# Actuarial Impacts of Rating Revisions in United States Agricultural Insurance

Francis Tsiboe, Senior Research Economist and Program Leader, Agricultural Risk Policy Center (ARPC), North Dakota State University, Richard H Barry Hall, 811 2nd Ave N, Fargo ND 58108-6050. Email: francis.tsiboe@ndsu.edu / ftsiboe@hotmail.com

**Acknowledgments**
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**Abstract**

The Federal Crop Insurance Program (FCIP) plays a critical role in U.S. agricultural risk management, backed by significant federal subsidies. While debates persist over cost savings versus potential declines in farmer participation, maintaining actuarially sound premium rates remains pivotal. This study assesses rate innovations through annual parameter updates from 2001 to 2023, using over three million observations spanning 49 commodities. Findings indicate that revisions generally nudged the program closer to its target loss ratio of 1, with reference rate updates proving especially impactful. However, heterogeneity across sectors emerges; some start far from 1, allowing for notable improvements, while others already hover near 1, rendering further adjustments less apparent. Over time, a pattern suggests diminishing returns on these updates as more acres are enrolled. Overall, the results underscore the complexity of calibrating premium rates to ensure both affordability for producers and long-term actuarial and fiscal soundness for the FCIP.

**Keywords:** crop insurance; premium rate; subsidies; actuarial science

**JEL codes:** Q14, G22, H51, Q18; Q12

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## 1. Introduction

In the dynamic and often unpredictable world of agricultural production, risk looms large, encompassing adverse events like drought, excess moisture, damaging freezes, hail, wind, disease, and price fluctuations. These risks not only threaten the livelihoods of farmers (Leip, Rovenskaya and Wildemeersch 2024; Wossen et al. 2018) but also pose significant challenges to food security (Savary et al. 2012; Lusk 2017), and development of rural economies (Azzam, Walters and Kaus 2021; Lee 2021). In this context, government-subsidized programs such as agricultural insurance emerge as critical mechanisms for mitigating these risks globally (Baldwin, Williams, Tsiboe, et al. 2023; Mahul and Stutley 2010; Smith and Glauber 2012; Belasco 2020; Turner and Tsiboe 2022; Tsiboe and Turner 2023b; Baldwin, Williams, Sichko, et al. 2023; Turner et al. 2023).[1] By providing a safety net, these programs enable farmers to manage the volatility inherent in agriculture, ensuring that they continue to produce food, maintain their businesses (Kim, Yu and Pendell 2019), and contribute to the economy despite these challenges.

The Federal Crop Insurance Program (FCIP) has become a major fixture in the United States' agricultural risk management strategy with the federal government subsidizing over 60% of the insurance premiums for farmers annually from 2001 to 2021 (Economic Research Service [ERS] 2022; Turner et al. 2023). Additionally, it allocated over $1.27 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 of the FCIP averaged $6.05 billion annually during this period, with an annual growth rate of 13.22%. This substantial financial commitment emphasizes

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

FCIP's crucial function in backing farmers, while also spotlighting 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 the program (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.

Central to the fiscal integrity of the FCIP 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. Additionally, 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]

[2] 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.

A substantial body of research has examined the RMA's insurance rating methods, focusing on various aspects such as actuarial soundness (Woodard, Sherrick and Schnitkey 2011), adverse selection (Skees and Reed 1986; Goodwin 1994), 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 to improve rates (Tsiboe and Tack 2022; Woodard and Verteramo-Chiu 2017; Liu and Ramsey 2023). Despite these efforts, a significant question remains largely unexplored: Have annual updates (i.e., innovations) to the actuarial parameters, which underpin the rates charged to producers, resulted in noticeable improvements in the FCIP? Addressing this question is essential for continuous improvement of the program, ensuring it remains both fair to producers and financially viable for the long term.

The aim of this study is to assess the impacts of rate innovations as captured by RMA's annual updates to FCIP's rating parameters with a focus on understanding how these contribute to the program's actuarial performance. The study employed a counterfactual simulation approach to calculate the hypothetical loss outcomes of the FCIP if the rating parameters for a given crop year had not been updated. The impacts of rate innovations were estimated by comparing the differences between the hypothetical outcomes (had the rates not been updated) and the actual observed outcomes following the updates. This simulation was retrospectively applied to the RMA's summary of business and actuarial data master from 2001 to 2023.

The study reveals a general improvement in actuarial soundness following updates to rating parameters, reflecting a move towards more accurate risk assessments and premium settings. Significant enhancements in actuarial performance were notably observed in 2005 and 2018. Conversely, the years 2006, 2012, and 2013 experienced downturns, highlighting periods of actuarial regression. The results further highlight substantial structural shifts influenced by each

Farm Bill from 2008 to 2018 and the introduction of the COMBO plans in 2011. Regarding specific parameters, updates to the reference rate and rating exponents significantly enhanced actuarial soundness. However, adjustments to reference yields generally decreased actuarial performance while updates to fixed rates marginally improved actuarial performance. An emerging pattern across crop years suggests updates significantly improve actuarial soundness for programs with roughly 35 to 60 years of historical data but yield negligible benefits for younger or more established programs, indicating diminishing returns beyond 60 years.

The influence of actuarial updates on the FCIP also shows considerable variation by commodity, state, and cumulative historical actuarial performance. Performance varies depending on policy patronage (acres insured) with each step towards actuarial soundness—a loss ratio (LR) of one—bolstering overall results. Some levels begin significantly distant from an LR of one, while others closer to this mark are challenging to evaluate or might not need adjustments. Specifically, nuts and field crops demonstrated marked improvements, whereas forages and fruits saw less favorable outcomes. Geographically, Arizona and Vermont showed significant gains in actuarial performance following updates, enhancing their alignment with actuarial expectations. In contrast, Washington and Iowa exhibited poorer results, indicating discrepancies with local agricultural risks. When considering perils that overshadow rate adjustments, significant weather events—especially widespread droughts—can negate the effects of adjustments aimed at improving insurance actuarial soundness, whereas more localized perils such as pests and flooding do not reduce the effectiveness of these adjustments.

The FCIP has achieved an overall loss ratio of 0.86 over the period 2001 to 2023, well below the actuarially sound threshold of 1.0, while covering over 80% of principal crop areas in the US. Despite this outcome, challenges persist in adjusting premiums equitably across diverse agricultural sectors and regions, compounded by political resistance to increasing farmer-paid premiums. This issue often results in rate discrepancies, causing some farmers to overpay and others to underpay, as evidenced by the variable impacts of actuarial updates analyzed in this study. Looking ahead, it is crucial to align legislative objectives with the operational realities of crop insurance. Finally, as the program matures, the effectiveness of yield data in marginally improving rates on a crop year basis decrease, suggesting a need to explore alternative factors for further enhancements.

This study enhances the FCIP ratemaking literature by offering unique, comprehensive insights into the multidimensional impacts of actuarial updates—an area previously overlooked. While earlier research (Woodard et al. 2011; Skees and Reed 1986; Goodwin 1994; Adhikari et al. 2012; Seo et al. 2017; Harri et al. 2011; Annan et al. 2014; Tsiboe and Tack 2022; Woodard and Verteramo-Chiu 2017; Liu and Ramsey 2023) has examined various facets of FCIP ratemaking, this work makes a significant contribution through its detailed analysis of rating parameter changes for premium calculations across modern FCIP. It employs a novel approach that leverages the timing of lagged rating adjustments based on past loss experiences, effectively revealing the directional impact of these changes on actual loss rates. Although caution is advised when interpreting these findings, the method broadens our understanding of these issues and underscores the importance of accurately capturing rating adjustments. Additionally, by utilizing more granular data (i.e., disaggregating observational units into insurance pools within each county), this study reduces the potential for aggregation bias, ensuring that units with similar crop insurance and production characteristics are analyzed together. Finally, unlike prior research that focused only on major row crops, this study includes a broad range of 49 commodities and seven crop insurance plans, representing about 82% [71%] of the FCIP's crop book of business liability [acreage insured] from 2001-2023. This nuanced analysis at a more granular level not only deepens the understanding of actuarial adjustments within the FCIP but also illuminates the complex interdependencies among different actuarial factors, producer groups (crops and states), and perils which typically influence policy direction.

The remainder of the paper is structured as follows. Section 2 outlines the mechanisms behind the FCIP premium rating and its updates, setting the foundation for understanding the adjustments 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 discussed the heterogeneity in outcomes with Section 6 providing the conclusions.

## 2. FCIP Premium Rating and Update Mechanisms

Premium rating in the FCIP is guided by a complex principle known as the loss-cost ratio rate-making (Coble et al. 2010; Coble et al. 2020) to develop insurance pool level (the lowest sub-county aggregation for rating in the FCIP) rates for a common coverage level, and subsequent adjustments via mechanisms analogous to how other property and casualty insurance rate factors are developed from a combination of experience and differential exposure information (Sherrick, Schnitkey and Woodward 2014). Here, the aim is to simplify this process, especially in relation to plans based on actual on-farm experiences (i.e., actual production history [APH], yield protection [YP], revenue protection [RP], and RP with harvest price exclusion [RP-HPE] plans).

Individual-level yield insurance plans (YP and APH) consist of eight main components: rate yield ($\bar{y}$), approved yield ($\ddot{y}$), coverage level ($\theta$), indemnity ($I(y)$), premium rate ($\tau$), premium ($P$), and subsidy ($S$). The rate and approved yields are calculated from the average actual production history (APH) reported by farmers. The key distinction is that the approved yield is typically adjusted upwards through various elements of the RMA's actuarial process, such as yield exclusion, yield substitution, and trend adjustments.[3] For each contract, producers may insure their approved yield at a chosen coverage level ($\theta$), establishing a yield guarantee (liability) of $\theta\ddot{y}$. The indemnity per acre, given a specific yield outcome y, is calculated as $I(y) = \max[0, \theta\ddot{y} - y]$.

Premium rates are designed to be actuarially fair, implying that over time, the total premiums collected equal the total indemnities paid. The premium rate per dollar of liability is thus defined as:

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

Here, $f(y)$ represents the probability density function of y, which assumes that indemnities are stochastic and not predetermined when the policy is issued. Crop insurance policies are generally developed under the assumption that $f(y)$ is conditional upon an adjustment mechanism. This mechanism adjusts for the underlying risk profile of the insured producer, which, although not directly observable, is estimated by comparing the producer's productivity to that of their peers. The extent of this adjustment is derived using RMA's "continuous rating formula" (Milliman & Robertson 2000; Risk Management Agency [RMA] 2000; Risk Management Agency [RMA] 2009).

For simplicity, the continuous rating formula for yield-based plans (YP and APH) is specified according to the following equation

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

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[3] Higher approved yields result in higher yield guarantees leading to higher indemnities for a given yield outcome which improves producer welfare (Adhikari, Knight and Belasco 2013).

where the subscript ijt represents an insured (i) seeking protection defined by an insurance pool (j) for crop year t.[4] The parameters $\alpha_{jt}$ and $\delta_{jt}$ respectively represent the reference rate and catastrophic fixed loading factor for a common coverage level (conventionally at the 65% level) for the insurance pool. The term $\bar{y}_{ijt}$ (the rate yield) represents a producer's simple average yield of their actual production history, and $\bar{y}_{jt}$ represents the average yield of producers in the county. Thus, the term $(\bar{y}_{ijt}/\bar{y}_{cjt})$ represents a producer's typical yield relative to the typical yield of other producers in their chosen pool. This ratio is then adjusted by a negative continuous rating exponent, $\beta_{jt}$, which has the effect of scaling the rate down for more productive producers.[5] The entire term, $(\bar{y}_{ijt}/\bar{y}_{cjt})^{\beta_{jt}}$, is referred to as the rate multiplier curve. The terms $F_{ijt}^{\theta}$ and $F_{ijt}^{u}$ represents a scaling factor that adjusts the rate based on the producer's choice of coverage level ($\theta_{ijt}$) and insurance unit election ($u_{ijt}$).[6]

For a producer seeking revenue protection (RP and RP-HPE), premium rates are calculated using a simulation that combines yield and price distributions with their correlation. This process yields a "revenue load" by subtracting a simulated yield rate from a simulated revenue rate. The revenue load, representing the extra risk of covering revenue over yield, is added to the base rate of yield

[4] Currently, RMA has predefined insurance pools formed by the unique combination of county, crop, crop type, and production practices.

[5] This is done under the assumption that risk covaries with yield such that more productive farms are less risky which is based on an early body of research (Botts and Boles 1958; Skees 1986).

[6] The unit structure election allows fields to be either separately insured or aggregated into a single policy. Optional Units (OU) allow for the most granular insurance coverage by separately insuring each field. Basic Units (BU) offer insurance based on a combination of crop, county, and share/ownership, simplifying the structure. Enterprise Units (EU) further consolidate insurance contracts by combining all sections and share/ownership of a specific crop within a county.

insurance plans (YP and APH). This approach ensures the premium rate charged for revenue coverage accurately reflects the additional risk, providing a fair and tailored insurance solution for producers.[7] The total price of the insurance contract, P, is set equal to the product of the premium rate, $\tau(.)$, and the yield guarantee, $\theta\ddot{y}$ , such that $P = \tau(.)\theta\ddot{y}$. The final price paid by the insured is subsidized at a rate $S(\theta, u)$ that is tied to coverage level and insurance unit and not to location or the crop.

Each year, the RMA sets rating parameters for thousands of county/crop insurance programs, with multiple policy designs available for each. By law, RMA must ensure these policies are actuarially sound, a task handled by its Actuarial Branch (AB) through a rigorously defined filing schedule and stringent control measures. This branch is split into three specialized teams: Rates, Prices, and Filing, which are respectively led by a Senior Statistician, Senior Economist, and Senior Risk Management Specialist. These leaders report to the Actuarial Branch Chief. The teams regularly update rating parameters—such as $\alpha, \delta, \beta$, and $\bar{y}_c$—to reflect technological, methodological advances, environmental changes like climate variation, and on the ground expert opinion from their regional offices. Each team member is assigned specific crops, ensuring that parameters are established and updated in compliance with agency guidelines and then disseminated to the insurance industry for premium calculation.

The annual rating cycle begins with the Rates Team (RT) Leader loading the latest data into a database known as "StatPlan" and initiating a normalization process for rating purposes.[8] After validating the results, the RT Leader triggers a routine that identifies county and crop programs for

[7] It is worth noting that the correlation between yields and prices is more pronounced in higher production regions, necessitating regional-specific adjustments to other parameters.

[8] The Statplan is the standardized database of all policies written by the FCIC since 1948 and is used to support sound actuarial decisions.

potential parameter reviews. The Rate Specialists assess these suggestions for accuracy and reasonableness and may adjust the list based on their expertise and external recommendations. The finalized recommendations are reviewed and approved sequentially by the RT Leader, AB Chief, APDD Director, Senior Actuary, and Deputy Administrator for Program Management. The approved list is included in a rate methodology memorandum, signed by the Agency Administrator. Post-approval, the AB implements the recommendations, with scope for additional reviews if required by documented circumstances.

The process for establishing rating parameters begins when the RT Leader ensures the StatPlan Database is updated and instructs contractors to execute parameter calculation routines.[9] AB Rate Specialists then assess these system-generated parameters for completeness and reasonableness, notifying Regional Office staff for further review. If the Regional Office agrees with the parameters, they are approved; if not, they may propose alternatives with supporting documentation, which AB Rate Specialists accepts or rejects. In cases where the AB Rate Specialists and Regional Office staff cannot reach an agreement, the dispute escalates to the AB Chief and Regional Office Director, and potentially to the Deputy Administrators for Program Management and Insurance Services for final resolution. Upon mutual agreement on all parameters, the RT Leader informs the AB Chief, indicating that parameters are established and ready for the subsequent phases of rate development and publication.

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 ($\alpha$) for an insurance pool is calculated as the annual average of the pool's historical loss cost ratio (LCR),

[9] Support for all automated federal systems has been outsourced to the private sector for several years to improve efficiency and reduce the federal workforce.

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 1 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. Before 2010, reference yields were not systematically updated, though recent modifications have introduced a regular updating mechanism. Reference yields for any given crop across all counties are synchronized with rate reviews occurring every three years and incorporate the latest 10 years of yield data (Rejesus et al. 2010).

Historically, the RMA predominantly relied on data from the National Agricultural Statistics Service (NASS) for setting reference yields, which often did not cover many crops, crop types, and cropping practices insured under the FCIP. This gap necessitated the use of proxy measures to derive reference yield parameters. Relying on outdated or proxy reference yields potentially distorts the accuracy of premium rates in reflecting the actual risk of loss. Addressing these limitations, a 2006 RMA-commissioned study thoroughly reviewed the reference yield methodology, recommending an approach that incorporates rate yields derived from RMA's own experience data. This study highlighted the critical need for regular updates to reference yields to prevent actuarial deficiencies. Following this study, methodologies for updating reference yields in counties with sparse data have been established, with updates incorporating data from both NASS and RMA's experience records.

Before 2011, the RMA lacked a method to update the exponents that shape the rate multiplier curve. A 2008 internal memo revealed that the exponents in use were designed for yield spans prior to the 2001 implementation of the continuous rating system. The memo found that sampling variability in limited samples (4–10 years) for individual rate yields significantly affects the relationship between average yields and premium rates, making it possible to estimate positive exponents. This variability explained the extreme exponent values found in a 2007 RMA-contracted study that used ordinary least squares (OLS) regression with a log-transformed specification. Addressing the shortcomings of the 2007 study, the 2008 memo recommended an alternative estimation approach using nonlinear least squares (NLS) regression. This method produced exponents with a narrower range and significantly lower values, resulting in a flatter yield ratio curve compared to both the current and 2007 exponents. The memo noted that these smaller exponent estimates might be due to the prevalence of zero loss cost ratios in the data.

Currently 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 the average yields, derived from a producer's historical data over a period of 4-10 years, with the actual realized yields at the end of the insurance coverage period. This process helps estimate 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).

## 3. Data and Variable Construction

Primary data used in this study is RMA's most granular summary of business for crop years 2001 to 2023, referred as "Summary of Business" by "Type, Practice, Unit Structure" or "SOBTPU" for short.[10] Each SOBTPU entry represents the aggregated loss experience information for groups of producers defined by a similar contract choice (i), the insurance pool they selected into (j), and a crop year (t). The contract choices are defined by unique combinations of insurance plan (e.g., APH, RP, etc..), coverage level, and unit structure (OU, EU, etc..). On the other hand, insurance pools are the lowest level of rate making in the FCIP and are defined by unique combinations of county, crop, crop type (e.g., corn is grain or silage), and production practice (e.g., irrigation, organic, etc..). In addition to the SOBTPU, the study also retrieved actuarial information (i.e., continuous rating parameters) from RMA's Actuarial Data Master (ADM) spanning 2001 to 2023.[11,12]

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

[11] 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.

[12] ADM files for each insurance year are available on the RMA website (Risk Management Agency [RMA] 2023a). RMA price addendums are available at https://legacy.rma.usda.gov/tools/. RMA

The data are limited to experiences from insurance plans rated via continuous rating. Additionally, the analysis period saw significant transformations in continuously rated plans, particularly with the introduction of COMBO plans in 2011. These changes consolidated existing plans into three main categories: APH plans for crops with active futures markets were restructured into YP; Crop Revenue Coverage (CRC) and Revenue Assurance (RA) with the harvest price option (HPO) were rebranded as RP; and both Income Protection (IP) and RA-HPE were combined into RP-HPE. As a result, all entries previously classified as APH in both the SOBTPU and ADM databases were recoded to YP; CRC entries were recoded to RP; and RA and IP entries were recoded to RP-HPE.

The loss experience information retrieved from the SOBTPU includes coverage level ($\theta_{ijt}$), net insured acres ($A_{ijt}$), liability ($L_{ijt}$), total premium ($P_{ijt}$), subsidy amount ($S_{ijt}$), and indemnity amount ($I_{ijt}$). Each SOBTPU entry's premium per dollar of liability ($\tau_{ijt}$) was calculated as the total premium divided by total liability and the subsidy per dollar of premium ($s_{ijt}$) calculated as the subsidy amount divided by the total premium. The insurance actuarial information retrieved from the ADM includes the county reference rate ($\alpha_{jt}$), fixed rate ($\delta_{jt}$), rating exponent ($\beta_{jt}$), county reference yield ($\bar{y}_{cjt}$), and differential factors separately for coverage level ($F_{ijt}^{\theta}$) and unit structure ($F_{ijt}^{u}$). For a given SOBTPU entry, these parameters were taken as their exact values retrieved from the ADM. In some cases, coverage level differential factors were missing and were estimated using a regression framework, where the differential is modeled separately for each crop and crop year as a multivariate quadratic function of the coverage level and the reference rate at the 65% coverage level (Coble et al. 2010). Finally, given the retrieved variables, the rate yield

reinsurance reports are available at https://www.rma.usda.gov/en/Information-Tools/Reinsurance-Reports

($\bar{y}_{ijt}$), which approximates the productivity of the producers whose experience constitute the information in the SOBTPU entry was calibrated as

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

Table 1 shows the descriptive statistics of the data used in this study which consists of 3,849,979 observations (i.e., SOBTPU entries) encompassing 49 commodities.[13] The sample represents 82.13% of the total non-livestock liability within the FCIP from 2002 to 2023. On average an observation in the data set had an insured liability of $459,540 with an insured area of 1,297 acres and a coverage level of 71% purchased at a premium cost of $46,052 of which $28,675 was paid for by government subsidies. Respectively, the overall mean for premium per dollar of liability and subsidy per dollar of premium is $0.13 and $0.63. Corn, soybeans, wheat, cotton, sorghum, barley, and rice comprised 93.46% of the total insured area in the sample, with pool level insured area and liability averaging 1,528 acres ($741,818), 1,472 acres ($468,726), 1,406 acres ($229,301), 1,242 acres ($417,506), 708 acres ($112,281), 691 acres ($100,026), and 1,316 acres ($656,845), respectively. The overall mean for premium per dollar of liability (subsidy per dollar of premium) for these crops were $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), respectively.

To evaluate the dynamics in actuarial updates, the elasticity of each parameter change is first considered as the annual percentage change in its value. Figure 2, panel (a), shows that not all

[13] 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

parameter innovations are equal. Notably, the reference yield exhibits the highest absolute elasticity, at about 4.14% annually across all pools from 2002 to 2023. This outcome is not surprising, given how the reference yield is updated, as discussed previously. After the reference yield, the next largest changes are seen in the rating exponent (2.51%), followed by the reference rate (-1.63%) and then fixed rate (-0.55%). Panel (b) of Figure 2 illustrates the elasticity of change for premium rates in three scenarios: (1) a farm is less productive than the pool it selects into (yield ratio = 0.5), (2) a farm is equally productive as the pool (1.0), and (3) a farm is more productive than the pool (1.5). These results suggest that the magnitude of elasticity for premium rates—stemming from updates to the rating parameters—is negatively related to a farm's relative productivity. On average, farms with lower productivity experienced a reduction in premiums of about -3.53% annually across all pools from 2002 to 2023. In contrast, more productive farms experienced an increase in premiums, averaging about -0.7% annually over the same period.

Next, is the "update rate" for each crop year calculated as the percentage of actual insured acreage that received actuarial parameter updates. In any given insurance pool, an update event is identified if the parameter value in the ADM for the incumbent crop year (i.e., the previous crop year) differs from that of the successor crop year (i.e., the current crop year). The annual variations in actuarial update rate within the FCIP from 2002 to 2023, as depicted in Figure 3, illustrate the program's adherence to the structured review process conducted by the RMA. Notably, significant peaks in the any update percentages - approaching or achieving 100% - in years such as 2004 (96.25%), 2005 (100%), 2009 (96.06%), 2018 (97.57%), and 2021 (96.56%), align with the RMA's triennial review cycle. These peaks indicate comprehensive revisions that integrate extensive historical data, reflecting emerging risks and shifting market conditions. In contrast, years with lower update percentages, notably in 2011 (47.84%), 2008 (47%), and 2002 (25.47%), are likely mid-cycle years necessitating only minor adjustments. Similar patterns are observed for the specific parameter updates with the one key exception that before 2012, the rating exponent hardly saw any updates. The apparent discontinuity in the case of the county reference yield update is partly due to a change in the RMA methodology. Previously, updates relied on transitional yields (T-yields) as the basis, however, the current method - starting in 2011 - predominantly uses an acre-weighted average of the yields reported by crop insurance participants for the most recently available crop year.[14]

Regarding specific crops shown on Figure 4, field crops exhibited the highest mean annual percentage of actual insured acreage with actuarial parameter updates estimated at 77.73%. Field crops are succeeded by updates for forages (64.39%), vegetables (60.48%), nuts (57.21%), and finally fruits (47.99%). Among field crops, corn depicts the highest update rate with mean of 85.95%. Corn is followed by 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%). Additionally, as shown on Figure 4, for a given crop, there is a marked variation across states. Particularly, states cultivating fruits, nuts, and vegetables that have low acreage representation in the program register the lowest percentages, illustrating the diverse nature of actuarial updates across different regions.

## 4. Counterfactual Simulation Design

The patterns in the update percentages shown on Figures 3 and 4 underscores the FCIP's proactive and dynamic strategy in ensuring the agricultural sector's insurance coverage remains relevant and

[14] 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.

accurate. This section lays out the counterfactual simulation used to assess how these updates affected the actuarial performance of the program.

The simulation design consists of two main components. The first involves modifying the current crop year's FCIP loss experience, as recorded in the SOBTPU, to represent scenarios both with and without updated ADM parameters. The key rationale behind this modification is that historical loss data used to rate a given crop year's program does not include that same year's data or data from the two preceding years (see Figure 1 for a demonstration). Consequently, contract choices and participation data from the current crop year serve as an out-of-sample test for two consecutive ADM databases. For example, selections and participation data from 2019 provide a basis for comparing the 2019 ADM with the 2018 ADM. Notably, the 2019 loss experience was not incorporated when developing either ADMs.

Although data from 2017 and 2018 is not used in rating the 2018 and 2019 crop years, it is inappropriate to rely on their contract choices and participation for out-of-sample evaluation of the 2018 and 2019 ADMs. In particular, the 2017 experience is linked to the 2017 ADM, so including it requires holding the 2017 experience constant (twice) when assessing the 2018 and 2019 rates. Meanwhile, excluding the 2018 experience aligns with the forward-looking nature of the simulation (i.e., updates are not applied retrospectively in practice). By focusing solely on 2019 contract choices and participation, the study holds demand constant only once for the 2018 rates, while still preserving the chronological flow of the simulation.

The key assumption underlying the simulations are that; demand and farmer behavior before and after the purchase of insurance is the same had the update not occurred. This means that adverse selection, moral hazard, and FCIP choices such as insured acreage and coverage level are constant. The consensus among studies is that the significant premium subsidies offered have lessened the impact of adverse selection in the FCIP (Tsiboe and Turner 2023b; Coble and Barnett 2013; Just, Calvin and Quiggin 1999; Glauber 2013; Glauber 2004). Although there remains some debate regarding the presence of moral hazard, particularly in how inputs are used (Smith and Goodwin 2017; Horowitz and Lichtenberg 1993; Yu and Hendricks 2020), its effect on yields (and by extension losses) is minimal (Coble et al. 1997; Babcock and Hennessy 1996; Quiggin, Karagiannis and Stanton 1993; Mieno, Walters and Fulginiti 2018), with weather and climate variations being the main factors influencing annual yield fluctuations, rather than decisions on input use.[15] Several studies have indicated that the demand for the FCIP is relatively inelastic (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), with recent responses to producer-paid-premium rates, estimated at -0.052 and -0.022 for demand at the extensive (insured acres) and intensive (coverage level) margins, respectively (Tsiboe and Turner 2023b), indicate that changes in premium rates within the span of one year have limited impacts on crop insurance demand. This holds particularly true for the coverage level election (i.e., intensive margin demand), where the premium rate needs to increase by more than 20% to prompt a switch between coverage levels. Simultaneously, for any given producer, FCIP rates are designed not to fluctuate by more than approximately 20%. Therefore, substantial shifts in crop insurance demand (particularly coverage level) appear unlikely under current rate volatility constraints.

[15] In the FCIP, weather-related perils have been the predominant cause of indemnified losses, particularly since 2000. Notably, 42% of total indemnity payments were attributed to losses caused by drought or high temperatures, while excess moisture claims accounted for another 28% of indemnities, highlighting the significant impact of weather conditions on FCIP claims.

The crop insurance demand elasticities estimated by previous studies capture the net effects of both rating parameter updates and producers' risk preferences. To isolate the impact of rating parameter updates, this study conducted a regression analysis on the annual percentage change in insurance pool-level insured acreage against annual percentage changes in the rating parameters considered. The analysis incorporated pool fixed effects and crop year fixed effects as control variables. Two versions of the model were estimated: (1) an unconditional version, where each rating parameter was separately included, and (2) a conditional version, where all rating parameters were included simultaneously. Each version was estimated over 15 distinct periods ending in 2023 (i.e., 2005-2023, 2006-2023, ..., 2019-2023), using data from insurance pools that consistently appeared each year within the respective period. The results, presented in Figure S1 of the online appendix, indicate that percentage changes in rating parameters within a year lead to insignificant changes in insurance pool-level insured acreage, suggesting that annual updates in rating parameters have minimal impact on the scale of insured acreage. This insight is robust across type of rating parameter, the model versions (unconditional vs conditional), and the 15 distinct periods considered.

The literature evidence, along with the estimation results depicted in Figure S1, justifies the simulation assumption that demand and farmer behavior before and after the purchase of insurance is the same had the update not occurred. This provides a methodologically simple but sound framework for evaluating the direct impacts of ADM updates. Offering a clear baseline for initial analyses, this strategy facilitates systematic recalibrations as new data become available or as further complexities are integrated into the model. Such an approach ensures analytical clarity and supports structured, incremental investigations into the impacts of policy changes, thereby enhancing the reliability and precision of policy assessments. Nonetheless, in the results section, supplemental simulations are conducted where demand is altered based on estimated elasticities to assess the relevance of the violation of the constant demand assumption, ensuring a more nuanced understanding of these dynamics.

Following from the assumptions, the process begins by holding 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] constant at their values in the year of the parameter update, mirroring the actual observed data for each SOBTPU entry. Premium rates for each entry were then computed separately for the case of an update ($r^{b}_{ijt}$) and no-update ($r^{a}_{ijt}$) as

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

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

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

The key distinction between Equations (4) and (5) is that parameters underlying the rate for the update case is based on the updated parameters in year ($t$) and that of the no-update case is based on parameters from the previous crop year ($t - 1$). To align with RMA practices and legislation, constraints are place on $r^{a}_{ijt}$ to ensure that it thus not vary by more than 20% of $r^{b}_{ijt}$. As shown in Figure 2, panel (b), the average annual changes in premium rates—considering the relative productivity of producers—rarely exceed ±20% across all the pools in our sample from 2022 to 2023. Total premiums ($P^{b}_{ijt}$ for updates and $P^{a}_{ijt}$ for no-updates) are calculated by adjusting the observed SOBTPU total premium ($P_{ijt}$) according to the ratio $r^{a}_{ijt}/r^{b}_{ijt}$ for the no-update case and taken as the observed entry for the update case. Subsidy amounts under each case are then determined by $S^{k}_{ijt} = s_{ijt}P^{k}_{ijt}$, $\forall k = a, b$.

In the second part of the simulation, the modified SOBTPU data for each case is aggregated on a crop year level. This aggregated data is subsequently analyzed to assess differences in program level outcomes. For evaluating actuarial performance, Loss Ratios (LR) are calculated by summing indemnities for each update scenario and then dividing by the corresponding total premiums for that scenario. To evaluate the actuarial soundness resulting from parameter updates, the absolute deviation of each case's LR from unity - the ideal value for an actuarially sound program - is used. The difference in actuarial soundness is then computed by subtracting the absolute deviation of the no-update case LR from the update case LR, and this result is multiplied by 100 to convert it into a percentage points. A negative value in this calculation indicates an improvement due to the update, signifying a reduction in the discrepancy of the LR from unity.

In the baseline scenario, the study estimates the effects of an update which includes the simultaneous modification of any combination of parameters ($\alpha, \delta, \beta$, and $\bar{y}_c$). However, subsequent scenarios implement targeted updates where only one parameter is altered while the others remain constant. For these targeted updates, the parameter value for the non-update parameters is held at the previous crop year value while that of targeted parameter is taken as given in the current years ADM. This approach allows the nuances associated with individual parameter updates to be disentangled and to identify which updates contribute most significantly to the observed impacts.

Each scenario is limited to the comparison of update and no-update to county-crop programs appearing in both incumbent and successor ADMs. By restricting the analysis to county-crop programs that appear in both the “incumbent” and “successor” ADM tables, the study necessarily excludes any new county-crop combinations introduced each year (for which there is no prior parameter) as well as any that may have been discontinued. This approach ensures there is a valid basis for comparison—i.e., one identifies whether a specific rating parameter changed over time—but it also means that the final dataset concentrates on county-crop programs with a continuous presence across the years studied. Consequently, the analysis may underrepresent counties or crops where insurance coverage has recently expanded (or contracted). Nonetheless, the remaining dataset captures most (over 80%) insured volume, allowing the study to focus on those segments where meaningful year-over-year comparisons are feasible. The final estimate for each impact metric is calculated as the mean of the crop-year-specific estimates spanning from 2002 to 2023.

For statistical inference, standard errors are estimated using a bootstrap procedure with 100 replications. In each replication, 665,482 insurance pools—each defined as a unique combination of county, crop, crop type, and production practice—are drawn with replacement. Once an insurance pool is selected, all its observations across the available crop years are included in the analysis. Repeating this process 100 times produces a distribution of estimates from which standard errors are derived.

## 5. Results and Discussions

Table 2 presents the simulation results. Column (1) reports outcomes for updates that involve the simultaneous modification of any combination of parameters, while Columns (2) through (5) focus on targeted updates to the reference rate, fixed rate, rating exponent, and reference yield, respectively. Figures 5 through 8 illustrate the differences between no-update and update scenarios across several key dimensions. The findings are divided into three subsections: the first highlights the core results, the second provides robustness checks, and the third discusses the observed heterogeneity in these core findings.

## Core findings

Table 2 Column (1) shows that, holding demand constant at observed values [Annual evaluation with unadjusted demand], updating any parameter in the FCIP over the period of the analysis do lead to improvements of actuarial soundness of the program. The absolute discrepancy between observed LR and the actuarially sound value of 1 is reduced by about 0.857 percentage points due to the updates. When considered on a crop year basis, Figure 5 shows that overall, 59% of these estimates shows that updates to any FCIP rating parameter does lead to improvements of actuarial soundness of the program. While improvements are underscored by more producers coming into the program (i.e., more data to rate on), better data integration, or improved actuarial models, notably, years like 2005 and 2018 show high impacts of -9.775 and -2.306 percentage points, respectively, which coincides with substantial update rates of 100 and 98 %, respectively. On the other hand, years like 2012, 2013, and 2006, where the values are notably positive (8.587, 3.37, and 2.513 percentage points, respectively), suggest that updates in these years may have led to a deterioration in actuarial performance. Generally, Figure 4 shows that since the introduction of the COMBO products, updates have led to sustained improvement in the LR.

Table 2 Columns (2) to (5), panel "Annual evaluation with unadjusted demand", shows results that closely tracks the nuanced impacts of targeted parameter updates within the FCIP through the lens of actuarial performance. Again, holding demand constant at observed values, updates to the reference rate significantly enhance actuarial performance, with mean impact estimated at -1.805 percentage points, indicating improvement toward achieving actuarial soundness. The rating exponent updates also show a significant enhancement to actuarial performance with a mean impact of -1.269; however, the fixed rate updates show a modest enhancement impact of only -

0.802. Conversely, reference yield updates presented a mean impact of 1.537 percentage points, generally leading to poorer actuarial outcomes.

**Robustness checks**

To evaluate the reliability of the main findings (presented in Table 2, panel "Annual evaluation with unadjusted demand"), three primary robustness checks are conducted. The first addresses the assumption that demand and farmer behavior—both before and after the purchase of insurance—would have remained the same if the update had never occurred. To examine this assumption, we performed supplemental simulations in which demand was adjusted based on dynamically estimated elasticities derived from observed data for the update year and the preceding five crop years. [16] These elasticities were then used to modify insured acres according to the extent to which the update changed premium rates. The results of these supplemental simulations, presented in Table 2 under the panel "Annual evaluation with adjusted demand," show that, for targeted scenarios focusing on individual parameter updates, actuarial soundness does indeed improve. However, in cases involving the simultaneous modification of multiple parameters, the findings run counter to this trend.

The core findings also rely on evaluating actuarial performance based on the loss ratio in the year following an update, serving as a measure of "improvement" or accuracy. However, focusing on a

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[16] Adopted from previous works (Tsiboe and Turner 2023b; Tsiboe and Turner 2023a), the model was of the form $\ln A_{it} = \beta_0 + \beta_r \ln r_{it} + \boldsymbol{\beta}_w \mathbf{w}_{it} + v_{it} + \varepsilon_{it}$. where the net insured acreage, $A_{it}$, is modeled as a function of the same set of covariates which include the producer-paid premium rate, $r_{it}$ and a vector of control variables, $\mathbf{w}_{it}$, which contains the log expected price for the $i^{th}$ pool's crop, log planted acres for the respective crop for the $i^{th}$ pool's county, the rental rate for land for the $i^{th}$ pool's state, crop-specific time trends, and year-fixed effects. The term $v_{it}$ captures crop-insurance pool fixed effects. The error term for each equation, $\varepsilon_{it}$, is assumed to have an expected value of zero but can be heteroskedastic and autocorrelated since the data is an unbalanced panel.

single year is problematic because insurance strategies often span multiple years and involve various cross-sectional units (such as counties and crops). Despite these concerns, the study uses the year following the database update to provide an out-of-sample assessment of two consecutive ADM databases. Including all subsequent years in the evaluation misrepresents the frequency of rate updates typically conducted by the RMA. To examine whether using only one year is appropriate, Table 2 panel "Cumulative evaluation with unadjusted demand" presents incremental improvements in cumulative loss ratios from 1997 to the release year. The results show a pattern consistent with the study's main findings, although the magnitude of effects is somewhat muted.

Finally, we included a robustness check that expands the out-of-sample evaluation window from 1 to 10 years in one-year increments. This comprehensive approach helps clarify how actuarial performance evolves over longer periods while remaining consistent with the RMA's operational practices. In general, the effects shown on Table 2 panel "Annual evaluation with unadjusted demand - actuarial impact" become muted as the evaluation window is widened. However, one key exception is the targeted update to the reference yield, where the direction of the effect shifts from a deterioration to an improvement in actuarial performance.

**Observed Heterogeneity**

The program-level analysis, which aggregates all counterfactual outcomes into a single metric, indicates that updates reduce the absolute discrepancy between the observed loss ratio and the actuarially sound benchmark of 1 by approximately 0.857 percentage points. However, these overall figures masks considerable variation across different contexts. This subsection examines how rating parameter updates influence actuarial performance across various observable characteristics by summarizing the results by those characteristics. The analysis focuses exclusively on scenarios involving any parameter update under the annual evaluation framework with unadjusted demand. Additionally, the 2001–2023 annual average insured acres and LR are presented alongside the effects.

Diminishing return on parameter updates.

Figure 5 suggests a diminishing return on parameter updates, as evidenced by the decreasing gap from unity in the program's loss ratio when additional crop years are factored in. To explore this further, county crop programs are classified by their "age," defined as the number of years from 1948 up to each update year, grouped in five-year increments up to 70+ years. As shown in Figure 6, updates for programs with fewer than 36 years of historical loss data yield negligible improvements in actuarial soundness. Once programs surpass 35 years of data, they show significant gains in soundness following an update—though these gains become insignificant beyond 60 years of historical data. This pattern indicates that incorporating more yield information generally improves rating accuracy but eventually reaches a point of diminishing marginal returns. Recent findings reinforce this view: when farms have 4–10 entries in their APH, premiums based solely on yield data are more precise. Conversely, farms with fewer than four entries see substantial benefits from integrating soil information to enhance rating performance. (Tsiboe and Tack 2022).

Commodity and state-level variation in update outcomes

The results by commodity and State shown on Figure 7 illustrate varying impacts of rating parameter updates on actuarial performance across different agricultural sectors. Particularly, the Fruits commodity group experienced the most significant improvement with a decrease in loss ratio deviation of approximately -1.41 percentage points, indicating highly effective updates. The field crops category also saw a beneficial impact, albeit more moderate, with a reduction of -0.87 percentage points in LR deviation from unity while forages showed a slight improvement, with a decrease of -0.58. On the other hand, vegetables and nuts did not fare well; recording an increase in deviation (0.57 and 1.25 percentage points, respectively), suggesting that the updates may have been less effective or adverse due to the unique challenges of low participation (hence less data in terms of both quantity and quality to rate on) associated with these crops.

Figure 7 also shows that among field crops, the commodity group with the most insured acres, rice depicts the highest gain in actuarial performance with mean impact estimated at -3.86 percentage points. Rice is followed by canola (-3.03), corn (-2.37), cotton (-1.94), dry peas (-1.51), soybeans (-1.46), sorghum (-1.44), wheat (-0.73), sugarcane (-0.39), and peanuts (-0.31). On the contrary, updates for barley (1.61), sugar beets (2.39), and sunflowers (2.67) generally lead to poorer actuarial outcomes.

As shown on Figure 7, the impact by crop and commodity grouping also have a pronounced geographical distribution. Across all crops, the states (major crop in that state) demonstrating the most significant improvements include Hawaii (macadamia), Connecticut (corn), Arizona (cotton), Illinois (corn), and Iowa (corn), with loss ratio deviations of -23.01, -5.73, -5.65, -5.55, and -5.18 percentage points, respectively. Conversely, the states that experienced stark deterioration in actuarial performance are Montana (wheat), Oregon (wheat), Alaska (barley), Idaho (wheat), Nevada (forage), and Washington (wheat), with changes in loss ratio deviations of 1.24, 1.89, 2.02, 2.83, 7.64, and 9.73 percentage points, respectively.

When it comes to specific crops, 66.67% of all corn producing states exhibits gains in actuarial performance with notable exceptions being Nevada, Texas, Massachusetts, Rhode Island, Kansas, Alabama, Illinois, Kentucky, Iowa, and Oregon. About 72.97% of all soybeans producing states exhibits gains in actuarial performance with notable exceptions being Georgia, Maine, Washington, and Oregon. For wheat, 55.81% of the producing states exhibits gains. For cotton

[rice] only Alabama and Kansas [Louisiana, and Missouri] did not show gains in actuarial performance following any parameter updates.

Separating out the impact of subsidies and information

Actuarial performance has improved since the early 2000s due to two main factors: (1) increased subsidies that broadened the applicant pool and reduced overall risk, and (2) enhanced actuarial data that improved rating accuracy. Findings from this study align more strongly with the argument that better information is the key driver. Although the evidence suggests that premium subsidies likely mitigated adverse selection—thereby supporting the assumption of constant demand—it does not fully counter the view that subsidies alone bolster actuarial outcomes by attracting a larger, lower-risk pool. To distinguish the effects of subsidies from the effects of information on actuarial performance, the study examines heterogeneity based on the observed subsidy rate. A categorical variable is used to capture the subsidy per dollar of premium (sit) faced by producers, defined in 5% increments (e.g., $I[0.55<s_{it}\leq 0.60] = 1$ indicates a 55–60% subsidy rate). Because pools with a subsidy rate above 80% are rare, all such pools are grouped under a single category. Similarly, pools at or below 40% are combined into one category.

Results from the simulations in Figure 7, organized by the observed subsidy rate, indicate that pools receiving an aggregate subsidy of 55% or more experience gains in actuarial performance following any rating parameter update. In contrast, pools receiving subsidies of 50% or less exhibit a deterioration in actuarial performance after updates. Within the higher-subsidy group (above 50%), gains tend to decrease as the subsidy level increases. This inverse relationship suggests that even when subsidies are present, better information drives additional improvements in actuarial performance.

### Historical loss ratios and the road to actuarial soundness via updates

Progression toward actuarial soundness (LR=1) is critical for each crop-county program. Some programs begin far from 1, while others start close to 1—where rating adjustments may be unnecessary or difficult to evaluate. To analyze how rating updates influence this progression, the results are grouped using a categorical variable for the crop-county program's cumulative loss ratio from 1999 to the year before an update occurs. The levels of this LR-based categorical variable align with cutoffs from the Standard Reinsurance Agreement. As shown in Figure 7, county programs with LRs near 1 exhibit minimal improvements in actuarial soundness following updates.

### Perils that overshadow rate adjustments

It is important to recognize that within-year weather events—especially those occurring in major crop regions—can overshadow the intended direction of improvements in insurance rate changes. For example, the 2012 drought had such a profound effect on loss rates in some regions that it effectively nullified the impact of any adjusted rates, even those correctly modified to account for previously lower losses. This residual effect remains partially visible in Figure 5. To determine which specific perils undermines the benefits of "correctly" modified rates, results are categorized by peril incidence at the county level. In any given update year, a peril is flagged (via a binary variable) for a county if at least one acre is reported as lost to that peril. As shown in Figure 8, temperature-related perils and widespread drought events tend to reduce the effectiveness of rate updates in achieving actuarial soundness. In contrast, localized events such as biotic stress (e.g., pests and diseases) or excess moisture (e.g., flooding) do not appear to diminish the positive impact of these rate adjustments.

## 6. Conclusion

Since its establishment in the 1930s, the Federal Crop Insurance Program (FCIP) has been integral to U.S. agricultural risk management, receiving substantial federal support including over 60% annual subsidy on farmer premiums and significant funding to Approved Insurance Providers, to deliver the program. This investment underscores the program's importance and financial challenges, with ongoing debates about the potential cost savings versus the risk of reduced farmer support if subsidies are decreased. At the core of these perennial fiscal cut is the necessity of setting premiums that are actuarially sound and accurately reflect crop loss risks, as mandated by Section 508(d) of the Federal Crop Insurance Act. While extensive research has examined various aspects of the RMA methodologies, this study delves into the less-explored impacts of rate innovations through RMA's annual parameter updates to FCIP. It focuses on how these adjustments enhance the program's actuarial performance.

The study shows improved actuarial soundness from rating parameter updates, with major gains in 2005 and 2018 but setbacks in 2006, 2012, and 2013. Significant structural changes stemmed from the 2008–2018 Farm Bills and 2011's COMBO plans. Updating reference rates and rating exponents boosted soundness, whereas reference yields largely reduced it, and fixed rates brought minor improvements. The updates most benefitted programs with about 35–60 years of data but had negligible effects on newer or older programs. Differences emerged across commodities, states, and prior actuarial performance. Loss ratio (LR) targets near 1 remain the benchmark: nuts and field crops approached this target more effectively, while forages and fruits lagged. Arizona and Vermont saw strong gains, aligning closer to expected risk levels, whereas Washington and Iowa lagged. Large-scale weather events, especially widespread droughts, can undermine these improvements, though more localized perils (such as pests or flooding) are less disruptive. Overall, updates help move programs toward LR-based actuarial soundness, but the degree of improvement varies by historical data coverage, commodity, location, and the nature of perils encountered.

Thirty years after the implementation of actuarial soundness requirements, the Federal Crop Insurance Program (FCIP) has generally succeeded, maintaining an overall loss ratio of 0.86, below the mandated 1.0 threshold. This indicates broad actuarial stability for a program that covered over $197 billion in liabilities in 2022. Despite reforms intended to stabilize the program, questions remain regarding the practical application of actuarial soundness across diverse agricultural sectors and regions. The fundamental dilemma involves balancing sufficient premium intake against political resistance to raising farmer-paid premiums. This dynamic complicates rate adjustments, potentially leading to discrepancies where some farmers overpay and others underpay, achieving a national loss ratio of 1.0 but potentially at the expense of true actuarial soundness at the crop, state, or regional levels. This study's analysis of commodity-specific and state-level impacts of actuarial updates from 2002 to 2023 illustrates significant variability.

As the program moves forward, it remains crucial to balance the legislative intent with the operational realities of crop insurance, ensuring that adjustments not only meet statutory loss ratio targets but also reflect the actual risk landscapes across America's agricultural spectrum. This will likely involve a complex interplay of policy adjustments, premium rate recalibrations, and continuous monitoring and analysis to maintain the actuarial integrity and financial sustainability of the FCIC's operations. Future explorations will need to delve deeper into these issues, potentially redefining what actuarial soundness means in the context of a modern, dynamically changing agricultural economy.

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## Tables and Figures

Table 1: Means and Standard Deviations of US Federal Crop Insurance Outcomes (2001-23).

| Variables | Full sample | Corn | Soybeans | Wheat | Cotton | Sorghum | Barley | Rice |
|---|---|---|---|---|---|---|---|---|
| Summary of business outcomes | | | | | | | | |
| Coverage level (%) | 70.72 (9.66) | 73.18 (9.13) | 72.42 (9.56) | 68.97 (8.17) | 63.97 (9.40) | 66.70 (7.85) | 69.02 (8.91) | 61.87 (12.35) |
| Net insured area (acres) | 1297 (4318) | 1528 (4765) | 1472 (4565) | 1406 (4865) | 1242 (3829) | 708 (1897) | 691 (1790) | 1316 (3731) |
| Total insured liability ($ 1,000) | 460 (2079) | 742 (3011) | 469 (1741) | 229 (1006) | 418 (1405) | 112 (363) | 100 (290) | 657 (1855) |
| Total premium ($ 1,000) | 46.05 (201.51) | 65.90 (268.58) | 41.57 (158.34) | 37.01 (167.09) | 72.41 (319.30) | 22.98 (77.71) | 12.79 (38.93) | 37.75 (104.04) |
| Total subsidy ($ 1,000) | 28.68 (135.40) | 40.54 (181.24) | 25.76 (105.36) | 22.93 (106.16) | 48.23 (228.69) | 14.62 (52.13) | 7.88 (25.67) | 24.30 (64.92) |
| Total indemnity ($ 1,000) | 38.24 (298.65) | 52.12 (389.71) | 24.76 (144.08) | 33.65 (222.65) | 89.59 (625.31) | 22.50 (132.17) | 10.85 (50.68) | 64.92 (562.93) |
| 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 (0.16) | 0.15 (0.10) | 0.07 (0.05) |
| 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 | -1.41 (0.57) | -1.43 (0.57) | -1.60 (0.44) | -1.52 (0.49) | -1.05 (0.37) | -1.43 (0.58) | -1.42 (0.50) | -1.27 (0.64) |
| Coverage level differential factor @ 50% | 0.66 (0.12) | 0.66 (0.11) | 0.63 (0.11) | 0.67 (0.11) | 0.71 (0.12) | 0.68 (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 (0.14) | 0.79 (0.11) | 0.82 (0.10) |
| Coverage level differential factor @ 60% | 0.85 (0.12) | 0.85 (0.11) | 0.83 (0.11) | 0.85 (0.12) | 0.87 (0.13) | 0.85 (0.14) | 0.87 (0.12) | 0.89 (0.09) |
| Coverage level differential factor @ 65% | 0.95 (0.12) | 0.95 (0.11) | 0.95 (0.11) | 0.95 (0.12) | 0.95 (0.12) | 0.93 (0.14) | 0.96 (0.12) | 0.97 (0.08) |
| Coverage level differential factor @ 70% | 1.07 (0.12) | 1.07 (0.12) | 1.11 (0.13) | 1.06 (0.12) | 1.04 (0.11) | 1.04 (0.13) | 1.06 (0.11) | 1.08 (0.09) |
| Coverage level differential factor @ 75% | 1.22 (0.15) | 1.21 (0.13) | 1.30 (0.17) | 1.18 (0.11) | 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) | 1.35 (0.16) |
| Coverage level differential factor @ 85% | 1.56 (0.28) | 1.55 (0.21) | 1.77 (0.32) | 1.46 (0.19) | 1.43 (0.18) | 1.51 (0.18) | 1.47 (0.14) | 1.53 (0.23) |
| Basic unit differential factor | 1.03 (0.03) | 1.03 (0.03) | 1.03 (0.03) | 1.04 (0.02) | 1.05 (0.02) | 1.02 (0.02) | 1.05 (0.03) | 1.04 (0.02) |
| Enterprise unit differential factor | 1.01 (0.04) | 1.00 (0.05) | 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 | 665322 | 136367 | 183734 | 128917 | 32134 | 32644 | 24104 | 9652 |
| Number of observations | 3849979 | 1083588 | 1017154 | 714331 | 215633 | 172029 | 90407 | 43152 |

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 2: Impacts of actuarial updates on actuarial performance in the United States Federal Crop Insurance Program (2002-23)

| | Type of actuarial data master parameter update | | | | |
|---|---|---|---|---|---|
| | Any update | Only reference rate updated | Only fixed rate updated | Only rating exponent updated | Only reference yield updated |
| Annual evaluation with unadjusted demand†† | | | | | |
| Incumbent ADM loss ratio [a] | 0.975*** (0.007) | 0.966*** (0.007) | 0.976*** (0.007) | 0.971*** (0.007) | 1.001*** (0.007) |
| Successor ADM loss ratio [b] | 0.984*** (0.007) | 0.984*** (0.007) | 0.984*** (0.007) | 0.984*** (0.007) | 0.984*** (0.007) |
| Actuarial impact [c] | -0.857*** (0.173) | -1.805*** (0.166) | -0.802*** (0.158) | -1.269*** (0.159) | 1.537 (0.856) |
| Annual evaluation with adjusted demand | | | | | |
| Incumbent ADM loss ratio [a] | 1.005*** (0.014) | 1.07*** (0.017) | 1.017*** (0.018) | 0.97*** (0.01) | 0.91*** (0.012) |
| Successor ADM loss ratio [b] | 0.984*** (0.007) | 0.984*** (0.007) | 0.984*** (0.007) | 0.984*** (0.007) | 0.984*** (0.007) |
| Actuarial impact [c] | 1.165 (1.215) | -5.336*** (2.045) | -0.09 (1.689) | -1.364* (0.766) | -7.422*** (1.011) |
| Cumulative evaluation with unadjusted demand | | | | | |
| Incumbent ADM loss ratio [a] | 0.82*** (0.001) | 0.819*** (0.001) | 0.821*** (0.001) | 0.82*** (0.001) | 0.823*** (0.001) |
| Successor ADM loss ratio [b] | 0.821*** (0.001) | 0.821*** (0.001) | 0.821*** (0.001) | 0.821*** (0.001) | 0.821*** (0.001) |
| Actuarial impact [c] | -0.114*** (0.006) | -0.222*** (0.006) | -0.081*** (0.004) | -0.099*** (0.005) | 0.16*** (0.005) |
| Annual evaluation with unadjusted demand - actuarial impact [c] | | | | | |
| One crop year update window†† | -0.857 (0.705) | -1.805 (1.185) | -0.802 (0.652) | -1.269 (0.92) | 1.561 (1.437) |
| Two crop year update window | -0.735*** (0.041) | -1.596*** (0.038) | -0.754*** (0.022) | -1.487*** (0.053) | 0.844 (1.058) |
| Three crop year update window | -0.743*** (0.037) | -1.51*** (0.032) | -0.733*** (0.022) | -1.584*** (0.05) | -0.53 (1.085) |
| Four crop year update window | -0.664*** (0.034) | -1.397*** (0.029) | -0.733*** (0.023) | -1.446*** (0.046) | -1.916*** (0.292) |
| Five crop year update window | -0.61*** (0.154) | -1.28*** (0.027) | -0.735*** (0.055) | -1.664*** (0.047) | -1.952*** (0.03) |
| Six crop year update window | -0.563** (0.207) | -1.189*** (0.027) | -0.734*** (0.165) | -1.822*** (0.051) | -2.013*** (0.032) |
| Seven crop year update window | -0.497 (0.32) | -1.075*** (0.026) | -0.737** (0.286) | -1.823*** (0.054) | -1.974*** (0.034) |
| Eight crop year update window | 0.057 (0.503) | -1.177*** (0.152) | -0.786 (0.444) | -1.766*** (0.052) | -1.96*** (0.037) |
| Nine crop year update window | -0.258 (0.781) | -0.76 (1.25) | -0.602 (0.699) | -2.989*** (0.728) | -2.321*** (0.276) |
| Ten crop year update window | -0.464 (1.45) | 0.855 (1.373) | 0.429 (0.895) | -1.234 (2.152) | -2.061*** (0.63) |

[c] Calculated as the absolute deviation of loss ratio form 1 between incumbent and successor ADM: abs (a*100 - 100) - abs (b*100 - 100)
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. Cumulative evaluation is based on loss ratio calculated over the period 1997 to the release year. Adjusted demand allows insured acres to shift based on their responsiveness to paid premium rates. The preferred model is ††. 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: Graphical Representation of the Premium Rating Parameter Updating Sequence in the United States Federal Crop Insurance Program

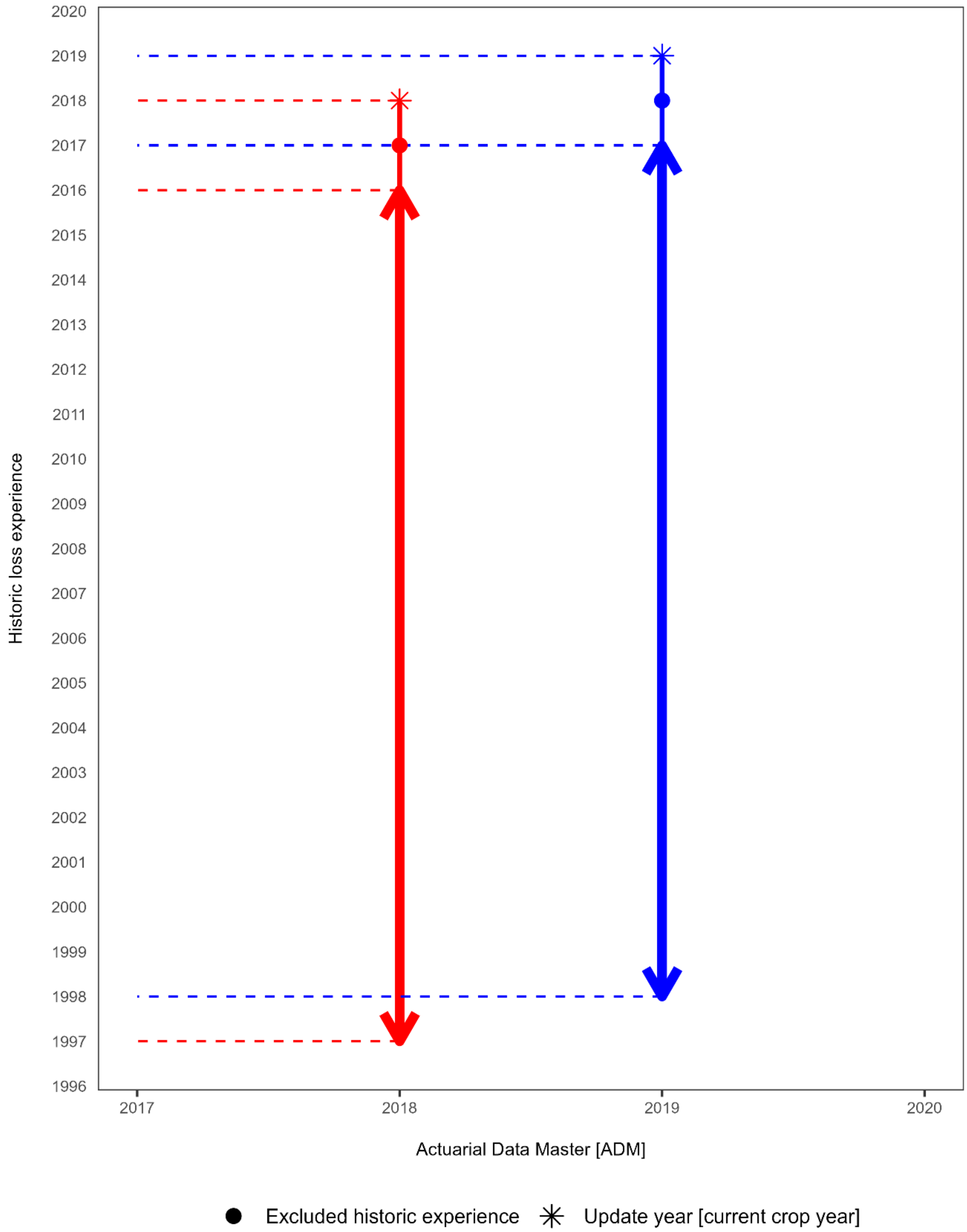


Figure 2: Annual percentage in parameters and premium rates in the United States Federal Crop Insurance Program (2002-23)

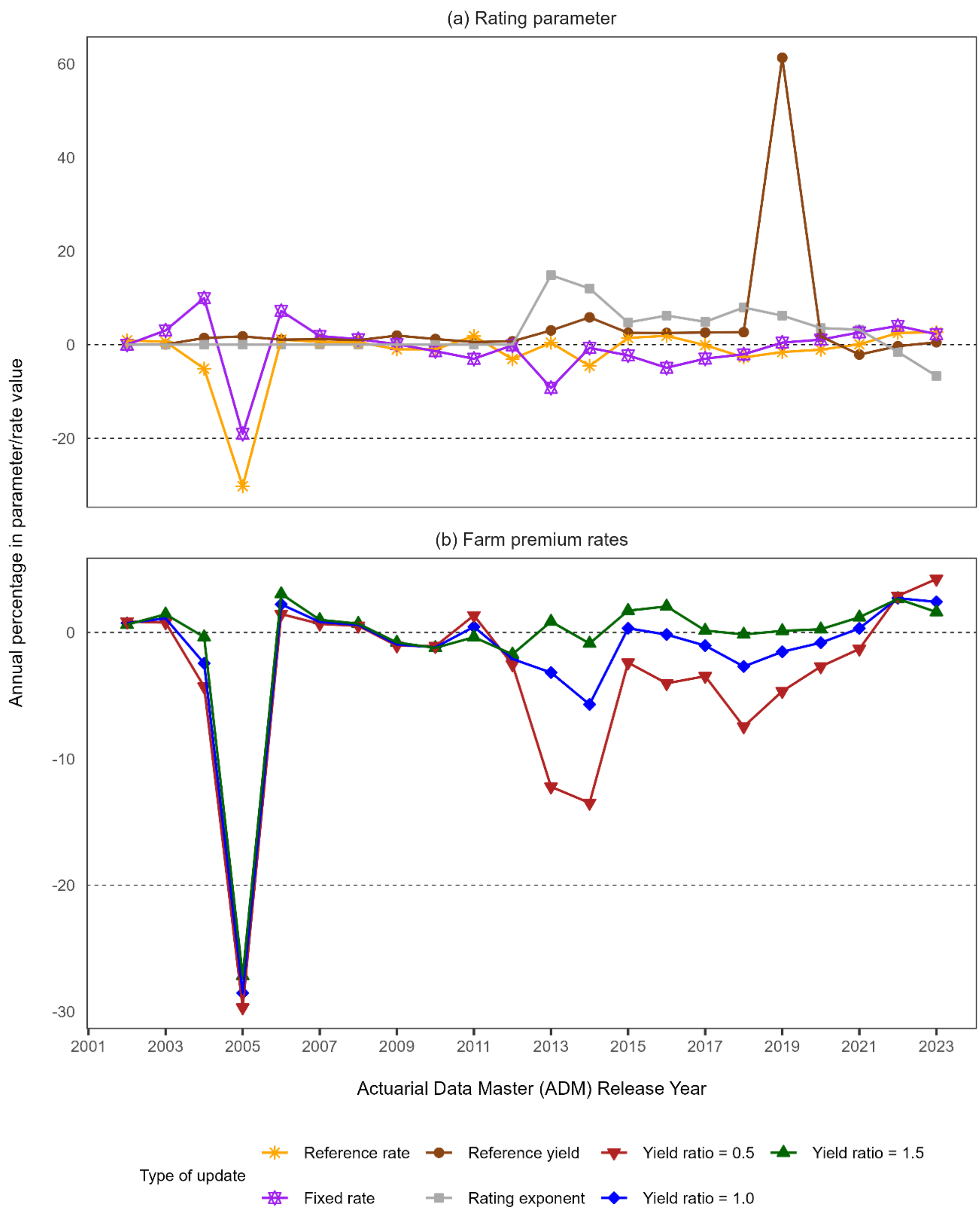


Figure 3: Annual variation in actuarial updates in the United States Federal Crop Insurance Program (2002-23)

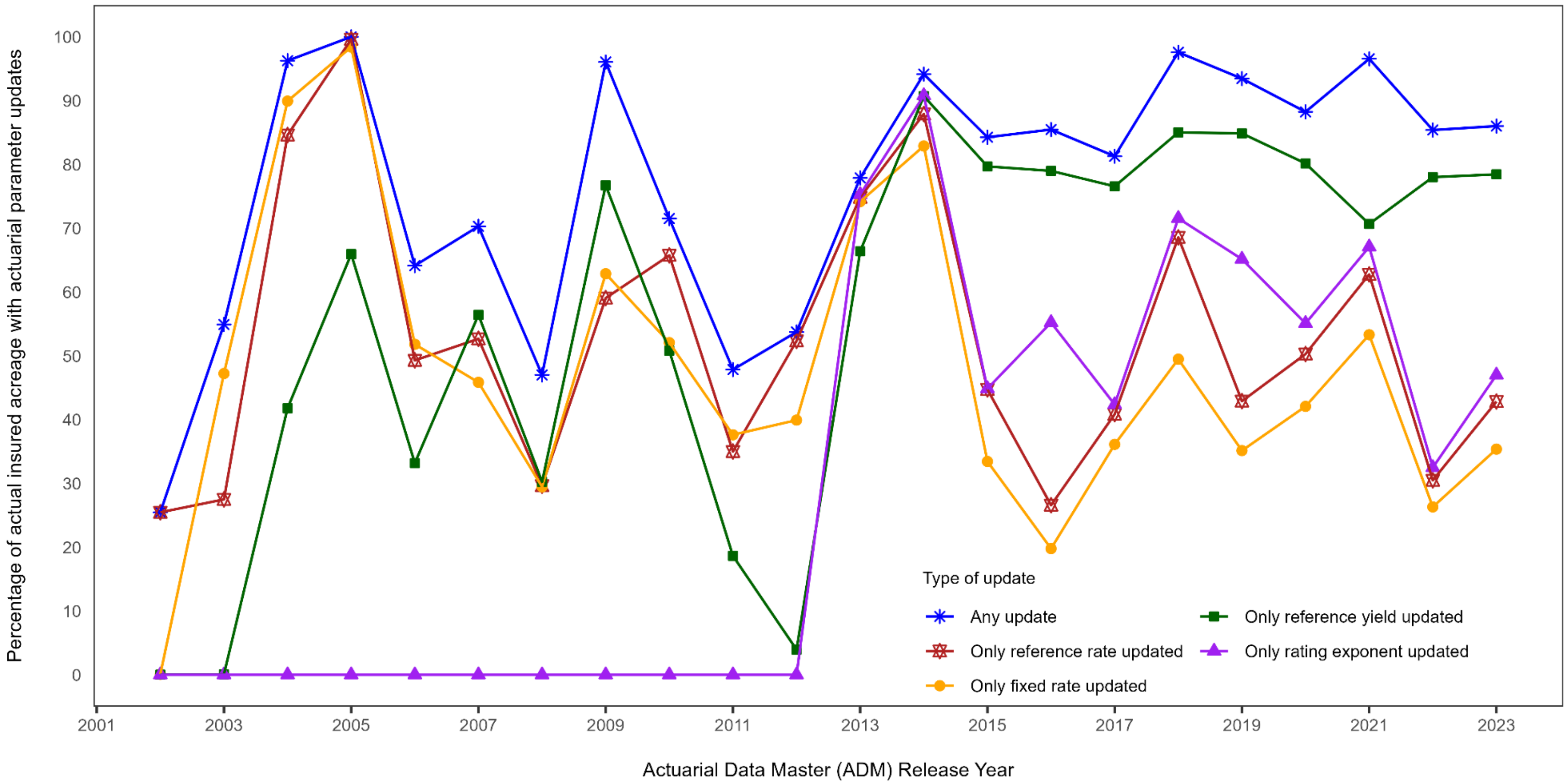


Figure 4: Variation in annual actuarial updates in the United States Federal Crop Insurance Program by state and commodity grouping (2002-23).

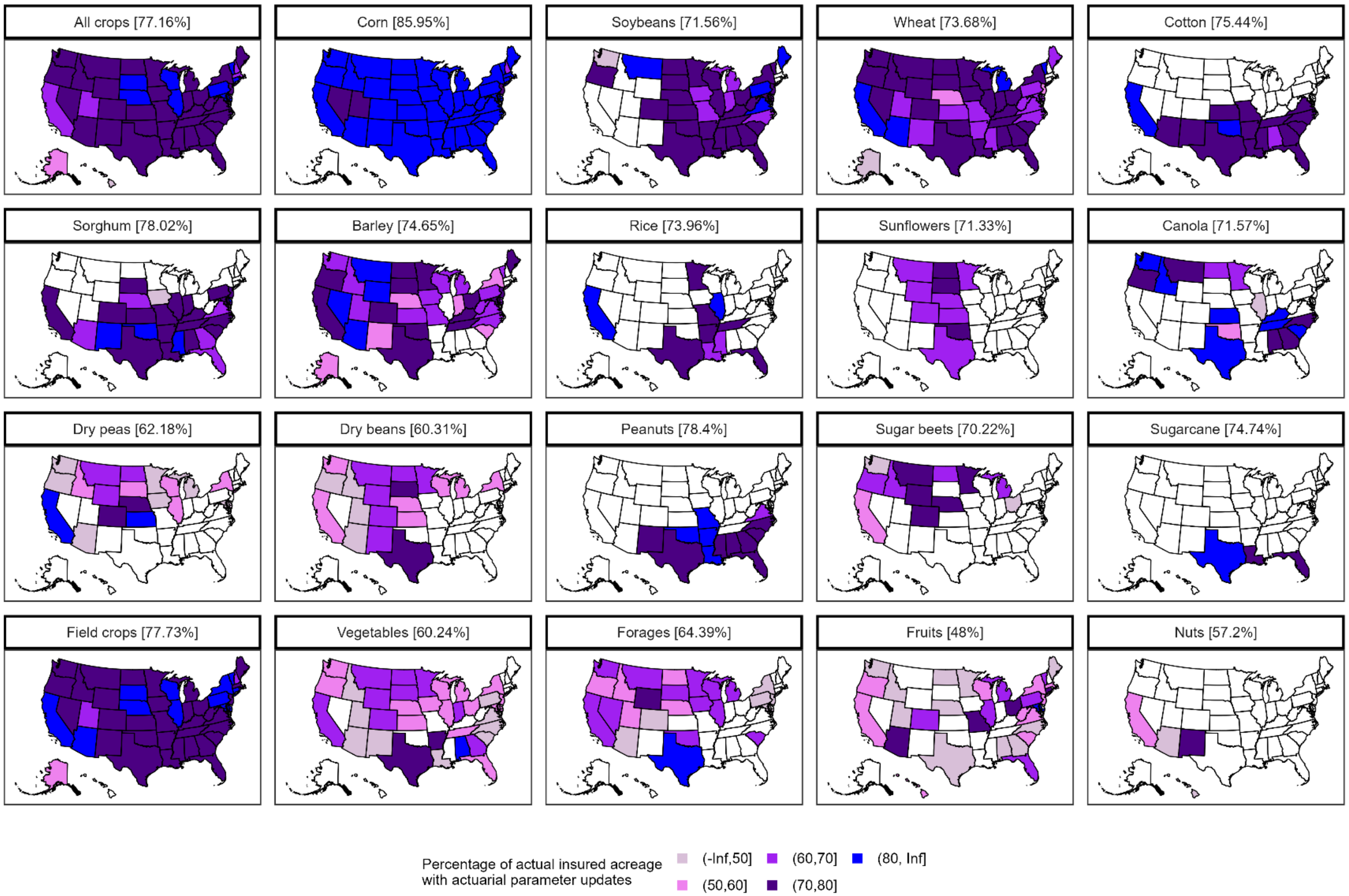


Figure 5: Temporal variation in the impacts of actuarial updates on actuarial performance in the United States Federal Crop Insurance Program (2002-23)

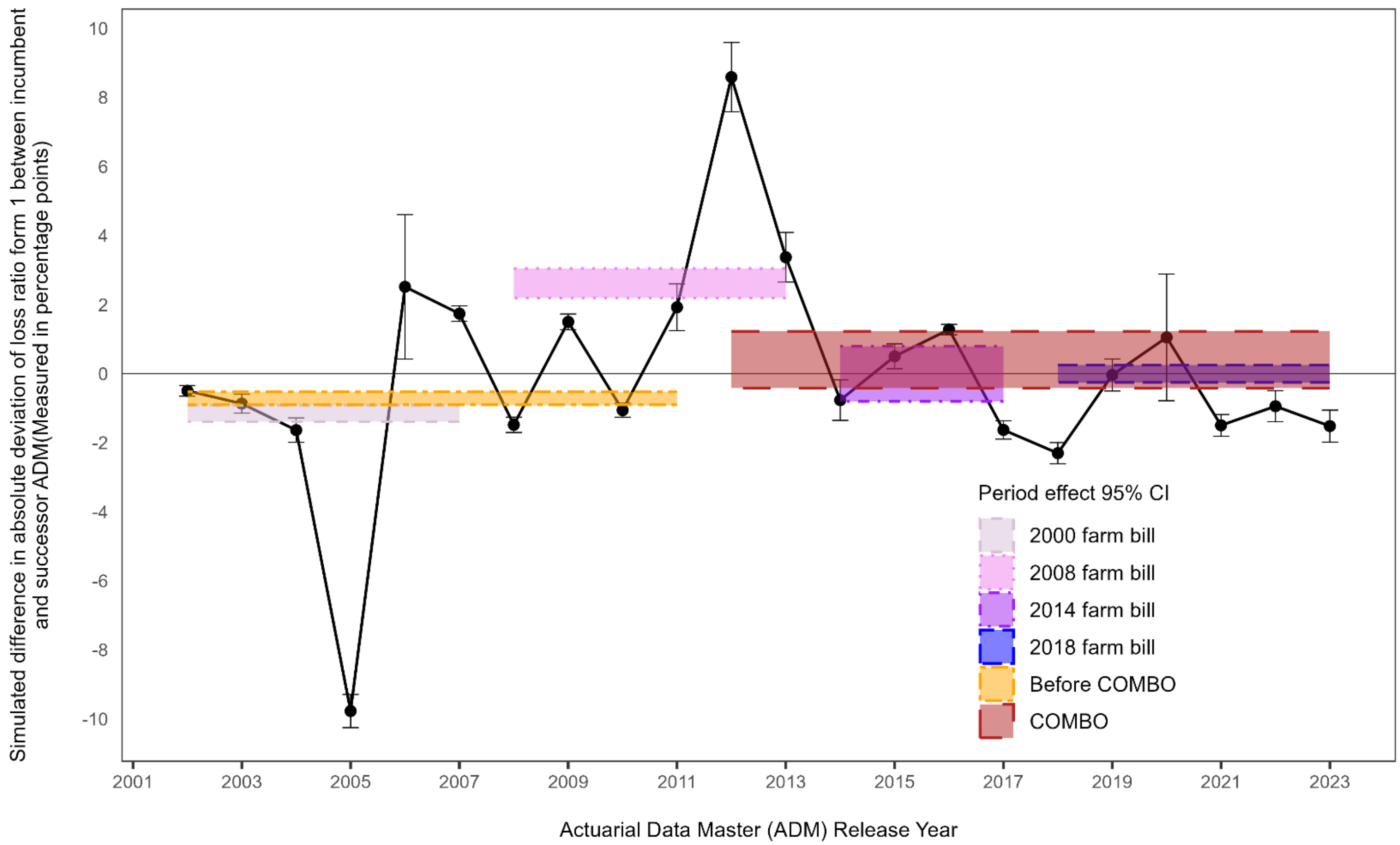


Figure 6: Diminishing returns to actuarial impacts of rate updates in the United States Federal Crop Insurance Program (2002-23).

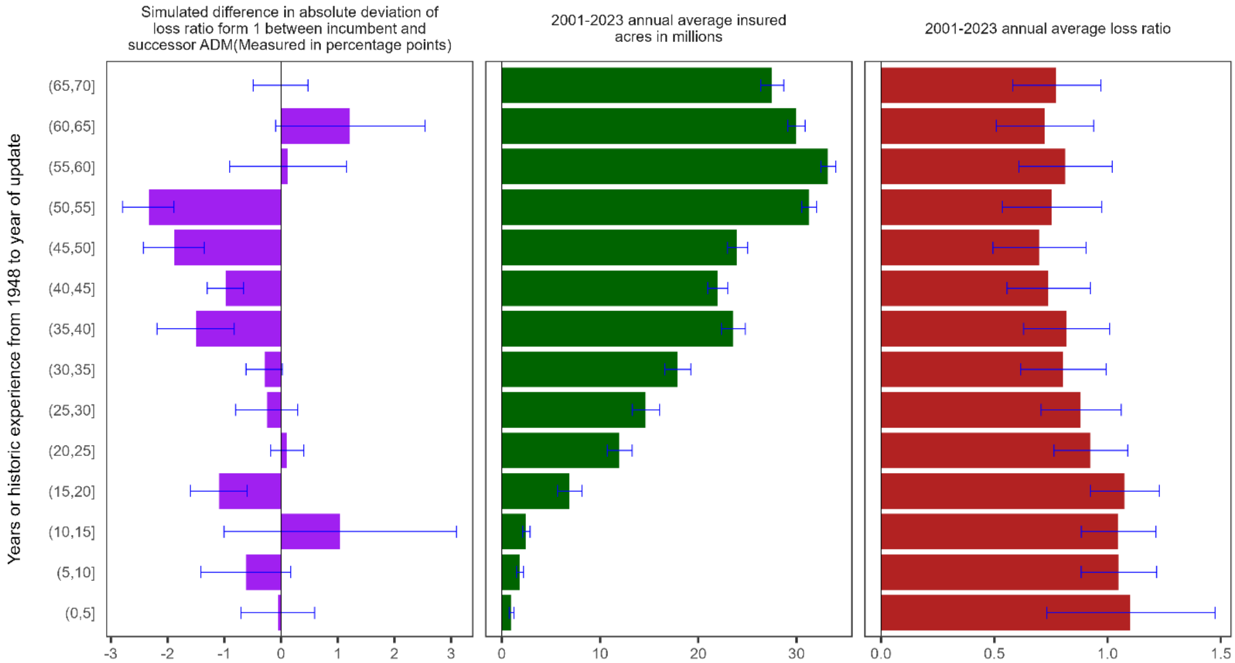


Figure 7: Actuarial impacts of actuarial updates in the United States Federal Crop Insurance Program by state and crop (2002-23).

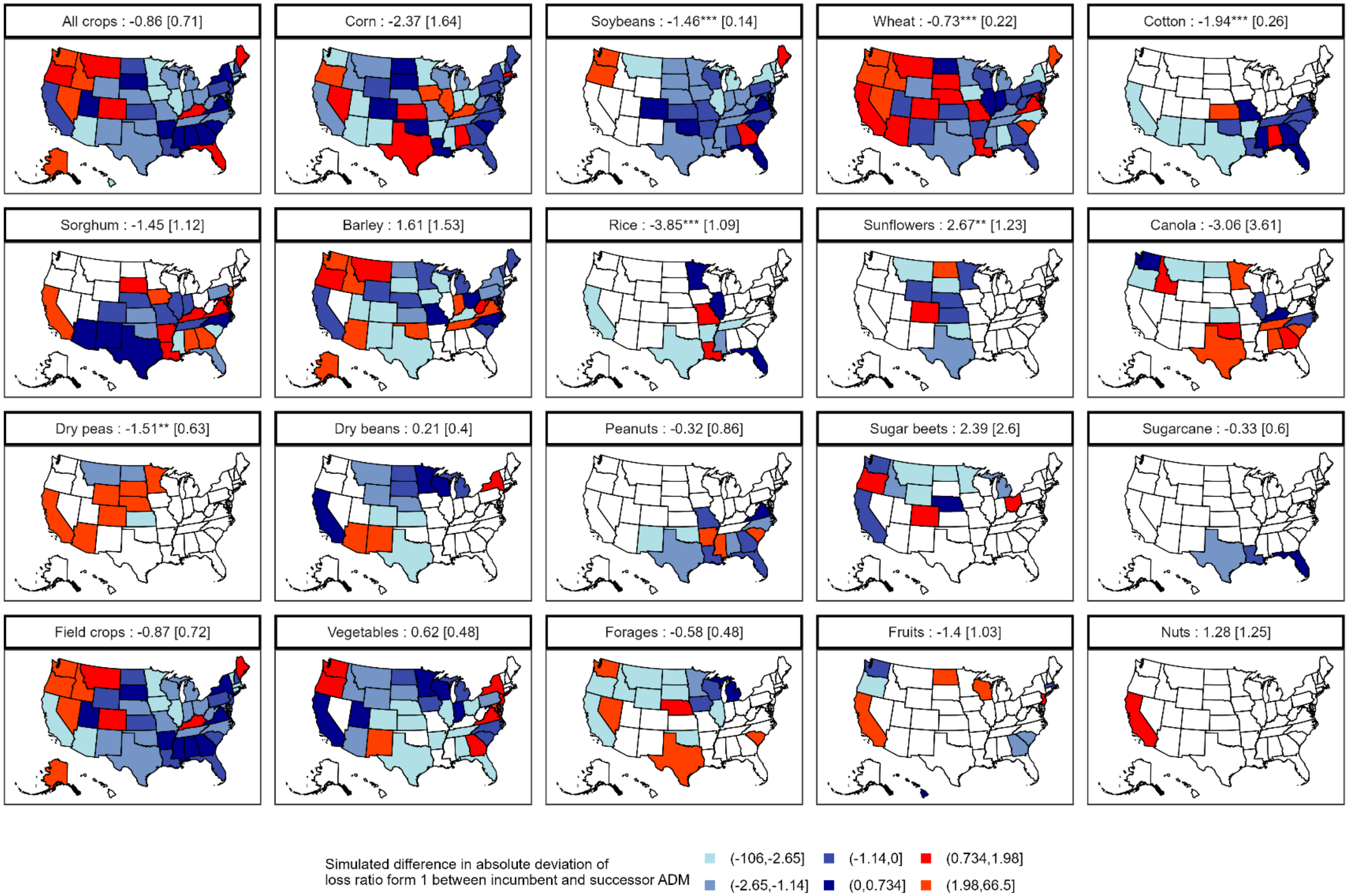
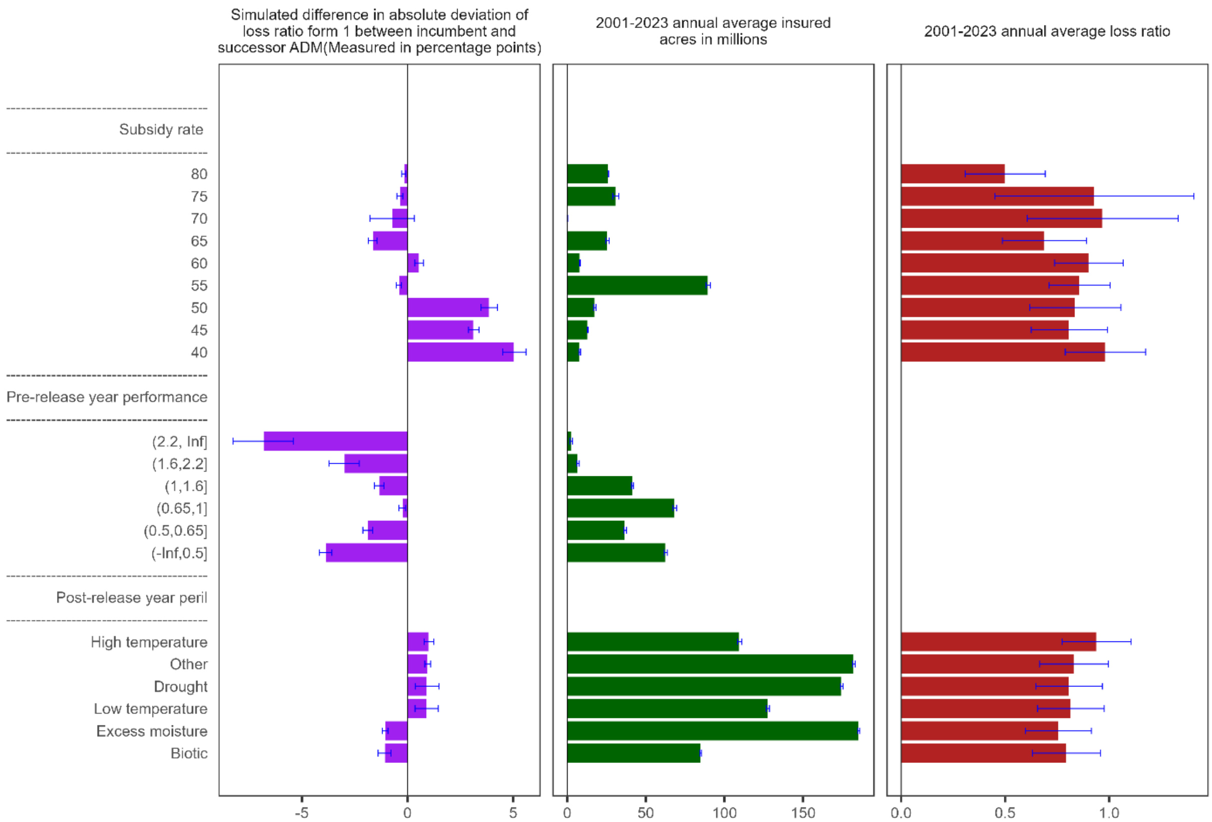


Figure 8: Actuarial impacts of actuarial updates in the United States Federal Crop Insurance Program by Historic Performance and type of Post Release Year Peril (2002-23).



## Appendix

Note S1: Explanation of the rate yield calculation

The key continuous rating formula parameters involved include the county reference rate ($\alpha_{jt}$), fixed rate ($\delta_{jt}$), rating exponent ($\beta_{jt}$), county reference yield ($\bar{y}_{cjt}$), and differential factors separately for coverage level ($F^{\theta}_{ijt}$) and unit structure ($F^{u}_{ijt}$). All these parameters are available in the Actuarial Data Master (ADM).

For each SOBTPU entry, the premium per dollar of liability ($\tau_{ijt}$) was calculated as the total premium divided by the total liability. The ADM and SOBTPU datasets are merged using common identifiers. After merging, the rate yield for each SOBTPU entry is estimated by rearranging the continuous rating formula. This process effectively derives the yield implied by the observed premium rate, after accounting for adjustments from differential factors and fixed rates. The calculation involves the following steps:

1. Adjust the observed premium rate ($\tau_{ijt}$) by removing the effects of coverage level and unit structure differentials: $\tau'_{ijt} = \frac{\tau_{ijt}}{F^{\theta}_{ijt}F^{u}_{ijt}}$
2. Subtract the fixed rate ($\delta_{jt}$) from the adjusted premium rate: $\tau''_{ijt} = \tau'_{ijt} - \delta_{jt}$
3. Normalize by the county reference rate ($\alpha_{jt}$): $\tau'''_{ijt} = \frac{\tau''_{ijt}}{\alpha_{jt}}$
4. Apply the rating exponent ($\beta_{jt}$) to solve for the rate yield factor: $\tau''''_{ijt} = \left[\tau'''_{ijt}\right]^{\frac{1}{\beta_{jt}}}$
5. Calculate the rate yield ($\bar{y}_{ijt}$) by multiplying with the county reference yield: $\bar{y}_{ijt} = \bar{y}_{cjt}\tau''''_{ijt}$

Summarizing the above steps, the formula for the rate yield is: $\bar{y}_{ijt} = \bar{y}_{cjt}\left[\left(\frac{\tau_{ijt}}{F^{\theta}_{ijt}F^{u}_{ijt}} - \delta_{jt}\right)\frac{1}{\alpha_{jt}}\right]^{\frac{1}{\beta_{jt}}}$

Table S1: 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 (%) | 68.38 (7.45) | 68.29 (6.62) | 66.05 (9.17) | 68.40 (7.68) | 71.00 (5.60) | 70.93 (9.57) | 67.55 (8.32) | 55.33 (8.06) | 58.57 (8.82) | 59.96 (10.24) |
| Net insured area (acres) | 497 (1314) | 714 (1677) | 428 (809) | 810 (1877) | 1627 (5611) | 1338 (4414) | 606 (1565) | 524 (1971) | 224 (724) | 2266 (6076) |
| Total insured liability ($ 1,000) | 169 (443) | 132 (421) | 212 (431) | 150 (364) | 343 (1526) | 462 (2028) | 261 (1285) | 83 (368) | 659 (2209) | 5291 (12654) |
| Total premium ($ 1,000) | 24.54 (76.99) | 24.18 (73.19) | 19.75 (53.01) | 24.13 (64.54) | 60.39 (288.33) | 47.02 (204.97) | 27.04 (85.46) | 9.94 (37.08) | 51.53 (190.59) | 188.84 (468.84) |
| Total subsidy ($ 1,000) | 14.96 (47.66) | 15.83 (51.60) | 11.86 (30.55) | 14.73 (40.36) | 38.98 (192.21) | 29.27 (137.88) | 16.60 (52.90) | 6.90 (27.06) | 33.53 (125.49) | 117.80 (300.28) |
| Total indemnity ($ 1,000) | 19.70 (90.94) | 22.99 (99.82) | 21.25 (128.57) | 27.27 (110.64) | 49.38 (248.42) | 38.96 (303.39) | 24.77 (113.36) | 7.83 (61.23) | 43.97 (222.72) | 160.13 (884.57) |
| 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 (0.05) | 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 (0.11) | 0.04 (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) | 0.03 (0.01) | 0.02 (0.02) | 0.01 (0.01) |
| Rating exponent | -1.36 (0.67) | -1.56 (0.56) | -1.01 (0.28) | -0.68 (0.66) | -1.44 (0.61) | -1.45 (0.53) | -1.12 (0.72) | -0.79 (0.84) | -0.31 (0.57) | -1.03 (0.66) |
| Coverage level differential factor @ 50% | 0.69 (0.12) | 0.70 (0.12) | 0.64 (0.09) | 0.71 (0.11) | 0.71 (0.10) | 0.67 (0.11) | 0.68 (0.12) | 0.65 (0.13) | 0.59 (0.18) | 0.50 (0.11) |
| Coverage level differential factor @ 55% | 0.79 (0.13) | 0.78 (0.13) | 0.76 (0.10) | 0.84 (0.07) | 0.79 (0.11) | 0.76 (0.12) | 0.81 (0.12) | 0.81 (0.10) | 0.76 (0.13) | 0.68 (0.07) |
| Coverage level differential factor @ 60% | 0.87 (0.13) | 0.86 (0.14) | 0.86 (0.10) | 0.92 (0.05) | 0.88 (0.11) | 0.85 (0.12) | 0.88 (0.11) | 0.89 (0.09) | 0.87 (0.08) | 0.81 (0.07) |
| Coverage level differential factor @ 65% | 0.95 (0.12) | 0.94 (0.14) | 0.97 (0.10) | 0.99 (0.04) | 0.96 (0.11) | 0.95 (0.12) | 0.96 (0.11) | 0.97 (0.09) | 0.99 (0.05) | 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 (0.10) | 1.07 (0.12) | 1.07 (0.11) | 1.08 (0.09) | 1.14 (0.09) | 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 (0.15) | 1.20 (0.15) | 1.20 (0.13) | 1.30 (0.18) | 1.45 (0.13) |
| Coverage level differential factor @ 80% | 1.35 (0.23) | 1.26 (0.07) | 1.52 (0.27) | 1.27 (0.11) | 1.29 (0.09) | 1.38 (0.20) | 1.34 (0.21) | 1.30 (0.17) | 1.45 (0.29) | 1.70 (0.16) |
| Coverage level differential factor @ 85% | 1.52 (0.33) | 1.39 (0.10) | 1.76 (0.40) | 1.38 (0.15) | 1.41 (0.12) | 1.57 (0.28) | 1.49 (0.31) | 1.41 (0.24) | 1.62 (0.42) | 1.99 (0.22) |
| Basic unit differential factor | 1.03 (0.03) | 1.03 (0.02) | 1.06 (0.03) | 1.05 (0.02) | 1.05 (0.03) | 1.03 (0.03) | 1.04 (0.03) | 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) | 1.01 (0.02) | 1.00 (0.01) |
| Number of insurance pools | 16597 | 16310 | 12491 | 10629 | 6676 | 613036 | 32309 | 15469 | 3661 | 847 |
| Number of observations | 58159 | 56513 | 63680 | 38419 | 22067 | 3634964 | 122472 | 65403 | 19690 | 7450 |

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.

Figure S1: Estimated elasticities