Incorporating A Buy-up Price Loss Coverage into the United States Farm Safety Net

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Acknowledgments
The authors extend their sincere gratitude to the institutions granting access to the datasets that underpinned this study. It is crucial to understand that the analyses, findings, and conclusions presented in this publication reflect solely the perspectives and interpretations of the authors. As such, they should not be considered as reflecting the official stance, policies, or determinations of the institutions of the authors.

Abstract
This study evaluates a proposed Price Loss Coverage (PLC) buy-up option to improve price protection for commodity producers. Using 2014–2023 USDA-RMA data, it applies crop insurance principles to model the product and assess its impact. Results show that combining PLC-buy-up with current farm-based insurance policies reduces revenue variability by 23% compared to no risk management. While this approach offers better risk mitigation than existing programs, it comes with higher expected government costs per unit of reduced variability.

Keywords: crop insurance, Index insurance, Price Loss Coverage, PLC

JEL codes: Q14, Q18, G22.

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Introduction

Agriculture and food systems are constantly buffeted by diverse threats ranging from extreme weather events and natural disasters to the uncertainties in market prices, policy shifts, and economic fluctuations. These perils, in addition to jeopardizing the livelihoods of producers and agricultural stakeholders, also test the resilience of agriculture and food systems. Agricultural producers, who form the foundation of agricultural and food systems, utilize various strategies to mitigate these risks, such as precautionary savings (Mishra, Uematsu and Powell 2012; Adhikari and Khanal 2022), irrigation (Lin, Mullen and Hoogenboom 2008; Barham et al. 2011), on-farm diversification (Katchova 2005; Aguilar et al. 2015; MacDonald, Hoppe and Newton 2018), hedging with futures and options (Walters and Preston 2018; Coffey and Schroeder 2019; Maples et al. 2022), and off-farm work participation (Key, Prager and Burns 2017; Whitt and Todd 2020; Khanal 2020). However, none of these approaches are a panacea. Unprecedented challenges such as the recent COVID-19 pandemic (Baldwin, Williams, Tsiboe, et al. 2023), geopolitical wars (e.g., Russia-Ukraine war and China–United States trade war) (Morgan et al. 2022), and climate change (Shew et al. 2020; Perry, Yu and Tack 2020; Ortiz-Bobea et al. 2021) underscore the role of Governments in maintaining the resilience of their respective agriculture and food systems (Belasco 2020; Tsiboe and Turner 2023b; Baldwin, Williams, Sichko, et al. 2023).

In the United States, agricultural policy is typically legislated and authorized by the Farm Bill. Although several Federal policies help attenuate risk indirectly, Federal risk management programs are primarily offered through Title I (commodity programs) and Title XI (crop insurance) of the 2018 Farm Bill (Turner et al. 2023). At a subsidized premium, The Federal Crop Insurance Program (FCIP), authorized via Title XI, offers a wide variety of crop insurance plans that allow producers to select a policy that best addresses their unique situation. Alternatively, at no cost to producers, programs authorized under Title I, such as Price Loss Coverage (PLC) and Agriculture Risk Coverage (ARC) provide a safety net for widespread systematic declines in farm revenue.

A unifying characteristic of most of the currently available programs for crop producers under Title I and Title XI of the farm bill is that they provide protection against declining yields (i.e., yield protection crop insurance policies) or declining revenues (i.e., revenue protection crop insurance policies or ARC). [1] Among Title I and Title XI, the PLC program is the sole option for crop producers that face limited yield risk (and thus do not wish to purchase revenue protection policies) but wish to buffer against declining market prices. [2] Since it was introduced in the 2014 Farm Bill, PLC has disbursed approximately $17.6 billion in commodity support (as of the end of 2022). By comparison, the FCIP paid out $66.9 billion in indemnity payments over the same period. However, recent policy discussions have raised concerns about the program's reference prices (which effectively determine the coverage level of the program) being too slow to adjust to changing production costs and market prices.

Commodity interest groups contend that the PLC reference prices, which determine the extent of a market price decline necessary to trigger PLC payments, are outdated and don't capture the recent rise in market prices (Outlaw 2022; Carson 2023; Cates 2023; Cheyne 2023a; Cheyne 2023b;

[1] The Noninsured Crop Disaster Assistance Program is also a Title I program but effectively functions as a catastrophic FCIP protection policy.

[2] The marketing assistance loan program is also part of Title I of the farm bill and has the potential to provide price protection through the non-recourse commodity loans. Specifically, producers have the option to not repay their loan, forfeit their harvested commodity, and receive the marketing loan rate for their harvest. However, this practice is generally discouraged, and loan rates are set such that large declines in price (i.e., over 50% decline for most major commodities) must occur before this would be an advantageous option.

Flansburg 2023; Larew 2023; Meeker 2023; Moore 2023; Ragland 2023; Satterfield 2023; Wolle 2023). To address this, the 2018 farm bill introduced “effective reference prices” allowing reference prices to rise by up to 15% based on the five-year Olympic average market prices. Yet, for some crops, this mechanism to increase the reference prices is viewed as inadequate.

As of May 2024, both the senate (U.S. Senate Committee on Agriculture, Nutrition, and Forestry 2024) and house (U.S. House Committee on Agriculture 2024) agriculture committees were proposing increases in statutory reference price of between 5%-20% for the next farm bill. A counter argument to this approach is the overall spending increases that are likely to accompany across the board reference price increases. One proposed compromise is to impose limits on payment rates—an approach that would increase the likelihood of PLC payments while capping their potential magnitude (Coppess et al. 2024). Another concern that has been raised is the disproportionate level of support that can occur across different commodities when static proportional increases are applied.[3]

From the perspective of economic incentives, as reference prices rise (and if base acres are approximately equal to planted acres), the levels of support provided by the PLC program becomes a closer substitutes for formal insurance products, especially when combined with other crop insurance offerings that insure other risks.[4] One concern is that higher levels of risk protection in

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[3] It has been estimated that a 10% increase in statutory reference prices applied uniformly to all crops would lead to a $17.4 billion increase in spending on the PLC program between 2024-2033 – a 42% increase over the estimated budgetary expenditures under current statutory reference prices (Schnitkey et al. 2024).These estimates are highly variable by crop due to the variance in how current reference prices relate to current commodity prices. For example, the same analysis estimated a 10% increase in reference prices would lead to a 140% increase in PLC payments to rice whereas an 8% increase was estimated for soybeans.

[4] For example, when MYA prices are close to reference prices and base acres are roughly equal to planted acres, enrolling in PLC and purchasing a yield protection crop insurance policy can provide

commodity support programs that do not charge a premium will crowd out demand for formal insurance that provides similar protection but with the added expense of the farmer paid premium. This point is especially relevant after 2020 when the decision to enroll in ARC or PLC became an annual decision.[5] From the perspective of economic efficiency, raising reference prices by a static proportion is problematic, since the reference price increase that maximizes total welfare is unknown given that there is currently no mechanism to reveal the producer's willingness to pay for PLC.[6]

Although there appears to be general support to reform reference prices among commodity interest groups and both congressional agriculture committees, there is no unanimous agreement on the specifics of how to do so. One potential approach that addresses many of the concerns raised above is to develop a price-based index insurance product to potentially supplement traditional counter-cyclical support programs like PLC. Although ARC has analogous FCIP products (SCO and ECO), no such analog exists for PLC. [7] The objective of this paper is to assess the potential efficacy of a hypothetical buy up PLC product (here after "PLC-buy-up") by comparing it to other combinations of federal risk management products currently available (FCIP policies, PLC, and ARC). By

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a similar level of total protection against declining revenue as compared to a formal revenue protection insurance policy.

[5] Under the 2014 Farm Bill, the decision to enroll in ARC or PLC was a decision that was fixed for the duration of the farm bill. Under the 2018 Farm Bill, producers were given the option to change their election, which would be fixed for 2019 and 2020, after which the election decision could be changed annually (Turner et al. 2023).

[6] I.e. a producer with zero (or marginally greater than zero) WTP for PLC may still sign up given their out-of-pocket cost is zero. In such a case, the accrued marginal benefit to the producer is trivial and much lower than the marginal cost of the program which is not borne by the producer.

[7] The Supplemental Coverage Option (SCO) and Enhanced Coverage Option (ECO) are FCIP products that can be combined with traditional crop insurance policies to provide additional area-based revenue coverage.

combining a public data set consisting of FCIP insurance pool-level observations with recent methods (Tsiboe, Turner and Yu 2025), we are able to calibrate yield data for 936,311 insurance pool level observations consisting of producers of barley, canola, corn, cotton, sorghum, oats, peanuts, rice, safflower, soybeans, sunflowers, and wheat from 2014-2023.[8] We determine actuarial parameters for the hypothetical PLC-buy-up product by combining elements of the existing PLC program with existing FCIP index products. Finally, we simulate and compare the effects to mean revenue and revenue variability, actuarial properties, and cost to taxpayers across various policy counterfactuals to assess the feasibility of all PLC-buy-up products as an addition to the current farm safety net.

Overall, our results suggest that PLC-buy-up coverage, when combined with traditional FCIP policies, is more effective at reducing revenue variability than any other combination of currently available risk management products. Similarly, among the combinations of risk management programs that produced the top 3 largest increases to mean revenue, relative to no use of a risk management program, all incorporated PLC-buy-up coverage. In addition to favorable risk mitigation properties, the hypothetical PLC-buy-up coverage has relatively good actuarial performance, if all agents bought it, with loss ratios below one for most crops and coverage levels - indicating that indemnities are likely to be covered by premiums. The recognized benefits of PLC-buy-up coverage come at the expense of financial efficiency. Specifically, we find that the government spending required to reduce revenue variability by a fixed amount is higher for PLC-buy-up coverage compared to existing yield and revenue crop insurance policies. However,

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

estimates suggest that PLC-buy-up coverage is more financially efficient at reducing risk compared to some existing programs including countercyclical commodity support programs (ARC and PLC) and area, index, and margin protection crop insurance policies.

To our knowledge, this study is the first to provide a comprehensive assessment of the implications of expanding the PLC program to include additional optional tiers of purchasable coverage. The remainder of the article is organized as follows. In section 2, we give a background on the US Federal risk management policy environment. Section 3 introduces our data sources. Our methodology, outlined in section 4, involves in-depth explanations of the PLC-buy-up design, simulation methods employed, and the approaches to evaluating and comparing options. The results of our analysis are presented in section 5. The final section summarizes our findings and discusses the implications of the results.

Federal Risk Management Policy Environment

In the United States, agricultural policy is legislated and authorized by the Farm Bill. This multi-year legislative package, typically refreshed every five years, regulates a vast array of agricultural and food systems programs.[9, 10] Notably, two titles of this bill - the Commodity title (Title I) and Title XI (Crop Insurance) - are specifically tailored to address the risk management needs of producers.

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[9] Titles in the most recent farm bill (The Agriculture Improvement Act of 2018, Public Law [P.L.] 115-334) encompassed farm commodity revenue supports, agricultural conservation, trade and foreign food assistance, farm credit, research, rural development, forestry, bioenergy, horticulture, and domestic nutrition assistance.

[10] Recent official Federal Government reports provide detailed overview of agricultural risk management programs (Turner et al. 2023; McFadden and Hoppe 2017; Hrozencik, Perez-Quesada and Bocinsky 2024) and annual policy developments (Baldwin, Williams, Tsiboe, et al. 2023; Baldwin, Williams, Sichko, et al. 2023; Baldwin, Turner and Tsiboe 2024).

The Federal Crop Insurance Program (FCIP), authorized by Title XI, provides a subsidized premium for a range of insurance options, enabling producers to tailor a farm safety net to their specific operational risks annually. The FCIP offers two main types of insurance plans: individual-based policies and area or index-based policies (Turner and Tsiboe 2022; Turner et al. 2023). Individual-based policies compensate based on the actual losses experienced by a producer, making them highly specific to individual circumstances. In contrast, area or index-based policies are linked to the broader experiences of a group of producers, such as those within a county, which may not perfectly reflect an individual's loss. Both types of policies can be categorized further into yield-based, protecting against quantity decreases, or revenue-based, covering income losses due to price drops or reduced yields. Some area or index-based policies also provide margin protection, covering the decrease in operating margins (revenue minus input costs). Coverage levels vary, with individual policies allowing insurance of 50-85% of expected yield or revenue, and area or index plans offering 50-95% coverage of expected yield, revenue, or margin.

In contrast to the FCIP, at no cost to producers, programs such as the Price Loss Coverage (PLC) and Agriculture Risk Coverage (ARC) under Title I of the farm bill provide a safety net for long-term systematic declines in farm revenue, typically persisting over multiple seasons and affecting national or county-wide scales. The ARC and PLC programs are sometimes referred to as "counter-cyclical" due to their design which counteracts the prevailing market trend. In other words when prices or revenues decline, support payments are issued, whereas when market conditions improve, support is automatically halted. This contrasts with crop insurance policies which typically provide support based on the individual outcomes of a particular producer, regardless of the broader market conditions.

Although PLC compensates for low prices and ARC mitigates revenue risks, both programs make payments based on historical "base" acres which are not tied to current production.[11] Initially, farmers had to make a one-time election between ARC or PLC that lasted through the 2014 Bill (Farm Service Agency 2014). This tasked farmers with selecting the program that they expected to provide the greatest level of support over the next 5 years (Taylor et al. 2017; Westhoff, Gerlt and Glauber 2015). The 2018 Farm Bill allowed a change in the initial choice (Farm Service Agency 2019). The 2018 election into ARC or PLC was again fixed, although only for the first two years (2019 and 2020), after which the choice became an annual decision.

Payment calculations for the ARC and PLC programs are based on specific commodity price thresholds, yield measures, and national average prices. Under PLC, producers are paid the difference between the reference price and the national marketing year average (MYA) price, multiplied by their program yield, calculated as 90% of the historical average yield on planted acres.[12] If the MYA price is below the national loan rate (NMLR) for a crop, the loan rate is substituted for the MYA price for purposes of payment calculation. The final payment is then determined by multiplying this amount by 85% of the producer's enrolled base acres for the covered commodity. The PLC payment calculation is summarized in equations (1) – (2).

$$\text{PLC Payment Rate} = \begin{cases} 0 & if \quad \text{ERP} \leq \text{MYA} \\ (\text{ERP} - \text{MYA}) \times \text{Yield} & if \quad \text{NMLR} < \text{MYA} < \text{ERP} \\ (\text{ERP} - \text{NMLR}) \times \text{Yield} & if \quad \text{MYA} \leq \text{NMLR} \end{cases} \tag{1}$$

[11] Base acres refer to a farm's historical planted acres for a specific commodity used for purposes of administering FSA programs and do not necessarily represent a farm's current planted acreage.

[12] Under the 2014 Farm Bill, producers were given the option to update their program yields to 90% of the farm's 2008-2012 average yield per planted acre. A similar option was offered under 2018 Farm Bill that allowed producers to set their payment yield equal to 90% of their average 2013-2017 per acre yield multiplied by the ratio of their average 2008-2012 per acre yield to their average 2013-2017 yield.

$$\text{Final PLC Payment} = 0.85 \times \text{Crop Base Acres} \times \text{PLC Payment Rate} \quad (2)$$

The 2018 Farm Bill introduced an adjustment mechanism (known as the "escalator provision") to update the statutory reference prices established in the 2014 Farm Bill. This procedure adjusts the 2014 statutory reference prices when commodity prices trend upwards. The adjusted prices, known as "effective reference prices" (ERP), incorporate the Olympic average (OA) of the last 5 years of the MYA prices. Specifically, the ERP is set at 85% of the OA price if this value exceeds the statutory reference price, with a cap at 115% of the statutory reference price. [13,14]

Figure 1 plots the relationship between Statutory Reference Prices (SRP), MYA prices, and ERP for each crop in our analysis where it is clear that there is significant heterogeneity by crop.[15] Soybeans, for instance, have never had MYA prices decline below the relevant reference price (SRPs from 2014-2018 and ERPs from 2019 onward) whereas peanut MYA prices have been below the relevant trigger price every year from 2014-2021. Unsurprisingly, enrollment in PLC varies significantly based on the past (and expected) relationship between MYA and reference prices. Soybeans have generally had the lowest rates of enrollment in PLC while Peanuts have had some of the highest (Turner et al. 2023).[16]

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[13] For example, program year 2019 used an OA calculated from the 2013/14 – 2017/18 marketing year average prices.

[14] This contrasts with ARC which does not utilize a statutory reference price. The benchmark revenue calculation used for ARC is based simply on the 5-year OA of national marketing year average prices, and the 5-year OA of county yields for each commodity.

[15] Figure 1 plots ERPs going back to 2014 even though they were only introduced following the 2018 farm bill. As discussed later, this is done to create a consistent policy environment in which to counterfactually estimate the performance of PLC buy up coverage.

[16] Producers of other commodities like long grain rice, peanuts, and canola have predominantly chosen PLC possibly due to the high statutory reference prices set for these crops in addition to lower yield risk relative to other crops For rice in particular, yield risk tends to be low relative to

In recent discussions amongst commodity interest groups regarding PLC, a common critique is that the program lacks the flexibility to respond to current agricultural economic conditions (Outlaw 2022; Carson 2023; Cates 2023; Cheyne 2023a; Cheyne 2023b; Flansburg 2023; Larew 2023; Meeker 2023; Moore 2023; Ragland 2023; Satterfield 2023; Wolle 2023). Farmers express discontent with PLC because its payouts are predicated on reference prices derived from historical data, potentially rendering them outdated in a rising price environment. This structure means that PLC does not trigger payments when market prices are high, effectively functioning as designed by not disbursing funds when they are deemed unnecessary. However, this leads to farmer dissatisfaction primarily during periods of price inflation or rising production costs. While the 2018 farm bill introduced the escalator provision and the resulting effective reference prices as a solution, the speed at which effective reference prices adjust to new price norms can be slow since they are based on moving 5-year Olympic averages. With these concerns as a backdrop, the remainder of this paper explores the feasibility of incorporating buy-up coverage into the PLC program.

Data

Data for our analysis is based on RMA's summary of business for crop years 2014-2023 aggregated by county, crop, crop type, production practice, insurance plan, coverage level, and insurance unit (abbreviated as "SOBTPU").[17] We only consider data for policies that are rated based on

other major crops like corn, soybeans, or cotton meaning price is the predominant concern (Biram 2023).

[17] The options for the crop type (e.g., corn can be grain or silage), production practice (e.g., irrigation), and insurance plan (e.g., APH, ARH, RP, YP, etc.) are taken as defined by RMA for each year. SOBTPU files for each insurance year are available at the RMA website (Risk Management Agency [RMA] 2023b).

continuous rating, which includes insurance plans classified as Yield Protection (YP), Actual Production History (APH), Revenue Protection (RP), and Revenue Protection with Harvest Price Exclusion (RP-HPE) and drop all pools with less than four years of data points. Policy rating parameters and insurance policy commodity prices (projected and harvest) are retrieved from RMA's Actuarial Data Master (ADM) and price addendums. Additionally, we calculate reinsurance state level fund allocation ratios using data from RMA's reinsurance reports.[18] For Marketing Year Average (MYA) prices, we rely on the USDA National Agricultural Statistics Service's (NASS) Quick Stats database. Lastly, the PLC and ARC payment factors are obtained from the USDA Farm Service Agency.

The complete data consists of 936,311 FCIP observations with 130,681 unique insurance pools across 12 crops (barley, canola, corn, cotton, sorghum, oats, peanuts, rice, safflower, soybeans, sunflowers, and wheat) and represents about 53% of FCIP liability for the listed crops. The average number of insured acres in an insurance pool was 1,633 (s.d. of 5,381) with an average insured liability of $423,558 (s.d. of $1,574,000). The average total collected premium per insurance pool was $41,941 (s.d. of $160,561) while the average value of premium subsidies per insurance pool was $27,042 (s.d. of $117,378).

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

Methods

Additional Price Loss Coverage (PLC-buy-up) Program Design

The core component of PLC-buy-up coverage is an additional level of coverage, g, that represents an additional coverage level above what is provided by PLC in its current form. If the typical price floor provided by the PLC effective reference price is defined as $\tilde{p}_j$, the price floor under PLC-buy-up coverage can be represented by $\ddot{p}_{j,g,t} = \tilde{p}_{j,t} \cdot (1 + g)$ where g is some value greater than zero. For example, when g = 0.3, the price floor under PLC-buy-up coverage is 30% higher than the price floor provided under traditional PLC coverage. Although formulating the price guarantee for PLC-buy-up coverage is simple, the appropriate premium rate to charge for a chosen value of g is not straightforward given that there is no premium rating processes associated with PLC. However, PLC is effectively an index insurance product, meaning methods used for pricing other single peril index insurance products, such as the Pasture, Rangeland, and Forage Rainfall Index (PRF-RI) insurance plan, are also generally applicable (Tsiboe, Tack and Yu 2023).

The full technical details of setting premium rates for PLC-buy-up coverage are presented in appendix note S2. However, the essence of this process is that it follows the premium rating process for PRF-RI and defines payment calculation factors which track the percentage deviations of the relevant index value (marketing year average prices and effective reference prices in this case) from the index trigger value over time. The premium rate is then defined to commensurate with the average deviation implied by the payment calculation factors. In other words, premiums are higher for commodity prices that have a high variance (and thus have a higher probability of moving beyond the threshold that triggers payments). Figure S1 in the appendix shows the resulting premium rates (per dollar of insured liability) for each crop that are suggested by this rating process including the premium rate implied for the existing PLC program. Figure S2 shows the producer paid premium rate factoring in a subsidy rate of 65% (based on current subsidy rates for the FCIP's supplemental coverage option). Paid premium rates are zero for the 0% coverage level (i.e. regular PLC coverage) and rise to between \$0.03-\$0.05 per dollar of insured liability for the highest coverage level (depending on crop).

Simulation

In addition to PLC-buy-up, the study simulates revenue series associated with various portfolios of risk management products that a producer could participate in. These portfolios are made up of combinations of FCIP insurance policies, PLC, ARC, and PLC-buy-up that are allowable under current legislation. To implement these simulations, we use the notion of a 'representative agent', which acts as a single observational unit that embodies a group of similar agricultural producers. Each agent corresponds to an entry in SOBTPU, as outlined in the data section meaning that each representative agent consists of producers that share the same set of crop insurance options, cultivate the same crop, adhere to similar farming practices, and are subject to identical insurance premium rates.

Key variables for this analysis include end-of-season crop yields and prices. While price data are publicly accessible, end-of-season yield data are not readily available at the SOBTPU level. To bridge this gap, we employ recent methodology (Tsiboe, Turner and Yu 2025) to estimate insurance pool level yields using the deterministic relationship between annual variations in crop insurance rating parameters and pool-level yield changes. This process is described in greater detail in appendix note S2. The 936,311 calibrated yield observations spanning 130,681 insurance pools from 2014–2023 exhibit a great amount of cross-sectional and temporal variation (figure S3 in the appendix). Means and standard deviations for the calibrated yields for each crop are reported in table S1. Prior work demonstrates that the total liability, total premium, and subsidy amount simulated from these calibrated yields aligns with the actual observed values for the same period based on the SOBTPU experience, from which the calibrated yields are derived (Tsiboe, Turner and Yu 2025).

Our primary aim is to determine how each risk management portfolio would be fair at preserving agent's revenue. In other words, our objective is to assess the actuarial properties of each portfolio rather than the success of a portfolio that is conditional on adoption and participation trends. Consequently, premiums and indemnities are simulated ex-post such that all agents in our data participate in all strategies for every year data is available for them. This ensures that adverse selection (since all agents participate in all available risk management portfolios) and moral hazard (yields remain the same under all strategies) are held constant. Furthermore, all simulations are performed on a per acre basis.

For simulation of risk management portfolios that involve FCIP policies, we consider four broad categories; (1) plans based on on-farm experience (YP/APH, RP, and RP-HPE); (2) plans based on group level experience (Area Yield Protection [AY], Area Revenue Protection [AR], and AR-HPE); (3) plans based on a short fall in margins (Margin Protection [MP] and MP-HPE); and (4) plans based on on-farm experience combined with the Supplemental Coverage Option (SCO). For each category we only consider the insurance plan and coverage level combination with the highest net enrolled acres from 2014-2023 (see table S2). Focusing on the most popular options within each group isolates the performance of each product category from extraneous factors such as agent risk preferences and instead focuses on differences due to the unique attributes that define each FCIP risk management product group. In a similar spirit, the coverage level for the hypothetical PLC-buy up was also held fixed when compared to existing policies. Here we determine crop specific coverage levels optimally by setting them to the coverage level that minimizes crop year revenue variability, as defined in the next subsection. As shown on table S2, the optimal coverage level for the PLC-buy up was determined to be 45% for canola and 50% for all other crops. Additionally, we adhered to regulatory restrictions on how PLC and ARC could be combined with specific FCIP policies (for example, SCO cannot be combined with ARC). PLC-buy up coverage was allowed to interact with FCIP plans and ARC as the traditional PLC program does in the current regulatory restrictions.

Throughout the simulation analysis, liabilities, premiums, subsidies, and indemnities for FCIP policies (as defined in the FCIP "Appendix III/M-13 Handbooks") are calculated according to standard practices within the FCIP. These practices are also generally applied to obtain outcomes (liabilities, total premiums, subsidies, and indemnities) for the PLC-buy-up option. Premium subsidies for PLC-buy-up coverage are set at 65% to mimic the subsidy rate set for the FCIP's supplemental coverage option. Revenues for each risk management option are based on the revenue provided by yields and any indemnities provided by the combination of risk management plans net of any producer paid premium. Full details of these calculations can be found in the appendix (note S1).

The actuarial performance of the hypothetical PLC-buy-up product can be assessed by examining the simulated loss ratios. Figure S4 shows that for most crops, except for peanuts, loss ratios are well below one indicating that expected indemnities are less than expected premiums to be collected.

Evaluation and Comparisons

To evaluate how effective each portfolio of risk management products is, we rely primarily on two metrics: relative mean revenue and relative revenue variability. Relative mean revenue is calculated by taking the average revenue each agent earns when participating in each portfolio of risk management products and dividing it by their average revenue in the absence of any risk management products. We assess the fluctuation in each agent's revenue over time using standard statistical measures including the coefficient of variation (CV) and the lower absolute partial moments (Antle 2010) which captures variance for the portion of the distribution below the mean, both of which are normalized to the default scenario of not participating in any of the risk management portfolios. To ensure that our findings are robust to high variability caused by small sample sizes, we limit our analysis to agents who have at least three years of simulated data available.[19] Finally, we aggregate these individual metrics across all agents to obtain an overall measure of a given risk management portfolio's impact on mean revenue and revenue variability.

The overall cost to the government for each portfolio of risk management products is conditional on variations in (A) total premiums, (B) premium subsidies, (C) indemnities; (D) program delivery costs, (E) reinsurance underwriting gains (F), and reinsurance underwriting losses. For each risk management portfolio and crop, cost items A, B, and C were taken as the summation of the relevant variables across all agents. For FCIP insurance plans (APH, YP, RP, RP-HPE, AY, AR, AR-HPE, MP, MP-HPE, and SCO) the delivery cost and subsidies were approximated as a proportion of the total premium amount using Administrative & Operating (A&O) expense subsidy factors retrieved from RMA's Insurance Control Elements database. We used a similar approach for the case of PLC, ARCCO, ARCIC, and PLC-buy-up, by using the average A&O expense subsidy factors for index based FCIP insurance plans (AY, AR, AR-HPE, MP, MP-HPE, and SCO).

For the case of costs associated with reinsurance, we follow the terms under which private companies sell, service, and underwrite federal crop insurance which is specified in the Standard

[19] Our dataset encompasses crop years 2014-2023 regardless of which pools are dropped with each pool having anywhere from 4-11 years underlying the individual pool outcomes.

Reinsurance Agreement (SRA). Under the SRA, companies retain risks, or alternatively cede risks to the Federal Government, by designating individual crop insurance policies to reinsurance funds (Assigned Risk, Developmental, or Commercial). Different parameters of each of the funds allow a company to retain or cede different proportions of premiums and associated liabilities (proportional reinsurance) and to share with the Federal Crop Insurance Corporation different amounts of the eventual underwriting gains or losses on retained premiums and liabilities (nonproportional reinsurance). For the case of proportional reinsurance, we set the retention and ceding proportions at the state level based on the actual observed proportions for each crop year. Once we determined the fund allocation for each program, we assumed that for the retained liability, the government pays increasing shares of the indemnities, depending on the program's state-level loss ratio (indemnities divided by total premium) in the fund, with government paying the entire loss when loss ratios exceed 5.0. Here, the underwriting gains [losses] are determined as the value of the nonproportional reinsurance where the state-level loss ratio is below [above] unity. Given the above cost items, the total cost of each program by crop was calculated as (A-B)-C-D+E.

Results

For each performance measure, we present pooled results in figure 2 which are based on averaging the unitless relative performance measures across all crops in the sample. The legend orders each risk management portfolio in accordance with how much the portfolio reduced revenue variability. In general, participation in FCIP policies that contain plans based on on-farm experiences (APH/YP/RP/RP-HPE) are the best at limiting revenue variability. Prior studies have also found this risk mitigation effects of these on-farm experience-based policies (Tsiboe, Turner, Baldwin, et al. 2025; Gaku and Tsiboe 2024). The top eight risk management portfolios all incorporate one of these policies. Leading the list is the combination of APH/YP/RP + SCO + PLC-buy-up, which showed a 24% reduction in revenue variability (figure 2, panel B) and a 20% increase in mean revenue (figure 2, panel A) relative to the case of no enrollment in a risk management program. The combination of APH/YP/RP + PLC-buy-up also demonstrated reductions in risk of similar magnitude. Conversely, strategies involving MP, especially those combined with ARC-IC or PLC, were found to be the least effective at controlling revenue variability. These strategies increased variation in revenue by up to 18% compared to scenarios without participation in a risk management program.

Panel C of figure 2 reports the LAPM of revenue. The ordering of portfolios in panel C is roughly the same as in panel B (coefficient of variation). The best performing portfolios in terms of minimizing downside variability are “APH/YP/RP + ARC-IC”, “APH/YP/RP + PLC-buy-up”, and “APH/YP/RP + SCO + PLC-buy-up”. Although these three portfolios were also the best performing according to their effect on the coefficient of variation, “APH/YP/RP + ARC-IC” moved from the third best to first best when evaluating the portfolios in accordance with their effect on LAPM. This is consistent with the program design of these policies. Since PLC-buy-up and SCO are index-based products, they have basis risk which means they may not be as well correlated with actual losses. ARC-IC, on the other hand, is based on individual on-farm revenue, meaning sufficiently large losses will always result in ARC-IC payments being made.

In general, portfolios that incorporate risk management tools that are characterized by basis risk, tend to perform worse when measuring LAPM compared to the coefficient of variation. For example, “AY/AR + PLC-buy-up”, reduces variability in revenue compared to no risk management use (“k” in panel B), but increases variation in the portion of the revenue distribution below the mean (“k” in panel C). Similarly, “ARC-CO only” reduces variation in general (“m” in panel B) but increases downside risk variation ("m" in panel C). Analogous results to those presented in figure 2, but differentiated by crop, can be found in figures S5 – S7 in the appendix. Although there is heterogeneity in results by crop, the ranking of the different risk management portfolios is generally consistent with what is observed in the pooled results.

Although the effect that the various risk management portfolios have on revenue is of interest, these effects alone provide an incomplete picture as they ignore the cost to both the government and producer of providing and adopting these portfolios. Table 1 provides a measure of how much each risk management portfolios costs that is normalized by how much these portfolios increase mean revenue and reduce revenue variability. Columns [A] and [B] in table 1 indicate the percentage reduction in revenue variability and the percentage increase in mean revenue, respectively, that each risk management portfolio produces relative to the baseline of using no risk management products (i.e. these are the same values from panel B and panel A in figure 1). The remaining columns in table 1 report the costs to both the government and producer of increasing mean revenue by 1% and decreasing revenue variability by 1%. These measures are calculated by calculating the total cost per acre of each risk management portfolio and dividing by the percentage change to mean revenue and revenue variability (as reported in the first two columns).

The individual cost items that factor into the total government cost are reported in table S3 in the appendix. Producer costs are equivalent to the out of pocket paid premium (i.e. total premiums – premium subsidy). Focusing on the top ranked portfolio in terms of reducing revenue variability ("APH/YP/RP + SCO + PLC-buy-up"), the government cost per acre to reduce revenue variability by 1% through administration of the individual programs in this portfolio is \$5.31 and the government cost to increase mean revenue by 1% is \$6.21. Meanwhile, the producer's cost for these same outcomes is \$1.67 and \$1.95 respectively. Despite this portfolio providing one of the largest increases in mean revenue and largest reductions in revenue variability, it is not the most efficient once the effects are normalized by cost. Accounting for the cost to achieve the unit of risk reduction leads to an on-farm crop insurance policy "APH/YP/RP" being the best performing at $2.51 for a 1% reduction in revenue variability while "APH/YP/RP + ARCCO" is the best performing in terms of increasing mean revenue at a cost of $5.48 per 1% increase in mean revenue.

When the out-of-pocket cost to the producer is the metric of interest, the most financially efficient risk management product is one of either PLC, ARC-CO, or ARC-IC, solely because these programs do not charge the producer a premium. When only portfolios that contain a premium earning program are considered, PLC-buy-up coverage is the most financially efficient at $1.10 and $0.99 for a unit reduction in revenue variability and increase in mean revenue respectively. However, the producer's cost of PLC-buy-up is again greatly reduced since the underlying coverage provided by regular PLC does not charge a premium. Among the remaining portfolios, "APH/YP/RP + ARCIC" is the most cost efficient for the producer in terms of reducing revenue variability ($0.90) where as "MP + ARCIC" is the most cost efficient at increasing mean revenue ($1.00). Notably, PLC-buy-up coverage is comparable in cost to the most efficient premium earning portfolios from the point of view of the producer at $1.10 and $0.99 and marginally more cost efficient compared to regular PLC, despite PLC-buy-up providing much larger effects to both revenue variability (-10.27% vs -6.46%) and mean revenue (11.42% vs 6.96%).

Crop specific measures of cost efficiency are provided for both revenue variability and mean revenue are reported in the appendix (tables S4 and S5). In general, the crop specific cost efficiency measures provide a similar ordering of risk management portfolios as the pooled results, however, the magnitude of the costs associated with each risk management portfolio vary significantly across crops. Several factors that contribute to the differences in cost efficiency are associated with the same risk management portfolio across different commodities. First, differences in historical market conditions are the primary reason for variation among ARC-CO, ARC-IC, PLC, and PLC-buy-up as the underlying policy design for these products does not vary by crop. For example, the "APH/YP/RP + PLC" portfolio reduces revenue variation by 1% at a cost of $10.66 for peanuts and a cost of $2.06 for soybeans. As is shown in figure 1, market prices for soybeans have never been below the relevant reference prices (statuary reference prices from 2014-2018 and effective reference prices from 2019 onward) to cause PLC payments to be triggered for soybeans. Consequently, all the reductions in revenue variability that are achieved by this portfolio come from the revenue transfers supplied by APH/YP/RP component, which on its own is one of the most cost-efficient portfolios for reducing revenue variability.

Another reason for differences in cost efficiency for the same plan across crops is that variation in loss ratios (i.e. premiums divided by indemnities) exist across crops meaning the indemnities paid relative to premiums collected vary. For example, a 1% reduction in revenue variability for rice achieved via the "APH/YP/RP only" portfolio costs the government $6.44 – the highest among all commodities analyzed. As has been discussed in previous literature, rice has consistently had one of the highest loss ratios, in part due to the prevalence of prevented planting indemnities paid to rice (Turner et al. 2025). This means that every indemnity payment made to rice producers, on average, is supported by relatively fewer collected premiums compared to indemnities paid to other crops. This phenomenon, however, negatively affects only financial efficiency from the point of view of the government. The same 1% reduction in revenue variability provided by "APH/YP/RP only" costs the producer approximately $1.46, which is comparable to the cost observed across most of the other commodities.

Conclusion

This paper investigates the potential performance of a hypothetical Price Loss Coverage (PLC) buy-up product as an enhancement to existing counter-cyclical commodity programs, specifically within the context of broader federal risk management portfolios. Motivated by ongoing concerns from commodity groups regarding the adequacy of current statutory reference prices, we evaluate the PLC-buy-up's contribution to both revenue enhancement and risk mitigation across a wide range of crops and portfolio configurations.

Our results show that the PLC-buy-up product meaningfully contributes to improved farm revenue outcomes, particularly when layered with individual-level Federal Crop Insurance Program (FCIP) plans and the Supplemental Coverage Option (SCO). The portfolio consisting of APH/YP/RP + SCO + PLC-buy-up achieved the largest reduction in revenue variability (24%) and one of the largest gains in mean revenue (20%) compared to the baseline scenario of no risk management participation. Notably, portfolios containing index-based products generally increased mean revenue, but often resulted in increased revenue variability, highlighting that these products are often poorly correlated with actual losses due to the basis risk associated with index-based indemnity triggers.

In terms of cost efficiency, on farm experience crop insurance plans (APH/YP/RP) were often included in risk management portfolios that reduced revenue variation at the lowest cost to the government. From the producer's perspective, portfolios containing counter-cyclical programs ARC and PLC (including PLC-buy-up) were the most cost-effective to achieve a given change to revenue. However, this is due to these programs having no premiums, or partial premiums (in the case of PLC-buy-up), which ultimately lead to the costs being borne by the government.

One class of program not considered in this analysis, which was a long-term staple of farm support prior to 2014, is direct payments that were uncorrelated with any market conditions. From a cost efficiency standpoint, it can be argued that direct payments may be preferrable given that administrative and delivery expenses are likely lower without having to handle enrolment, deal with farm yields, or perform any kind of loss adjustment or compliance checks. Although precise delivery costs of direct payment expenses are not available, looking at current estimated delivery costs (which are based on current administrative and operating expenses of existing area-based crop insurance plans) used in the analysis (table S3) provides some insights into the potential savings. PLC on average provided indemnities of $33.24 per acre with delivery costs of $10.64 per acre meaning there is an estimated 32% overhead for providing the supplemental revenue coming from the indemnity payments. PLC-buy-up has a slightly better overhead percentage at 26%. If direct payments have none of the overhead expense of PLC (which is unlikely to be the case) means that 20%-30% savings is a reasonable upper bound on potential savings that would occur from a direct payment program relative to PLC. However, the downside of direct payments is that revenue variation would likely increase without any mechanism to correlate payments with losses. Whether direct payments maximize utility largely depends on assumptions about producers' risk preferences and their appetite to accept variability in exchange for potentially higher mean revenue.

The performance of PLC-buy-up coverage (a hypothetical enhancement of the traditional PLC program) also offers insights into the broader implications of increasing the reference price for the traditional PLC program, a subject of interest for many commodity groups. The effectiveness of PLC-buy-up coverage in reducing revenue variability suggests that a similar increase in the PLC reference price could significantly enhance risk mitigation by reducing revenue variability, on average, by about 10%. Although analysis of the cost efficiency of PLC buy-up coverage suggests it is more expensive per unit of risk reduction compared to existing on farm yield and revenue protection insurance policies, it is marginally less expensive from the government's point of view due to collected premiums, and slightly more expensive in terms of total cost (producer borne cost + government cost). One concern associated with federal subsidized price protection insurance policies, that is beyond the scope of this paper but has recently garnered attention through the Livestock Risk Protection insurance plan, is subsidy harvesting. As noted by Baker, 2023 if there are exchanged traded put options for the commodity being insured by the subsidized insurance policy, simultaneous purchase of a put option and insurance policy can allow the producer to capture the difference in producer paid premiums between the two contracts. Overall, the results presented here suggest that higher PLC reference prices can achieve desired risk management goals, however, the ultimate success and adoption of an altered version of PLC will likely depend on how costs are shared between producers and the government.

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Table and Figures

Table 1: Cost Per Unit of Risk Reduction

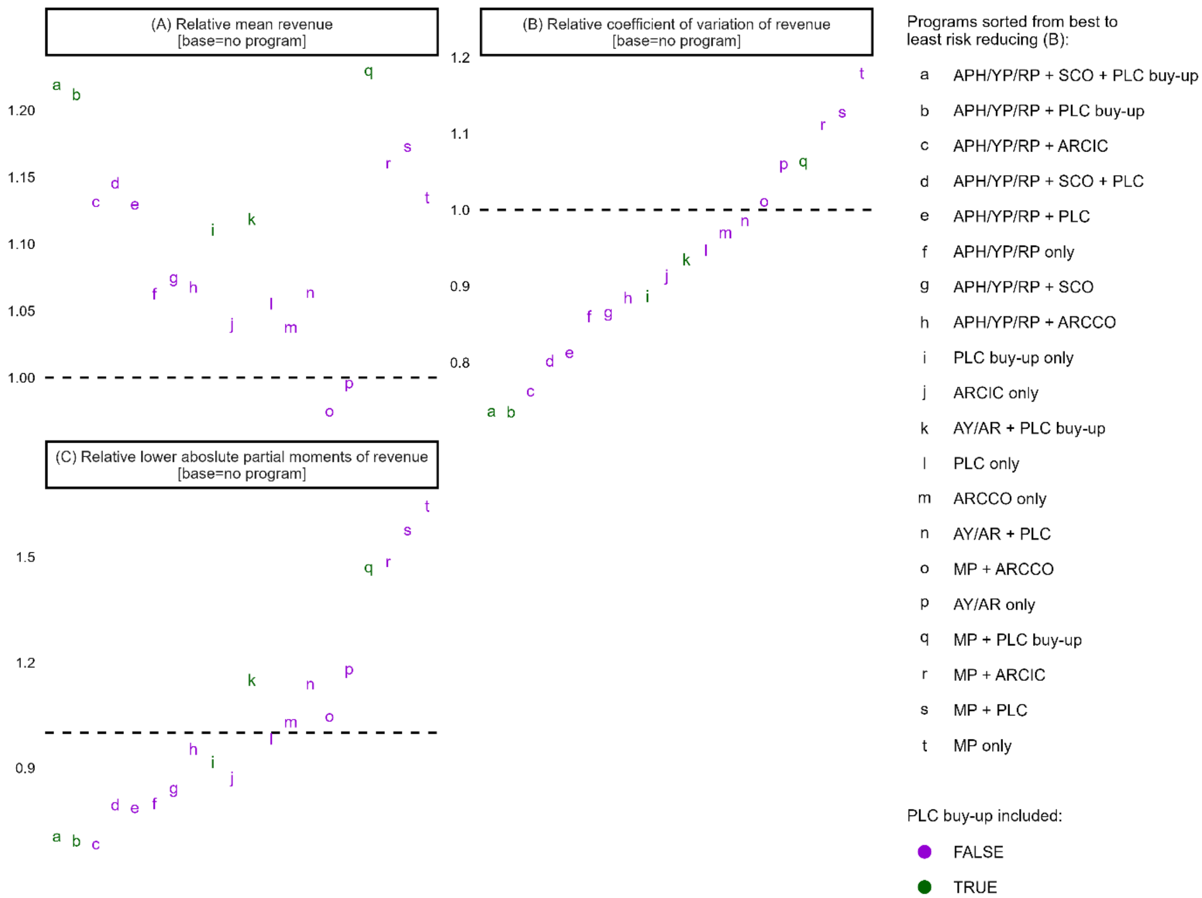
Safety Net Portfolio	Percent reduction in revenue variability [A]	Percent increase in mean revenue [B]	Government Cost of [A]	Government Cost of [B]	Producer Cost of [A]	Producer Cost of [B]
APH/YP/RP + SCO + PLC buy-up	-23.61	20.17	$5.31	$6.21	$1.67	$1.95
APH/YP/RP + PLC buy-up	-23.30	19.39	$5.18	$6.22	$1.45	$1.74
APH/YP/RP + SCO + PLC	-20.77	15.16	$4.49	$6.16	$1.26	$1.73
APH/YP/RP + ARCIC	-19.89	15.68	$4.78	$6.06	$0.90	$1.14
APH/YP/RP + ARCCO	-19.78	15.82	$4.36	$5.45	$0.98	$1.22
APH/YP/RP + PLC	-19.54	13.48	$4.14	$6.01	$0.97	$1.40
APH/YP/RP only	-14.27	6.54	$2.51	$5.48	$1.37	$3.00
APH/YP/RP + SCO	-13.81	7.38	$3.10	$5.81	$1.97	$3.69
PLC buy-up only	-10.27	11.42	$6.94	$6.24	$1.10	$0.99
PLC only	-6.46	6.96	$7.04	$6.53	$0.00	$0.00
ARCCO only	-3.74	4.89	$7.45	$5.69	$0.00	$0.00
AY/AR + PLC buy-up	-3.16	9.00	$21.24	$7.45	$12.65	$4.44
ARCIC only	-2.69	3.90	$9.18	$6.33	$0.00	$0.00
AY/AR + PLC	-0.77	5.30	$52.86	$7.63	$34.78	$5.02
AY/AR only	5.35	-0.90	$-0.46	$-2.70	$-5.19	$-30.72
MP + PLC buy-up	9.37	25.91	$-20.83	$7.53	$-4.39	$1.59
MP + ARCCO	14.81	17.57	$-8.50	$7.16	$-1.44	$1.21
MP + PLC	14.88	20.85	$-10.67	$7.61	$-1.73	$1.23
MP + ARCIC	16.75	21.47	$-8.61	$6.72	$-1.28	$1.00
MP only	17.90	13.46	$-5.47	$7.28	$-1.62	$2.15

Notes: Safety net portfolios that include on farm yield or revenue plans tend to produce the largest reductions in revenue variability and increases in mean revenue. However ARC and PLC based portfolios, from the perspective of the producer, are more financially efficient per unit of risk reduction due to these programs not charging premiums.

Figure 1: Effective reference prices, marketing year average prices, and Olympic average prices

Notes: Effective Reference Prices were introduced as part of the 2018 Farm bill, thus, ERP data points prior to 2018 are hypothetically calculated using established formulas for purposes of constructing a consistent policy environment to evaluate PLC-buy up coverage. MYA prices prior to 2014 are used only for constructing the 5-year OA of the MYA prices for 2014. “Short/medium grain rice” also includes temperate japonica varieties.

Figure 2: Risk Reduction and Revenue Transfer Potential of Safety Net Combination Strategies



Notes: Risk management portfolios with the two largest improvement in mean revenue relative to no insurance (panel A) and the largest reduction in revenue variation (panel B) both contained PLC-buy-up coverage as part of the risk management portfolio.

Appendix

Note S1: Details on setting premium rates for PLC-buy-up coverage

The core components that are required to set premium rates for the PLC-buy-up option are the traditional PLC effective reference price ($\tilde{p}_{j,t}$), the five-year Olympic average (OA) ($\bar{p}_{j,t}$) of the national MYA price ($p_{j,t}$), and the guaranteed price ($\ddot{p}_{j,g,t} = \tilde{p}_{j,t} \cdot (1+g)$) for a given coverage level (g) above $\tilde{p}_j$. Here, the subscripts j and t are for commodity and crop year, respectively. In what follows, we use these components (shown on Figure 1) to determine payment calculation factors (PCF) and premium rates associated with protection above traditional PLC.

For a given additional coverage level (g) beyond traditional PLC, we first calculate the PCF for the traditional PLC as $PCF_{j,t}^{0} = max\left\{0, \frac{\tilde{p}_{j,t} - \bar{p}_{j,t}}{\tilde{p}_{j,t}}\right\}$ and an initial PCF for PLC-buy-up as $PCF_{j,g,t}^{1} = max\left\{0, \frac{\ddot{p}_{j,g,t} - \bar{p}_{j,t}}{\ddot{p}_{j,g,t}}\right\}$. The final PCF for PLC-buy-up is then taken as the additional payment above the traditional PLC which we calculate as $PCF_{j,g,t} = PCF_{j,g,t}^{1} - PCF_{j,t}^{0}$. We use historic values of $PCF_{j,g,t}$ to estimate base premium rates for a given coverage level (g) above traditional PLC by following a rating process adapted from related works (Tsiboe and Turner 2023a; Tsiboe et al. 2023) which is partly based on PRF-RI (Coble et al. 2020). First, we define the stochastic historic payment calculation factors for each commodity and coverage combination as $\{PCF_{j,g,t-s}\}_{s=2}^{21}$, and use its mean as the estimate of an empirical burn rate ($\bar{\tau}_{j,g,t}^{BR}$). Finally, a disaster reserve factor is incorporated into rates by dividing the empirical burn rate by 0.88; $\bar{\tau}_{j,g,t}^{RR} = \bar{\tau}_{j,g,t}^{BR}/0.88$. The study utilizes the $PCF_{j,g,t}$, and the base premium rate $\tau_{j,g,t}$ (taken as the loaded raw rate, $\bar{\tau}_{j,g,t}^{RR}$) as the actuarial parameters for PLC-buy-up coverage which we use in the simulation that follows.

The liability, premiums, subsidy, and indemnities for the FCIP policies are calculated as outlined in the FCIP Appendix III/M-13 Handbooks, and the payment factors for the PLC and ARC are the same as those established by FSA. For the case of a PLC-buy-up product, we merged established procedures for index-based insurance plans in the FCIP and those for the traditional PLC. Particularly for a given agent (i), we perform the following liability ($L_{i,j,g,t}$), total premium ($P_{i,j,g,t}$), subsidy ($S_{i,j,g,t}$), and indemnity ($I_{i,j,g,t}$) calculations:

$$L_{i,j,g,t} = \bar{y}_{i,j,t} \cdot \tilde{p}_j \cdot (1+g) \cdot 0.85 \tag{3}$$

$$P_{i,j,g,t} = \tau_{j,g,t} \cdot L_{i,j,g,t} \tag{4}$$

$$S_{i,j,g,t} = P_{i,j,g,t} \cdot 0.65 \tag{5}$$

$$I_{i,j,g,t} = L_{i,j,g,t-1} \cdot \left(PCF_{j,t-1}^{0} + PCF_{j,g,t-1}\right) \tag{6}$$

Here 0.85 is applied to the implied liability to account for the fact that current counter cyclical programs (PLC and ARC-CO) are paid on only 85% of base acres. We also apply a flat subsidy rate of 65% to PLC-buy-up premiums to mimic current subsidy rates available for SCO under the FCIP. Final estimated premium rates per dollar of insured liability for PLC-buy-up coverage is reported in Figure S4 for each crop and coverage level.

Since PLC-buy-up is designed to mimic the underlying PLC program, which is counter cyclical in nature, PLC-buy-up payments are made when representative final prices are established which happens about a year after the crop year has ended. Additionally, we assume the delivery of the PLC-buy-up will follow current FCIP procedure, thus, after indemnities are processed, an indemnity check, and a summary of indemnity payment will be issued showing any deductions to the amount of indemnity for outstanding premiums, interest, or administrative fees. Considering these temporal dynamics, PLC-buy-up indemnities are paid one year after the crop year ends. The revenue ($\pi^a_{i,j,t}$) associated with a given portfolio of risk management programs (a) for each agent (i) and commodity (j) , in crop year, (t), is calculated as $\pi^a_{i,j,t} = y_{i,j,t} \cdot p_{j,t} + I^a_{i,j,t} + \tilde{P}^a_{i,j,t}$ where $\tilde{P}^a_{i,j,t}$ is the out of pocket premium cost to producers[20], defined as $\tilde{P}^a_{i,j,t} = P^a_{i,j,t} - S^a_{i,j,t}$. Based on availability, this revenue is separately calculated for each of the 20 specific alternative risk management portfolios shown in Table 1.

[20] Although most FCIP premiums are subsidized, the subsidies are not passed directly to the producer, instead the producer observes a single out of pocket premium rate which implicitly reflects the current subsidy rate.

Note S2: The Relationship between Yields, Premium Rates, and Indemnity Payments

The summary provided here draws heavily from detailed descriptions contained in (Tsiboe, Turner and Yu 2025). The objective here is to provide a condensed summary of the relevant information from underlying stud, at a level of detail that will allow the reader to understand the calibration process. Given that objective, the structure, and wording of this note closely follows that of relevant section of the underlying document. To improve the readability of this chapter we do not repeatedly cite the document in the conventional manner. Therefore, this note is not represented as original work that does not draw heavily from another source.

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

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

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

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

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

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

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

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

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

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

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

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

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

In the optimization process, we explore all n_{t-1} and n_t combinations within their defined limits. n_{t-1} varies from 2 to 10, and n_t, always greater or equal to n_{t-1}, ranges from n_{t-1}'s current value to 10. For each insurance pool and n_{t-1}, n_t pair, we set Δy_{t-1}'s bounds based on the pool's approved yield ($\ddot{y}_t$) and chosen coverage level (θ_t), from a minimum of 0 to a maximum of $2\ddot{y}_{t-1}$

minus the guaranteed yield ($\theta_{t-1}\dddot{y}_{t-1}$). We then determine the Δy_{t-1} within this range that minimizes our optimization function (Equation [S4]) for the given n_{t-1}, n_t, and other parameters, recording the minimal function value and corresponding n_{t-1}, n_t, and Δy_{t-1}. We repeat this for all feasible n_{t-1}, n_t, and Δy_{t-1} combinations, retaining the set with the lowest function value as the optimal solution for each pool. The intuition behind this methodology is that by varying n_t and n_{t-1}, we can solve for the remaining variable, the marginal yield Δy_{t-1}. The optimal solution is the n_t, n_{t-1}, and Δy_{t-1} trio that yields a premium rate, via the CRF, closest to the premium per liability dollar observed. This strategy relies on the fact that year to year APH values tend to be very stable over time meaning the derived yields are not very sensitive to the choice of n_t, and n_{t-1}.

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

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

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

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

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

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

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

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

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

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

Table S1: Descriptive Statistics for Calibrated Yields

Crop	**Unit**	**Mean Yield**	**Standard Deviation**
Barley	bu	66	43
Canola	bu	1,324	516
Corn	bu	135	69
Cotton	lb	1,158	614
Sorghum	bu	63	36
Oats	bu	59	28
Peanuts	lb	3,643	1,425
Rice	lb	5,488	2,626
Safflower	bu	684	436
Soybeans	bu	43	21
Sunflowers	lb	1,128	592
Wheat	bu	48	30

Table S2: Most popular insurance plan and coverage level election based on total net insured acreage from 2014-2023

	Popular insurance plan			**Popular coverage level**			
	On-farm experience FCIP plans category	**Group experience FCIP plans category**	**Margin FCIP plans category**	**On-farm experience FCIP plans category**	**Group experience FCIP plans category**	**Margin FCIP plans category**	**PLC buy-up**
Oats	Yield Protection	-	-	70%	-	-	50%
Sunflowers	Revenue Protection	-	-	75%	-	-	50%
Wheat	Revenue Protection	Area Revenue Protection	Margin Protection with Harvest Price Option	70%	90%	95%	50%
Sorghum	Revenue Protection	Area Revenue Protection	-	70%	90%	-	50%
Soybeans	Revenue Protection	Area Revenue Protection	Margin Protection with Harvest Price Option	75%	90%	95%	50%
Canola	Revenue Protection	-	-	75%	-	-	50%
Barley	Revenue Protection	-	-	75%	-	-	50%
Cotton	Revenue Protection	Area Revenue Protection	-	70%	70%	-	50%
Corn	Revenue Protection	Area Revenue Protection	Margin Protection with Harvest Price Option	75%	90%	95%	50%
Peanuts	Yield Protection	-	-	70%	-	-	50%
Safflower	Yield Protection	-	-	CAT	-	-	50%
Rice	Revenue Protection	Area Yield Protection	Margin Protection with Harvest Price Option	75%	90%	95%	50%

Notes: For most crops, yield and revenue protection policies at the 70% or 75% coverage level, area revenue protection at the 70% or 75% coverage level, and margin protection with harvest price option at the 95% coverage level are the most participated in policies within their respective classes.

Table S3: Individual Cost Components

Safety Net Portfolio	Total Premium ($/acre) [A]	Premium Subsidy ($/acre) [B]	Indemnities ($/acre) [C]	Delivery Cost ($/acre) [D]	Underwriting Gains ($/acre) [E]	Underwriting Losses ($/acre) [F]	Total Government Cost ($/acre) [B+C+D+E-F-A]
APH/YP/RP + SCO + PLC buy-	$170.68	$131.36	$123.71	$31.13	$9.82	$0.03	$125.32
APH/YP/RP + PLC buy-up	$155.93	$122.14	$117.72	$27.49	$9.23	$0.03	$120.63
APH/YP/RP + SCO + PLC	$133.08	$106.93	$89.58	$24.70	$5.21	$0.02	$93.30
APH/YP/RP + ARCIC	$120.70	$102.87	$87.85	$21.22	$3.76	$0.01	$94.99
APH/YP/RP + ARCCO	$122.35	$102.99	$79.55	$21.60	$4.45	$0.01	$86.23
APH/YP/RP + PLC	$109.12	$90.20	$76.48	$19.44	$4.00	$0.02	$80.98
APH/YP/RP only	$47.94	$28.35	$45.09	$9.09	$1.24	$0.01	$35.81
APH/YP/RP + SCO	$68.55	$41.35	$54.22	$13.78	$2.08	$0.02	$42.86
PLC buy-up only	$95.28	$83.99	$62.64	$16.21	$3.72	$0.02	$71.26
PLC only	$62.66	$62.66	$33.24	$10.64	$1.58	$0.01	$45.45
ARCCO only	$57.44	$57.44	$16.88	$9.85	$1.12	$0.00	$27.85
AY/AR + PLC buy-up	$152.86	$112.91	$78.49	$23.53	$5.01	$0.01	$67.08
ARCIC only	$56.78	$56.78	$14.22	$9.74	$0.73	$0.00	$24.69
AY/AR + PLC	$114.77	$88.15	$46.80	$17.04	$3.24	$0.00	$40.45
AY/AR only	$50.88	$23.10	$23.11	$6.11	$1.01	$0.01	$2.44
MP + PLC buy-up	$166.89	$125.78	$199.79	$30.22	$6.26	$0.02	$195.14
MP + ARCCO	$115.91	$94.56	$123.96	$21.18	$2.09	$0.01	$125.86
MP + PLC	$123.00	$97.25	$159.87	$22.59	$2.04	$0.01	$158.73
MP + ARCIC	$111.36	$89.93	$142.92	$20.40	$2.28	$0.01	$144.17
MP only	$51.73	$22.76	$115.66	$10.40	$0.92	$0.01	$98.01

Table S4: Government cost per 1% reduction in revenue variability by crop (producer cost in parenthesis)

Safety Net Portfolio	All	Barley	Canola	Corn	Cotton	Sorghum	Oats	Peanut	Rice	Safflower	Soybeans	Sunflowers	Wheat
APH/YP/RP + SCO + PLC	$5.31 ($1.67)	$3.63 ($1.59)	$3.51 ($1.25)	$5.26 ($2.66)	$4.94 ($1.8)	$3.34 ($1.35)	$2.54 ($1.06)	$13.92 ($2.67)	$10.55 ($2.02)		$3.28 ($1.81)	$2.55 ($1.34)	$2.64 ($0.91)
APH/YP/RP + PLC buy-up	$5.18 ($1.45)	$3.6 ($1.54)	$3.38 ($1.12)	$5.11 ($2.18)	$4.36 ($1.32)	$2.92 ($1.04)	$2.47 ($1.2)	$13.71 ($2.42)	$10.4 ($1.78)		$3.19 ($1.52)	$2.59 ($1.27)	$2.49 ($0.74)
APH/YP/RP + SCO + PLC	$4.49 ($1.26)	$2.66 ($1.23)	$3.01 ($1.04)	$3.93 ($2.27)	$4.84 ($1.63)	$3 ($1.21)	$1.91 ($0.69)	$10.94 ($1.25)	$9 ($1.28)		$2.28 ($1.55)	$2.12 ($1.27)	$2.03 ($0.66)
APH/YP/RP + ARCIC	$4.78 ($0.9)			$5.58 ($1.23)	$6.37 ($1.15)	$2.05 ($0.66)			$8.41 ($1.15)		$2.91 ($0.69)		$2.17 ($0.46)
APH/YP/RP + ARCCO	$4.36 ($0.98)			$3.83 ($1.45)	$6.11 ($1.19)	$1.66 ($0.7)			$8.33 ($1.17)		$2.28 ($0.82)		$1.86 ($0.53)
APH/YP/RP + PLC	$4.14 ($0.97)	$2.56 ($1.14)	$2.76 ($0.87)	$3.64 ($1.7)	$4.24 ($1.13)	$2.44 ($0.84)	$1.68 ($0.75)	$10.66 ($1.01)	$8.85 ($1.04)	$0.84 ($0)	$2.06 ($1.13)	$2.1 ($1.15)	$1.87 ($0.49)
APH/YP/RP only	$2.51 ($1.37)	$2.85 ($1.93)	$1.86 ($1.99)	$3.37 ($1.96)	$3 ($1.34)	$1.2 ($1.1)	$1.14 ($1.16)	$2.06 ($4.21)	$6.44 ($1.46)	$0.59 ($0)	$1.56 ($1.13)	$1.13 ($1.1)	$1.21 ($0.84)
APH/YP/RP + SCO	$3.1 ($1.97)	$2.55 ($2.01)	$2.85 ($2.7)	$3.54 ($2.78)	$3.71 ($1.91)	$2.04 ($1.84)	$1.44 ($0.88)	$2.39 ($5.43)	$6.83 ($1.85)		$1.77 ($1.59)	$1.65 ($2)	$1.47 ($1.16)
PLC buy-up only	$6.94 ($1.1)	$5.6 ($1.32)	$4.2 ($0.45)	$8.62 ($2)	$3.58 ($0.38)	$5.72 ($0.68)	$4.08 ($1.24)	$14.71 ($1.62)	$11.69 ($1.74)	$1.89 ($0.83)	$5.59 ($1.97)	$3.97 ($0.78)	$3.53 ($0.56)
PLC only	$7.04 ($0)	$6.81 ($0)	$3.45 ($0)	$12.36 ($0)	$3.47 ($0)	$6.08 ($0)	$7.32 ($0)	$12.26 ($0)	$10.16 ($0)	$3.92 ($0)	Undefined (Undefined)	$4.96 ($0)	$2.98 ($0)
ARCCO only	$7.45 ($0)	$7.17 ($0)	$4.84 ($0)	$9.58 ($0)	$9.71 ($0)	$3.96 ($0)	$1.89 ($0)	$13.47 ($0)	$11.93 ($0)	$10.36 ($0)	$15.82 ($0)	$4.06 ($0)	$3.61 ($0)
AY/AR + PLC buy-up	$21.24 ($12.65)			-$28.31 (-$60.86)	$3.5 ($1.29)	-$5.4 (-$3.2)			$12.32 ($2)		-$8.44 (-$30.8)		$8.04 ($5.14)
ARCIC only	$9.18 ($0)	$6.33 ($0)	$8.57 ($0)	$7.98 ($0)	$52.21 ($0)	$4.7 ($0)	$2.79 ($0)	-$31.39 ($0)	$19 ($0)	$1 ($0)	$7.7 ($0)	$3.26 ($0)	$4.94 ($0)
AY/AR + PLC	$52.86 ($34.78)			-$0.25 (-$12.31)	$3.21 ($0.91)	-$4.09 (-$2.47)			$10.17 ($0.14)		-$2.09 (-$6.33)		$9.34 ($6.92)
AY/AR only	-$0.46 (-$5.19)			-$2.58 (-$8.8)	$1.68 ($1.24)	-$1.21 (-$1.62)			$9.97 ($4.96)		-$3.44 (-$6.56)		-$0.79 (-$3.67)
MP + PLC buy-up	-$20.83 (-$4.39)			-$11.19 (-$1.91)					$17.7 ($3.54)		-$12.23 (-$2.88)		-$6.44 (-$2.2)
MP + ARCCO	-$8.5 (-$1.44)			-$7.27 (-$1.02)					$18.66 ($2.65)		-$6.3 (-$1.1)		-$2.8 (-$0.95)
MP + PLC	-$10.67 (-$1.73)			-$7.73 (-$1.07)					$16.39 ($2.01)		-$6.4 (-$1.19)		-$3.37 (-$1.13)
MP + ARCIC	-$8.61 (-$1.28)			-$9.05 (-$0.96)					$26.27 ($4.14)		-$7.95 (-$1.2)		-$2.2 (-$0.72)
MP only	-$5.47 (-$1.62)			-$6.44 (-$1.34)					$37.18 ($13.45)		-$5.06 (-$1.39)		-$1.31 (-$0.99)

Notes: costs efficiency metrics are undefined for “PLC only” for the case of soybeans since market prices have never declined to a sufficient level to trigger PLC payments. Results for rice include the averaged effects for short/medium and long grain rice.

Table S5: Government cost per 1% increase in mean revenue by crop (producer cost in parenthesis)

Safety Net Portfolio	All	Barley	Canola	Corn	Cotton	Sorghum	Oats	Peanut	Rice	Safflower	Soybeans	Sunflowers	Wheat
APH/YP/RP + SCO + PLC buy-up	$6.21 ($1.95)	$4.83 ($2.11)	$3.9 ($1.39)	$9.23 ($4.66)	$5.58 ($2.03)	$3.69 ($1.49)	$2.34 ($0.97)	$12.68 ($2.43)	$8.9 ($1.71)		$6.49 ($3.59)	$4.22 ($2.22)	$3.4 ($1.17)
APH/YP/RP + PLC buy-up	$6.22 ($1.74)	$5.12 ($2.19)	$3.72 ($1.23)	$8.85 ($3.79)	$5.25 ($1.59)	$3.6 ($1.28)	$2.64 ($1.28)	$12.39 ($2.19)	$8.75 ($1.5)		$6.29 ($2.98)	$4.1 ($2.02)	$3.32 ($0.99)
APH/YP/RP + SCO + PLC	$6.16 ($1.73)	$5.63 ($2.6)	$3.77 ($1.31)	$9.71 ($5.59)	$5.4 ($1.82)	$3.66 ($1.48)	$2.47 ($0.9)	$12.07 ($1.38)	$8.46 ($1.2)		$6.97 ($4.74)	$4.36 ($2.62)	$3.16 ($1.03)
APH/YP/RP + ARCIC	$6.06 ($1.14)			$7.59 ($1.67)	$6.64 ($1.2)	$3.24 ($1.05)			$7.97 ($1.09)		$5.32 ($1.25)		$3.14 ($0.67)
APH/YP/RP + ARCCO	$5.45 ($1.22)			$8.06 ($3.06)	$4.29 ($0.84)	$2.98 ($1.26)			$7.68 ($1.08)		$4.85 ($1.75)		$3.2 ($0.91)
APH/YP/RP + PLC	$6.01 ($1.4)	$6.21 ($2.76)	$3.53 ($1.12)	$8.68 ($4.05)	$5.06 ($1.34)	$3.51 ($1.21)	$3.06 ($1.37)	$11.53 ($1.1)	$8.24 ($0.97)	$1.72 ($0)	$6.48 ($3.57)	$4.46 ($2.44)	$3.04 ($0.79)
APH/YP/RP only	$5.48 ($3)	$6.32 ($4.27)	$4.29 ($4.59)	$8.12 ($4.71)	$5.36 ($2.38)	$3.64 ($3.33)	$6.12 ($6.26)	-$220.57 (-$451.24)	$8 ($1.82)	$1.91 ($0)	$4.99 ($3.62)	$2.35 ($2.3)	$2.91 ($2.01)
APH/YP/RP + SCO	$5.81 ($3.69)	$6.09 ($4.81)	$5.14 ($4.88)	$9.74 ($7.64)	$5.65 ($2.91)	$4.53 ($4.09)	$1.69 ($1.04)	-$53.26 (-$120.85)	$8.07 ($2.19)		$5.5 ($4.94)	$4.29 ($5.18)	$3.08 ($2.44)
PLC buy-up only	$6.24 ($0.99)	$5.07 ($1.2)	$3.68 ($0.39)	$9.21 ($2.14)	$5.84 ($0.62)	$3.51 ($0.42)	$3.22 ($0.97)	$11.49 ($1.26)	$9.8 ($1.46)	$2.26 ($0.99)	$7.03 ($2.48)	$3.82 ($0.75)	$3.42 ($0.54)
PLC only	$6.53 ($0)	$7.53 ($0)	$3.41 ($0)	$12.26 ($0)	$5.48 ($0)	$3.34 ($0)	$6.91 ($0)	$10.59 ($0)	$9.5 ($0)	$2.17 ($0)	Undefined (Undefined)	$4.35 ($0)	$3.16 ($0)
ARCCO only	$5.69 ($0)	$5.8 ($0)	$3.97 ($0)	$9.03 ($0)	$5.68 ($0)	$3.19 ($0)	$1.63 ($0)	$12.02 ($0)	$9.68 ($0)	$1.58 ($0)	$7.78 ($0)	$4.27 ($0)	$3.52 ($0)
AY/AR + PLC buy-up	$7.45 ($4.44)			-$45.16 (-$97.08)	$4.54 ($1.68)	$5.5 ($3.26)			$10.02 ($1.62)		-$6.2 (-$22.62)		$3.38 ($2.16)
ARCIC only	$6.33 ($0)	$5.1 ($0)	$5.74 ($0)	$8.05 ($0)	$9.31 ($0)	$3.54 ($0)	$1.46 ($0)	$20 ($0)	$11.66 ($0)	$1.19 ($0)	$6.2 ($0)	$3.27 ($0)	$4.73 ($0)
AY/AR + PLC	$7.63 ($5.02)			-$0.25 (-$12.27)	$4.18 ($1.19)	$5.95 ($3.59)			$9.53 ($0.13)		-$1.94 (-$5.88)		$3.33 ($2.47)
AY/AR only	-$2.7 (-$30.72)			-$3.26 (-$11.1)	$3.29 ($2.42)	-$76.66 (-$103.12)			$7.19 ($3.58)		-$3.3 (-$6.28)		$6.08 ($28.32)
MP + PLC buy-up	$7.53 ($1.59)			$8.87 ($1.51)					$9.11 ($1.82)		$6.56 ($1.55)		$4.19 ($1.43)
MP + ARCCO	$7.16 ($1.21)			$8.52 ($1.19)					$8.33 ($1.18)		$5.88 ($1.03)		$4.67 ($1.58)
MP + PLC	$7.61 ($1.23)			$8.82 ($1.22)					$8.75 ($1.08)		$6.59 ($1.22)		$4.58 ($1.53)
MP + ARCIC	$6.72 ($1)			$7.73 ($0.82)					$8.46 ($1.33)		$5.69 ($0.86)		$3.94 ($1.29)
MP only	$7.28 ($2.15)			$8.15 ($1.7)					$7.37 ($2.66)		$5.26 ($1.44)		$10.95 ($8.32)

Notes: costs efficiency metrics are undefined for “PLC only” for the case of soybeans since market prices have never declined to a sufficient level to trigger PLC payments

Figure S1: Total premium rates for PLC-buy-up coverage.

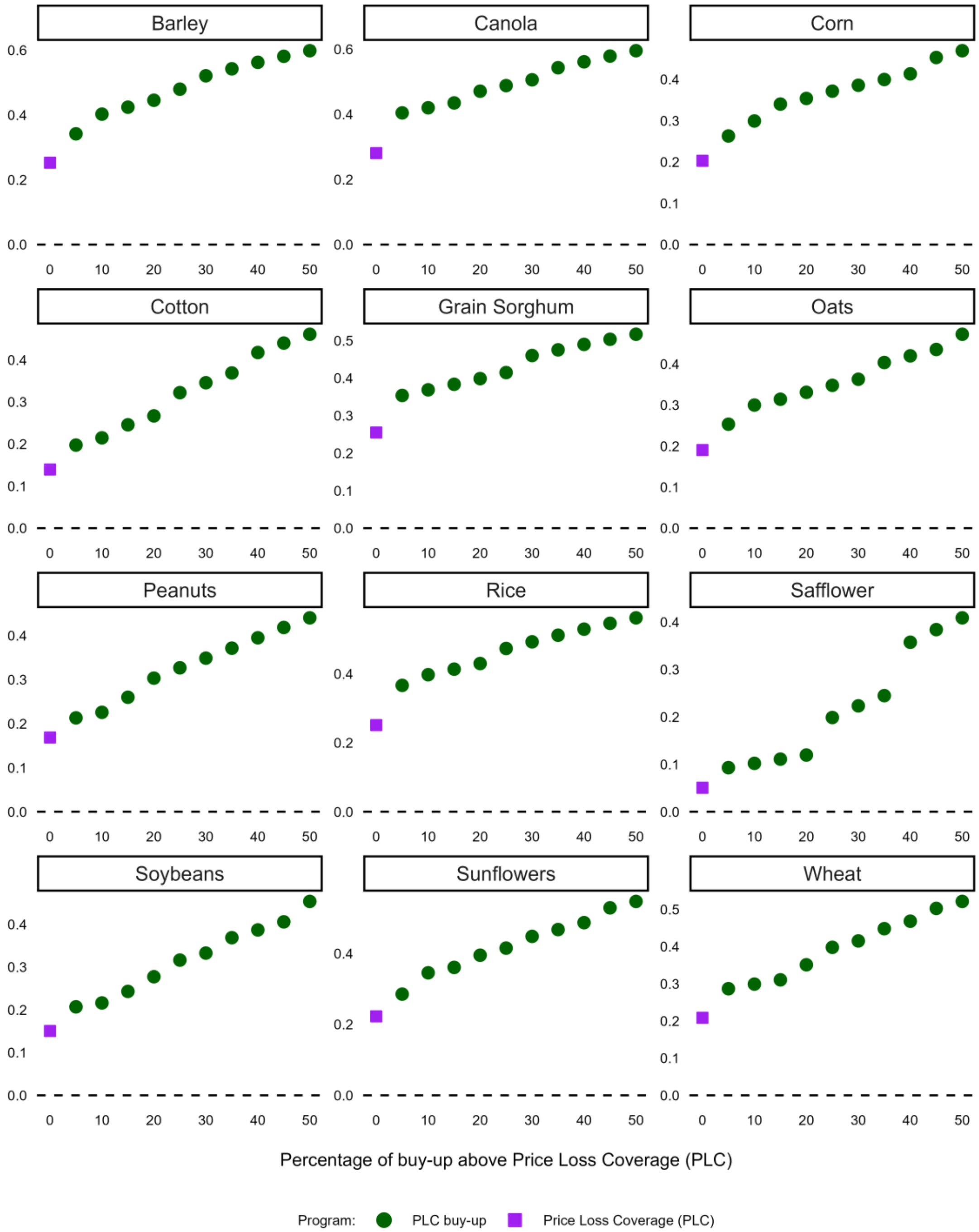


Figure S2: Paid premium rates for PLC-buy-up coverage.

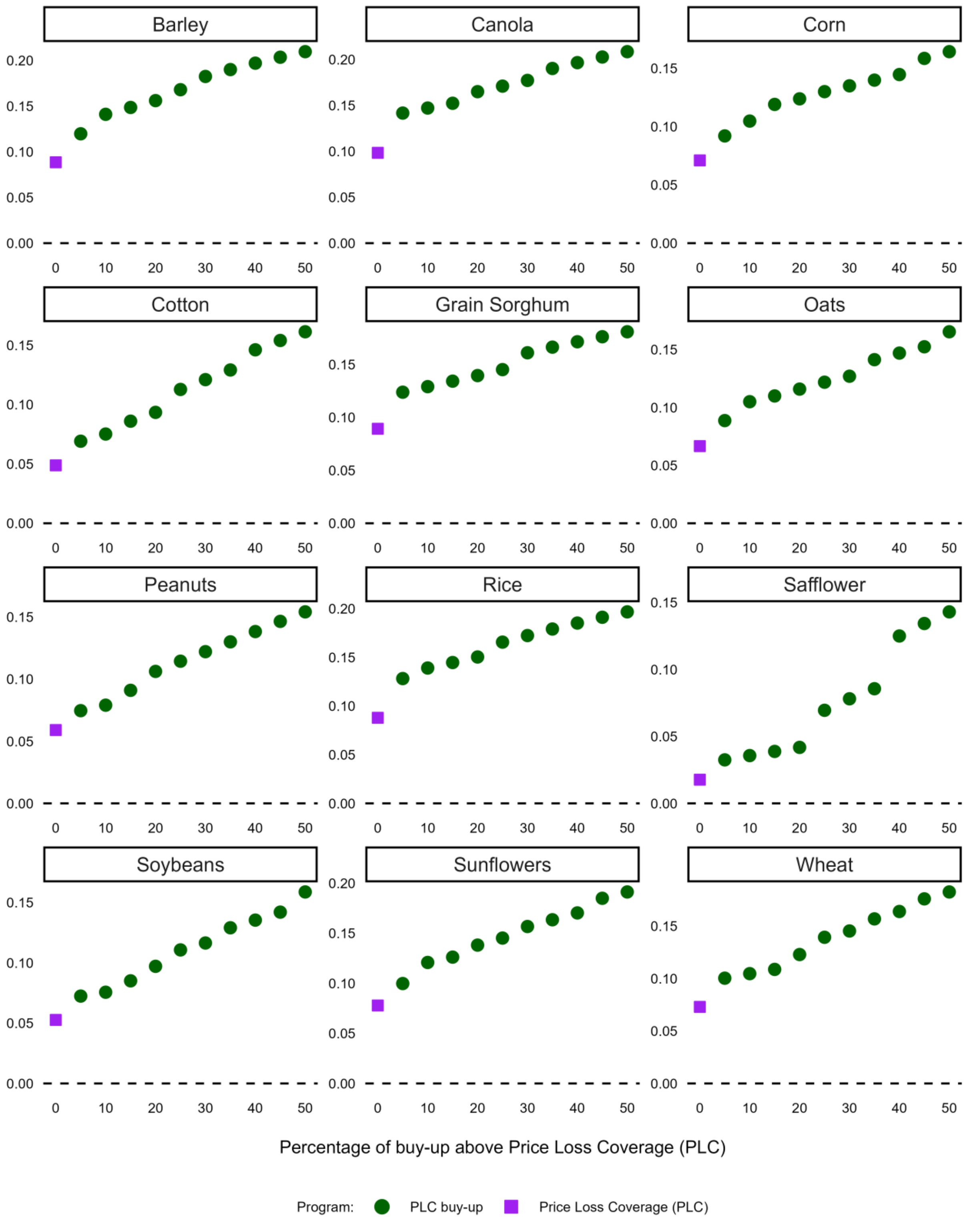
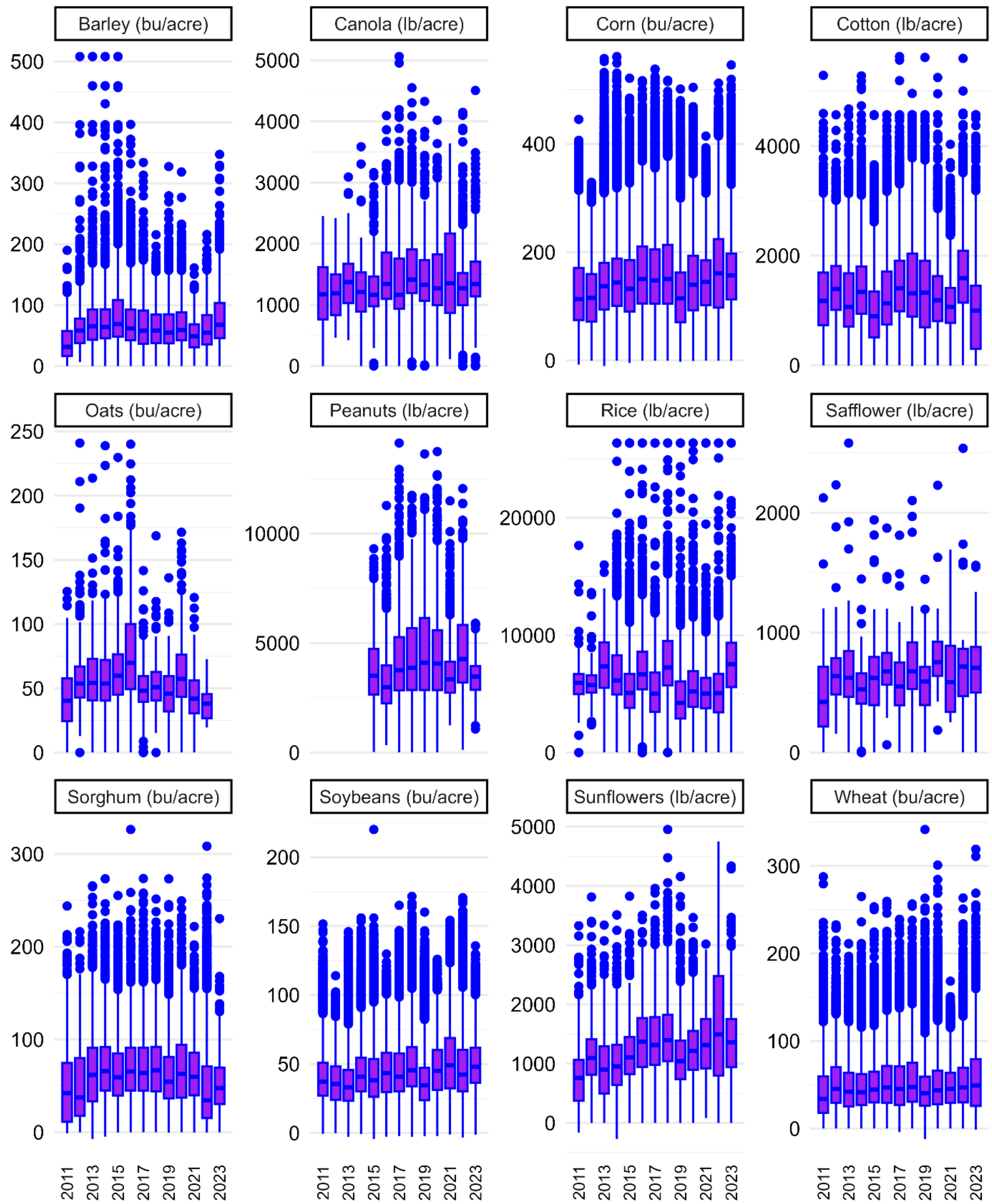
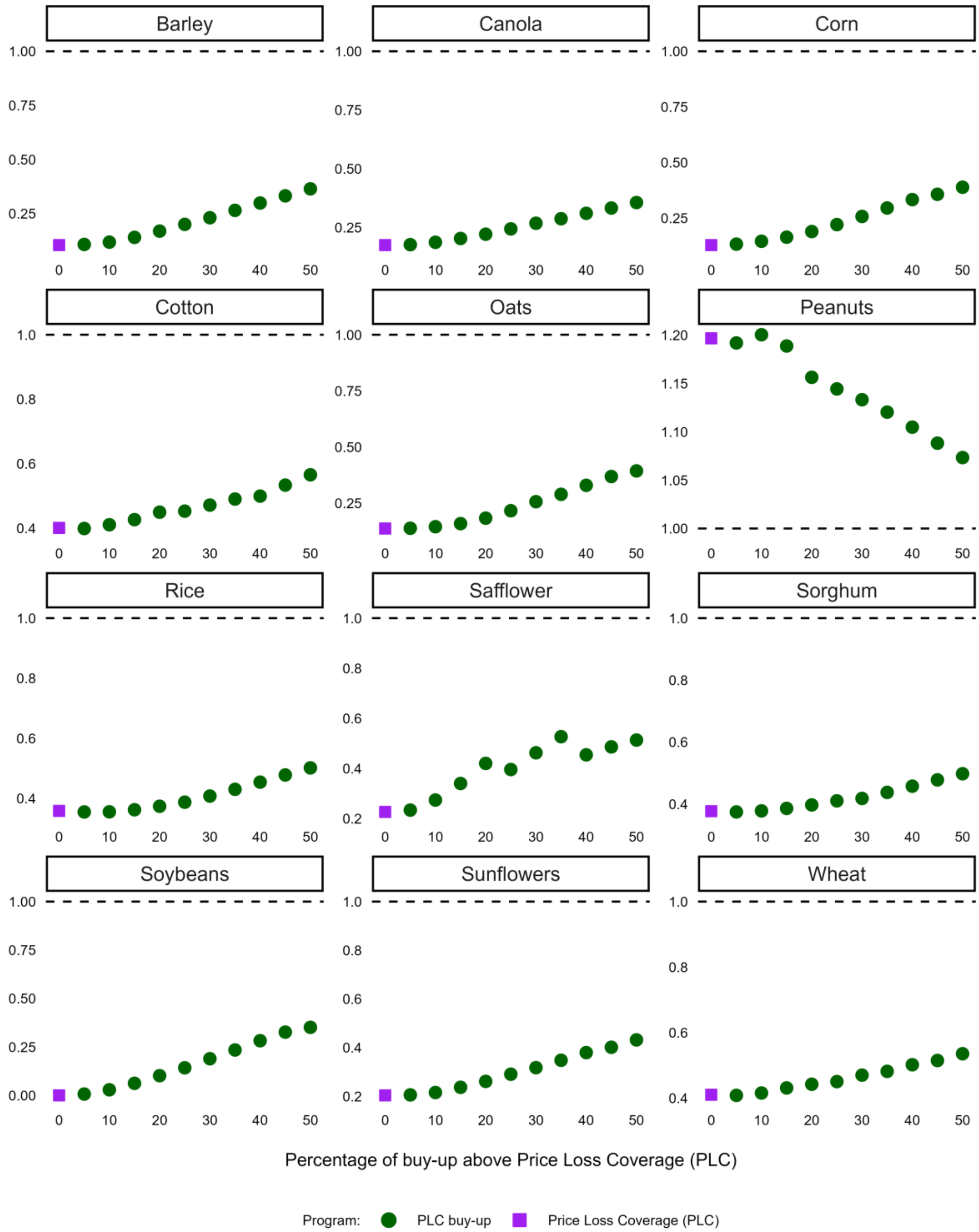


Figure S3: Boxplots of calibrated insurance pool-level yields (2011-2023)



Notes: Formulated by the authors using insurance pool-level data provided by United States Department of Agriculture, Risk Management Agency.

Figure S4: Simulated loss ratios for PLC-buy-up coverage



Notes: Loss ratios for the 0% coverage level are based on if base PLC coverage charged the premium rate set using the methods described in section 4.

Figure S5: Relative mean revenue [base = no risk management plan]

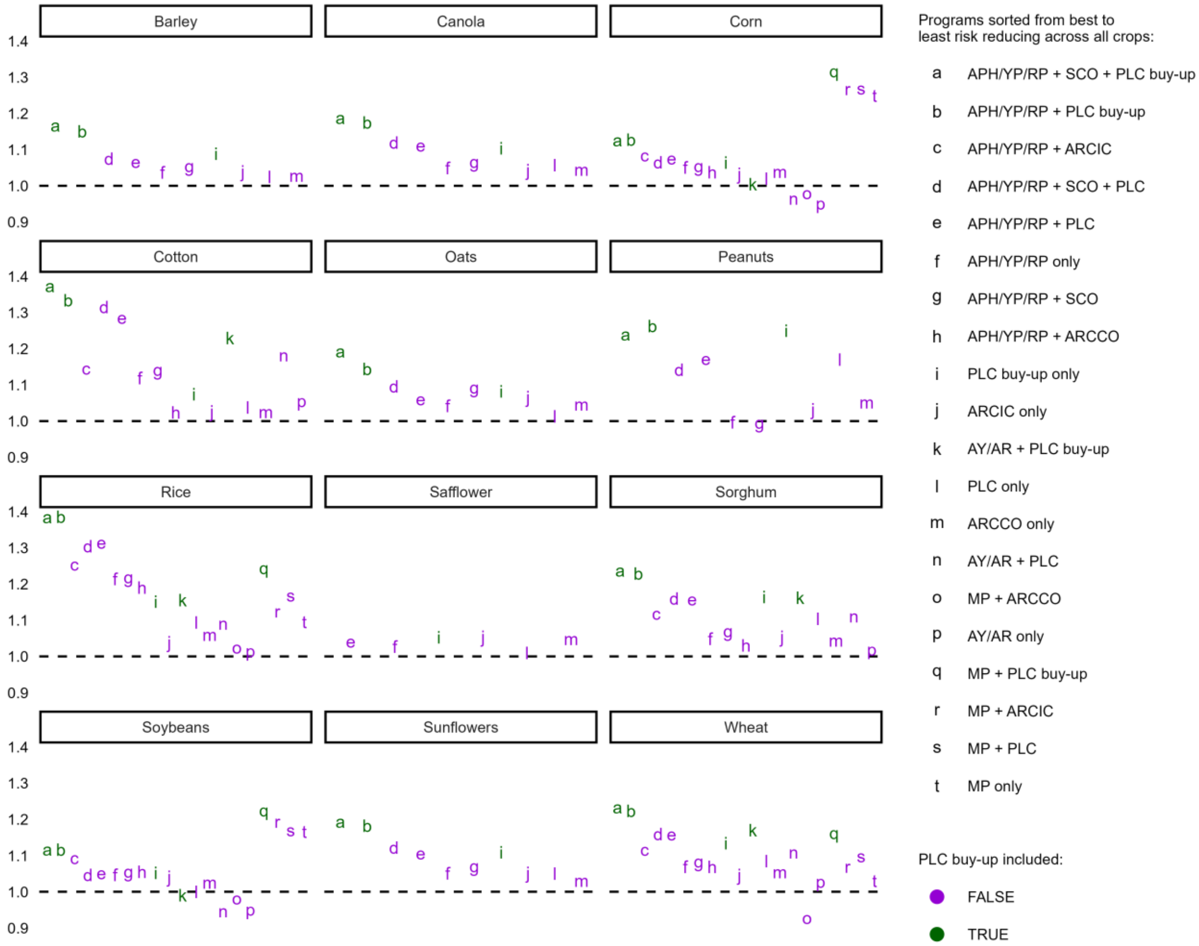


Figure S6: Relative coefficient of variation in revenue [base = no risk management plan]

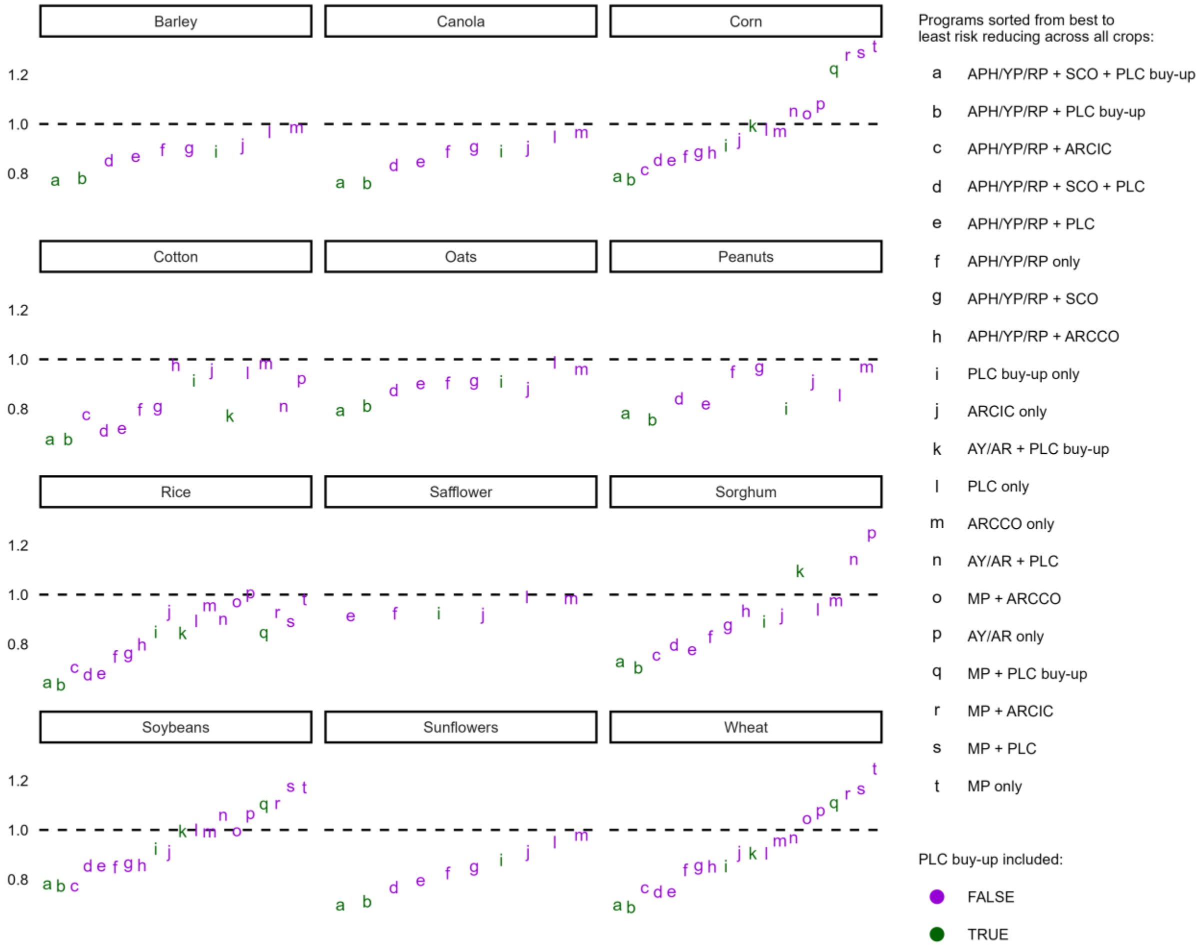


Figure S7: Relative LAPM of revenue [base = no risk management plan]

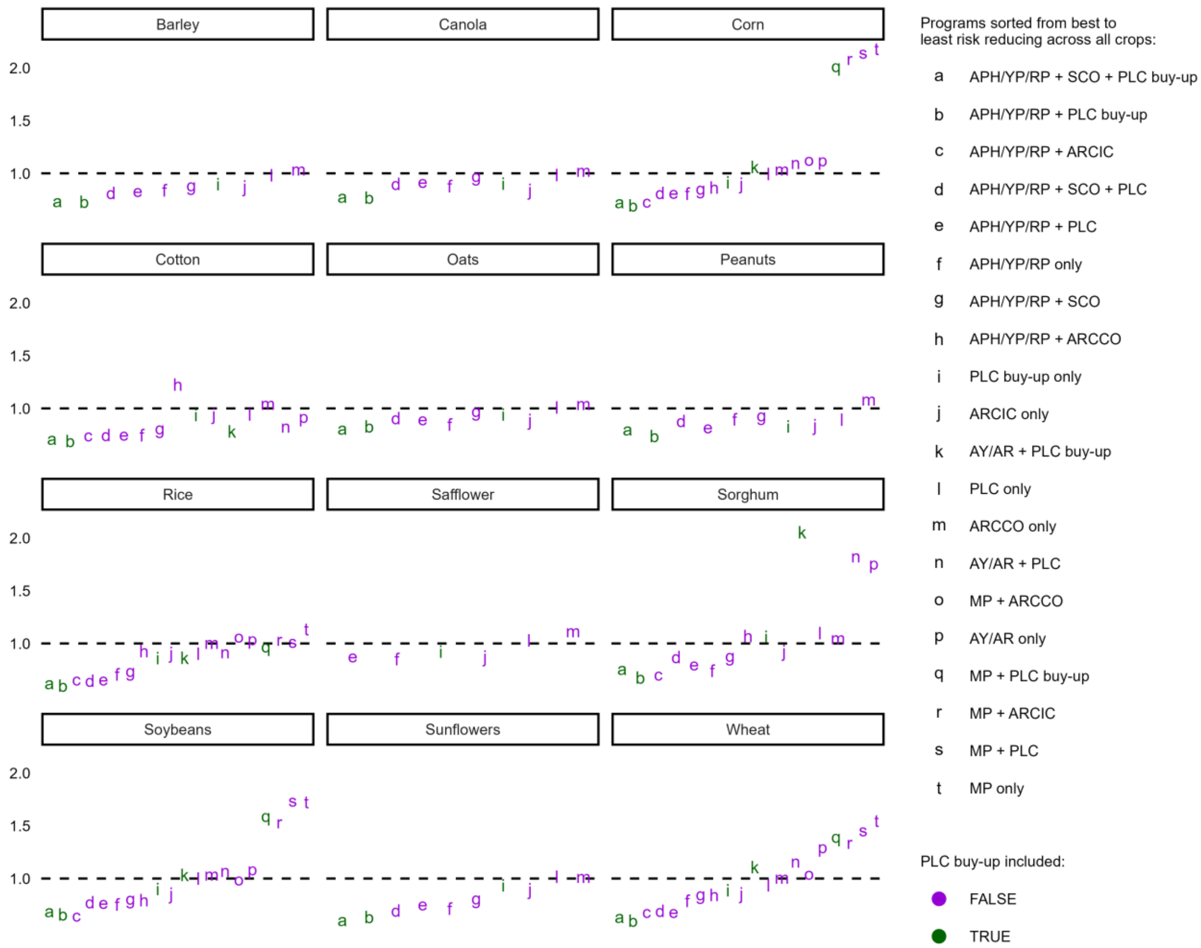


Figure S8: Relative mean revenue [base = no risk management plan]

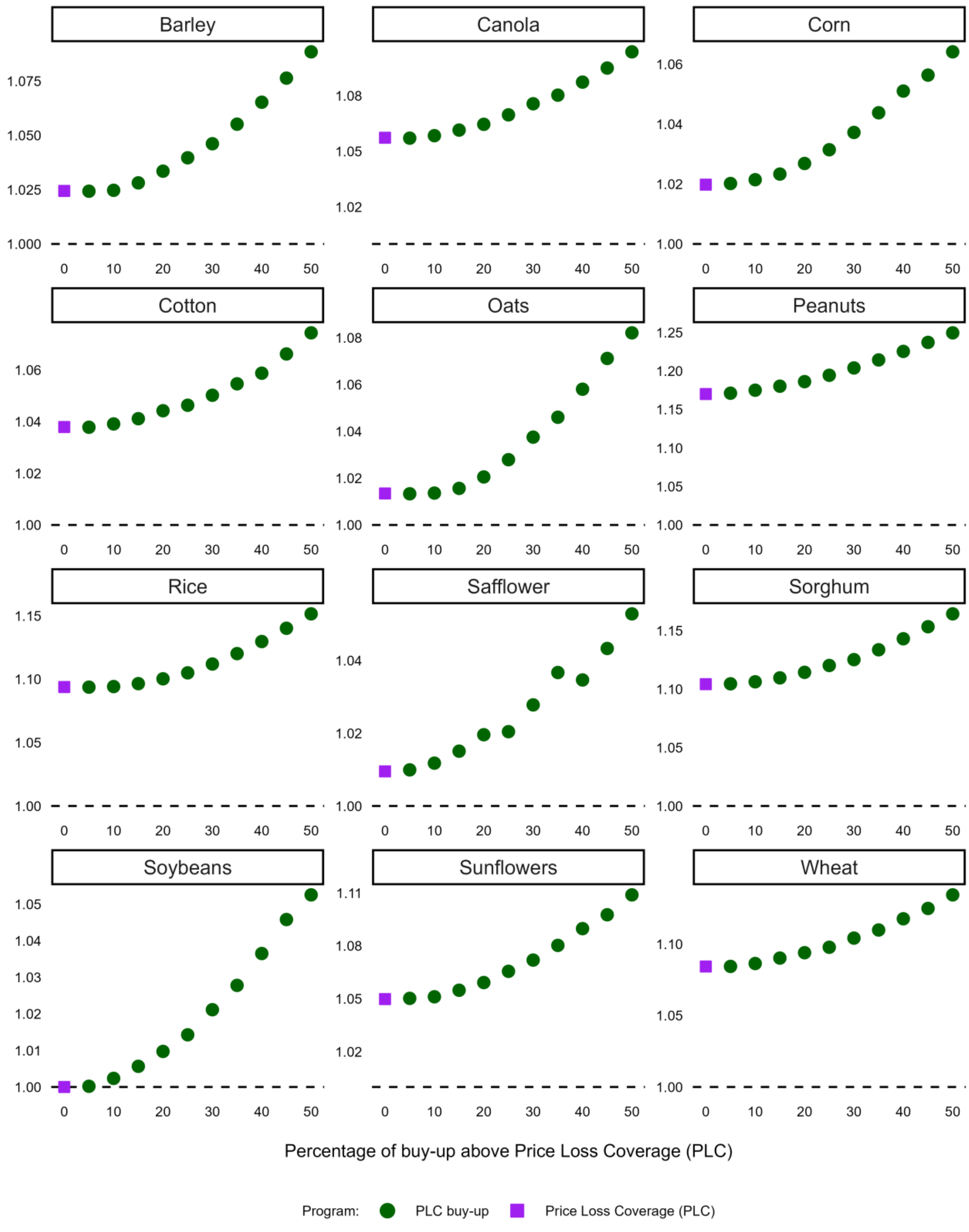


Figure S9: Relative coefficient of variation in revenue [base = no risk management plan]

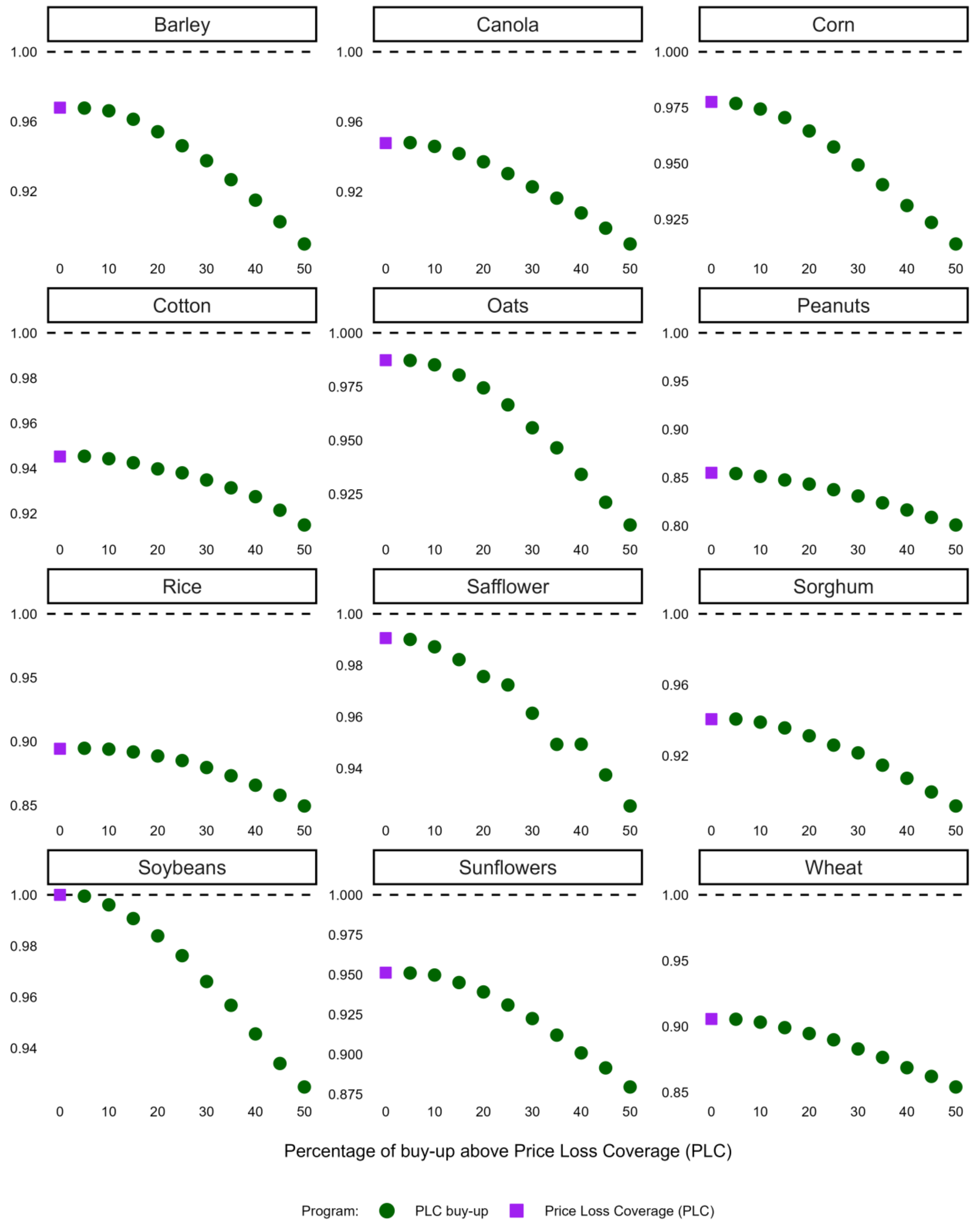


Figure S10: Relative LAPM of revenue [base = no risk management plan]