves products, sets premium rates, subsidizes farmers' premiums, covers AIPs' Administrative & Operating (A&O) costs, and reinsures catastrophic losses. Additionally, FCIC reinsures publicly delivered crop insurance in Puerto Rico through the Corporación de Seguros Agrícolas, ensuring comprehensive coverage for America's producers.

[3] Of the 13 RMA-designated insurers in 2022, six with U.S.-domiciled parent companies accounted for 28% ($1.0 billion), and seven with foreign-domiciled parents in Australia, Bermuda, Canada, Japan, and Switzerland, accounted for 72% ($2.7 billion) of total A&O subsidies and underwriting gains.

The RMA administers the program through the standard reinsurance agreement (SRA) and the livestock price reinsurance agreement, setting terms for policy servicing, A&O subsidies, and underwriting gains/losses. The current SRA was last renegotiated in 2010, and the current livestock agreement was last renegotiated in 2002.

2.2 FCIP fiscal landscape

Unlike many farm programs, the FCIP is permanently authorized under the Federal Crop Insurance Act (7 U.S.C. §1501 et seq.), which provides "such funds as are necessary" for administrative and operating costs, premium subsidies, and related uses. In contrast, RMA resources and employee renumerations relies on discretionary funding through annual appropriations, which averaged about $75 million per year from 2001 to 2024 with a 1.35% annual growth rate during the same period (see Table S1 in the online appendix). External program funding may come from three main sources: (1) producer-paid premiums, (2) producer-paid Catastrophic coverage (CAT) fees, and (3) underwriting losses assigned to AIPs. For cost, this study categorizes program costs into: (1) premium subsidies provided directly to producers, (2) total indemnities fronted by FCIC, (3) program delivery costs, and (4) underwriting gains allocated to AIPs.

Subsidies

The federal crop insurance program features three primary subsidies: producer premium subsidies, A&O and Catastrophic Loss Adjustment Expense (CAT LAE) payments to AIPs, and shared underwriting risk with AIPs. Table 1 provides an overview of total premiums (column 2) and producer premium subsidies (column 3) from 2001 to 2023. Congress has raised premium subsidy rates several times—most notably in 1980, 1994, 1998, 1999, and 2000. Generally, subsidy rates decrease as coverage levels increase, except for supplemental policies with static premium subsidy rates. As shown in Table S2, yield and revenue policies with higher coverage levels have subsidy rates between 37 and 80 percent, while CAT remains fully subsidized (100 percent). From 2001 through 2023, premium subsidies totaled $169.66 billion in 2023-adjusted dollars — an average of roughly $7.38 billion per year — and in 2023 alone, these subsidies totaled around $11.75 billion. These premium subsidies, which have historically been the primary policy tool to increase program participation (Tsiboe and Turner 2023; Coble and Barnett 2013; Just, Calvin and Quiggin 1999; Glauber 2013; Glauber 2004), represent the largest share of total program cost.

Program delivery generally involves marketing, application processing, premium collection, and claim adjustment. The FCIC offsets these costs for AIPs by paying two subsidies: A&O for buy-up coverage, and CAT LAE for CAT coverage. Both are paid separately by the government, calculated as a percentage of premium rather than actual costs. Under the SRA, A&O from 2000-2024 ranged from 18% to 28% depending on the insurance plan and coverage level of the policy being delivered (see Table S3), with a "snapback" bonus in states whose loss ratio exceeds 1.2, while CAT LAE is set at 6%. In 2011, the SRA imposed annual A&O limits (a $1.3 billion cap and a $1.0 billion cup), which remain unchanged through 2024. Certain CAT LAE and A&O subsidies are excluded from these limits.

Compensation to crop insurance agents is the largest single delivery expense for AIPs. Because RMA sets premium rates, AIPs cannot compete on price, so they focus on agent relationships and customer service, hiring successful agents to drive business (U.S. Government Accountability Office [U.S. GAO] 2023; Congressional Research Service [CRS] 2018). This has led to a highly competitive agent market (DeLay and Walters n.d.). The 2011 SRA and subsequent agreements limit what AIPs can pay agents by capping the portion of A&O and CAT LAE used for base commissions at 80% per state. However, AIPs may offer up to 100% under certain conditions.

There is no specific restriction on any individual agent's compensation if the total statewide limit is not exceeded. Thus, an AIP could pay one agent the entire 80% allowance in a state, provided no commissions go to any other agent in that state. Table 1 shows that from 2001 through 2023, the federal government paid private insurance companies about $42.50 billion in 2023-adjusted dollars—an average of roughly $12.02 billion per year—to deliver the program. In 2023 alone, these subsidies totaled around $2.59 billion.

Indemnities

Indemnity payments are the funds FCIP pay to producers with a crop insurance policy to compensate them for covered losses. All indemnity payments are initially counted as an FCIC cost. However, under the SRA, these payments are shared between FCIC and AIPs when calculating underwriting gains or losses. From 2001 to 2023, the FCIP paid a total of $231.5 billion in indemnities, adjusted to 2023 dollars, averaging $10.06 billion per year. In 2023 alone, indemnity payments reached $17.13 billion. Although annual payouts vary, they have generally trended upward, with real indemnities rising about 24.52 percent each year. Notably, real indemnities spiked in 2012, 2022, and 2019 by 52.91 percent, 70.62 percent, and 46.02 percent, respectively, often in response to extreme weather events such as severe droughts. The 2022 Census of Agriculture also indicates significant regional disparities in these payments, reflecting diverse risks and losses nationwide (Tsiboe 2024).

Underwriting

Under reinsurance agreements, the government and private insurers share underwriting gains and losses (See Tables S4 in the online appendix). Insurers retain a portion of total premiums (retained premiums) and cede higher-risk policies to the government, typically through the Assigned Risk

Fund. This fund often covers areas prone to greater losses—such as those with frequent drought or flooding—while insurers keep lower-risk policies in the Commercial Fund. Each year, companies' gains or losses are determined by the difference between retained premiums and the share of claims they pay, adjusted by gain/loss and quota sharing provisions. Net underwriting gains are when premiums exceed total payments to producers for claims while net underwriting losses are when premiums are less than payments for claims.

From 2001 to 2023, AIPs retained about 80% of total premiums, and Table 1 shows that this resulted in the FCIC paying a total net underwriting gains of $43.6 billion in 2023-adjusted dollars to AIPs—an average of roughly $1.90 billion per year. Among the three major cost items examined in this study, underwriting gains paid by FCIC to AIPs ranked second in overall direct FCIP expense, comprising about 18% of total costs annually. In 2023 alone, FCIC paid AIPs $2.38 billion in underwriting gains. From 2001 to 2023, the AIPs paid a total net underwriting loss of $1.53 billion to the FCIC—an average of roughly $0.07 billion per year. These shared underwriting costs—or gains—change with annual losses. Typically, the FCIC pays significant underwriting gains to AIPs, but in 2002 and 2012, AIPs transferred funds back to the FCIC.

<u>Net direct cost – Taxpayer obligation</u>

The AIPs collect producer premiums and transfer them to FCIC within weeks. FCIC does not directly pay premium subsidies; instead, these are factored into underwriting gains and losses. Each AIP has an FCIC-funded escrow account through which FCIC initially pays all indemnities. On a monthly basis, the RMA then calculates each AIP's share of these indemnities based on retained risk and FCIC-paid premium. Depending on the calculation, AIPs may owe FCIC a portion of the indemnities already advanced. At the end of each reinsurance year, a final settlement process accounts for all risk-sharing terms—such as fund allocation, proportional reinsurance, and nonproportional reinsurance—across crops and states, determining the final division of gains or losses.

From 2001 to 2023, non-taxpayer inflows—primarily from collected premiums and underwriting losses paid by AIPs to FCIC—totaled \$278.08 billion (in 2023-adjusted dollars), averaging \$12.09 billion per year. Except for 2002 and 2012, these inflows came solely from premiums. Meanwhile, premium subsidies, indemnities, A&O expenses, and underwriting gains paid by FCIC to AIPs reached \$487.27 billion, or \$21.19 billion annually. Subtracting inflows from outflows, the FCIP's net direct cost was -\$209.19 billion over the period, an average of -\$9.10 billion per year. This net cost is covered by permanent funding authorized under the Federal Crop Insurance Act (7 U.S.C. §1501 et seq.), providing "such funds as are necessary" for the program's operations, premium subsidies, and related expenses.

According to the Congressional Budget Office's May 2023 estimates, the crop insurance program will cost over \$101 billion (around \$10.1 billion per year) from 2024 to 2033. This underscores the continued challenge of balancing financial sustainability with risk management, ensuring protection for producers against both routine and catastrophic agricultural risks.

2.3 FCIP actuarial updates

Producers that purchase a crop insurance policy within the FCIP must choose from several options that ultimately define the policy and the price they pay for it. These include which insurance plan to enroll in, a coverage level for the plan, and which unit structure to insure under. The combination of these choices in addition to where they are located (county), what they produce (commodity), and how they produce (production practice) alters the properties of the final insurance policy allowing a producer to customize their policy to fit their unique risk management needs.

Given the complexity of the producer's choice, premium rates are established through a sophisticated method known as loss-cost ratio ratemaking (Coble et al. 2010; Coble et al. 2020). Under this framework, rates are first determined at the sub-county (insurance pool) level for a standard coverage option, and then adjusted using techniques that mirror the experience-based and risk-differentiation approaches found in property and casualty insurance (Sherrick, Schnitkey and Woodward 2014). The objective here is to simplify these procedures, with particular attention to policies derived from producers' actual farm-level data—namely Actual Production History (APH), Yield Protection (YP), Revenue Protection (RP), and Revenue Protection with Harvest Price Exclusion (RP-HPE)

Yield-based policies (YP and APH) include eight key elements: the rate yield ($\bar{y}$), approved yield ($\ddot{y}$), coverage level (θ), indemnity ($I(y)$), premium rate (τ), premium (P), and subsidy (S). Both the rate yield and the approved yield are computed using a producer's average historical production, as reported in the APH. However, the approved yield often undergoes upward adjustments through various components of RMA's actuarial processes (e.g., yield exclusion, yield substitution, and trend adjustments). Once a coverage level θ is selected, the producer secures a yield guarantee (liability) equal to $\theta\ddot{y}$. The per-acre indemnity, given an observed yield y, is determined by $I(y) = max[0, \theta\ddot{y} - y]$.

Because premium rates are intended to be actuarially sound, the total premiums collected over time should match total indemnities paid. To achieve this, the premium rate per dollar of liability is defined as:

$$\tau(\theta) = \frac{E[I(y)]}{\theta\ddot{y}} = \frac{1}{\theta\ddot{y}}\int_0^{\theta\ddot{y}}(\theta\ddot{y} - y)f(y)dy \tag{1}$$

where $f(y)$ is the probability density function describing the underlying yield distribution. In practice, RMA assumes that $f(y)$ depends on a risk-adjustment mechanism which estimates a producer's risk level relative to their peers. This adjustment is captured via the RMA's "continuous rating formula" (Milliman & Robertson 2000; Risk Management Agency [RMA] 2000; Risk Management Agency [RMA] 2009). For yield-based coverage (YP and APH), the continuous rating formula is approximated by

$$\tau_{ijt} = \left[\alpha_{jt}\left(\bar{y}_{ijt}/\bar{y}_{cjt}\right)^{\beta_{jt}} + \delta_{jt}\right] F_{ijt}^{\theta} F_{ijt}^{u} \tag{2}$$

where ijt identifies a specific insured producer i, in a given insurance pool j for crop year t. The parameters α_{jt} and δ_{jt} serve as, respectively, the reference rate and a fixed loading factor for catastrophic events at a standard coverage level (often 65%). The term $\bar{y}_{ijt}$ (rate yield) is the producer's average historical yield, and $\bar{y}_{cjt}$ is the mean yield for all producers in the same county, making $\bar{y}_{ijt}/\bar{y}_{cjt}$ a measure of the producer's performance relative to their insurance pool. A negative exponent β_{jt} scales rates downward for more productive operations, and this component is known as the rate multiplier curve ($\left(\bar{y}_{ijt}/\bar{y}_{cjt}\right)^{\beta_{jt}}$). Finally, F_{ijt}^{θ} and F_{ijt}^{u} adjust the rate based on the chosen coverage level (θ_{ijt}) and insurance unit (u_{ijt}).[4]

For those opting for revenue-based protection (RP or RP-HPE), the premium rate is calculated using a simulation that blends yield and price distributions—along with their correlation—to produce a "revenue load." This load, equal to the difference between a simulated revenue-based

[4] Producers may choose different unit structures to customize the scope of their insurance coverage. In the most detailed option, Optional Units (OUs) treat each field as a separate policy, enabling highly specific coverage. At the other end of the spectrum, Enterprise Units (EUs) group all fields of a given crop within a county into a single contract, maximizing consolidation. Basic Units (BUs) offer a middle ground by pooling land based on crop, county, and ownership/share arrangements.

rate and a yield-based rate, is added to the base yield insurance rate to reflect the extra risk of covering revenue variability. Consequently, the final premium rate for revenue coverage is adjusted to account for this additional risk.

The overall cost of the contract is then $P = \tau(.)\theta\ddot{y}$. Producers benefit from a subsidy, $S(\theta, u)$, which depends on the chosen coverage level and insurance unit type, rather than on their location or specific crop.

The RMA sets and periodically revises the continuous rating parameters (α, δ, β, and $\bar{y}_c$), incorporating advances in technology, methodology, and factors like climate change. Using empirical methods from the early 1980s (Sherrick et al. 2014) augmented with weather weighting (Rejesus et al. 2015) to adjust insurance experience, the reference rate (α) for an insurance pool is calculated as the annual average of the pool's historical loss cost ratio (LCR), which is capped to mitigate the impact of outlier catastrophic events (Coble et al. 2010). The excess risk from the capped LCR determines the catastrophic fixed loading factor (δ), which also includes prevented planting, replant, and quality adjustment loads. The RMA reviews these rates every three years, analyzing data from a rolling 20-year period starting two years prior to the relevant crop year (see Figure S1 for the case of updating rates for 2018 and 2019 crop years).

Program yields are regularly updated to reflect changes in weather, climate conditions, genetics, technology, and farming practices. Specifically, reference yields are determined from the acre-weighted average of yields reported by crop insurance participants for the most recent crop year. In situations with limited data, the RMA utilizes different levels of aggregation or statistical models. These yield reviews are synchronized with rate reviews occurring every three years and incorporate the latest 10 years of yield data (Rejesus et al. 2010).

The RMA employs hierarchical structuring of data to estimate exponents, organizing individual data within counties, then grouping these within climate regions, and finally nesting within states. This approach supports the use of sophisticated multilevel modeling techniques, which strike a balance between no pooling (estimating the exponent separately for each geographic area) and total pooling (using a single exponent for all areas). Multilevel models allow for nuanced assessments that reflect regional yield variations and loss ratios. RMA calculates these exponents by correlating producer-reported average yields with actual realized yields over historical data, thus estimating the exponential relationship between unit-level yield ratios and loss cost ratios (Tsiboe and Tack 2022). Aside the parameters relevant to this study, RMA also implements regular reviews of other aspects of the program such as dates, maps, availability, and reporting to ensure that the program remains adaptive and accurate (Baldwin, Williams, Tsiboe, et al. 2023; Baldwin, Williams, Sichko, et al. 2023).

In what follows, this study simulates the impacts of RMA's actuarial updates on the fiscal landscape previously discussed in this section.

3. Data and Variable Construction

The core dataset for this study comes from the RMA's most detailed Summary of Business, which spans the 2001–2023 crop years. Referred to as "SOBTPU" (Summary of Business by Type, Practice, Unit Structure), each record in this dataset merges the collective outcomes of producers who share the same insurance pool, contract attributes, and same crop year.[5] Insurance pools reflect the smallest geographic units used by the FCIP to set rates, and are defined by unique combinations of county, crop, crop type (for instance, grain versus silage for corn), and production practice (e.g.,

[5] SOBTPU files for each crop year are available at (Risk Management Agency [RMA] 2023b).

irrigated, organic). The contract choices are defined by unique combinations of insurance plan (e.g., APH, RP, etc..), coverage level, and unit structure (OU, EU, etc..).

The study concentrates on insurance plans that use the continuous rating framework. Over the analysis period, multiple continuous-rating plans were restructured through the introduction of "COMBO" policies in 2011, which consolidated existing products. Specifically, APH plans for crops trading on well-established futures markets became YP; Crop Revenue Coverage (CRC) and Revenue Assurance (RA) plans with a harvest price option (HPO) were merged into RP; and RA without HPO and Income Protection (IP) were combined into RP-HPE. As a result, any SOBTPU or ADM entry previously labeled APH was recoded as YP, any CRC entry was recoded as RP, and any RA or IP entry was reclassified as RP-HPE.

Each record from SOBTPU includes core loss experience variables: coverage level (θ_{ijt}), net insured acres (A_{ijt}), liability (L_{ijt}), total premium (P_{ijt}), subsidy amount (S_{ijt}), and indemnity amount (I_{ijt}). From these, the premium rate per dollar of liability (τ_{ijt}) is derived by dividing the total premium by total liability, while the subsidy per dollar of premium (s_{ijt}) is computed by dividing the subsidy amount by the total premium.

In addition to the SOBTPU, the study also uses RMA's Actuarial Data Master (ADM) for 2001–2023.[6] From the ADM, parameters are extracted necessary for continuous rating, including the county reference rate (α_{jt}), county fixed rate (δ_{jt}), county rating exponent (β_{jt}), county reference yield ($\bar{y}_{cjt}$), and differential factors separately for coverage level (F^{θ}_{ijt}) and unit structure (F^{u}_{ijt}). For a given SOBTPU entry, these parameters were taken as their exact values retrieved from the ADM.

[6] ADM files for each insurance year are available at (Risk Management Agency [RMA] 2023a). The aggregation of ADM information is based on initial work by (Tsiboe and Tack 2022) using Beocat, a High-Performance Computing (HPC) cluster at Kansas State University.

For missing coverage-level adjustment factors, a regression-based strategy is applied, modeling each factor as a quadratic function of the coverage level and the 65% reference rate, estimated separately for each crop and year (Coble et al. 2010).

Given the SOBTPU and ADM data, the rate yield ($\bar{y}_{ijt}$)—intended to approximate the average productivity for the group of producers aggregated in each SOBTPU record—is back-calculated according to

$$\bar{y}_{ijt} = \bar{y}_{cjt}\left[\left(\frac{\tau_{ijt}}{F^{\theta}_{ijt}F^{u}_{ijt}} - \delta_{jt}\right)\frac{1}{\alpha_{jt}}\right]^{\frac{1}{\beta_{jt}}} \tag{3}$$

Table 2 summarizes the descriptive statistics for the dataset, which comprises 3,849,979 SOBTPU entries covering 49 crops between 2002 and 2023. [7] Overall, the sample represents 82.13% of the non-livestock liability in the FCIP during this period. On average, each entry corresponds to an insured area of 1,297 acres, a coverage level of 71%, and a total liability of \$459,540. The associated total premium is \$46,052, with approximately \$28,675 (62%) subsidized by the government, yielding mean values of \$0.13 for premium per dollar of liability and \$0.63 for subsidy per dollar of premium. The dataset is dominated by seven crops—corn, soybeans, wheat, cotton, sorghum, barley, and rice—which together account for 93.46% of the insured acreage. At the pool level, these crops have average insured acres (and corresponding liabilities) of 1,528 acres (\$741,818) for corn; 1,472 acres (\$468,726) for soybeans; 1,406 acres (\$229,301) for wheat; 1,242 acres (\$417,506) for cotton; 708 acres (\$112,281) for sorghum; 691 acres (\$100,026) for barley; and 1,316 acres (\$656,845) for rice. Their respective average premium per dollar of liability

[7] The crops included alfalfa seed, almonds, avocado, banana, barley, buckwheat, camelina, caneberries, canola, clary sage, coffee, corn, cotton, cranberries, cucumbers, dry beans, dry peas, flax, forage, grapefruit, grass seed, mandarin/tangerine, millet, mint, mustard, oats, onions, orange, papaya, peaches, peanuts, potatoes, rice, rye, safflower, sesame, sorghum, soybeans, sugar beets, sugarcane, sunflowers, sweet corn, tangelo, tangors, tobacco, tomatoes, triticale, walnuts, and wheat

(subsidy per dollar of premium) are $0.11 ($0.63), $0.11 ($0.62), $0.16 ($0.63), $0.18 ($0.66), $0.22 ($0.65), $0.15 ($0.63), and $0.07 ($0.62). See Table S5 in the online appendix for other major crops not listed on Table 2.

To examine how actuarial parameters change over time, the "update rate" for each crop year, defined as the percentage of insured acreage that experienced any change in its actuarial parameters. For each insurance pool, an update event is flagged whenever the parameter value in the ADM for the upcoming crop year differs from that of the preceding year. As shown in Figure 2, annual variations in update rates within the FCIP (2002–2023) reflect the RMA's structured review cycle. Specifically, certain years—such as 2004 (96.25%), 2005 (100%), 2009 (96.06%), 2018 (97.57%), and 2021 (96.56%)—feature near-complete or total updates, consistent with the comprehensive reviews that draw on extensive historical data and account for new risks and changing market conditions. Conversely, years with lower update percentages, such as 2011 (47.84%), 2008 (47%), and 2002 (25.47%), typically fall mid-cycle when fewer adjustments are necessary.

A comparable pattern emerges when looking at individual parameter updates, although before 2012 the rating exponent saw minimal revisions. In addition, the county reference yield exhibits a notable break in continuity due to a shift in the RMA's approach. Previously, reference yields were updated using transitional yields (T-yields), but beginning in 2011, the RMA transitioned to calculating yield updates based primarily on an acre-weighted average of yields reported by crop insurance participants for the most recent available year. [8]

[8] Although T-yields were employed under the assumption that they align reference yields more closely with the average yield of producers in the county, the old method overlooked the latency effect. This effect stemmed from the comprehensive T-Yield reviews conducted only every 4 to 5 years.

Figure 3 illustrates that field crops exhibit the highest mean annual rate of actuarial parameter updates, at approximately 77.73% of their insured acreage. This figure is followed by forages (64.39%), vegetables (60.48%), nuts (57.21%), and fruits (47.99%). Corn shows the largest update frequency among field crops, averaging 85.95%. Next come peanuts (78.4%), sorghum (78.02%), cotton (75.44%), sugarcane (74.74%), barley (74.65%), rice (73.96%), wheat (73.68%), canola (71.57%), soybeans (71.56%), sunflowers (71.33%), and sugar beets (70.22%). These trends also vary considerably by state. Notably, crops such as fruits, nuts, and vegetables in states where they comprise a smaller share of total insured acreage tend to record lower rates of updates, underscoring the regional diversity in how actuarial parameters are revised across the program.

4. Counterfactual Simulation Design

The update percentages in Figures 2 and 3 highlight the FCIP's adaptive approach to maintaining accurate insurance premiums. This section presents a counterfactual simulation aimed at examining how these adjustments affect the program's fiscal outcomes.

The simulation has two primary steps. First, it modifies the FCIP loss experience data from the current crop year, as recorded in the SOBTPU, to create scenarios both with and without new ADM parameters. The rationale behind this adjustment is that the historical loss data used for rating a given crop year's policies excludes that same year's data as well as data from the two preceding years (see Figure S1 for a schematic). Thus, contract selections and participation information for the current crop year serve as an out-of-sample test against two consecutive ADM databases. For instance, producer decisions from 2019 can be used to compare the 2019 ADM with the 2018 ADM, noting that the 2019 loss experience was not incorporated when either ADM was developed.

Key to the simulations is the assumption that farmer demand and behavior remain largely unchanged whether updates occur or not. Adverse selection is minimal (coverage levels are fixed but acres insured is not), and moral hazard is stable (yields and prices remain constant). While moral hazard can arise through input-use decisions (Smith and Goodwin 2017; Horowitz and Lichtenberg 1993; Yu and Hendricks 2020), studies suggest limited impact on yields (Coble et al. 1997; Babcock and Hennessy 1996; Quiggin, Karagiannis and Stanton 1993; Mieno, Walters and Fulginiti 2018), which are mainly driven by weather and climate. Since 2000, drought and high temperatures account for 42% of FCIP indemnities, and excess moisture adds another 28%. These figures underscore the predominant role of weather in driving losses rather than shifts in production decisions. Furthermore, multiple studies suggest that premium subsidies in the FCIP have substantially reduced adverse selection (Tsiboe and Turner 2023; Coble and Barnett 2013; Just et al. 1999; Glauber 2013; Glauber 2004), while other research consistently finds relatively inelastic demand for coverage (Gardner and Kramer 1986; Barnett, Skees and Hourigan 1990; Calvin 1990; Goodwin 1993; Goodwin and Kastens 1993; Hojjati and Bockstael 1988; Coble et al. 1996; Yi, Bryant and Richardson 2020; Maisashvili, Bryant and Jones 2020; Bulut and Hennessy 2021). Recently estimated elasticities for producer-paid rates (-0.052 for acres insured and -0.022 for coverage level) demonstrate minimal response to one-year changes (Tsiboe and Turner 2023). This is especially apparent at the intensive margin, where premium rates must rise by over 20% to trigger a coverage-level switch. Since the FCIP generally limits year-to-year fluctuations in individual rates to around 20%, broad or rapid shifts in crop insurance demand—particularly with respect to coverage levels—are unlikely under current rate volatility.

Prior research on crop insurance demand elasticities typically combines the effects of rating parameter changes with producers' risk preferences. To distinguish the influence of parameter updates, this study regresses the annual percentage change in pool-level insured acreage on the annual percentage changes of selected rating parameters, controlling for pool and crop-year fixed effects. Two model variants—unconditional (each parameter tested separately) and conditional (all parameters tested together)—are estimated over periods ending in 2023 (e.g., 2005–2023 to 2019–2023), using insurance pools that appear consistently each year. As shown in Figure S2, changes in rating parameters within a given year led to negligible shifts in insured acreage, regardless of parameter type, model specification, or time window.

Drawing on the literature and the regression findings shown in Figure S2, the simulations assume that only the extensive margin (insured acreage) changes in response to rating updates, while moral hazard (final yields and market prices) remains unchanged. This simplified yet robust approach offers a clear baseline for analyzing how ADM updates directly affect the program's finances. It also allows for systematic re-simulation when new data emerges, or greater complexity is introduced. By focusing on a well-defined framework, analysts can make incremental adjustments that enhance clarity and precision, ensuring reliable assessment of policy changes.

Building on these assumptions, the simulation starts by fixing each SOBTPU entry's insured acres (A_{ijt}), liability (L_{ijt}), indemnity (I_{ijt}), subsidy per dollar of premium (s_{ijt}), and calibrated rate yield ($\bar{y}_{ijt}$) [Equation (3)] at their observed values for the update year. Next, two premium rates are calculated for each entry: one with updated parameters (r^{b}_{ijt}) and one without (r^{a}_{ijt}). Formally,

$$r^{b}_{ijt} = \left[\alpha_{jt}\left(\bar{y}_{ijt}/\bar{y}_{cjt}\right)^{\beta_{jt}} + \delta_{jt}\right] F^{\theta_t}_{ijt} F^{u_t}_{ijt} \quad (4)$$

$$r^{a}_{ijt} = \left[\alpha_{jt-1}\left(\bar{y}_{ijt}/\bar{y}_{cjt-1}\right)^{\beta_{jt}} + \delta_{jt-1}\right] F^{\theta_t}_{ijt-1} F^{u_t}_{ijt-1} \quad (5)$$

$$\text{s.t } r^{b}_{ijt} \times 0.8 \le r^{a}_{ijt} \le r^{b}_{ijt} \times 1.2 \qquad \text{and} \qquad r^{k}_{ijt} \in (0,1), \forall k = a, b$$

Parameters for the update scenario ($\mathrm{r}_{\mathrm{ijt}}^{\mathrm{b}}$) come from the current year (t), while those for the no-update scenario ($\mathrm{r}_{\mathrm{ijt}}^{\mathrm{a}}$) are from the previous year ($\mathrm{t}-1$). The 20% range limit on ($\mathrm{r}_{\mathrm{ijt}}^{\mathrm{a}}$) aligns with RMA guidelines. A recent study suggests that annual premium rate changes exceeding ±20% are uncommon in the FCIP (Tsiboe 2025).

For the update scenario, the insured acres ($A_{\mathrm{ijt}}^{\mathrm{b}}$) directly reflect the observed values in the SOBTPU dataset. Given this observed value, the insured acreage for the no-update is calculated based on crop by crop years level estimated elasticities (e_{jt}) (see Figure S3) given the difference between update and no-update rates; $A_{\mathrm{ijt}}^{\mathrm{a}} = A_{\mathrm{ijt}}^{\mathrm{b}} * e_{jt}\left(\frac{\mathrm{r}_{\mathrm{ijt}}^{\mathrm{a}}}{\mathrm{r}_{\mathrm{ijt}}^{\mathrm{b}}} - 1\right) \times 100$. Similarly, while total liability ($L_{\mathrm{ijt}}^{\mathrm{b}}$), total premiums ($P_{\mathrm{ijt}}^{\mathrm{b}}$), subsidy amounts ($S_{\mathrm{ijt}}^{\mathrm{b}}$), and indemnities ($I_{\mathrm{ijt}}^{\mathrm{b}}$) for the update scenario is taken as given in the SOBTPU, the no-update case analogues are respectively calculated as; $L_{\mathrm{ijt}}^{\mathrm{a}} = \frac{L_{\mathrm{ijt}}^{\mathrm{b}} A_{\mathrm{ijt}}^{\mathrm{a}}}{A_{\mathrm{ijt}}^{\mathrm{b}}}$, $P_{\mathrm{ijt}}^{\mathrm{a}} = \mathrm{r}_{\mathrm{ijt}}^{\mathrm{a}} L_{\mathrm{ijt}}^{\mathrm{a}}$, $P_{\mathrm{ijt}}^{\mathrm{a}} = \frac{P_{\mathrm{ijt}}^{\mathrm{b}} P_{\mathrm{ijt}}^{\mathrm{a}}}{S_{\mathrm{ijt}}^{\mathrm{b}}}$, and $I_{\mathrm{ijt}}^{\mathrm{a}} = \frac{I_{\mathrm{ijt}}^{\mathrm{b}} A_{\mathrm{ijt}}^{\mathrm{a}}}{A_{\mathrm{ijt}}^{\mathrm{b}}}$.

In the second phase of the simulation, the study recalculates the financial outcomes from Section 2 using the revised SOBTPU data for both the update and no-update scenarios. The results are aggregated by crop year to enable direct comparisons. A reduction in total fiscal outflows — comprising premium subsidy, indemnity payments, program delivery costs, and underwriting gains— when moving from the no-update to the update scenario clearly indicates an improvement in the program’s fiscal stability.

In the baseline scenario, the study models an update reflecting the current RMA update pattern— which implies a comprehensive simultaneous update to all four parameters (α, δ, β, and $\bar{\mathrm{y}}_{\mathrm{c}}$), whether on the same or staggered schedules. This scenario reflects what RMA did in terms of these updates, thus only the no-update state of the world is simulated whilst the up-to-date state is taken as the observed SOBTPU. By contrast, subsequent simulations focus on “targeted” updates, where only one parameter is allowed to change at a time, with the remaining parameters held at their values from the previous crop year. In these targeted scenarios, demand is adjusted accordingly for both states of the world. This design reveals how individual parameter changes influence the outcomes and highlights which specific updates carry the most potent impact.

Each scenario focuses on comparing updates versus no-updates solely for county-crop programs included in both the “incumbent” and “successor” ADM. As a result, any newly introduced or discontinued county-crop combinations are excluded, ensuring a valid basis for identifying whether a given parameter changed over time. This approach narrows the dataset to county-crop programs present consistently throughout the years studied, potentially underrepresenting areas with recent coverage expansions or contractions. Still, these continuously tracked county-crop combinations account for over 80% of the insured volume. Finally, each impact metric is calculated as the average of annual estimates from 2002 to 2024.

For statistical inference, standard errors are computed using a bootstrap approach with 100 replications. In each iteration, 665,482 insurance pools—defined by unique combinations of county, crop, crop type, and production practice—are sampled with replacement. Whenever a pool is chosen, every observation from its available crop years is included. After 100 rounds of sampling and simulations, the distribution of resulting estimates is used to derive standard errors.

5. Results and Discussions

This section presents the main findings of the simulation analysis. It begins by establishing a baseline scenario that reflects actuarial and fiscal outcomes under the assumption that no rating updates occurred during the 2002–2024 period. The subsequent analysis assesses the overall effects of actuarial updates by comparing this baseline to scenarios in which rating parameters were periodically revised. The discussion then turns to a comparison between targeted and comprehensive updates, highlighting differences in their relative impacts. Finally, the section examines temporal and spatial heterogeneity in outcomes across crop years and geographic regions, identifying areas where updates are most effective and where notable disparities persist.

5.1 Establishing the baseline

Table 3 presents the primary findings from the analysis across the full sample. Under the baseline "no update" scenario, the mean annual gross book of business was simulated at 207 million acres and $97 billion in liability. The simulated annual loss ratio of 0.814 is close to the program's official mean of 0.840 observed from 2001 to 2023. Fiscal inflows—comprising total premiums of $9.90 billion and underwriting losses of $0.47 billion—are slightly lower than the official figures reported in Table 1. Similarly, the modeled fiscal outflows total $17.94 billion, broken down into a premium subsidy of $6.16 billion, indemnity payments of $8.01 billion, program delivery costs of $2.03 billion, and underwriting gains of $1.74 billion; these, too, are beneath the official values. Consequently, the overall direct cost of $7.57 billion is also lower than the official amounts. Two main factors explain these differences. First, the analysis only simulates the portion of the FCIP book of business related to plans rated under continuous rating, thereby excluding livestock, dollar plans, and area and index products that are incorporated in the official values of Table 1. Second, as premium rates have generally been declining in recent times, the baseline "no update" scenario—characterized by relatively high premium rates—results in a simulated decline in demand compared to official historical data.

5.2 The main effect

Table 3 offers a comprehensive comparison of the fiscal outcomes related to periodic actuarial updates in the FCIP over 2002–2024. The "baseline" (column 2) represents a scenario with no actuarial updates, while the alternative scenario uses the current RMA update pattern (column 3), with all results shown as percentage changes relative to the baseline. Almost every percentage change is statistically significant ($p < 0.01$), indicating that these differences are highly unlikely to be due to chance.

Under the update scenario, key metrics such as insured area and liability increase moderately by 1.431% and 1.801%, respectively, suggesting a modest expansion in the program's scope. At the same time, the loss ratio declines by 1.273%, reflecting improved underwriting and more accurate risk assessment. This effect underscores recent findings that showed a general enhancement in actuarial soundness following rate updates, as more precise risk assessments lead to better-calibrated premium settings (Tsiboe 2025).

Ensuring the actuarial soundness of the FCIP is essential to managing its escalating fiscal burden. When the premiums collected—both from farmers and government subsidies—accurately reflect the underlying risk, the program operates more efficiently, reduces taxpayer exposure, and maintains fairness in subsidy distribution. However, when rating parameters become outdated or fail to align with actual loss experience, costs to the government increase due to higher-than-expected indemnities, and opportunities for private insurers to transfer risk back to the public emerge. Table 3 further breaks down fiscal flows into inflows and outflows. Regarding inflows, premium revenue experiences a modest boost of 0.543%, whereas underwriting losses see a significant reduction of 44.839%. Despite the premium increase, total inflows declined by 1.507%, reflecting a nuanced overall revenue impact. On the expenditure side, premium subsidies and program delivery costs increased slightly by 0.477% and 0.512%, respectively, while indemnity payments rose by 2.692%. Notably, underwriting gains drop dramatically by 50.221%, leading to an overall decline of 3.437% in total outflows. Cumulatively, these changes result in a significant reduction in the direct net cost to taxpayers — falling by 6.082% from a baseline of $7.568 billion.

5.3 Targeted vs comprehensive updates

Columns (4) through (7) of Table 3 present the effects of targeted updates to individual ADM parameters—reference rate, fixed rate, rating exponent, and reference yield—and reveal significant differences in their impact on net taxpayer cost. Specifically, updating only the reference rate reduces net taxpayer cost by 8.090%, while isolated updates to the fixed rate and rating exponent yield reductions of 10.429% and 11.681%, respectively. The most pronounced effect occurs when only the reference yield is updated, reducing net taxpayer cost by 14.045%. These findings underscore the disproportionate influence of certain parameters—particularly the reference yield—in shaping taxpayer liabilities and aligning premiums with actual loss experience.

In contrast, the current RMA approach, which applies simultaneous revisions to multiple rating parameters (either concurrently or on staggered schedules), yields smaller average cost reductions. This difference in impact stems from the interaction effects inherent in joint updates. Simultaneous adjustments may produce compensatory or offsetting effects among parameters, dampening the influence of any single correction. Targeted updates, by isolating specific components of the actuarial framework, more precisely calibrate premiums to expected losses, enhancing cost containment and fiscal efficiency—especially in cases where a particular parameter is misaligned with observed risk patterns.

This distinction is shaped by the broader regulatory context. The Federal Crop Insurance Act, under Section 508(d), requires that premium rates cover not only expected indemnities but also include a reasonable reserve margin for catastrophic losses. [9] This statutory requirement obligates RMA to balance actuarial soundness with financial resilience, often prompting the use of multi-parameter updates to address the diverse risk factors embedded in the program. Despite these complexities, RMA has consistently maintained a national average loss ratio of approximately 0.8 since 1997, indicating that collected premiums generally exceed indemnity payments by a sufficient margin to meet reserve targets [33].

These results contribute to ongoing policy discussions by demonstrating that while comprehensive updates support broad program stability, strategically targeted revisions—particularly to the reference yield—offer greater fiscal savings without compromising actuarial integrity. A hybrid approach that combines the consistency of comprehensive updates with the precision of targeted adjustments may yield the most effective outcome for future rate-setting practices.

5.4 Temporal and spatial heterogeneity

Figure 4 demonstrates substantial year-to-year variation in several fiscal measures of the FCIP attributable to rating parameter updates. When it comes to net taxpayer costs, while most years generated savings—evidenced by negative percentages—there are notable exceptions. Years like 2005 (16.47%), 2002 (4.92%), and 2024 (2.09%) show that updates in those periods increased

[9] The FCIP, guided by Congressional mandates, requires that premium rates not only cover expected indemnities but also include a reasonable disaster reserve. This is articulated in the FCIP's utilization of a disaster reserve factor, which was set at 0.88 in 1991 based on historical data analysis from 1948-1988. The aim was to ensure financial stability 85% of the time across any 10-year period, leading to the inclusion of an additional 13.6% in the premium rates for disaster reserves. Despite statutory expectations for a loss ratio of 1.0, the practical adjustments and recalibrations of insurance parameters—often described as a 'whack-a-mole' problem—have resulted in RMA maintaining an average loss ratio closer to 0.8 since 1997, indicating a consistent performance above the target disaster reserve ratio. This information reflects the ongoing evaluation and adaptation of rating parameters to meet legislative and operational objectives.

taxpayer costs, possibly due to under-adjustment to emerging risks or overestimated revenue expectations. In contrast, certain years yielded substantial fiscal savings, with the most dramatic being 2016, where the update reduced taxpayer cost by 40.97%. Other strong-performing years include 2007 (–20.51%), 2009 (–17.56%), and 2017 (–18.75%). Moderate savings were common in years such as 2010, 2014, and 2018, with reductions between 10% and 13%. These temporal patterns suggest that the effectiveness of RMA updates in reducing taxpayer costs has been largely consistent over time. Periods of strong savings may reflect improvements in rating accuracy or better alignment with observed risk, while costlier years are tied to significant weather and market disruptions, lagged adjustments, or structural model limitations. Overall, this temporal heterogeneity highlights the importance of continuously refining actuarial practices and reinforces the case for incorporating more adaptive or targeted updates to maintain fiscal discipline within the FCIP.

Figure 5 demonstrates that when it comes to net taxpayer costs, most states fall within negative ranges, implying net savings to taxpayers relative to the baseline, although the specific extent of these savings differs widely. Agricultural states in the Midwest with a high FCIP footprint in terms of acres enrolled—such as Illinois, Iowa, Indiana, Minnesota, and Missouri—tend to show notably negative values, suggesting greater fiscal savings that may reflect more stable yields or more precise information for premium rate setting. In contrast, states like Alaska and New Hampshire feature positive ranges well above 20%, implying notably higher costs to taxpayers. These outliers often have smaller program footprints or more volatile production risks, which can magnify losses and drive-up government outlays. A few other states, such as Florida, Texas, and Vermont, also exhibit modest positive net costs, underscoring regional diversity in crop types, climatic conditions, and program participation. Overall, the state-level results highlight that crop insurance's fiscal impact depends on a complex interplay of factors—such as farm characteristics, climate risk, and underwriting parameters—and that improved targeting of actuarial practices could potentially moderate the extremes in cost variation across different regions.

6. Conclusion

This study evaluated the fiscal impacts of updating rating parameters in the Federal Crop Insurance Program (FCIP) over the period 2002–24. By using a counterfactual simulation that compared a no-update baseline with scenarios featuring both a comprehensive update (the current RMA update pattern) and targeted single-parameter updates, the study demonstrated that precise risk assessments play a key role in reducing the program's financial burden on taxpayers—by about 6% annually. These improvements in actuarial practices significantly enhance fiscal stability by aligning premium calculations more closely with actual loss experiences, thereby avoiding the potential for net underwriting gains that would otherwise increase costs.

A notable insight from the analysis is that targeted, single-parameter updates may produce even larger cost savings than the overall holistic update approach. In particular, the impact of adjusting high-impact components like the reference yield—which the RMA updates more frequently than other parameters—is especially pronounced, achieving savings of up to 14%. This suggests that simultaneously updating all parameters may dilute the potential benefits of the most influential components, highlighting the critical importance of tailoring updates to specific risk parameters rather than relying solely on an all-encompassing approach.

In the broader context, the FCIP has long been a cornerstone of U.S. agricultural policy, operating as part of a public–private partnership that supports farmers and sustains domestic food production while contributing to macroeconomic stability. With taxpayer support averaging about $2.18 per month per American since 2008, optimizing program management through refined actuarial methodologies is essential. The findings underscore that focused adaptive updates not only reduce taxpayer liabilities and strengthen fiscal discipline but also ensure the efficient use of government funds. These insights provide valuable guidance for policymakers seeking to balance fiscal efficiency with robust support for the agricultural sector while maintaining a secure food supply.

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Tables and Figures

Table 1: Crop year Government cost of Federal Crop Insurance Program

Crop year	Total premium [A]	Premium subsidy [B]	Indemnities [C]	Program delivery cost [D]	UW Losses Paid by AIPs to FCIC [E1]	UW Gains Paid by FCIC to AIPs [E2]	Total direct cost [F= A -B-C-D+E1-E2]
	Billion 2023 US dollars						
2001	6.189	3.701	6.168	0.731	0.000	1.341	-5.753
2002	6.426	3.837	8.947	0.000	0.022	1.382	-7.718
2003	6.933	4.137	6.548	0.765	0.000	1.477	-5.994
2004	7.460	4.404	5.757	1.237	0.000	1.589	-5.527
2005	7.227	4.278	4.329	1.671	0.000	1.518	-4.570
2006	8.379	4.902	6.396	1.507	0.000	1.755	-6.181
2007	10.030	5.841	5.418	2.403	0.000	2.037	-5.670
2008	13.219	7.631	11.643	1.468	0.000	2.694	-10.218
2009	13.859	8.400	8.090	3.556	0.000	2.507	-8.694
2010	10.902	6.757	6.102	2.750	0.000	1.965	-6.673
2011	14.494	9.023	13.127	2.026	0.000	1.645	-11.327
2012	12.767	8.004	20.023	0.000	1.507	1.608	-15.362
2013	13.299	8.210	13.603	0.724	0.000	1.571	-10.809
2014	11.126	6.856	10.075	1.146	0.000	1.527	-8.478
2015	11.738	7.307	7.595	2.169	0.000	1.717	-7.049
2016	12.676	7.963	5.334	3.541	0.000	1.962	-6.124
2017	13.395	8.444	7.258	3.469	0.000	1.967	-7.743
2018	13.454	8.512	9.961	2.879	0.000	2.092	-9.989
2019	14.102	8.840	14.723	0.701	0.000	2.177	-12.340
2020	14.720	9.155	13.037	1.928	0.000	2.387	-11.788
2021	16.935	10.485	11.523	3.853	0.000	2.227	-11.152
2022	18.031	11.228	18.718	1.386	0.000	2.079	-15.381
2023	19.196	11.748	17.130	2.587	0.000	2.377	-14.646
Averages							
2001-2010	9.062	5.389	6.940	1.609	0.002	1.827	-6.700
2011-2023	14.303	8.906	12.470	2.031	0.116	1.949	-10.937
2001-2023	12.024	7.377	10.066	1.848	0.066	1.896	-9.095
	Average annual growth rate (%)						
2001-2010	7.461	7.776	8.180	15.891	-	5.376	6.192
2011-2023	5.049	4.952	15.944	23.937	-	1.877	9.726
2001-2023	6.036	6.107	12.768	20.718	-	3.308	8.280

Source: Compiled by authors, using data from USDA, Risk Management Agency as of 3/11/2024

This table includes standard livestock, Puerto Rico and is based on crop year. **Total premium** is comprised of producer paid premium and premium subsidy. **Premium subsidy** represents the subsidized portion of Total Premium. **Indemnities** are payments to Approved Insurance Providers (AIP) for insurable losses, sometimes called loss claims. **Program delivery costs** are payments to the AIPs to cover administrative and operating expenses associated with delivering the crop insurance program. **Underwriting gains** represent the AIP portion of the earnings on the insurance book of business. If the insurance book of business is a loss, AIP would pay FCIC for their portion of the **Underwriting losses**. **Total direct** costs are all costs associated with the crop insurance program.

Table 2: Means and Standard Deviations of US Federal Crop Insurance Outcomes (2001-24).

Variables	**Full sample**	**Corn**	**Soybeans**	**Wheat**	**Cotton**	**Sorghum**	**Barley**	**Rice**
Summary of business outcomes								
Coverage level (%)	70.88 (9.62)	73.33 (9.08)	72.59 (9.50)	69.10 (8.13)	64.15 (9.38)	66.87 (7.82)	69.07 (8.91)	62.20 (12.37)
Net insured area (acres)	1302 (4357)	1540 (4833)	1487 (4631)	1408 (4886)	1240 (3843)	710 (1918)	686 (1776)	1305 (3667)
Total insured liability ($ 1,000)	472 (2128)	759 (3080)	484 (1800)	234 (1028)	425 (1434)	115 (373)	101 (294)	686 (1969)
Total premium ($ 1,000)	47.06 (206.15)	67.28 (275.27)	42.42 (161.45)	37.67 (169.10)	74.22 (330.83)	23.51 (79.74)	12.88 (39.05)	40.56 (114.12)
Total subsidy ($ 1,000)	29.36 (139.07)	41.47 (186.34)	26.34 (107.74)	23.38 (107.75)	49.59 (238.48)	14.98 (53.74)	7.93 (25.77)	26.00 (71.60)
Total indemnity ($ 1,000)	39.16 (300.42)	52.65 (387.39)	26.00 (147.87)	33.90 (222.43)	92.89 (641.66)	22.74 (131.07)	10.99 (50.96)	70.43 (566.02)
Premium per dollar of liability	0.13 (0.11)	0.11 (0.09)	0.11 (0.09)	0.16 (0.11)	0.18 (0.14)	0.22 (0.15)	0.15 (0.10)	0.07 (0.06)
Subsidy per dollar of premium	0.63 (0.13)	0.63 (0.13)	0.62 (0.13)	0.63 (0.12)	0.66 (0.12)	0.65 (0.12)	0.63 (0.14)	0.62 (0.16)
Producer paid premium rate	0.05 (0.05)	0.04 (0.04)	0.04 (0.04)	0.06 (0.05)	0.07 (0.06)	0.08 (0.07)	0.06 (0.05)	0.03 (0.03)
Actuarial data master outcomes								
Reference rate	0.11 (0.09)	0.08 (0.07)	0.09 (0.08)	0.11 (0.08)	0.16 (0.12)	0.17 (0.12)	0.12 (0.08)	0.03 (0.02)
Fixed rate	0.03 (0.02)	0.03 (0.02)	0.02 (0.01)	0.03 (0.02)	0.03 (0.01)	0.04 (0.02)	0.03 (0.02)	0.02 (0.01)
Rating exponent	-1.38 (0.58)	-1.41 (0.57)	-1.58 (0.44)	-1.50 (0.49)	-1.04 (0.36)	-1.40 (0.58)	-1.40 (0.50)	-1.25 (0.63)
Coverage level differential factor-50%	0.66 (0.11)	0.66 (0.11)	0.63 (0.11)	0.67 (0.11)	0.71 (0.12)	0.69 (0.12)	0.70 (0.11)	0.74 (0.10)
Coverage level differential factor-55%	0.77 (0.12)	0.76 (0.11)	0.73 (0.11)	0.77 (0.12)	0.80 (0.13)	0.77 (0.13)	0.79 (0.11)	0.83 (0.10)
Coverage level differential factor-60%	0.85 (0.11)	0.85 (0.11)	0.83 (0.10)	0.86 (0.12)	0.87 (0.13)	0.85 (0.14)	0.87 (0.11)	0.89 (0.09)
Coverage level differential factor-65%	0.95 (0.11)	0.95 (0.11)	0.96 (0.11)	0.95 (0.12)	0.95 (0.12)	0.94 (0.14)	0.96 (0.11)	0.97 (0.08)
Coverage level differential factor-70%	1.08 (0.12)	1.07 (0.12)	1.11 (0.13)	1.06 (0.11)	1.05 (0.11)	1.04 (0.12)	1.06 (0.11)	1.08 (0.09)
Coverage level differential factor-75%	1.22 (0.14)	1.21 (0.13)	1.30 (0.17)	1.18 (0.12)	1.16 (0.10)	1.17 (0.11)	1.18 (0.09)	1.20 (0.12)
Coverage level differential factor-80%	1.38 (0.20)	1.37 (0.16)	1.52 (0.23)	1.31 (0.14)	1.29 (0.12)	1.33 (0.12)	1.32 (0.10)	1.34 (0.16)
Coverage level differential factor-85%	1.56 (0.29)	1.55 (0.22)	1.77 (0.32)	1.46 (0.20)	1.43 (0.18)	1.50 (0.18)	1.47 (0.14)	1.52 (0.24)
Basic unit differential factor	1.03 (0.03)	1.03 (0.03)	1.03 (0.03)	1.04 (0.02)	1.05 (0.02)	1.03 (0.02)	1.05 (0.02)	1.04 (0.02)
Enterprise unit differential factor	1.01 (0.03)	1.00 (0.04)	0.99 (0.04)	1.02 (0.01)	1.03 (0.01)	1.01 (0.01)	1.03 (0.01)	1.02 (0.01)
Number of insurance pools	680644	138352	186469	130564	32596	34128	24471	9815
Number of observations	4019543	1129234	1060415	739660	224860	178646	93297	45842

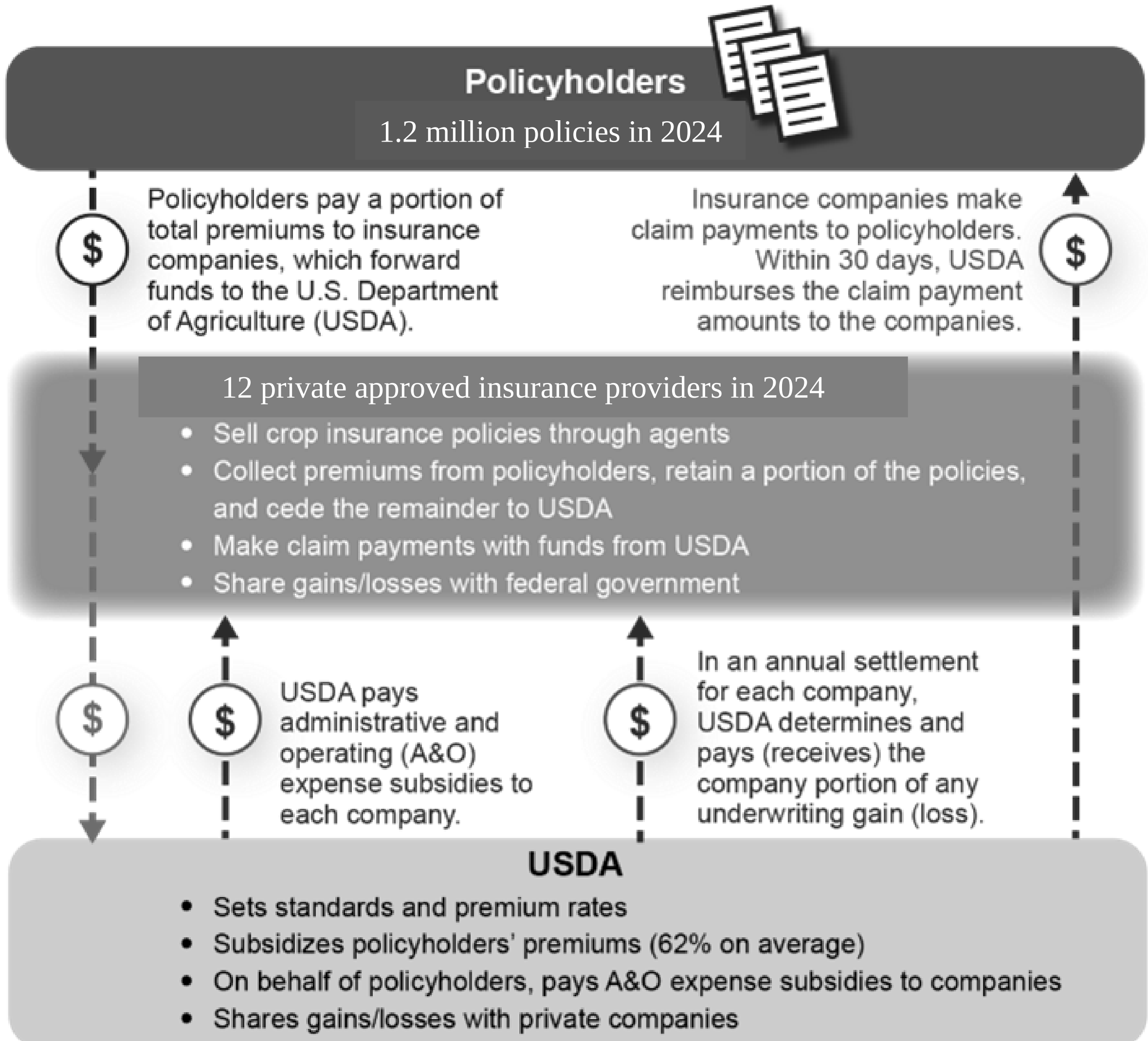
The data was constructed by the authors using primary data from (1) Risk Management Agency's summary of business and actuarial data master files that contain insurance metrics aggregated by county, crop, crop type, production practice, insurance plan, coverage level, and insurance unit.

Table 3: Fiscal impacts of actuarial updates in the United States Federal Crop Insurance Program (2002-24)

	Assumed no update (baseline)	Type of actuarial data master parameter update				
		Current RMA update pattern	Assumed Reference rate only updated	Assumed Reference fixed rate only updated	Assumed Rating exponent only updated	Assumed Reference yield only updated
<u>Gross book of business</u>		Expressed as percentage change over no update case				
Area insured (million acres)	207.547 (3.881)	1.431*** (0.067)	1.940*** (0.081)	0.689*** (0.028)	0.283*** (0.022)	-1.425*** (0.048)
Liability (billion $)	97.052 (2.274)	1.801*** (0.074)	1.867*** (0.073)	0.904*** (0.039)	0.497*** (0.041)	-1.348*** (0.046)
Loss ratio	0.814 (0.007)	-1.273*** (0.115)	-1.782*** (0.094)	-0.335*** (0.033)	-0.430*** (0.036)	1.103*** (0.033)
<u>Fiscal inflows (billion $)</u>						
Premium	9.904 (0.201)	0.543*** (0.072)	-0.081 (0.068)	0.081*** (0.027)	0.047 (0.038)	0.419*** (0.051)
Underwriting losses	0.468 (0.017)	-44.839*** (1.923)	-58.383*** (1.601)	-62.481*** (1.432)	-67.177*** (1.431)	-67.580*** (1.513)
Total inflows	10.372 (0.212)	-1.507*** (0.128)	-2.714*** (0.119)	-2.745*** (0.112)	-2.989*** (0.117)	-2.652*** (0.118)
<u>Fiscal outflows (billion $)</u>						
Premium subsidy	6.162 (0.125)	0.477*** (0.069)	-0.175** (0.066)	0.065*** (0.027)	0.061* (0.033)	0.452*** (0.049)
Indemnity	8.011 (0.173)	2.692*** (0.184)	2.439*** (0.154)	0.643*** (0.048)	0.753*** (0.056)	-0.979*** (0.056)
Program delivery cost	2.030 (0.041)	0.512*** (0.069)	0.136** (0.070)	0.084*** (0.028)	0.020 (0.033)	0.138** (0.057)
Underwriting gains	1.736 (0.042)	-50.221*** (0.756)	-62.266*** (0.649)	-65.150*** (0.664)	-72.487*** (0.521)	-74.309*** (0.543)
Total outflows	17.940 (0.363)	-3.437*** (0.123)	-4.982*** (0.124)	-5.986*** (0.111)	-6.656*** (0.115)	-7.458*** (0.122)
Net total direct cost to taxpayers (billion $)	7.568 (0.157)	-6.082*** (0.335)	-8.090*** (0.358)	-10.429*** (0.364)	-11.681*** (0.355)	-14.045*** (0.377)

Simulation: Actuarial Data Master [ADM] (successor) for the release year (e.g., 2023) was replaced with the ADM for the previous year (incumbent) (e.g., 2022) and the premiums were recalculated for the actual loss experience outcomes associated with the successor in the release year. Crop insurance demand at the extensive margin (insured acres) is allowed to shift based on responsiveness to paid premium rates.
Significance levels - *p<0.1 ** p<0.05, ***p<0.01. Standard errors in parentheses are estimated by resampling insurance pools 100 times.

Figure 1. Overview of Entities Involved in the United States Federal Crop Insurance Program Implementation



Source: Updated by author given U.S. Government Accountability Office (U.S. GAO) adaptation from the Congressional Research Services, and analysis of USDA, Risk Management Agency (RMA) data and documents.

Notes: The federal crop insurance program (FCIP) is implemented as a public-private partnership. Farmer/rancher policyholders work with insurance agents to purchase crop insurance policies sold by private sector insurers, known as Approved Insurance Providers (AIPs). When farmers file claims on the insurance policies, AIPs hire loss adjustors to determine the extent of losses incurred by the farmers. USDA provides reinsurance to AIPs for a portion of the losses from crop insurance policies sold. AIPs may purchase additional reinsurance from third-party reinsurers. USDA also regulates the policies sold by AIPs, subsidizes farmer premiums, and subsidizes AIPs for the cost of selling and servicing crop insurance policies.

Figure 2: Annual variation in actuarial updates in the United States Federal Crop Insurance Program (2002-24)

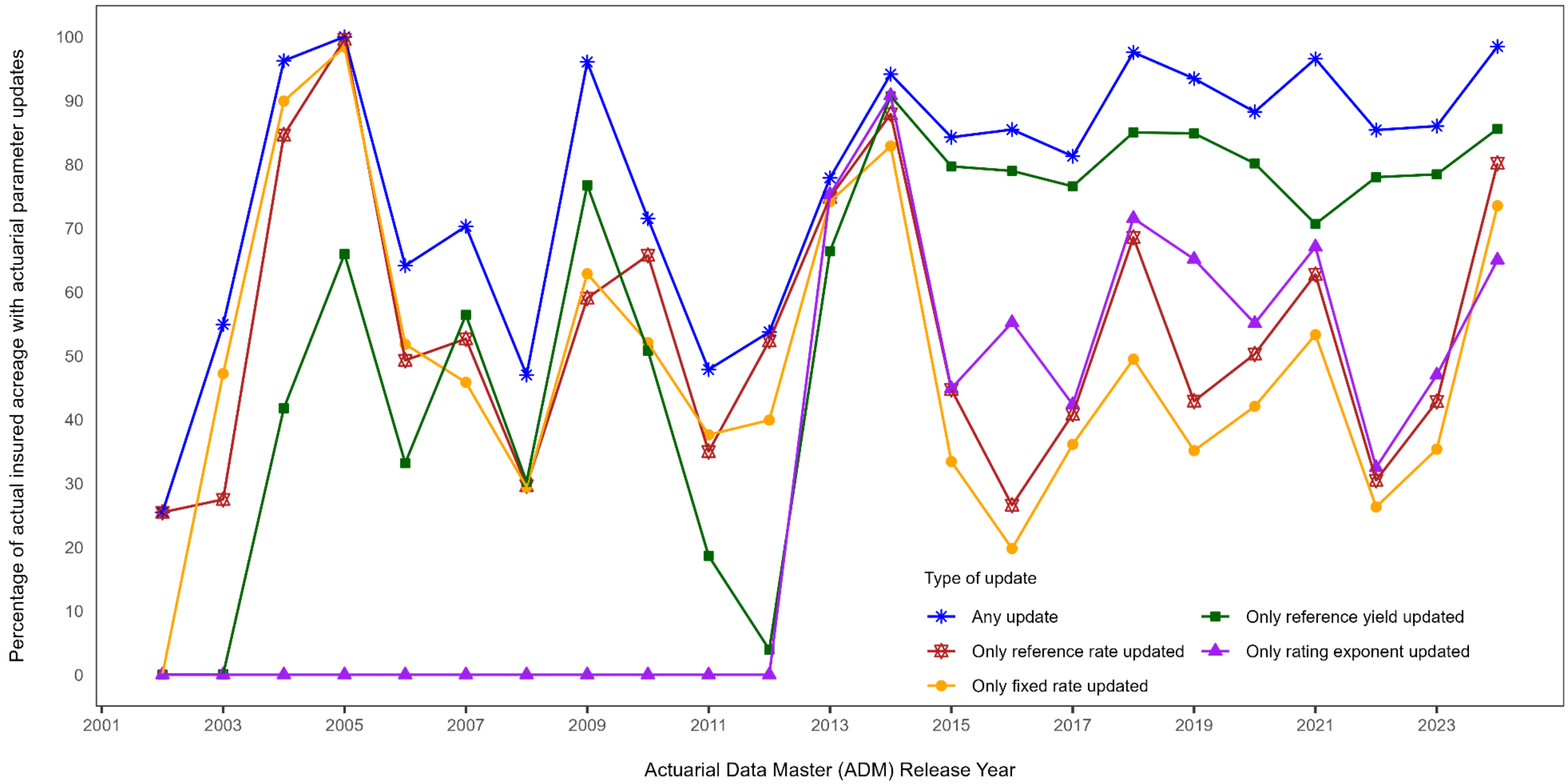


Figure 3: Variation in annual actuarial updates in the United States Federal Crop Insurance Program by state and commodity grouping (2002-24).

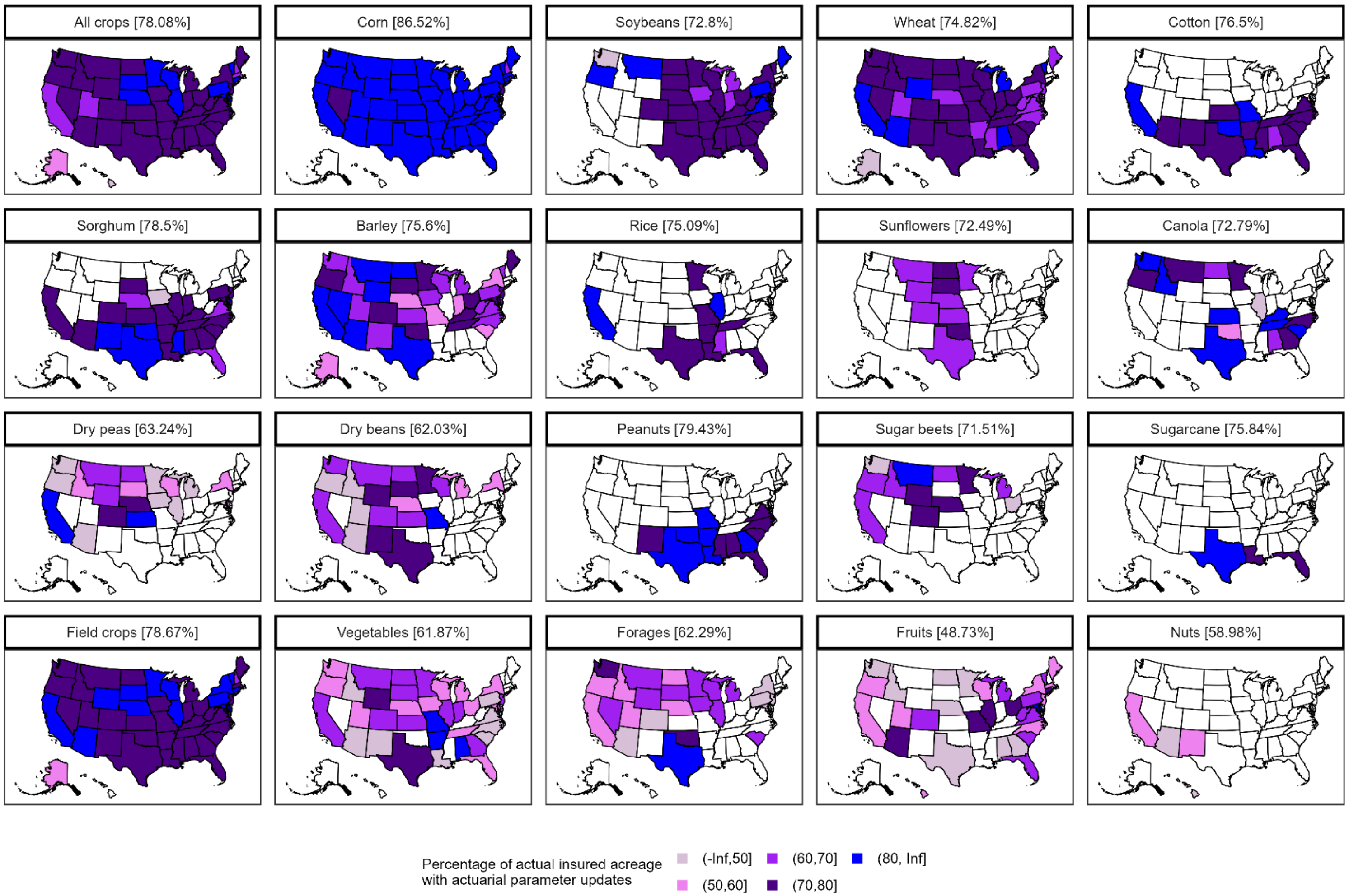


Figure 4: Temporal variation in the impacts of actuarial updates on the fiscal landscape of the United States Federal Crop Insurance Program (2002-24)

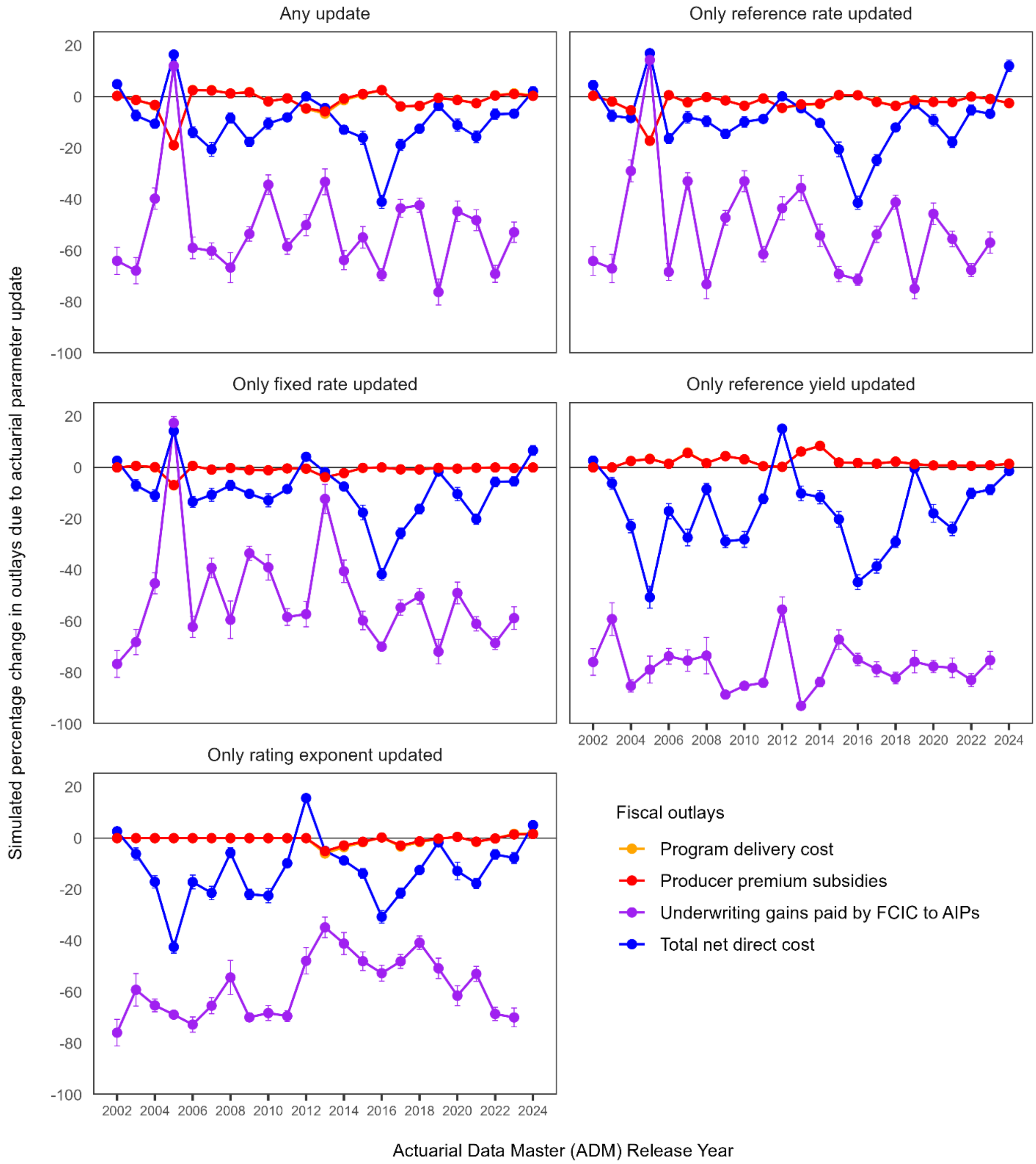
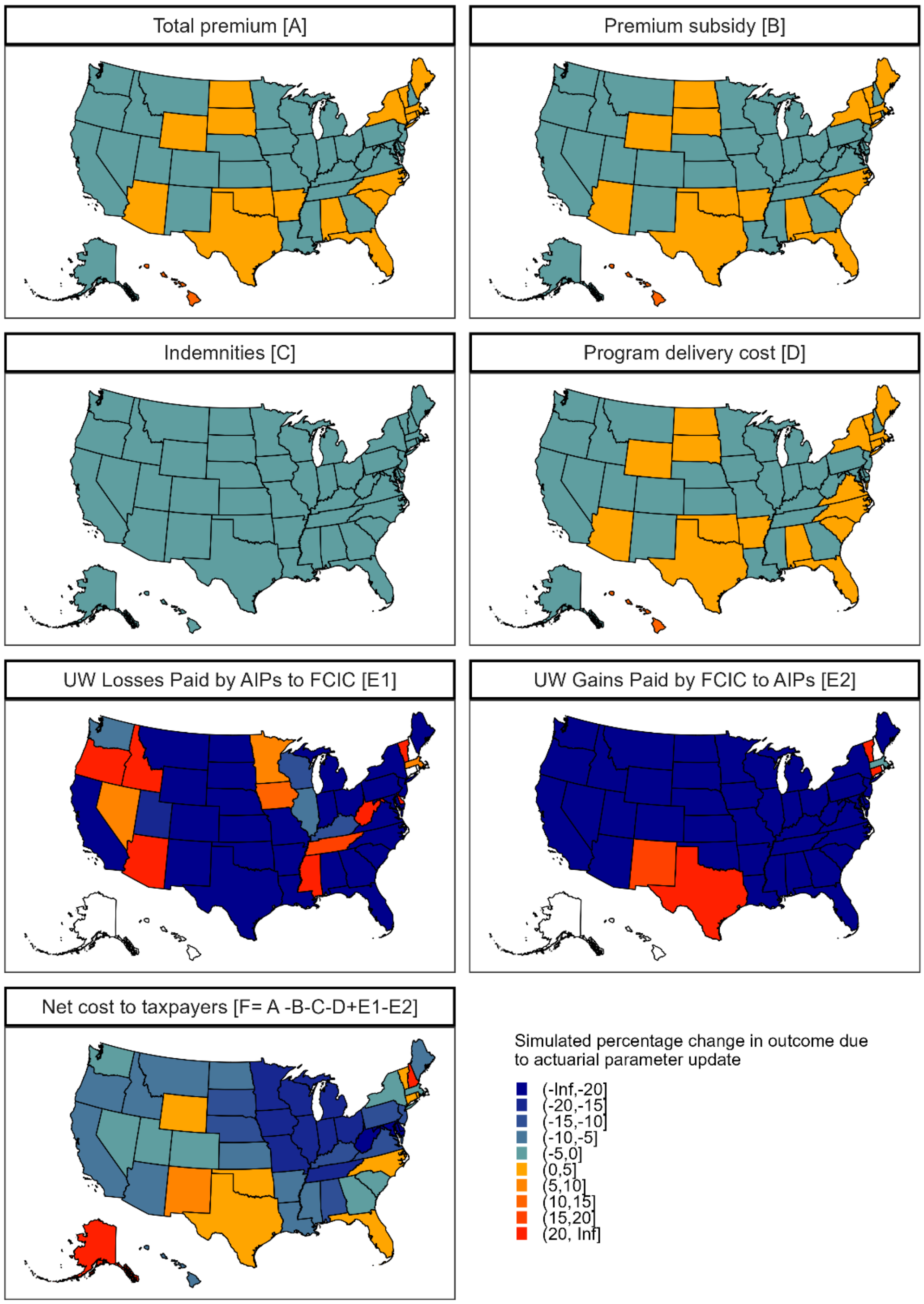


Figure 5: Fiscal impacts of actuarial updates in the United States Federal Crop Insurance Program by state (2002-24).



Appendix

Table S1: United States Department of Agriculture, Risk Management Agency Appropriations

Fiscal year	Appropriations
2001	$67,700,000
2002	$74,752,000
2003	$76,062,000
2004	$78,488,000
2005	$91,582,000
2006	$87,806,000
2007	$80,797,000
2008	$79,062,000
2009	$77,177,000
2010	$80,325,000
2011	$83,064,000
2012	$82,325,000
2013	$74,900,000
2014	$71,496,000
2015	$76,779,000
2016	$76,946,000
2017	$66,615,000
2018	$55,000,000
2019	$37,942,000
2020	$56,045,000
2021	$59,440,000
2022	$69,207,000
2023	$75,443,000
2024	$77,897,000
Averages	
2001-2010	$79,375,100
2011-2024	$68,792,786
2001-2024	$73,202,083
Average annual growth rate (%)	
2001-2010	1.522
2011-2024	1.225
2001-2024	1.349

Source:

Table S2: Crop Insurance Annual Mean Subsidy as a Percent of Total Premium From 2000-24

Insurance plan and unit type	**Coverage level**										
	CAT	**50%**	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**	**90%**	**95%**
Individual yield and revenue plans											
Basic/Optional unit	100%	66%	63%	63%	58%	58%	54%	47%	37%	-	-
Enterprise unit	-	74%	73%	73%	71%	71%	68%	59%	47%	-	-
Whole farm unit	-	80%	80%	80%	72%	71%	70%	62%	48%	-	-
Group based plans											
Yield protection	100%	-	-	-	-	61%	60%	56%	55%	51%	-
Revenue protection	100%	-	-	-	-	59%	57%	53%	45%	44%	-
Margin protection	-	-	-	-	-	59%	55%	55%	49%	44%	44%
Rainfall or vegetative index insurance	100%	-	-	-	-	60%	60%	55%	55%	51%	-
Supplemental plans											
Enhanced Coverage Option (ECO)	-	-	-	-	-	-	-	-	-	44%	44%
Supplemental Coverage Option (SCO)	-	65%	65%	65%	65%	65%	65%	65%	65%	-	-
Stacked Income Protection Plan (STAX)	-	-	-	-	-	-	80%	80%	80%	80%	-
Hurricane Insurance Protection - Wind Index (HIP-WI)	-	-	-	-	-	-	-	-	-	-	65%
Post-Application Coverage Endorsement (PACE)											
Basic/Optional unit	-	-	-	-	-	-	55%	48%	38%	39%	-
Enterprise unit	-	-	-	-	-	-	62%	55%	38%	43%	-
Livestock plans	-	-	-	-	-	-	-	55%	49%	44%	44%
Whole farm protection plans	-	77%	72%	73%	66%	74%	63%	58%	56%	-	-

Source: Author using data from RMA Actuarial data master database

Notes: CAT = catastrophic. A basic unit covers land in one county with the same tenants and landlords. An optional unit is a basic unit divided into small units by township section. An enterprise unit (EU) covers all land of a single crop in a county for a producer, regardless of tenant and landlord arrangements. EU can also be specified by practice or type as allowed by the crop provisions, and they can also be multicounty. Individual plans (yield or revenue) are based on the on-farm production experience of the producer.

Table S3: Crop Insurance Administrative & Operating (A&O) Subsidy Schedule From 2000-24

Insurance plan	**Coverage level**									
	50%	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**	**90%**	**95%**
Individual plans										
Yield protection	22%-27%	22%-27%	22%-27%	22%-27%	22%-27%	22%-27%	22%-27%	21%-27%	-	-
Revenue protection	18%-28%	18%-28%	18%-28%	18%-28%	18%-28%	18%-28%	18%-27%	18%-27%	-	-
Group based plans										
Yield protection	-	-	-	-	12%-25%	12%-25%	12%-25%	12%-25%	12%-25%	-
Revenue protection	-	-	-	-	12%-28%	12%-28%	12%-27%	12%-27%	12%	-
Margin protection	-	-	-	-	20%	20%	20%	20%	20%	20%
Rainfall or vegetative index insurance	-	-	-	-	20%-28%	20%-28%	19%-20%	18%-20%	20%	-
Supplemental plans										
Enhanced Coverage Option (ECO)	-	-	-	-	-	-	-	-	20%	20%
Supplemental Coverage Option (SCO)	20%	20%	20%	20%	20%	20%	20%	20%	-	-
Stacked Income Protection Plan (STAX)	-	-	-	-	-	20%	20%	20%	20%	-
Hurricane Insurance Protection - Wind Index (HIP-WI)	-	-	-	-	-	-	-	-	-	20%
Post-Application Coverage Endorsement (PACE)	-	-	-	-	-	22%	22%	22%	22%	-
Whole farm protection plans	21%-28%	21%-28%	21%-28%	21%-28%	21%-28%	21%-28%	19%-27%	19%-27%	-	-

Source: Author using data from RMA Insurance control elements database

Table S4: Shares of Underwriting Gains and Losses to Insurance Companies under the Standard Reinsurance Agreement 1998-25

	Assigned Risk Fund (ARF)	Developmental Fund (DF)			Commercial Fund (CF)		
		CAT	REV	OTHER	CAT	REV	OTHER
Panel A 1998-2011 reinsurance years							
Proportional reinsurance [a]							
Fund allocation	State max of 10-75%	All non- ARF designations			All non- ARF or -DF designations		
Retention within fund	20%	35-100% in 5% increment			50%-100% in 5% increment		
Non-proportional reinsurance [b]							
Percentage of loss on retained interest by loss ratio							
1.0–1.6	5.0	25.0	30.0	25.0	50.0	57.0	50.0
1.6–2.2	4.0	20.0	22.5	20.0	40.0	43.0	40.0
2.2–5.0	2.0	11.0	11.0	11.0	17.0	17.0	17.0
>5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of gain on retained interest by Loss ratio							
0.65–1.0	15.0	45.0	60.0	60.0	75.0	94.0	94.0
0.5–0.65	9.0	30.0	50.0	50.0	50.0	70.0	70.0
<0.5	2.0	4.0	6.0	6.0	8.0	11.0	11.0
Panel B: 2012-2025 reinsurance years							
Proportional reinsurance							
Fund allocation	State max of 75%				At least 25%		
Retention within fund	20%				35%-100% in 5% increment		
Non-proportional reinsurance [b, c]							
Percentage of loss on retained interest by loss ratio							
1.0–1.6	7.5	-	-	-	65.0 [42.5]	65.0 [42.5]	65.0 [42.5]
1.6–2.2	6.0	-	-	-	45.0 [20.0]	45.0 [20.0]	45.0 [20.0]
2.2–5.0	3.0	-	-	-	10.0 [5.0]	10.0 [5.0]	10.0 [5.0]
>5.0	0.0	-	-	-	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
Percentage of gain on retained interest by Loss ratio							
0.65–1.0	22.5	-	-	-	76.0 [97.5]	76.0 [97.5]	76.0 [97.5]
0.5–0.65	13.5	-	-	-	40.0 [40.0]	40.0 [40.0]	40.0 [40.0]
<0.5	3.0	-	-	-	5.5 [5.5]	5.5 [5.5]	5.5 [5.5]

CAT = Catastrophic insurance; REV=Revenue insurance plans; OTHER = All other crop insurance plans.

[a] After all reinsurance cessions, the AIP's must retain a percentage of net book premium and associated liability that equals or exceeds 35% of its book of business. If not, the AIP's retention of net book premium and associated liability for ultimate net losses for all contracts designated in the Assigned Risk Fund in all States will be increased on a pro rata basis to make the API's retention meet the minimum retention requirement.

[b] Share of loss or gain is determined incrementally by the realized loss ratio for a company's business in each state and fund

[c] The Percentage of loss/gain on retained interest by loss ratio for the Commercial Fund varied by three state grouping where the values in the bracket are for groups 2 and 3. "State Group 1" means Illinois, Indiana, Iowa, Minnesota, and Nebraska. "State Group 2" means Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Kansas, Kentucky, Louisiana, Michigan, Missouri, Mississippi, Montana, North Carolina, North Dakota, New Mexico, Ohio, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Texas, Virginia, Washington, and Wisconsin. "State Group 3" means Alaska, Connecticut, Delaware, Hawaii, Maine, Massachusetts, Maryland, Nevada, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Utah, Vermont, West Virginia, and Wyoming.

Table S5: Means and Standard Deviations of US Federal Crop Insurance Outcomes by Commodity (2001-23).

Variables	DRY BEANS	SUNFLOWERS	PEANUTS	DRY PEAS	CANOLA	Field crops	Vegetables	Forages	Fruits	Nuts
Summary of business outcomes										
Coverage level (%)	68.60 (7.46)	68.35 (6.62)	66.23 (9.17)	68.69 (7.66)	71.17 (5.59)	71.09 (9.52)	67.82 (8.32)	55.58 (8.15)	58.22 (8.91)	60.35 (10.40)
Net insured area (acres)	499 (1323)	713 (1672)	427 (802)	818 (1908)	1646 (5697)	1346 (4460)	611 (1581)	520 (1951)	208 (665)	2255 (5968)
Total insured liability ($ 1,000)	177 (470)	133 (422)	220 (448)	158 (399)	354 (1563)	475 (2082)	272 (1349)	84 (379)	671 (2100)	5212 (12401)
Total premium ($ 1,000)	25.50 (81.54)	24.46 (73.43)	20.46 (55.37)	25.70 (73.62)	61.82 (291.73)	48.05 (209.95)	28.24 (90.44)	10.12 (37.55)	50.64 (170.01)	185.77 (460.83)
Total subsidy ($ 1,000)	15.61 (51.71)	16.05 (51.88)	12.31 (32.13)	15.83 (48.03)	40.09 (195.62)	29.96 (141.81)	17.37 (56.89)	7.01 (27.30)	32.84 (111.38)	114.98 (293.38)
Total indemnity ($ 1,000)	20.54 (93.43)	23.05 (99.53)	23.01 (144.55)	28.37 (113.26)	49.09 (246.10)	39.86 (305.45)	25.78 (117.55)	8.02 (61.74)	47.44 (225.61)	161.85 (861.32)
Premium per dollar of liability	0.15 (0.09)	0.20 (0.11)	0.09 (0.07)	0.16 (0.09)	0.17 (0.08)	0.13 (0.11)	0.14 (0.10)	0.14 (0.10)	0.10 (0.11)	0.04 (0.03)
Subsidy per dollar of premium	0.63 (0.12)	0.63 (0.10)	0.65 (0.13)	0.62 (0.12)	0.62 (0.12)	0.63 (0.13)	0.63 (0.13)	0.69 (0.15)	0.66 (0.14)	0.64 (0.14)
Producer paid premium rate	0.06 (0.04)	0.08 (0.05)	0.04 (0.03)	0.06 (0.04)	0.07 (0.04)	0.05 (0.05)	0.06 (0.04)	0.05 (0.04)	0.04 (0.04)	0.02 (0.01)
Actuarial data master outcomes										
Reference rate	0.13 (0.07)	0.15 (0.08)	0.07 (0.06)	0.13 (0.07)	0.12 (0.06)	0.11 (0.09)	0.12 (0.08)	0.13 (0.08)	0.10 (0.10)	0.03 (0.02)
Fixed rate	0.04 (0.01)	0.04 (0.01)	0.03 (0.01)	0.03 (0.01)	0.04 (0.02)	0.03 (0.02)	0.03 (0.02)	0.02 (0.01)	0.02 (0.01)	0.01 (0.01)
Rating exponent	-1.33 (0.67)	-1.54 (0.57)	-1.00 (0.28)	-0.66 (0.64)	-1.39 (0.61)	-1.43 (0.53)	-1.09 (0.71)	-0.77 (0.83)	-0.20 (0.47)	-1.02 (0.64)
Coverage level differential factor-50%	0.69 (0.12)	0.70 (0.11)	0.64 (0.09)	0.71 (0.11)	0.71 (0.10)	0.67 (0.11)	0.68 (0.12)	0.64 (0.13)	0.60 (0.16)	0.49 (0.11)
Coverage level differential factor-55%	0.79 (0.12)	0.78 (0.13)	0.76 (0.10)	0.84 (0.07)	0.80 (0.11)	0.76 (0.12)	0.81 (0.11)	0.80 (0.10)	0.78 (0.12)	0.68 (0.07)
Coverage level differential factor-60%	0.87 (0.12)	0.86 (0.14)	0.86 (0.10)	0.92 (0.05)	0.88 (0.11)	0.85 (0.11)	0.88 (0.11)	0.89 (0.09)	0.88 (0.07)	0.81 (0.07)
Coverage level differential factor-65%	0.95 (0.12)	0.94 (0.13)	0.97 (0.10)	0.99 (0.04)	0.96 (0.11)	0.95 (0.12)	0.97 (0.10)	0.97 (0.09)	1.00 (0.04)	0.98 (0.08)
Coverage level differential factor-70%	1.06 (0.12)	1.03 (0.12)	1.12 (0.11)	1.08 (0.05)	1.06 (0.09)	1.07 (0.12)	1.07 (0.11)	1.08 (0.09)	1.13 (0.08)	1.19 (0.10)
Coverage level differential factor-75%	1.20 (0.16)	1.14 (0.08)	1.30 (0.16)	1.17 (0.08)	1.17 (0.08)	1.22 (0.14)	1.20 (0.14)	1.21 (0.13)	1.29 (0.17)	1.45 (0.13)
Coverage level differential factor-80%	1.35 (0.22)	1.26 (0.07)	1.50 (0.27)	1.27 (0.11)	1.28 (0.09)	1.38 (0.20)	1.33 (0.21)	1.30 (0.16)	1.43 (0.27)	1.71 (0.16)
Coverage level differential factor-85%	1.51 (0.32)	1.38 (0.10)	1.73 (0.40)	1.38 (0.15)	1.40 (0.12)	1.56 (0.28)	1.48 (0.31)	1.41 (0.24)	1.58 (0.39)	2.00 (0.22)
Basic unit differential factor	1.03 (0.02)	1.03 (0.02)	1.06 (0.03)	1.05 (0.02)	1.06 (0.03)	1.03 (0.03)	1.04 (0.02)	1.03 (0.02)	1.04 (0.02)	1.03 (0.02)
Enterprise unit differential factor	1.02 (0.01)	1.02 (0.01)	1.03 (0.02)	1.03 (0.01)	1.03 (0.01)	1.01 (0.04)	1.02 (0.01)	1.01 (0.01)	1.02 (0.02)	1.00 (0.01)
Number of insurance pools	17138	16384	12920	11076	6902	624196	33486	16571	5496	895
Number of observations	60887	57564	67782	41016	23420	3783943	129045	68907	29591	8057

The data was constructed by the authors using primary data from (1) Risk Management Agency's summary of business and actuarial data master files that contain insurance metrics aggregated by county, crop, crop type, production practice, insurance plan, coverage level, and insurance unit.

Table S6: Fiscal impacts of actuarial updates in the United States Federal Crop Insurance Program (2002-24) – Unadjusted Demand

	Assumed no update (baseline)	Type of actuarial data master parameter update				
		Current RMA update pattern	Assumed Reference rate only updated	Assumed Reference fixed rate only updated	Assumed Rating exponent only updated	Assumed Reference yield only updated
Gross book of business		Expressed as percentage change over no update case				
Area insured (million acres)	211.587 (3.959)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Liability (billion $)	99.466 (2.348)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Loss ratio	0.814 (0.007)	-1.170*** (0.052)	-1.736*** (0.035)	-0.550*** (0.015)	-0.502*** (0.022)	1.571*** (0.018)
Fiscal inflows (billion $)						
Premium	10.194 (0.207)	-1.500*** (0.062)	-2.181*** (0.047)	-0.816*** (0.018)	-0.738*** (0.029)	2.241*** (0.022)
Underwriting losses	0.521 (0.019)	-26.842*** (1.703)	-32.367*** (1.822)	-39.966*** (1.743)	-47.757*** (1.585)	-67.362*** (1.426)
Total inflows	10.715 (0.220)	-2.732*** (0.083)	-3.648*** (0.089)	-2.719*** (0.089)	-3.023*** (0.100)	-1.142*** (0.123)
Fiscal outflows (billion $)						
Premium subsidy	6.322 (0.128)	-1.362*** (0.061)	-2.104*** (0.046)	-0.793*** (0.019)	-0.601*** (0.026)	2.177*** (0.023)
Indemnity	8.291 (0.182)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Program delivery cost	2.084 (0.042)	-1.358*** (0.060)	-2.158*** (0.045)	-0.793*** (0.018)	-0.664*** (0.026)	2.270*** (0.023)
Underwriting gains	1.786 (0.042)	-48.712*** (0.461)	-47.735*** (0.435)	-47.433*** (0.478)	-55.536*** (0.469)	-78.271*** (0.384)
Total outflows	18.483 (0.377)	-5.326*** (0.098)	-5.575*** (0.093)	-4.943*** (0.093)	-5.646*** (0.098)	-6.562*** (0.106)
Net total direct cost to taxpayers (billion $)	7.768 (0.162)	-8.903*** (0.270)	-8.232*** (0.290)	-8.012*** (0.301)	-9.264*** (0.289)	-14.037*** (0.361)

Simulation: Actuarial Data Master [ADM] (successor) for the release year (e.g., 2023) was replaced with the ADM for the previous year (incumbent) (e.g., 2022) and the premiums were recalculated for the actual loss experience outcomes associated with the successor in the release year. Crop insurance demand is held fixed at actual observed values following an update.

Significance levels - *p<0.1 ** p<0.05, ***p<0.01. Standard errors in parentheses are estimated by resampling insurance pools 100 times.

Figure S1: Graphical Representation of the Premium Rating Parameter Updating Sequence in the United States Federal Crop Insurance Program

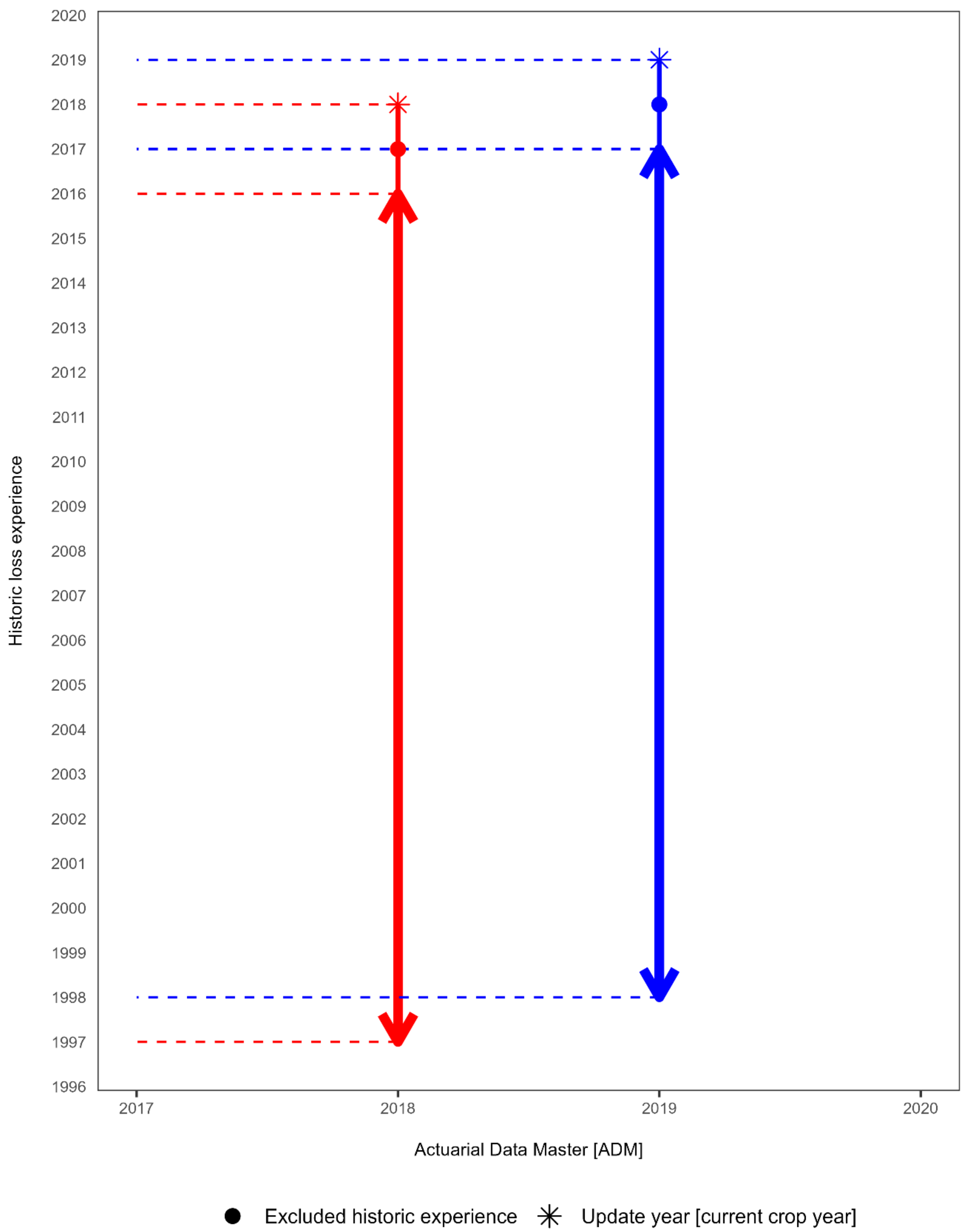


Figure S2: The responsiveness of insured acres to rating parameter updates in the US Federal Crop insurance Program

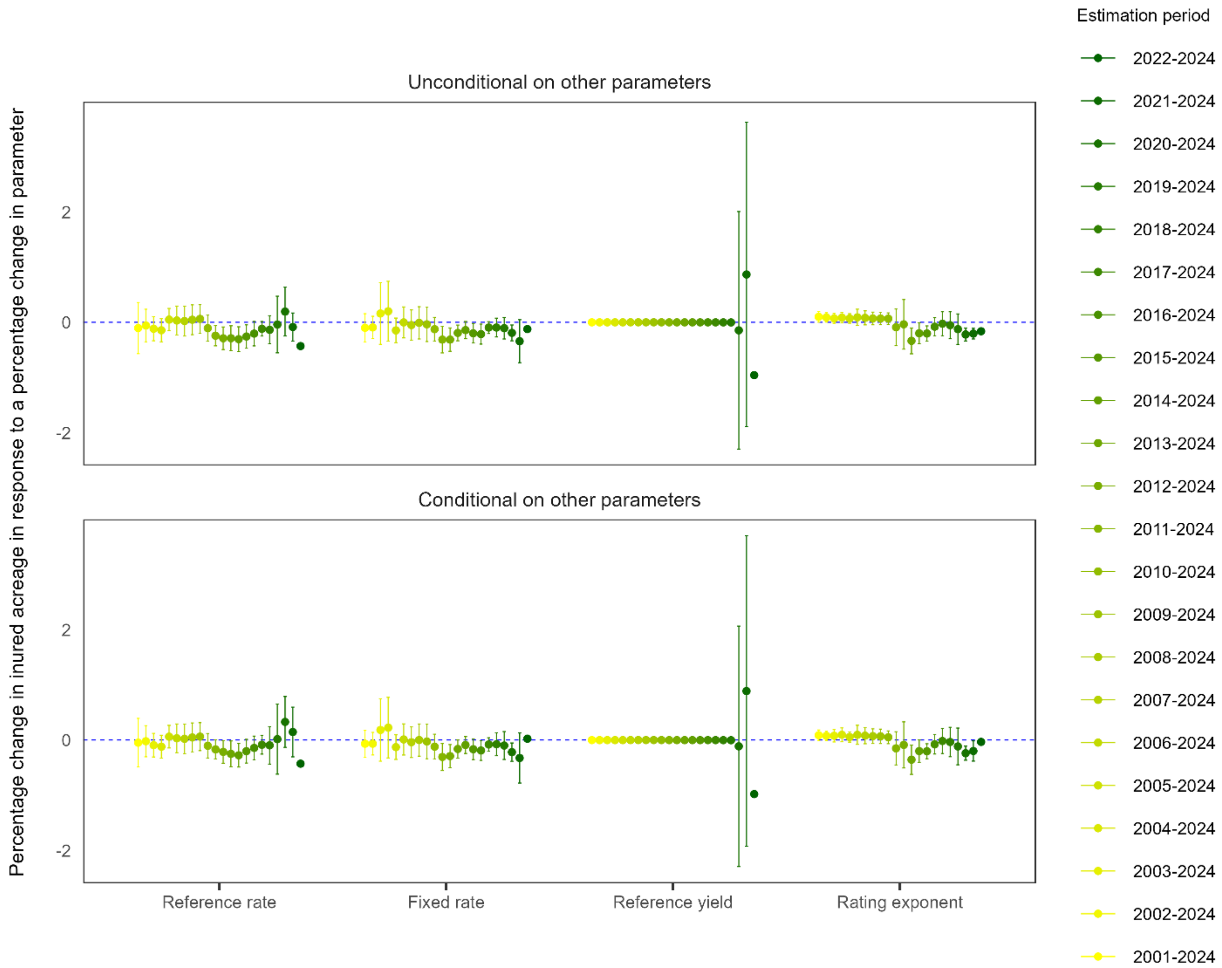


Figure S3: Estimated elasticities