The Hidden Harvest: Unintended Consequences of Subsidized Livestock Price Insurance

Michael K. Adjemian
Professor
University of Georgia

A. Ford Ramsey
Associate Professor
University of Georgia

November 2025

Abstract

USDA designed the Livestock Risk Protection (LRP) policy to insure against price declines for fed cattle, feeder cattle, or swine. Its indemnities are determined by prices in derivatives markets, making the policies very similar to put options. Beginning in 2019, USDA made several changes that encouraged LRP takeup, including increasing premium subsidies. We introduce a theoretical model to show that subsidizing LRP invites producers to ”subsidy harvest”, or extract the subsidy as an arbitrage by simultaneously taking an offsetting position in the options market—potentially removing the downside protection the program was intended to establish. As a pure rent, the subsidy harvest does not arise from value creation; it is also costlier than a direct payment because it requires administrative oversight and federally-subsidized delivery through approved insurance providers. Our model indicates that the subsidy leads producers to favor LRP over market-based strategies alone, with the optimal choice depending on risk tolerance and wealth objectives. Taking our model to data, we exploit (1) joint changes in options trading and insurance takeup and (2) the exogenous government-set subsidy schedule to estimate the causal effect of the LRP program on derivatives markets, using an instrumental variables approach. We show that subsidies led LRP to crowd out derivatives trading in swine, and encouraged arbitrage behavior in cattle markets. For the latter, we estimate that producers harvested \$12.5 million [95% CI: \$3.5m - \$21.4m] through arbitrage, representing 3% [95%CI: 1%-5%] of the federal LRP subsidies paid to fed and feeder policy holders between 2015 and 2024.

This work is partially supported by USDA OCE cooperative agreement #58-0111-24-012. Adjemian is an academic consultant with the Commodity Futures Trading Commission. The analyses and conclusions expressed in this paper are those of the authors and do not necessarily reflect the views of the USDA Office of the Chief Economist, the USDA, Commission staff, the Commission's Economic Research Section, or the Commission. The authors thank conference participants at the 2025 annual meeting of the Agricultural & Applied Economics Association for their helpful feedback.

1 Introduction

Since 1938, the U.S. government has offered federal crop insurance through the Federal Crop Insurance Program (FCIP), which is responsible for facilitating the private delivery of insurance to the producers of most field crops, many specialty crops, a limited set of livestock and animal products, and managers of grazing lands—-worth a combined $150 billion (Rosch, 2022). FCIP insurance policies can be customized to a farm's specific risk management objectives and are sold and serviced by approved insurance providers (AIPs). The Risk Management Agency (RMA) regulates the terms of the available policies and their pricing. To induce farmers to purchase coverage, which protects them from adverse events that could affect their operations, from weather shocks to pest infestations to unexpected declines in commodity prices, FCIP policies are heavily subsidized (Rosch, 2021, 2022). In addition, the United States Department of Agriculture (USDA) provides subsidies to AIPs to compensate them for the costs of administering the program. The federal government also shares in the underwriting risk on FCIP policies through a favorable reinsurance agreement.

For nearly a century, livestock insurance in the United States was largely confined to dairy producers, who participated in price and income support programs created during the New Deal era (Glauber, 2022). But in 2000, USDA initiated pilot programs to cover livestock products in the form of both price and margin (i.e., the difference between revenue and input costs) coverage tied to futures prices. In contrast, most crop insurance available through the FCIP is designed to insure against production or revenue risk. Today, three programs make up the bulk of the livestock insurance offered through the FCIP: Livestock Risk Protection (LRP), Livestock Gross Margin (LGM), and Dairy Revenue Protection (DRP) (Glauber, 2022). Each program ties indemnity payments to declines in corresponding futures prices over the period of coverage; participation is encouraged through premium subsidies.

Until 2019, participation in livestock insurance programs was limited due to (1) a statutory cap on related annual government spending, (2) relatively low subsidies on livestock insurance products, and (3) a prohibition against simultaneously covering dairy producers under both the Dairy Margin Coverage program (an income support program administered by the USDA Farm Service Agency) and dairy insurance offered through the FCIP. The 2018 Farm Bill eliminated both (1) and (3), while substantially raising subsidy rates (Glauber, 2022).

Following these changes, livestock insurance program participation increased dramatically. According to RMA data (2024), between 2018 and 2024, the number of livestock head covered under these programs increased from 460,000 to over 43 million. At the same time, liabilities increased from $512 million to nearly $29 billion, while producer subsidies increased from $3.5 million to $472 million. The rise in LRP participation explains most of those increases; LRP currently accounts for almost 31 million head, $16 billion in liability, and $295 million in subsidies, compared to 2018 figures of 343,000 head, liabilities of $176 million, and subsidies under one million dollars (Boyer and Griffith, 2023a).

Rapid increases in LRP takeup, and livestock insurance takeup more broadly, have drawn scrutiny from market observers and policymakers. It seems likely that higher subsidy rates and other recent changes drew livestock producers into the programs, mirroring increased liability on the crop side of the Federal Crop Insurance Corporation's book of business (Goodwin and Smith, 2013). Some have wondered about the potential for increased LRP participation to affect prices in the futures markets (Carrico, 2024). Little work has been done on the market effects of livestock insurance, although research on the impacts of subsidized crop insurance is more substantial (Horowitz and Lichtenberg, 1993; Young et al., 2001; Goodwin et al., 2004; Yu et al., 2018; Yu and Sumner, 2018). The design of LRP, and other similarly subsidized livestock insurance policies, is based on protecting against downside swings in the prices of existing commodity futures contracts. LRP, for example, operates like a put option on a futures contract——guaranteeing a floor price to the option purchaser (LGM and DRP can also be shown to operate like synthetic options contracts).[1] Since an LRP policy is a subsidized substitute for an existing derivative, it may be that the program crowds out participation in the target derivatives market (Glauber, 2022; Belasco, 2025), lowering trading volume. The consequences of reducing commercial interest in a commodity can be significant; it could harm the price discovery ability of a futures market.

Conversely, LRP might attract participants *into* the market, increasing trading volume. This effect could work through two channels: first, if LRP subsidies attract producers into insurance policies,[2] the AIPs who write them (and the reinsurers they purchase policies from) may use commodity derivatives to hedge at least some of the risk they take on—by purchasing options. Second, RMA provisions set the LRP policy premium near prevailing option premia (i.e., the price of an option), so it may be possible to earn an arbitrage profit equivalent to the subsidy level, termed a *subsidy harvest*, by simultaneously purchasing an LRP contract and selling an option on the related futures contract (Baker, 2023, 2024;

[1]Futures markets are zero-sum; for any contract to exist one party (*the long*) must promise to buy the underlying commodity at an *ex ante* known contract expiration, while another (*the short*) must agree to sell it for an agreed-upon price. All other elements of a futures contract are standardized. Trading futures or options requires collateral in the form of a *margin account*, held by the exchange and drawn from in case prices move adversely; *margin calls* can occur that require the account to be topped-up. A call option gives the holder the right, but not the obligation, to take a long position in a futures contract for the underlying commodity at a given *strike price*. Alternatively, a put option gives the holder the right, but again not the obligation, to take a short position in a futures contract for the underlying commodity at a given strike. A final bit of jargon to note is that the seller of an option is also called a writer.

[2]Historically, use of derivatives among livestock producers is not widespread (Hill, 2015; McKendree et al., 2021; Barua, 2024).

Carrico, 2024). LRP works like a long put option. By purchasing a contract and writing a look-alike market put option the producer can lock in a payoff equal to the terminal value of the livestock under the LRP plus the subsidy, less transaction costs and the opportunity cost of necessary margin account funds in the interim. Alternatively, although unremarked upon up to now,[3] the producer can instead combine an LRP policy with short call option to lock in the covered price today plus the subsidy, after transaction and margin costs. We term the first type of arbitrage trade, which exposes the producer to downside risk, a *dirty* subsidy harvest; we refer to the other type, which fixes a producers' return less costs, as *clean*.

Subsidy harvesting should increase the open interest of options trades, although would-be participants face two constraints: (1) producers are capped in the number of policies they can take out in a given crop year and (2) capturing the subsidy harvest requires holding the option until it expires. Heavy options writing could affect futures prices to the extent that traders believe it represents true market sentiment with a directional view on prices: bearish or bullish.[4] If, on the other hand, sophisticated market participants anticipate subsidy harvesting by rational producers, prices will not be affected.

Subsidy harvesting via the sale of look-alike options tied to USDA insurance products can present several problems for the viability of the FCIP's livestock insurance portfolio. First, producers may take on additional risk, contravening the statutory purpose of livestock insurance as a risk management tool: a dirty subsidy harvest totally eliminates the downside protection afforded by LRP. Moreover, writing options requires margin maintenance, so producers need access to cash or credit to preserve the margin as positions are marked to market each day until options contract expiry. Second, clean subsidy harvesting caps the upside. It offers producers only the ability to earn at most the current livestock price plus the policy subsidy, reducing potential producer welfare. Third, whichever arbitrage trade producers pursue, subsidy harvesting is an extraordinarily inefficient way to achieve that outcome from the perspective of taxpayers, due to the associated administrative costs USDA must pay to insurance firms and its own staff who monitor the program. Far better to simply issue a direct payment.

RMA acknowledged the potential for subsidy harvesting by modifying the basic LRP provisions effective from the 2026 crop year (Risk Management Agency, 2026). It defined subsidy capture as "The practice of exploiting the differences between premium owed by you for an SCE (specific coverage endorsement) and the cost of a privately traded livestock contract such as a put option, for the purpose of your financial gain" with further detail provided in the policy provisions. The insured and anyone with a substantial beneficial interest in the insured are prohibited from offsetting coverage for the purpose of

[3] At least as far as we can tell in our review of the related literature and media.

[4] Bearish traders expect commodity prices to fall; those who are bullish expect price to rise. Pun fully intended.

subsidy capture. Similar changes were made to DRP and LGM insurance. Although changes in policy provisions are an explicit recognition of the potential for subsidy harvesting, few attempts have yet been made to examine the potential arbitrage relationship between LRP and derivatives markets, theoretically or empirically (Boyer and Griffith, 2023b; Feuz, 2025).

We first construct a theoretical framework for livestock risk management under uncertainty in the presence of subsidized insurance related to price. The model predicts that strategies that involve subsidized insurance dominate unhedged behavior as well as using a market put option alone. Instead, based on their risk tolerance and wealth objectives a producer behaving optimally would choose between LRP alone and two types of subsidy harvests: one that insulates producers from risk and another that removes the protection offered by the insurance policy. The model generates several hypotheses that could link participation in livestock insurance programs to derivatives markets. We use public data on options held by different types of traders to conduct an empirical assessment of those hypotheses, and exploit the requirement for concurrent increases in options open interest (OI) to quantify potential subsidy capture. Using the government-set subsidy schedule as an instrument, we show that LRP subsidies crowded out derivatives trading in swine, and encouraged subsidy harvesting on the part of cattle producers.

2 Livestock Risk Protection Insurance

Liability in livestock insurance programs grew significantly starting in 2019 with changes to dairy insurance. Total liability in livestock programs also increased dramatically, starting in 2021, with increased uptake of Livestock Revenue Protection (LRP). By 2024, LRP, which covers feeder cattle, swine, and fed cattle, accounted for the majority of liability in livestock insurance programs. Values in figure 1 identify total LRP liability by commodity year, for each type of livestock. Roughly 68% of policies sold and 50% of total liability in 2024 were in feeder cattle. Premium subsidies by commodity are shown in figure 2. Premium subsidies in 2024 were around $320 million with the majority of the subsidy again accruing to producers of feeder cattle. LRP policy provisions specify an expected ending value for insured livestock, based on CME futures prices, and pay an indemnity if the actual ending value falls below a percentage of expected ending value.

The insured must identify the type of feeder cattle, swine, or fed cattle to be marketed and a target weight. For example, feeder cattle covers steer feeder cattle, heifer feeder cattle, Brahman feeder cattle, dairy feeder cattle, and three types of unborn feeder cattle. Steer feeder cattle with a target weight of 1.0-5.99 cwt comprise one type of steer feeder cattle, while those between 6.0-10.0 cwt comprise a second

Figure 1: LRP Liability by Commodity, 2005-2024

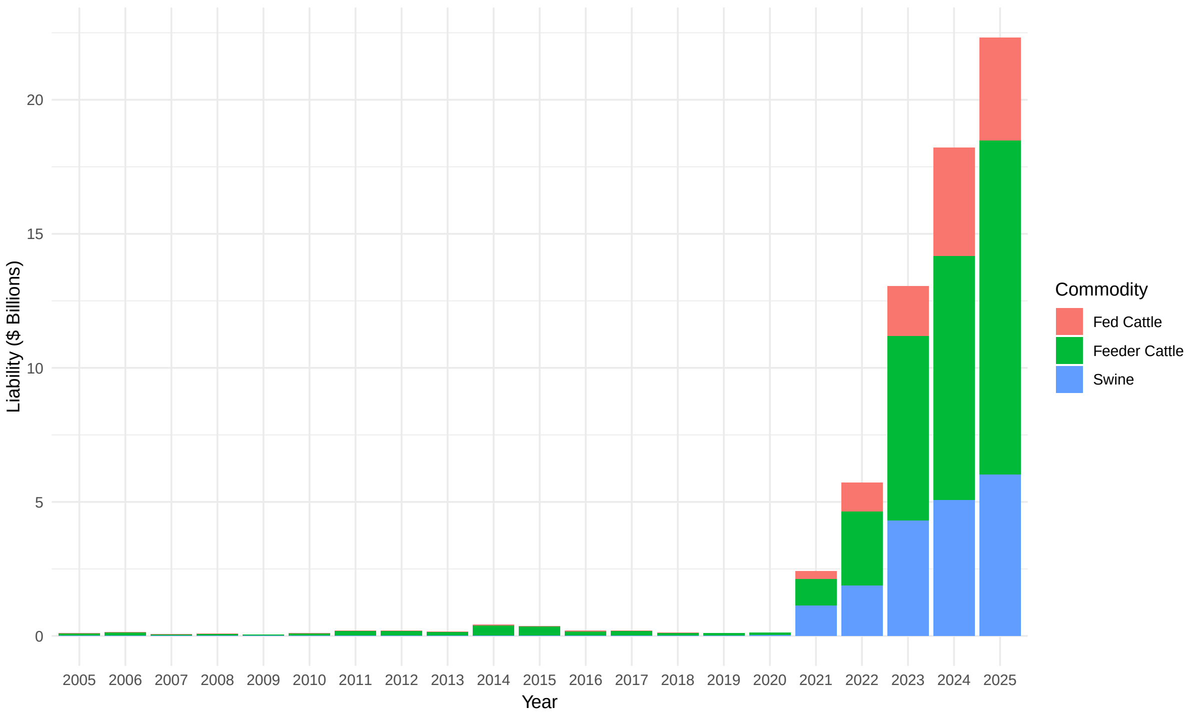
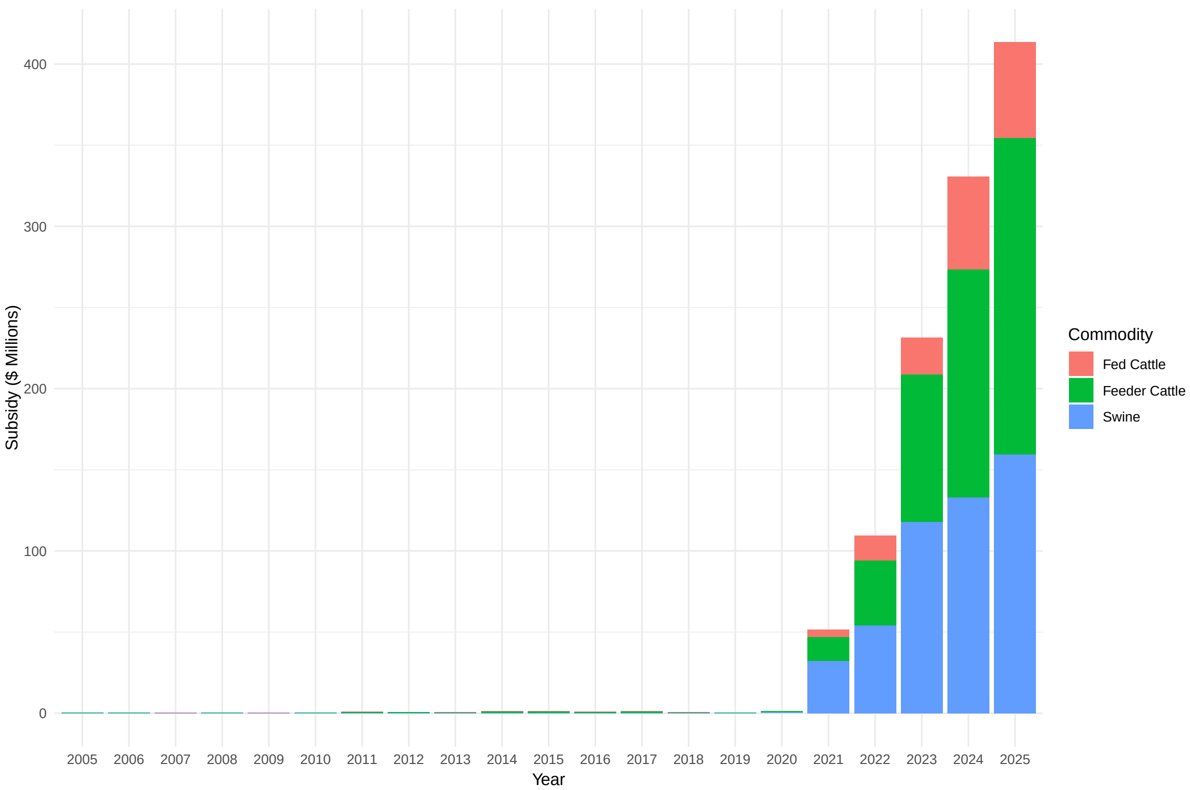


Figure 2: LRP Premium Subsidies by Commodity, 2005-2024



type. In all, there are 11 types of feeder cattle, one type of fed cattle, and two types of swine (swine and unborn swine) that can be insured under LRP.

Different types of livestock have different price adjustment factors, the reasoning for which is most obvious for feeder cattle. Coverage prices and actual ending prices for feeder cattle are based on the Chicago Mercantile Exchange (CME) Feeder Cattle Contract which is cash settled to the CME Feeder Cattle Index. The contract and index are based on prices for steers of a certain weight (700 to 899 pounds) and do not include Brahman or dairy breeds. Price adjustment factors are intended to account for differences between steer prices in the CME contract and prices of other types and weights of cattle. The price adjustment factors are used in calculating expected ending values and actual ending values. For instance, type 2 steers (6.0 - 10.0 cwt) are the closest to the type of cattle included in the CME contract or index and therefore have a price adjustment factor of 100%, i.e. the price used in calculating the expected and actual ending values is simply the price for the CME contract or index.

LRP policies are sold on a continuous, daily basis. Based on the type of livestock, the producer identifies a target date when the livestock will be ready for market or reach a desired weight. The insurance period for the policy should end within 60 days of the target date. Available insurance periods are shown in table 1. The insured also selects from one of 12 coverage levels available: 75%, 80%, 85%, 87.5%, 90%, 92.5%, 95%, 96%, 97%, 98%, 99%, and 100%. The coverage level is the percentage of the expected ending value of the livestock covered by the policy. Premium subsidies are based on the coverage level chosen by the producer. The subsidy rates are: 35% for coverage levels 95%, 96%, 97%, 98%, 99%, and 100%, 40% for coverage levels 90% and 92.5%, 45% for coverage levels 85% and 87.5%, 50% for coverage level 80%, and 55% for coverage at the 75% level.

Table 1: Available Insurance Periods by Commodity

Weeks	Feeder Cattle	Fed Cattle	Swine	Unborn Swine
13	X	X	X	
17	X	X	X	
21	X	X	X	
26	X	X	X	
30	X	X	X	X
34	X	X		X
39	X	X		X
43	X	X		X
47	X	X		X
52	X	X		X

Figure 3: LRP Loss Ratios, 2005-2024

Note: Loss ratios are only for LRP on fed cattle, feeder cattle, and swine. They do not include LRP for lamb which was discontinued in 2021.

The loss (indemnity) under an LRP policy can be calculated as

$$\text{Loss} = \max(0, (H \times TW) * (P_C - P_A)) \tag{2.1}$$

where H is the number of head insured, TW is the target weight, P_C is the coverage price, and P_A is the actual ending value (or actual price). The coverage price P_C is quoted in dollars per live cwt and is the expected ending value multiplied by the coverage level. Equation 2.1 shows indemnities under the policy are determined by the difference between the actual ending value and the coverage price. If the actual ending value is less than the coverage price, a loss is realized. Otherwise, there is no indemnity. Figure 3 shows loss ratios (total losses over total premiums) for LRP between 2005 and 2024. The total loss ratio is based on the premium remitted to the insurer, whereas the producer loss ratio is based on the producer-paid premiums. If the premiums on the policies are actuarially fair, then the loss ratio should average 100% over a long period of time. The loss ratio indicates good performance, which might be expected, given that there is limited potential for moral hazard or adverse selection under LRP (Boyer et al., 2024; Merritt et al., 2017; Haviland and Feuz, 2025).

Two crucial inputs to equation 2.1, which link LRP to the derivatives markets, are the expected ending value and the actual ending value. The expected ending value is published each day by RMA.[5] The expected ending values are widely understood to be derived from corresponding futures markets, with feeder cattle based on the CME feeder cattle futures, fed cattle based on CME live cattle futures, and swine based on CME lean hog futures (Boyer et al., 2024). The formulas used to convert futures prices to expected ending values provided on a daily basis for multiple insurance periods are not publicly available.

Actual ending values are based on the price of various indices at the end of the insurance period. In the case of LRP for feeder cattle, the actual ending value is the weighted average price of feeder cattle reported by the CME Feeder Cattle Reported Index at `https://www.cmegroup.com/market-data/browse-data/commodity-index-prices.html?redirect=/market-data/reports/cash-settled-commodity-index-prices.html`. For fed cattle, the price is calculated by the Agricultural Marketing Service (AMS) in the "5 Area Weekly Weighted Average Direct Slaughter Cattle" report at `https://mymarketnews.ams.usda.gov/viewReport/2477`. The calculated ending value for swine is slightly more complicated but is based on AMS price series used to settle the lean hog futures contract at CME. The report can be found online at `https://mymarketnews.ams.usda.gov/viewReport/2511`. Because the premiums and expected ending values for all LRP policies are ultimately based on futures markets, the potential for subsidy harvesting exists whether one is purchasing LRP for fed cattle, feeder cattle, or swine.

What little research has been conducted on LRP has mainly focused on the impact of changes to the subsidy structure on premiums (Boyer and Griffith, 2023a) or factors affecting takeup (Boyer and Griffith, 2023b; Boyer et al., 2024). A study by Merritt et al. (2017) examined the likelihood that producers would receive indemnities for feeder cattle under different insurance periods. A similar assessment for all types of livestock was published by Haviland and Feuz (2025). Feuz estimates maximum subsidy capture using LRP policies that align with option contract maturities (Feuz, 2025).

3 A Model of Livestock Producer Decisions with Subsidized Insurance

This section introduces a theoretical framework to analyze a livestock producer's strategic choices under price uncertainty, integrating futures markets, options, and subsidized insurance. The producer holds a fixed quantity of livestock and faces a decision among five distinct strategies: selling unhedged, purchasing subsidized price insurance (i.e., LRP), buying a market put option, conducting a clean subsidy

[5] See `https://public.rma.usda.gov/livestockreports/LRPReport.aspx`

harvest, or conducting a dirty subsidy harvest. Employing a Constant Absolute Risk Aversion (CARA) utility function, we compare strategies on the basis of wealth, expected wealth, its variance, and certainty equivalent. The model produces testable hypotheses that link insurance participation to options market dynamics.

3.1 Market Setup and Basic Assumptions

A livestock producer raises Q units of livestock to sell at time T and has a CARA utility function, $u(W) = -\exp(-\gamma W)$, where $\gamma > 0$ is the coefficient of absolute risk aversion and W is wealth. The producer can transact in a futures market, where the time t contract price for delivery at T is denoted $F(t,T)$. The spot price at maturity T, $P(T)$, follows a normal distribution with mean $F(t,T)$, so that the futures price is an unbiased expectation for the future cash market price, and variance σ_T^2, i.e., $P(T) \sim N(F(t,T), \sigma_T^2)$. European put and call options are available on this futures contract, each with a strike price equal to the current spot price at time t, $P(t)$; they expire at T and put options cost $\phi = \pi_{\text{fair}}$,[6] while call options yield a premium c, again assumed equal to π_{fair} for at-the-money options under symmetry. By their nature, call and put options censor the price distribution, and a put option's variance $\kappa\sigma_T^2$ is lower, where $\kappa < 1$.[7] Subsidized insurance replicates a put option with strike $P(t)$, costing a premium $\theta = \pi_{\text{fair}} - s$, where $\pi_{\text{fair}} = \mathbb{E}[\max(P(t) - P(T), 0)] = \delta\sigma_T$ is the actuarially fair premium and $s > 0$ is the government subsidy.

To build intuition, we first impose simplifying assumptions: first, no transaction costs for options market transactions. Second, no basis risk—the spot price the producer faces in his local market equals the indexed market price used as the basis for futures, $P(T) = I(T)$, and so $F(t,T) = \mathbb{E}[I(T)] = P(t)$. Third, we impose no margin requirements so options market participants face no margin costs. We relax these assumptions later to incorporate real-world frictions.

[6]Using European options, exercisable only at maturity, simplifies our expressions. Livestock options at the Chicago Mercantile Exchange are typically American in nature, meaning that they are exercisable anytime, but this assumption does not materially alter our conclusions, as we show in appendix C.

[7]For example, the effective sale price for a producer who holds the physical commodity and a long put with strike $P(t) = F(t,T)$ is $\max(P(T), P(t))$, since the option payoff $\max(P(t) - P(T), 0)$ raises the realized sale price whenever market prices fall. Such a strategy sets the floor price at the strike so that the put option holder is exposed only to upside fluctuations. As a result, the put option's expected value is $\mathbb{E}[\max(P(t) - P(T), 0)] = \delta\sigma_T$, where δ arises from the standard normal density's integral over positive values; it is calculated as $\delta = 1/\sqrt{2\pi} \approx 0.3989$. The put option's variance is $\kappa\sigma_T^2$, where $\kappa = (\pi - 1)/(2\pi) \approx 0.341$. Restricting prices to only the upper half of the normal distribution therefore reduces the variance of the long put option to only about one-third of σ_T^2, the variability of the livestock price itself.

3.2 Decision Framework and Certainty Equivalents

At $t = 0$, the producer maximizes expected utility, $\mathbb{E}[u(W)]$. Under CARA, the expected utility is:

$$\mathbb{E}[u(W)] = -\exp\left(-\gamma\mathbb{E}[W] + \frac{1}{2}\gamma^2\mathrm{Var}[W]\right) \tag{3.1}$$

[8] Since $u(W)$ is monotonic, maximizing $\mathbb{E}[u(W)]$ equates to maximizing the certainty equivalent (CE), which balances expected wealth and risk:

$$\mathrm{CE} = \mathbb{E}[W] - \frac{\gamma}{2}\mathrm{Var}[W] \tag{3.2}$$

A certainty equivalent represents the certain wealth yielding the same utility as a risky strategy's expected utility. It combines the strategy's expected wealth with a penalty for variance, scaled by risk aversion γ. We compare CEs under each of the five strategies: unhedged sale (u), subsidized insurance (i), market put option (p), clean subsidy harvest (h_c), and dirty subsidy harvest (h_d).

3.3 Illustrative Case

We begin with restrictive assumptions to isolate the core trade-offs among strategies. With no basis risk ($P(T) = I(T)$), no transaction costs, and no margin requirements, the producer faces price uncertainty only from $P(T) \sim N(F(t,T), \sigma_T^2)$, with strike $P(t) = F(t,T)$. We derive each strategy's wealth, expected wealth, variance, and certainty equivalent in order to reveal its risk-return profile, and then compare strategies to understand the factors that would lead producers to select one or another.

3.3.1 Unhedged Sale (u)

The producer waits until T and sells Q livestock at the cash market price $P(T)$:

$$W_u = Q \cdot P(T) \tag{3.3}$$

Under our simplifying assumptions his expected wealth is a function of the expected livestock price:

$$\mathbb{E}[W_u] = Q \cdot F(t,T) \tag{3.4}$$

[8] This relationship is exact when wealth W is normally distributed. However, nonlinear payoffs from options and insurance (e.g., $\max(P(T), P(t))$) result in non-normal wealth distributions. As a result, the CEs we derive are second-order Taylor approximation of $\mathbb{E}[u(W)]$ around $\mathbb{E}[W]$, neglecting higher-order moments like skewness. This mean-variance approximation is accurate for small risk aversion coefficients, and aligns with standard practice in financial economics.

And his wealth variance reflects a full exposure to price risk:

$$\mathrm{Var}[W_u] = Q^2 \cdot \sigma_T^2 \tag{3.5}$$

The certainty equivalent is:

$$\mathrm{CE}_u = Q \cdot F(t,T) - \frac{\gamma}{2} Q^2 \cdot \sigma_T^2 \tag{3.6}$$

This strategy incurs no costs but exposes the producer to the full range of price volatility, offering high returns if prices rise but significant losses if they fall. As a result it is unappealing to risk-averse producers.

3.3.2 Subsidized Insurance (i)

The producer purchases a subsidized insurance policy guaranteeing a minimum coverage price $P(t)$ in exchange for a premium that is partially subsidized $\theta = \pi_{\text{fair}} - s$. This strategy mimics a put option, ensuring a price floor of at least $P(t)$ per unit:

$$W_i = Q \cdot (\max(P(T), P(t)) - \theta) \tag{3.7}$$

Expected wealth is:[9]

$$\mathbb{E}[W_i] = Q \cdot (F(t,T) + s) \tag{3.8}$$

With the reduction offered by the price floor, the variance is now:

$$\mathrm{Var}[W_i] = Q^2 \cdot \kappa \sigma_T^2 \tag{3.9}$$

And the certainty equivalent is:

$$\mathrm{CE}_i = Q \cdot (F(t,T) + s) - \frac{\gamma}{2} Q^2 \cdot \kappa \sigma_T^2 \tag{3.10}$$

With insurance the producer receives a floor price of $P(t)$; the subsidy boosts the producer's expected wealth. This strategy's wealth variance is lower than being unhedged, making it attractive for risk-averse producers.

[9]With $P(t) = F(t,T)$, $\mathbb{E}[\max(P(T), P(t))] = F(t,T) + \delta\sigma_T$. Since $\theta = \pi_{\text{fair}} - s = \delta\sigma_T - s$, taking expectations generates $\mathbb{E}[W_i] = Q \cdot (F(t,T) + \delta\sigma_T - (\delta\sigma_T - s)) = Q \cdot (F(t,T) + s)$.

3.3.3 Market Put Option (p)

The producer could instead simply buy a market put option at the fair premium $\phi = \pi_{\text{fair}}$, securing a minimum price $P(t)$ as in the case of (fairly-priced) insurance:

$$W_p = Q \cdot (\max(P(T), P(t)) - \pi_{\text{fair}}) \tag{3.11}$$

Expected wealth is:[10]

$$\mathbb{E}[W_p] = Q \cdot F(t,T) \tag{3.12}$$

Wealth variance under the put matches that of the subsidized insurance strategy:

$$\text{Var}[W_p] = Q^2 \cdot \kappa\sigma_T^2 \tag{3.13}$$

And its certainty equivalent is the same, less the subsidy:

$$\text{CE}_p = Q \cdot F(t,T) - \frac{\gamma}{2} Q^2 \cdot \kappa\sigma_T^2 \tag{3.14}$$

Purchasing a put provides the same downside protection as subsidized insurance. Without benefit of the subsidy, however, it offers a lower expected wealth, making it less appealing.

3.3.4 Clean Subsidy Harvest (h_c)

To accomplish a clean subsidy harvest the producer first takes out a subsidized insurance policy at a given coverage price $P(t)$, and then writes a call option with an equivalent strike price. Their combined payoff is equivalent to the return of a short cash market position, plus the subsidy. Combined with the producer's endowed long cash market position, this locks in a risk-free payoff equal to the subsidy:

$$W_{h_c} = Q \cdot (P(T) + \max(P(t) - P(T), 0) - \theta + c - \max(P(T) - P(t), 0)) \tag{3.15}$$

Simplifying:[11]

$$W_{h_c} = Q \cdot (P(t) - \theta + c) \tag{3.16}$$

With $\theta = \pi_{\text{fair}} - s$, $c = \pi_{\text{fair}}$:

$$W_{h_c} = Q \cdot (P(t) + s) \tag{3.17}$$

[10]Since $\mathbb{E}[\max(P(T), P(t))] = F(t,T) + \delta\sigma_T$, and $\pi_{\text{fair}} = \delta\sigma_T$, then $\mathbb{E}[W_p] = Q \cdot (F(t,T) + \delta\sigma_T - \delta\sigma_T) = Q \cdot F(t,T)$.

[11]See Appendix A for a proof that $P(T) + \max(P(t) - P(T), 0) - \max(P(T) - P(t), 0) = P(t)$.

Since $P(t) = F(t,T)$, expected wealth is:

$$\mathbb{E}[W_{h_c}] = Q \cdot (F(t,T) + s) \tag{3.18}$$

By locking in the price today plus the subsidy, the producer's wealth variance is zero; the payoff is deterministic:

$$\text{Var}[W_{h_c}] = 0 \tag{3.19}$$

The certainty equivalent is:

$$\text{CE}_{h_c} = Q \cdot (F(t,T) + s) \tag{3.20}$$

This strategy eliminates price risk by synthetically selling the livestock forward at $F(t,T)$, capturing the subsidy without exposure to price changes, ideal for highly risk-averse producers.

3.3.5 Dirty Subsidy Harvest (h_d)

The dirty subsidy harvest pairs the long cash market position with subsidized insurance and a short put option, canceling downside protection but capturing the subsidy:

$$W_{h_d} = Q \cdot (P(T) + \max(P(t) - P(T), 0) - \theta + \phi - \max(P(t) - P(T), 0)) \tag{3.21}$$

Simplifying, with $\phi = \pi_{\text{fair}}$, $\theta = \pi_{\text{fair}} - s$:

$$W_{h_d} = Q \cdot (P(T) + s) \tag{3.22}$$

Expected wealth is:

$$\mathbb{E}[W_{h_d}] = Q \cdot (F(t,T) + s) \tag{3.23}$$

The variance reflects full price risk:

$$\text{Var}[W_{h_d}] = Q^2 \cdot \sigma_T^2 \tag{3.24}$$

The certainty equivalent is:

$$\text{CE}_{h_d} = Q \cdot (F(t,T) + s) - \frac{\gamma}{2} Q^2 \cdot \sigma_T^2 \tag{3.25}$$

This strategy also harvests the subsidy but retains full price exposure, akin to an unhedged position but with a wealth boost from s, appealing to those producers willing to speculate on price increases.

3.4 Comparing Strategies under Restrictive Assumptions

By comparing their certainty equivalents, we highlight which of the five strategies best suits a given producer. Without basis risk or frictions, differences arise purely from risk exposure and the subsidy's effect on wealth. Table 2 summarizes key features of each basic strategy. Of the five, our model indicates that the unhedged and market put strategies are dominated by those that involve LRP. A given producer chooses among the latter according to his risk tolerance and wealth objectives. We note that by abstracting away from the real world, our comparisons do not account for subjective expectations. In practice views about the future path of prices can tip the scales of even a risk-averse producer to choose a risky strategy over a riskless one. A producer who is bullish on the price of his livestock might choose a strategy that does not cap the upside, even if its certainty equivalent is lower than one with a (near-) deterministic payoff.

Strategy	**Exposure to $P(T)$ at T**	**Wealth at T**	**Var(W_T)**	**Key Features**
Unhedged (u)	Full	$Q \cdot P(T)$	$Q^2\sigma_T^2$	Nothing locked-in; pure speculation.
Subsidized Insurance (i)	Upside only	$Q \cdot [\max(P(T), P(t)) - \theta]$	$Q^2\kappa\sigma_T^2$	Subsidized floor at $P(t)$; retains upside.
Market Put (p)	Upside only	$Q \cdot [\max(P(T), P(t)) - \pi_{\text{fair}}]$	$Q^2\kappa\sigma_T^2$	Unsubsidized floor; more costly than insurance.
Clean Subsidy Harvest (h_c)	None	$Q \cdot (P(t) + s)$	0	Locks-in today's price + subsidy; no possible upside.
Dirty Subsidy Harvest (h_d)	Full	$Q \cdot (P(T) + s)$	$Q^2\sigma_T^2$	Unhedged but harvests the subsidy.

Table 2: Strategy summary under restrictive assumptions.

3.4.1 Dirty Subsidy Harvest (h_d) versus Unhedged (u)

The dirty subsidy harvest adds the subsidy to the spot price:

$$\mathbb{E}[W_{h_d}] - \mathbb{E}[W_u] = Q \cdot s \tag{3.26}$$

Since $\text{Var}[W_{h_d}] = \text{Var}[W_u] = Q^2 \cdot \sigma_T^2$, the certainty equivalent difference is:

$$\text{CE}_{h_d} - \text{CE}_u = Q \cdot s \tag{3.27}$$

Since $s > 0$, $\text{CE}_{h_d} > \text{CE}_u$. The dirty subsidy harvest dominates the unhedged strategy because it increases expected wealth by the subsidy s without altering variance. This dominance holds for all rational producers, including risk-neutral ($\gamma = 0$) and risk-averse ($\gamma > 0$), because the subsidy provides a cost-free (to the producer) wealth boost while retaining the same price exposure.

3.4.2 Subsidized Insurance (i) versus Market Put (p)

Subsidized insurance offers the same risk profile as the market put but includes the subsidy:

$$\mathbb{E}[W_i] - \mathbb{E}[W_p] = Q \cdot s \tag{3.28}$$

Since variances are equal ($\text{Var}[W_i] = \text{Var}[W_p] = Q^2 \cdot \kappa\sigma_T^2$), the certainty equivalent difference is:

$$\text{CE}_i - \text{CE}_p = Q \cdot s \tag{3.29}$$

Since $s > 0$, $\text{CE}_i > \text{CE}_p$. Subsidized insurance dominates the put option since the subsidy s increases producer wealth without affecting risk. Rational producers always prefer the subsidized insurance.

3.4.3 Subsidized Insurance (i) versus Clean Subsidy Harvest (h_c)

The clean subsidy harvest locks in a risk-free payoff:

$$\mathbb{E}[W_{h_c}] - \mathbb{E}[W_i] = 0 \tag{3.30}$$

However, its variance is lower:

$$\text{Var}[W_{h_c}] = 0 < Q^2 \cdot \kappa\sigma_T^2 = \text{Var}[W_i] \tag{3.31}$$

The certainty equivalent difference is:

$$\text{CE}_{h_c} - \text{CE}_i = \frac{\gamma}{2} Q^2 \cdot \kappa\sigma_T^2 \tag{3.32}$$

Since the variance term is positive ($\gamma > 0$), $\text{CE}_{h_c} > \text{CE}_i$. For risk-averse producers, the clean subsidy harvest's deterministic payoff makes it superior, locking in a return equal to the price today plus the subsidy, $F(t,T) + s$, without exposure to price fluctuations. Risk-neutral producers ($\gamma = 0$) are indifferent due to equivalent expected wealth.

3.4.4 Subsidized Insurance (i) versus Dirty Subsidy Harvest (h_d)

The dirty subsidy harvest retains full price exposure:

$$\mathbb{E}[W_{h_d}] - \mathbb{E}[W_i] = 0 \tag{3.33}$$

But its variance is higher:

$$\text{Var}[W_{h_d}] = Q^2 \cdot \sigma_T^2 > Q^2 \cdot \kappa \sigma_T^2 = \text{Var}[W_i] \tag{3.34}$$

The certainty equivalent difference is:

$$\text{CE}_{h_d} - \text{CE}_i = -\frac{\gamma}{2} Q^2 \cdot (1-\kappa)\sigma_T^2 \tag{3.35}$$

Since the variance term is negative ($\gamma > 0$), $\text{CE}_i > \text{CE}_{h_d}$. Subsidized insurance dominates for risk-averse producers, as its price floor reduces risk while matching the dirty subsidy harvest's expected wealth. Risk-neutral producers ($\gamma = 0$) are once again indifferent due to shared expected wealth across strategies.

3.4.5 Clean Subsidy Harvest (h_c) versus Dirty Subsidy Harvest (h_d)

The clean subsidy harvest eliminates risk, while the dirty version retains it (along with upside potential):

$$\mathbb{E}[W_{h_c}] - \mathbb{E}[W_{h_d}] = 0 \tag{3.36}$$

Variance comparison:

$$\text{Var}[W_{h_c}] = 0 < Q^2 \cdot \sigma_T^2 = \text{Var}[W_{h_d}] \tag{3.37}$$

Certainty equivalent difference:

$$\text{CE}_{h_c} - \text{CE}_{h_d} = \frac{\gamma}{2} Q^2 \cdot \sigma_T^2 \tag{3.38}$$

Since the variance term is positive, $\text{CE}_{h_c} > \text{CE}_{h_d}$ and the clean subsidy harvest dominates overall for risk-averse producers. It offers a risk-free payoff, while the dirty subsidy harvest is fully exposed to risk. Of course, risk-neutral producers ($\gamma = 0$) remain indifferent.

3.5 General Case: Relaxed Assumptions

We now relax the simplifying assumptions to incorporate real-world complexities: basis risk, transaction costs, and margin requirements. The cash market price is modeled as $P(T) = I(T) + b(T)$, where $I(T) \sim N(F(t,T), V_I)$ is the index or delivery market price tied to the relevant futures contract,[12] with variance $V_I = \sigma_T^2$, and $b(T) \sim N(\mu_b, V_b)$ is the local basis. The basis mean μ_b represents systematic differences (e.g., transportation costs or local supply and demand factors) between the producer's local

[12] At the Chicago Mercantile Exchange, futures prices for Feeder Cattle and Lean Hogs settle to a cash-price index, while Live Cattle may be physically delivered. For simplicity we refer to $I(T)$ as the index cash price.

price and the index price; thus, the expected cash market price is $\mathbb{E}[P(T)] = F(t,T) + \mu_b$, and the basis cannot be hedged away. Futures and options are written on the index, with $F(t,T) = \mathbb{E}[I(T)]$. We allow for a non-zero correlation ρ between $I(T)$ and $b(T)$, so the variance of $P(T)$ is $\text{Var}[P(T)] = V_I + V_b + 2\rho\sqrt{V_I V_b}$. Each option trade incurs a transaction cost $\tau > 0$, and writing options requires posting initial margin m (m_{call} for calls, m_{put} for puts), with an opportunity cost of $m \cdot (e^{r\Delta t} - 1)$, where $r > 0$ is the risk-free rate and $\Delta t = T - t$. These frictions introduce unhedgeable basis risk, reduce expected wealth through transaction and margin costs, and alter the relative attractiveness of strategies, particularly those involving option writing (clean and dirty subsidy harvests). Below, we describe each strategy and highlight how basis risk and costs modify outcomes compared to the illustrative case.

3.5.1 Unhedged Sale (u)

The producer sells Q units at the spot price $P(T) = I(T) + b(T)$:

$$W_u = Q \cdot (I(T) + b(T)) \tag{3.39}$$

Expected wealth includes the expected basis:

$$\mathbb{E}[W_u] = Q \cdot (F(t,T) + \mu_b) \tag{3.40}$$

Variance includes both index and basis risk, accounting for correlation:

$$\text{Var}[W_u] = Q^2 \cdot (V_I + V_b + 2\rho\sqrt{V_I V_b}) \tag{3.41}$$

The certainty equivalent is:

$$\text{CE}_u = Q \cdot (F(t,T) + \mu_b) - \frac{\gamma}{2} Q^2 \cdot (V_I + V_b + 2\rho\sqrt{V_I V_b}) \tag{3.42}$$

Unlike the illustrative case, where variance arises solely from $P(T)$, basis risk adds unhedgeable local price volatility. If non-zero, μ_b shifts expected wealth (higher if positive, lower if negative). A negative correlation ($\rho < 0$) may reduce variance below $V_I + V_b$, making this strategy less risky than under independence, but it remains exposed to both index and basis fluctuations, and perhaps less appealing than in the simplified scenario.

3.5.2 Subsidized Insurance (i)

The producer purchases subsidized insurance written on the index, guaranteeing a minimum price, but paying premium $\theta = \pi_{\text{fair}} - s$ and transaction cost τ:

$$W_i = Q \cdot (\max(I(T), P(t)) + b(T) - \theta - \tau) \tag{3.43}$$

Expected wealth accounts for transaction costs and the expected basis:[13]

$$\mathbb{E}[W_i] = Q \cdot (F(t,T) + s - \tau + \mu_b) \tag{3.44}$$

Variance includes basis risk, accounting for correlation:[14]

$$\text{Var}[W_i] = Q^2 \cdot (\kappa V_I + V_b + 2\rho\sqrt{\kappa V_I V_b}) \tag{3.45}$$

The certainty equivalent is:

$$\text{CE}_i = Q \cdot (F(t,T) + s - \tau + \mu_b) - \frac{\gamma}{2} Q^2 \cdot (\kappa V_I + V_b + 2\rho\sqrt{\kappa V_I V_b}) \tag{3.46}$$

Compared to the illustrative case, transaction costs reduce expected wealth and basis risk increases wealth variance, but the subsidized floor on $I(T)$ lowers index-related risk. If non-zero, μ_b adjusts expected wealth (higher if positive, lower if negative), and a negative ρ may reduce variance, making this strategy attractive if the subsidy outweighs costs and basis variance is low.

3.5.3 Market Put Option (p)

The producer buys a market put option on the index at the fair premium $\phi = \pi_{\text{fair}}$, incurring transaction cost τ:

$$W_p = Q \cdot (\max(I(T), P(t)) + b(T) - \pi_{\text{fair}} - \tau) \tag{3.47}$$

Expected wealth is:

$$\mathbb{E}[W_p] = Q \cdot (F(t,T) - \tau + \mu_b) \tag{3.48}$$

[13] As in the illustrative case, $\mathbb{E}[\max(I(T), P(t))] = F(t,T) + \delta\sigma_T$, and $\theta = \delta\sigma_T - s$, but τ reduces wealth and μ_b adds to the expected basis.

[14] This assumes correlation applies proportionally to censored variance, an approximation.

Variance matches the insurance strategy:

$$\mathrm{Var}[W_p] = Q^2 \cdot (\kappa V_I + V_b + 2\rho\sqrt{\kappa V_I V_b}) \tag{3.49}$$

The certainty equivalent is:

$$\mathrm{CE}_p = Q \cdot (F(t,T) - \tau + \mu_b) - \frac{\gamma}{2} Q^2 \cdot (\kappa V_I + V_b + 2\rho\sqrt{\kappa V_I V_b}) \tag{3.50}$$

Relative to the illustrative case, transaction costs lower wealth, and basis risk increases variance. The market put provides the same index floor as insurance but without the subsidy, making it less attractive unless insurance is unavailable. The basis μ_b adjusts expected wealth, and a negative ρ may reduce its variance.

3.5.4 Clean Subsidy Harvest (h_c)

The clean subsidy harvest combines the long spot position, subsidized insurance, and a short call option to lock in the index price:

$$W_{h_c} = Q \cdot \big(F(t,T) + b(T) + s - 2\tau - m_{\text{call}} \cdot (e^{r\Delta t} - 1)\big) \tag{3.51}$$

Expected wealth reflects frictions and the expected basis:

$$\mathbb{E}[W_{h_c}] = Q \cdot \big(F(t,T) + s - 2\tau - m_{\text{call}} \cdot (e^{r\Delta t} - 1) + \mu_b\big) \tag{3.52}$$

Variance arises only from basis risk:

$$\mathrm{Var}[W_{h_c}] = Q^2 V_b \tag{3.53}$$

The certainty equivalent is:

$$\mathrm{CE}_{h_c} = Q \cdot \big(F(t,T) + s - 2\tau - m_{\text{call}} \cdot (e^{r\Delta t} - 1) + \mu_b\big) - \frac{\gamma}{2} Q^2 V_b \tag{3.54}$$

Unlike the illustrative case's zero variance, basis risk introduces unhedgeable volatility, and transaction and margin costs erode wealth. The basis μ_b adjusts expected wealth, but basis variance remains the only risk, making this strategy appealing for risk-averse producers if costs are low.

3.5.5 Dirty Subsidy Harvest (h_d)

The dirty subsidy harvest pairs the long spot position with subsidized insurance and a short put option, canceling downside protection:

$$W_{h_d} = Q \cdot \left(I(T) + b(T) + s - 2\tau - m_{\text{put}} \cdot (e^{r\Delta t} - 1)\right) \tag{3.55}$$

Expected wealth is:

$$\mathbb{E}[W_{h_d}] = Q \cdot \left(F(t,T) + s - 2\tau - m_{\text{put}} \cdot (e^{r\Delta t} - 1) + \mu_b\right) \tag{3.56}$$

Variance includes both index and basis risk:

$$\text{Var}[W_{h_d}] = Q^2 \cdot (V_I + V_b + 2\rho\sqrt{V_I V_b}) \tag{3.57}$$

The certainty equivalent is:

$$\text{CE}_{h_d} = Q \cdot \left(F(t,T) + s - 2\tau - m_{\text{put}} \cdot (e^{r\Delta t} - 1) + \mu_b\right) - \frac{\gamma}{2} Q^2 \cdot (V_I + V_b + 2\rho\sqrt{V_I V_b}) \tag{3.58}$$

Compared to the illustrative case, frictions reduce wealth, and basis risk amplifies variance, aligning this strategy's risk profile with unhedged. The basis μ_b adjusts expected wealth, but full exposure to $V_I + V_b + 2\rho\sqrt{V_I V_b}$ makes it less attractive for risk-averse producers when costs are significant (unless $\rho < 0$).

3.6 Comparing Strategies under Relaxed Assumptions

Real-world frictions—basis risk, transaction costs, and margin requirements—alter the trade-offs among strategies compared to the illustrative case. Basis risk introduces unhedgeable local price volatility, transaction costs erode expected wealth, and margin costs penalize strategies involving option writing. "Locking in" a price means fixing wealth with respect to the index price $I(T)$, leaving only basis risk, while exposure to $I(T)$ offers potential upside but also downside risk. We compare certainty equivalents to determine the optimal strategy for a risk-averse producer, maintaining the comparison order from the illustrative case but explaining why dominance relationships differ due to frictions. As in the illustrative case, dominated strategies (unhedged and market put) are excluded from subsequent comparisons after establishing their dominance. As in the restrictive case, our relaxed model indicates that a rational producer chooses among the insured and subsidy harvest strategies according to his risk tolerance and wealth objectives.

Strategy	**Exposure at T**	**Wealth at T**	**Var**(W_T)	**Key Features**
Unhedged (u)	Full: $I(T)+b(T)$	$Q\cdot(I(T)+b(T))$	$Q^2(V_I+V_b+2\rho\sqrt{V_IV_b})$	No costs; max risk.
Subsidized Insurance (i)	$I(T)$ upside + $b(T)$	$Q\cdot(\max(I(T),P(t))+b(T)-\theta-\tau)$	$Q^2(\kappa V_I+V_b+2\rho\sqrt{\kappa V_IV_b})$	Subsidized index floor; basis unhedged.
Market Put (p)	$I(T)$ upside + $b(T)$	$Q\cdot(\max(I(T),P(t))+b(T)-\pi_{\text{fair}}-\tau)$	$Q^2(\kappa V_I+V_b+2\rho\sqrt{\kappa V_IV_b})$	Works like insurance but faces a higher cost.
Clean Subsidy Harvest (h_c)	Basis only: $b(T)$	$Q\cdot(F(t,T)+b(T)+s-2\tau-m_{\text{call}}(e^{r\Delta t}-1))$	Q^2V_b	Locks $F(t,T)$ + subsidy; basis & frictions remain.
Dirty Subsidy Harvest (h_d)	Full: $I(T)+b(T)$	$Q\cdot(I(T)+b(T)+s-2\tau-m_{\text{put}}(e^{r\Delta t}-1))$	$Q^2(V_I+V_b+2\rho\sqrt{V_IV_b})$	Subsidy harvest; full risk + costs.

Table 3: Summary of strategies under relaxed assumptions.

3.6.1 Dirty Subsidy Harvest (h_d) versus Unhedged (u)

The wealth difference includes frictions:

$$\mathbb{E}[W_{h_d}]-\mathbb{E}[W_u]=Q\cdot(s-2\tau-m_{\text{put}}(e^{r\Delta t}-1)) \tag{3.59}$$

This is positive as long as the subsidy exceeds costs ($s>2\tau+m_{\text{put}}(e^{r\Delta t}-1)$). Since variances are equal ($\text{Var}[W_{h_d}]=\text{Var}[W_u]=Q^2(V_I+V_b+2\rho\sqrt{V_IV_b})$), the certainty equivalent difference matches the wealth difference:

$$\text{CE}_{h_d}-\text{CE}_u=Q\cdot(s-2\tau-m_{\text{put}}(e^{r\Delta t}-1)) \tag{3.60}$$

Unlike the illustrative case, where the dirty subsidy harvest always dominated unhedged due to the cost-free subsidy ($\text{CE}_{h_d}>\text{CE}_u$ by $Q\cdot s$), transaction and margin costs could conceivably offset it, making dominance conditional on the net subsidy being positive. The basis affects μ_b both strategies equally, as both sell at $P(T)$, so it does not affect the dominance relationship. When dominance holds, rational producers would always choose the dirty subsidy harvest for its net wealth gain.

3.6.2 Subsidized Insurance (i) versus Market Put (p)

The wealth difference reflects the subsidy:

$$\mathbb{E}[W_i]-\mathbb{E}[W_p]=Q\cdot s \tag{3.61}$$

Since variances are equal ($\text{Var}[W_i]=\text{Var}[W_p]=Q^2(\kappa V_I+V_b+2\rho\sqrt{\kappa V_IV_b})$), the certainty equivalent difference is:

$$\text{CE}_i-\text{CE}_p=Q\cdot s \tag{3.62}$$

Since $s>0$, subsidized insurance dominates, consistent with the illustrative case. The dominance holds because both strategies incur the same transaction cost τ, and the subsidy provides a net wealth advantage without altering risk. Basis μ_b and its correlation to index price risk ρ affect both strategies equally. As a result the market put is dominated and excluded from further comparisons.

3.6.3 Subsidized Insurance (i) versus Clean Subsidy Harvest (h_c)

The clean subsidy harvest incurs additional costs:

$$\mathbb{E}[W_{h_c}] - \mathbb{E}[W_i] = Q \cdot (-\tau - m_{\text{call}}(e^{r\Delta t} - 1)) \tag{3.63}$$

On the other hand, its variance is lower:

$$\text{Var}[W_{h_c}] = Q^2 V_b < Q^2(\kappa V_I + V_b + 2\rho\sqrt{\kappa V_I V_b}) = \text{Var}[W_i] \tag{3.64}$$

The certainty equivalent difference is:

$$\text{CE}_{h_c} - \text{CE}_i = Q(-\tau - m_{\text{call}}(e^{r\Delta t} - 1)) + \frac{\gamma}{2} Q^2(\kappa V_I + 2\rho\sqrt{\kappa V_I V_b}) \tag{3.65}$$

Unlike the illustrative case, where the clean subsidy harvest always dominated due to its deterministic nature, basis risk (V_b) and costs (τ, m_{call}) make this a closer comparison. Basis μ_b shifts expected wealth for both equally, but its correlation to the index ρ does not affect the clean subsidy harvest's variance, which depends only on V_b. The cost difference favors insurance, but the variance is lower for the clean subsidy harvest. Therefore, highly risk-averse producers (large γ) or high index volatility (V_I) makes the clean subsidy harvest more attractive; it locks in $F(t,T) + s$ net of frictions. Instead, if transaction and margin costs are high and/or risk aversion is low, subsidized insurance may be preferred, especially if $\rho < 0$.

3.6.4 Subsidized Insurance (i) versus Dirty Subsidy Harvest (h_d)

The subsidy harvest again faces additional costs:

$$\mathbb{E}[W_{h_d}] - \mathbb{E}[W_i] = Q \cdot (-\tau - m_{\text{put}}(e^{r\Delta t} - 1)) \tag{3.66}$$

It likely also suffers from more wealth variance:

$$\text{Var}[W_{h_d}] = Q^2(V_I + V_b + 2\rho\sqrt{V_I V_b}) > Q^2(\kappa V_I + V_b + 2\rho\sqrt{\kappa V_I V_b}) = \text{Var}[W_i] \tag{3.67}$$

The certainty equivalent difference is:

$$\mathrm{CE}_{h_d} - \mathrm{CE}_i = Q(-\tau - m_{\text{put}}(e^{r\Delta t} - 1)) - \frac{\gamma}{2}Q^2[(1-\kappa)V_I + 2\rho\sqrt{V_I V_b}(1-\sqrt{\kappa})] \tag{3.68}$$

Both terms are typically negative (since ρ is likely small), and subsidized insurance dominates for risk-averse producers. Unlike the illustrative case, where insurance dominated due to lower variance alone, frictions here further penalize the dirty subsidy harvest's higher variance and added costs. The basis μ_b wealth difference affects both equally, and a negative ρ reduces variance for both, but insurance benefits more from the censored index variance (κV_I).

3.6.5 Clean Subsidy Harvest (h_c) versus Dirty Subsidy Harvest (h_d)

The wealth difference depends on margin costs, but the difference is likely to be quite small if requirements are similar:

$$\mathbb{E}[W_{h_c}] - \mathbb{E}[W_{h_d}] = Q \cdot (m_{\text{put}}(e^{r\Delta t} - 1) - m_{\text{call}}(e^{r\Delta t} - 1)) \tag{3.69}$$

The clean subsidy harvest variance is lower:

$$\mathrm{Var}[W_{h_c}] = Q^2 V_b < Q^2(V_I + V_b + 2\rho\sqrt{V_I V_b}) = \mathrm{Var}[W_{h_d}] \tag{3.70}$$

The certainty equivalent difference is:

$$\mathrm{CE}_{h_c} - \mathrm{CE}_{h_d} = Q(m_{\text{put}}(e^{r\Delta t} - 1) - m_{\text{call}}(e^{r\Delta t} - 1)) + \frac{\gamma}{2}Q^2(V_I + 2\rho\sqrt{V_I V_b}) \tag{3.71}$$

The variance term is positive (assuming $\rho > -1$), favoring the clean subsidy harvest for risk-averse producers. Unlike the illustrative case's clear dominance, basis risk and costs act to narrow the gap. Still, the clean subsidy harvest's elimination of index (underlying asset) risk makes it preferable when basis variance is low.

3.7 Testable Hypotheses

Our model predicts that insurance subsidies can alter producer risk management behavior. With the subsidy, producers choose between LRP alone and two different types of subsidy harvests. Yet, as we explain below, its effect on derivatives market trading activity is an empirical question.[15]

[15] Indeed, the LRP may differ across livestock commodities due to structural factors, like vertical integration in swine, which could affect producer incentives in risk management.

3.7.1 Crowding Out: Overall Options Open Interest

Higher subsidy levels might crowd out the use of commodity options, if risk-averse producers substitute them with insurance:

$$\mathrm{CE}_i - \mathrm{CE}_p = Q \cdot s > 0 \tag{3.72}$$

On the other hand, the effect may be tempered if the AIPs who write policies with producers, or the reinsurers they transact with, lay off their own LRP risk in options markets. We test the effect of subsidies on overall options trading activity by matching options open interest (OI) fluctuations to rises in LRP takeup.

3.7.2 Dirty Subsidy Harvesting Increases Short Put (Bullish) Options Trading by Producers

To capture s, dirty subsidy harvesting requires producers to write put options. Higher s amplifies arbitrage attractiveness, tempered by costs (τ, m_{put}). As a result, we compare producers' short put, or bullish, option OI levels with LRP insurance activity.

3.7.3 Clean Subsidy Harvesting Increases Short Call (Bearish) Options Trading by Producers

Likewise, clean subsidy harvesting requires producers to write call options, along with purchasing an LRP insurance plan. The effect is expected to be stronger with larger s, but costs (τ, m_{call}) may deter writing. To search for evidence of potential clean subsidy harvesting, we compare producers' short call options, or bearish, OI levels with policy takeup.

4 Data and Empirical Approach

4.1 Data

We draw daily, public LRP policy data from the Risk Management Agency, including for each policy the type of animals insured, the dates it covered, its subsidy, indemnity level, the premia paid, and number of covered head. Policies are available at daily frequency. We use ten years of data, from January 2015 - December 2024, and define subsidy regimes according to established changes in statute and subsidy rates (Glauber, 2022; Boyer and Griffith, 2023a): January 2015-January 2018 (regime 1, before the subsidy cap was removed), February 2018-July 2019 (regime 2), July 2019-June 2020 (regime 3), and July 2020 on (regime 1). Figure 4 aggregates the number of active LRP policies each day, by commodity; figure 5 sums the subsidies paid to the holders of those policies. Clearly, producer interest in LRP spiked in regime 4. While feeder cattle dominate in terms of the number of policies, the subsidy paid to producers is about equal between feeder cattle and swine, while fed cattle take up a smaller but still substantial share.

For options positions, we rely on the Commodity Futures Trading Commission's (CFTC) weekly Commitment of Traders (COT) reports for open interest in derivatives markets as of the close of trading each Tuesday. CFTC disaggregates both long and short positions using five different trader classifications: (i) producer/merchant/processor/user, (ii) swap dealers, (iii) managed money, (iv) other reportables, and (v) non-reporting traders. (Positions held by traders in the last group do not rise to the levels required for individual reporting to the exchange.) The commission publishes two versions of the COT: Disaggregated Futures-and-Options-Combined and Disaggregated Futures Only. By differencing the positions in these reports, we isolate the long and short options positions held by different trader groups.[16] Somewhat confusingly, long and short options positions in the COT do not identify whether the holder purchased or wrote an option, though. Rather, COT long options positions represent those whose value rises with a rise in the value of the underlying futures contract—that is, those that are bullish. Long call options and short put options fit into this category. On the other hand, bearish options positions, including long put positions and short call positions, are classified as short options in the COT.

We include nearby futures prices for each livestock contract in the analysis, in order to control for delta adjustment effects, which can if uncontrolled appear to raise or lower the CFTC OI positions as prices change; we source them from the Chicago Mercantile Exchange (CME).

[16] Note that the COT's options positions are delta-adjusted into their futures equivalent positions. Because an option mimics the behavior of a futures contracts, its delta value—which represents the way its price is affected by changes in the price of the underlying security—is used to make the adjustment.

Figure 4: Active LRP Policies by Livestock Commodity, 2015-2024

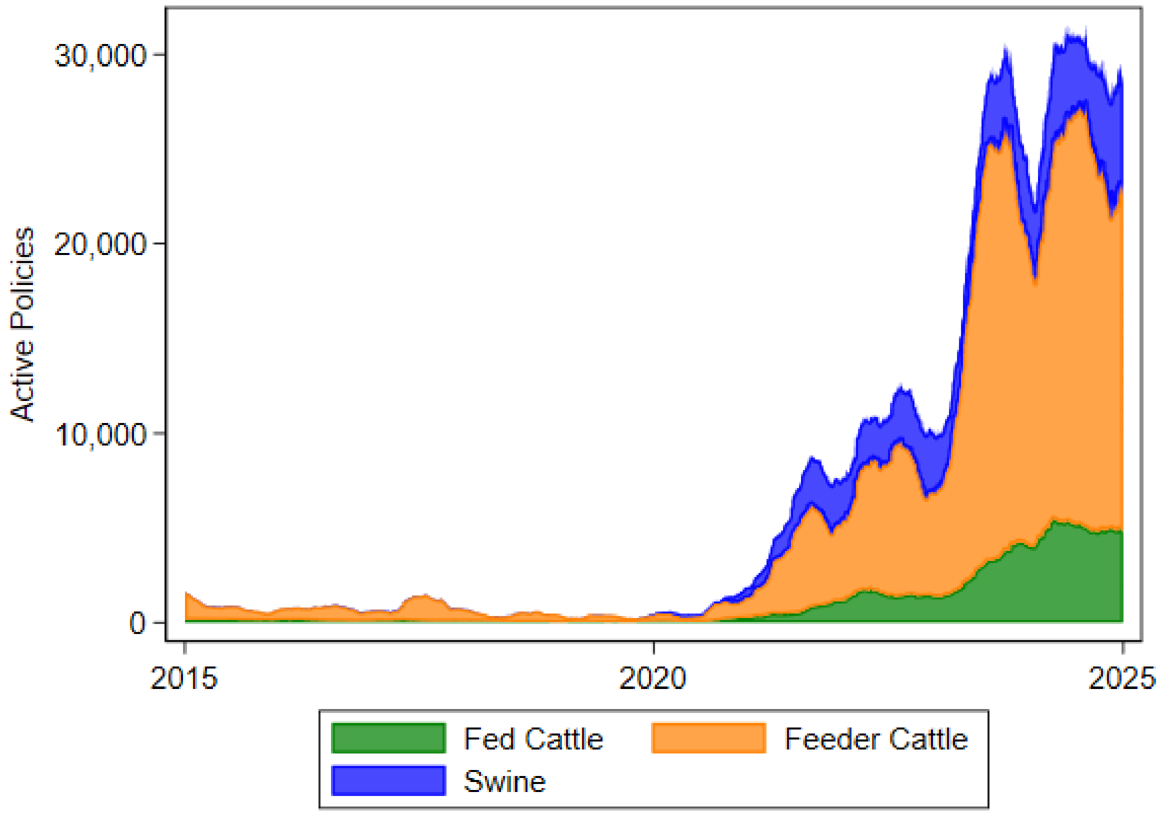
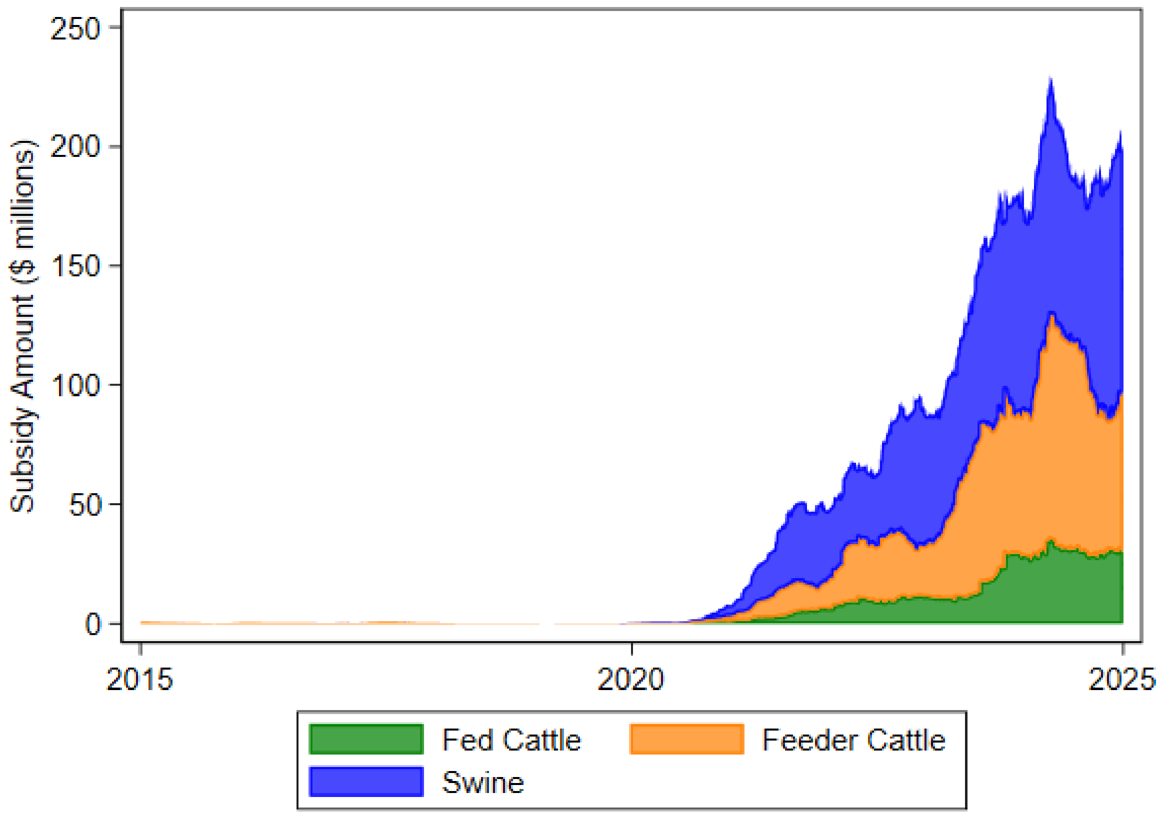


Figure 5: LRP Subsidies by Livestock Commodity, 2015-2024



4.2 Empirical Approach

Our objective is to understand the causal relationship of LRP policy takeup on derivatives trading: it offers insight into whether policy crowds in or out options markets, and helps establish the extent and magnitude of any arbitrage that may take place. A significant challenge we face is that many of the same forces that encourage LRP policy takeup—like market uncertainty as well as rising feed and other input costs—similarly drive producers to trade derivatives. Our identification strategy relies on two facts: (1) the LRP subsidy schedule is exogenous to the market, and (2) arbitrage requires concurrent increases in options open interest and LRP policies. We therefore devise an instrument based on the legislation-set subsidy schedule, and use it to isolate the portion of LRP takeup that is exogenous to market conditions. Specifically, we construct a subsidy generosity index G_t using historical LRP subsidy rates.[17] Using a two-stage least squares (2SLS) framework,[18] we first regress new insured hundredweight under LRP each week on the generosity index (as well as a set of controls that improve analytical precision), to isolate subsidy-induced LRP activity. In a second stage, we regress derivatives market open interest on the generosity-index predicted new LRP-insured hundredweight.

Because everything is in logs, this procedure generates elasticities of derivatives market open interest (both general and trader-specific) to LRP takeup. The instrument is relevant since LRP takeup should rise in theory with subsidy generosity—that is precisely what policy makers intended—and it is exogenous since premium subsidies themselves have no direct effect on market open interest. On the other hand, subsidy generosity satisfies the exclusion restriction since it could only affect open interest indirectly through LRP takeup.

To provide a baseline for comparison and to illustrate the endogeneity bias we seek to address, we begin with ordinary least squares (OLS) regressions before moving to the IV framework. All models are estimated separately for each commodity i (fed cattle, feeder cattle, and swine) using weekly, national data from 2015 onward, aggregated across public county-level LRP policy records and matched to Commodity Futures Trading Commission (CFTC) open interest reports. Under OLS open interest for commodity i in week t (suppressing an index for trader type j, which we use to model trader-specific

[17]Recall that LRP subsidy rate was 13% of the total premium cost until July, 2019, raised to 20% until July, 2020, and then set according to a tiered rate structure (35% for a coverage level between 95%-100%; 40% for a coverage level from 90%-95%; 45% for a coverage level between 85%-90%; 50% for a coverage level between 80%-85%; and 55% for a coverage level between 70% and 80%). For the last period we use the simple average of the premium subsidy coverage across tiers, so as not to introduce endogeneity in the form of selection on the part of producers.

[18]In case of weak instruments we use limited information maximum likelihood (LIML) to estimate the model.

positions) is specified as a function of:

$$\ln(OI_{i,t,j}) = \alpha_i + \beta_i \ln(W_{i,t}) + \varepsilon_{i,t} \tag{4.1}$$

where $\ln(OI_{i,t})$ is the natural log of open interest (plus one) for commodity i at week t and trader type j; $\ln(W_{i,t})$ is the natural log of new insured hundredweight (cwt) under LRP for commodity i in week t (plus one, capturing the weekly flow of new policies); α_i is a commodity-specific intercept; and $\varepsilon_{i,t}$ is the error term. The model in equation 4.1 provides a naive estimate of β_i: the elasticity of open interest to LRP takeup, although it is likely biased upward due to omitted variables that drive both $W_{i,t}$ and $OI_{i,t,j}$) or reverse causality (e.g., producers hedging in derivatives markets simultaneously with LRP purchases).

To mitigate bias, we enhance the OLS model with suitable controls:

$$\ln(OI_{i,t}) = \alpha_i + \beta_i \ln(W_{i,t}) + \gamma_i' X_{i,t} + \delta_i t + \eta_i t^2 + u_{i,t} \tag{4.2}$$

where $X_{i,t}$ is a vector of time-varying controls including the futures price for commodity i, the VIX index (as a proxy for marketwide uncertainty), the 3-month Treasury bill rate, feed costs (corn and soybeans), the 30-day constant maturity implied volatility of feed costs and the livestock commodity i, and first differences of each of these; t and t^2 are linear and quadratic time trends to capture secular changes in market participation; and $u_{i,t}$ is the error term. This specification is meant to absorb confounders that might spuriously correlate takeup with open interest. However, it may still fail to fully address confounding and omitted variable bias.

To obtain causal estimates of the true impact of the LRP program on derivatives markets, we instrument the hundredweight livestock insured through LRP that week $\ln(W_{i,t})$ with the subsidy generosity index G_t and its square G_t^2 (to capture potential nonlinear effects in the response to subsidy changes; these tend to produce much better first-stage fits given the rapid observed takeup after 2020's subsidy changes). The first stage isolates subsidy-induced takeup:

$$\ln(W_{i,t}) = \alpha_i + \pi_{1,i} G_t + \pi_{2,i} G_t^2 + \theta_i' X_{i,t} + \lambda_{1,i} t + \lambda_{2,i} t^2 + v_{i,t} \tag{4.3}$$

where the π coefficients capture the relevance of the instruments on LRP hundredweight, and the controls and trends are included for efficiency. We estimate 4.3 using Newey-West standard errors with a Bartlett kernel and bandwidth of 12 weeks to account for heteroskedasticity and autocorrelation (HAC). Predicted values $\widehat{\ln(W_{i,t})}$ based on 4.3 represent the exogenous, subsidy-driven component of

LRP takeup driven for commodity i.

In the second stage, we substitute the instrumented takeup:

$$\ln(OI_{i,t,j}) = \alpha_i + \beta_i \widehat{\ln(W_{i,t})} + \gamma_i' X_{i,t} + \delta_i t + \eta_i t^2 + \varepsilon_{i,t} \tag{4.4}$$

and estimate the model via 2SLS (or LIML) with the same HAC adjustments. The parameter of interest, β_i, is the elasticity of options market open interest to livestock hundredweight induced into LRP by subsidy changes. We run 4.4 for total OI and trader-specific positions to disentangle crowding in from crowding out, and also to better understand trader-specific sentiment-oriented trading behavior. Because CFTC trader-type open interest is delta-adjusted, all elasticity regressions include both the level and first difference of the corresponding futures price so that identified variation reflects trading behavior rather than mechanical, moneyness-dependent revaluation.

We run several diagnostics to validate our IV. First, for instrument strength we include the Kleibergen-Paap (KP) rank Wald F-statistic from the first stage. Values above 10 indicate strong instruments, ruling out substantial weak IV bias; for values below 10, we prefer LIML, which is less biased in finite samples with weak instruments. We also report the Cragg-Donald F-statistic as a robustness check, alongside Stock-Yogo weak identification test critical values. Second, to guard against overidentification (given that we use two instruments to predict a single endogenous regressor), we use the Sargan-Hansen J-statistic, testing the null that excluded instruments are valid and uncorrelated with $\varepsilon_{i,t}$. Finally, we report R-squared measures for overall fit, in order to to assess explanatory power.

4.2.1 Estimating Subsidy Capture

To estimate the portion of Livestock Risk Protection (LRP) subsidies that may be captured through arbitrage, we combine the IV-estimated elasticities with the predicted, subsidy-induced flows of new insured hundredweight from the first stage of our analysis. Let $\widehat{W}_{i,t}^{IV}$ denote the LRP weight (in cwt) for commodity i that is exogenously induced through the subsidy generosity schedule, as isolated by equation 4.3, while $\beta_{i,j}$ is the IV elasticity of open interest held by trader type j with respect to $\ln(W_{i,t})$, estimated in equation 4.4.

For each commodity–trader pair, we restrict attention to statistically significant positive elasticities, since arbitrage can only occur with *increases* in open interest and new insured hundredweight:[19]

$$\beta^{+}_{i,j} = \begin{cases} \beta_{i,j}, & \text{if } \beta_{i,j} > 0 \text{ and } p_{i,j} \leq 0.10, \\ 0, & \text{otherwise.} \end{cases}$$

Each elasticity $\beta^{+}_{i,j}$ is then applied to the predicted, subsidy-induced change in insured weight to obtain the implied increase in open interest attributable to the policy shock:

$$\widehat{\Delta OI}_{i,t,j} = \beta^{+}_{i,j} \cdot OI^{\text{base}}_{i,j} \cdot \widehat{\Delta \ln W}^{IV}_{i,t}, \tag{4.5}$$

where $OI^{\text{base}}_{i,j}$ is the representative level of open interest for trader type j, measured during a pre-policy baseline period.[20] The resulting $\widehat{\Delta OI}_{i,t,j}$ represents the change in derivatives positions, in hundredweight, causally attributable to subsidy-induced LRP participation.

Because arbitrage cannot exceed the amount of new insured weight created by the subsidy, these predicted responses are bounded by the subsidy-induced flow of insured weight:

$$\widehat{\Delta W}^{cap}_{i,t,j} = \min\left\{\max(\widehat{\Delta OI}_{i,t,j}, 0), \widehat{W}^{IV}_{i,t}\right\}. \tag{4.6}$$

Equation 4.6 thus defines the feasibly arbitraged share of new LRP hundredweight in week t for commodity i, constrained by the policy-induced supply of insurance coverage.

To express harvested subsidies in dollar terms, we estimate the share of weekly subsidy outlays associated with arbitraged weight, assuming a uniform subsidy-per-cwt rate within each week:

$$\widehat{S}^{cap}_{i,t,j} = \frac{\widehat{\Delta W}^{cap}_{i,t,j}}{W^{new}_{i,t}} \cdot S_{i,t}, \tag{4.7}$$

where $S_{i,t}$ is the total LRP premium subsidy attached that week to newly issued policies. As a result, $\widehat{S}^{cap}_{i,t,j}$ represents the dollar value estimate of subsidies potentially harvested through simultaneous increases in insured hundredweight and derivatives open interest.

We sum captured dollars across trader types and sentiment (bullish and bearish) to obtain total

[19] Although negative elasticities may indicate crowding out, they cannot contribute to subsidy harvesting, since they do not link LRP take-up with a subsidy-induced expansion in derivatives trading.

[20] In our implementation, $OI^{\text{base}}_{i,j}$ is calculated as the mean open interest for each trader and options sentiment pair over the first six months of 2018, just as the statutory cap on LRP subsides was removed by the Bipartisan Budget Act.

weekly captured subsidies:

$$\widehat{S}_{i,t}^{cap} = \sum_j \widehat{S}_{i,t,j}^{cap}.$$

Finally, aggregating over time and commodities yields the cumulative subsidy capture rate:

$$\text{Capture Share} = \frac{\sum_{i,t} \widehat{S}_{i,t}^{cap}}{\sum_{i,t} S_{i,t}}, \tag{4.8}$$

interpreted as the share of total LRP subsidies that were plausibly absorbed through arbitrage behavior in derivatives markets. Finally, we generate confidence intervals for $\widehat{S}_{i,t,j}^{cap}$ by propagating the standard errors of $\beta_{i,j}$ through equations 4.5–4.7, and then scaling them into dollar terms.

4.2.2 Limitations

Our approach isolates the exogenous, subsidy-driven component of LRP takeup, yet several limitations remain. First, the CFTC's trader classifications aggregate heterogeneous market participants. The "producer, merchant, processor, user" category includes producers as well as commercial firms whose positions may not be motivated by LRP-related hedging. As long as these firms' trading is uncorrelated with producers' LRP activity, their inclusion primarily introduces measurement error, which would attenuate our estimated elasticities toward zero. But if their trading covaries with producers' exposure, it could bias our results in unknown directions. CFTC position-reporting thresholds mean that smaller producers appear instead in the "non-reporting" category; we include this group as well because it likely captures a substantial share of producers' smaller trades.

Second, while LRP contracts can be traced to the county level, only one options market trades domestically for each livestock commodity in our study, and CFTC reports positions once per week. As a result we must aggregate LRP takeup nationally and weekly, which limits our ability to detect regional heterogeneity in producer response or within-week timing differences. In addition, open-interest data distinguish only between net bullish and bearish options positions. We cannot use CFTC's data to observe whether traders are buying or writing calls versus puts, nor can we link these directly to offsetting futures or spot positions. Consequently, our estimates of captured subsidies may be confounded by systematic hedging or portfolio adjustments that occurred at the same time as LRP takeup expended. Finally, since LRP policies cannot be matched to options market positions held by a given producer we must spread new subsidies over all new LRP policies to estimate subsidy capture. It may instead be that subsidy harvesters target policies with richer per-covered dollar subsidy rates, which may bias downward our arbitrage estimates. Nonetheless, our model provides transparent, elasticity-based estimates of the magnitude of subsidy-linked movements in derivatives markets and establishes a defensible estimate of subsidy capture consistent with observed trader behavior.

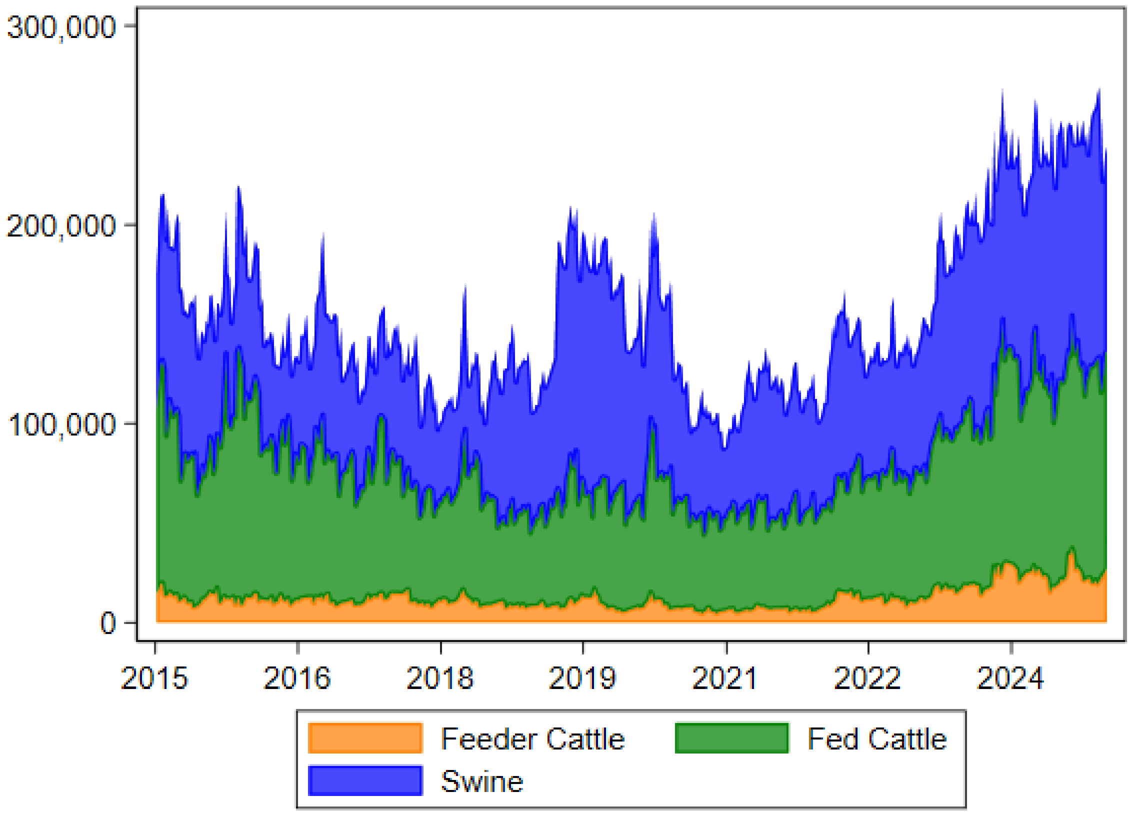
5 Results

5.1 Trends in Livestock Options Open Interest

According to our theoretical framework, if producers substitute subsidized LRP for market put options, overall OI might decline. Conversely, subsidy harvesting—either clean (short calls) or dirty (short puts)—could increase OI by prompting additional option writing activity. Figure 6 displays the weekly OI in livestock options contracts for fed cattle, feeder cattle, and swine from 2015 through the end of 2024. The chart stacks OI by commodity, so the top level represents the sum across all commodities. The figure reveals clear patterns in market activity over time. Prior to 2019, total options OI across all three commodities remained relatively stable. Fed cattle (green) and swine (blue) accounted for most of the OI, while feeder cattle (orange) displayed much less activity.

Beginning in late 2019, around the time of subsidy boost following the 2018 Farm Bill, OI began to rise noticeably—especially in swine. The upward trend is even more noticeable just after subsidy schedule increases in July 2020; recall the sharp subsidy increases paid on active policies observed in figure 5. Livestock options trading increases in every market. By the end of 2024, total options OI was nearly three times larger than it was at the beginning of 2021. This descriptive evidence admits a possible link between LRP subsidy expansions and heightened activity in the corresponding options markets, raising the question of whether subsidies affected options trading through crowding in. Although, the OI data alone do not distinguish between mechanisms or trader types.

Figure 6: Weekly Options Open Interest by Livestock Commodity, 2015-2024



5.2 Subsidy Effects on Overall Options Open Interest

Table 4 presents the elasticity relationships we measure between LRP subsidies for a given type of livestock and open interest in the relevant options market. We estimate three models per commodity: one that regresses OI on new LRP takeup alone, one that adds controls, and another that exploits the government-set subsidy generosity schedule as an instrument. The first two results for each commodity represent the correlation between OI activity and LRP takeup. Adding our suite of controls—levels and changes in livestock and feed futures prices, their implied volatility, the VIX and the tbill rate. Including the livestock price change—is important since (1) CFTC options position data are delta-adjusted, so they shift with the change in underlying futures prices, and (2) marketwide and agriculture-specific uncertainty and fundamentals can independently lead to LRP takeup and options trading. We interpret the IV result causally, as the expected percent increase in an options market's overall open interest resulting from a one percent increase in the new livestock weight insured through LRP in a given week.

Table 4: Elasticity of Options market Open Interest to LRP Takeup

	Fed Cattle	*Feeder Cattle*	*Swine*
OLS			
Log New LRP cwt	0.016***	0.053***	0.013***
p-value	0.000	0.000	0.000
OLS with Controls			
Log New LRP cwt	0.007**	0.010	−0.013***
p-value	0.004	0.103	0.000
Instrumental Variables with Controls			
Log New LRP cwt	0.014	0.023	−0.041**
p-value	0.164	0.430	0.016
Model	2SLS	2SLS	2SLS
First-stage KP LM statistic	42.303	27.192	30.067
p-value	0.000	0.000	0.000
KP Wald F statistic	67.492	25.118	28.918
Cragg–Donald Wald F	84.96	68.054	63.1
Stock–Yogo Weak ID test [10%]	19.93	19.93	19.93
Sargan/Hansen test	0.834	11.464	2.129
p-value	0.361	0.001	0.144
R^2	0.709	0.758	0.612
Observations	469	469	469

Notes: All regressions are estimated at the weekly frequency, and are estimated with heteroskedasticity- and autocorrelation-robust (HAC) standard errors using a Bartlett kernel with a bandwidth of 12 weeks. Controls include prices for livestock, corn, and soybeans as well as their first differences; implied volatilities for all those series and their differences, as well; the VIX, the tbill rate, their differences, and a time trend. IV specifications use the subsidy generosity schedule and its squared value as instruments. The table includes results for the preferred IV model—2SLS or LIML—depending on first stage fit. Significance levels: *p<0.10, **p<0.05, ***p<0.01.
Source: Authors' calculations based on USDA-RMA LRP policy microdata and CME options open-interest series.

If estimated without controls OLS elasticity values in table 4 are all positive and highly significant, indicating that options trading tends to increase with LRP takeup. This matches our intuition, since the same market forces that lead traders to options markets tend to lead producers to take up subsidized insurance. Adding controls soaks up a lot of that variation, however. Notice that the Feeder Cattle elasticity coefficient shifts from a strongly significant 0.053% to a much smaller 0.01%—and removes its statistical significance. For swine the elasticity even flips in sign, and is similarly significant. Only Fed Cattle remain positive and significant at an elasticity of 0.007%, after controls are added.

All IV results in the table are estimated via 2SLS. First-stage LM statistics strongly reject underidentification, and the KP and Craig-Donald Wald statistics are high (with the later exceeding the critical values proposed by Stock and Yogo)—indicating that no models face a problem of weak instruments. Model R-squared values are around 70% for each commodity, indicating a strong overall fit. Only the Feeder Cattle model has a potential issue with overidentification (we use two instruments against a single endogenous regressor of new LRP takeup). However, we preserve it to maintain consistency with models for the other commodities; its results do not depart from OLS w/controls in any case.

Our instrumental variables approach isolates the exogenous variation in LRP takeup associated with the subsidy generosity schedule alone, so it is not correlated with the market forces that cause LRP takeup and OI to move together. We therefore interpret its elasticities causally. None are both positive and significant: according to our analysis LRP subsidies *do not* themselves crowd in overall options trading. Rather, the reverse may be true for swine. A one percent rise in LRP-insured hogs reduces overall Lean Hogs options market OI by about 0.04%. In the context of our model, the findings in table 4 could indicate that LRP subsidies crowd out some derivatives trading, perhaps on the part of hog producers who now have the choice of a cheaper substitute to manage their price risk. However, it may instead be the case that these overall options results mask important heterogeneity among different types of options market participants. Many different types of traders operate in options markets, so the elasticity of LRP takeup on overall options OI mixes its potentially differential effects on producers, other supply chain participants, AIPs and reinsurance firms who write policies with producers, and even speculators. Trading behaviors by each of them are present in table 4 elasticities. Next, we focus more closely on producers in each market, and classify their positions by sentiment (bullish vs. bearish), to establish more evidence in support of potential subsidy harvesting.

5.3 Effect of LRP Takeup on Producer Positions in Livestock Options Markets

LRP is targeted at livestock producers, so we next estimate elasticities for the effect of LRP takeup on the options held by the CFTC's producer/merchant/processor/user ("producer") category in the COT data; the Commission's public options data are disaggregated into bullish (long calls or short puts) and bearish (long puts or short calls) positions. We also examine the effect of subsidies on the sentiment-oriented options positions held by non-reporting traders, since that category captures smaller producers whose outstanding derivatives portfolio falls below statutory reporting thresholds.

Once again, tables 5a- 5c (for Fed Cattle, Feeder Cattle, and Swine, respectively) present three sets of elasticities: one set estimated by OLS, another that adds controls, and a third estimated by IV that use the same instruments as the previous section. Recall that the OLS results are associative only, while we interpret the IV elasticities causally.

Without controls, the OLS elasticities reported in table 5a for Fed Cattle are positive and statistically significant for producer positions—both bearish and bullish. This indicates that, during periods of high LRP takeup, producer open interest in exchange-traded options tends to expand. The same underlying price risk that motivates hedging or speculative activity in options markets leads producers to turn to LRP for insurance. In contrast, the non-reporting trader elasticities in the table are small and statistically insignificant, implying that smaller participants below CFTC reporting thresholds behave differently. That is, until we introduce controls for prices, volatility, and interest rates. By absorbing a significant amount of co-movement between insurance demand and general market conditions, producer elasticities for Fed Cattle tend to decline in magnitude. This attenuation suggests that much of the unconditional association in the simple OLS specification reflects common responses to macro shocks rather than actual subsidy harvesting.

The instrumental variables results in table 5a rely on exogenous shifts in the subsidy generosity schedule to isolate the component of LRP takeup unrelated to contemporaneous market fundamentals. Diagnostic statistics confirm strong first stages: Kleibergen–Paap LM tests reject underidentification, and both KP Wald and Cragg–Donald F-statistics exceed Stock–Yogo thresholds. The resulting IV elasticities show that a one-percent increase in insured Fed Cattle weight causes approximately a 0.03% percent rise in producer-held bearish options open interest and a 0.04% rise in bullish options held by non-reporting traders, both highly significant. Although economically modest, these effects are statistically robust. Because they are causal, we interpret them to indicate the extra options OI in the market resulting from LRP takeup. They represent the amount plausibly arbitraged by producers. Other IV

Table 5a: Elasticity of Trader-Type Options Open Interest to LRP Takeup—Fed Cattle

	Producers Bearish	*Producers Bullish*	*Non-reporting Bearish*	*Non-reporting Bullish*
OLS				
Log New LRP Weight	0.047***	0.030***	0.001	−0.000
p-value	0.000	0.000	0.303	0.917
OLS with Controls				
Log New LRP Weight	0.016***	0.008	0.001	0.012***
p-value	0.000	0.169	0.529	0.001
Instrumental Variables with Controls				
Log New LRP Weight	0.030***	0.002	0.001	0.042***
p-value	0.001	0.952	0.894	0.008
Model	2SLS	2SLS	2SLS	2SLS
First-stage KP LM statistic	42.303	42.303	42.303	42.303
p-value	0.000	0.000	0.000	0.000
KP Wald F statistic	67.492	67.492	67.492	67.492
Cragg–Donald Wald F	84.96	84.96	84.96	84.96
Stock–Yogo Weak ID test [10%]	19.93	19.93	19.93	19.93
Sargan/Hansen test	0.951	2.450	7.409	2.231
p-value	0.330	0.118	0.006	0.135
R^2	0.840	0.487	0.566	0.328
Observations	469	469	469	469

Notes: All regressions are estimated at the weekly frequency, and are estimated with heteroskedasticity- and autocorrelation-robust (HAC) standard errors using a Bartlett kernel with a bandwidth of 12 weeks. Controls include prices for livestock, corn, and soybeans as well as their first differences; implied volatilities for all those series and their differences, as well; the VIX, the tbill rate, their differences, and a time trend. IV specifications use the subsidy generosity schedule and its squared value as instruments. The table includes results for the preferred IV model—2SLS or LIML—depending on first stage fit. Significance levels: *$p<0.10$, **$p<0.05$, ***$p<0.01$.
Source: Authors' calculations based on USDA-RMA LRP policy microdata and CME options open-interest series.

elasticities in the table are positive but not significant.

For Feeder Cattle (table 5b), the uncontrolled OLS coefficients are again positive and significant across nearly all trader types, but most of these associations vanish once controls are added—they account for much of the covariance in LRP takeup and options trading. The IV specification, however, recovers a positive and statistically significant elasticity of roughly 0.06% for non-reporting bearish positions——precisely the group likely to include smaller cow–calf producers whose trades fall below reporting thresholds. This finding suggests that subsidy-induced takeup among small cattle producers modestly increases their use of protective (bearish) option strategies, consistent with clean subsidy harvesting in our model. All other IV elasticities for Feeder Cattle are positive but statistically indistinguishable from zero, indicating that any arbitrage in the market is concentrated among smaller producers rather than larger firms.

Our Swine results in table 5c present a different pattern. OLS elasticities without controls tend to be

Table 5b: Elasticity of Trader-Type Options Open Interest to LRP Takeup—Feeder Cattle

	Producers Bearish	*Producers Bullish*	*Non-reporting Bearish*	*Non-reporting Bullish*
OLS				
Log New LRP Weight	0.079***	0.105***	0.006	0.043***
p-value	0.000	0.000	0.199	0.000
OLS with Controls				
Log New LRP Weight	−0.005	−0.001	0.021***	−0.006
p-value	0.665	0.943	0.000	0.507
Instrumental Variables with Controls				
Log New LRP Weight	0.027	0.064	0.057**	0.024
p-value	0.625	0.411	0.032	0.587
Model	2SLS	2SLS	2SLS	2SLS
First-stage KP LM statistic	27.192	27.192	27.192	27.192
p-value	0.000	0.000	0.000	0.000
KP Wald F statistic	25.118	25.118	25.118	25.118
Cragg–Donald Wald F	68.054	68.054	68.054	68.054
Stock–Yogo Weak ID test [10%]	19.93	19.93	19.93	19.93
Sargan/Hansen test	0.456	0.072	0.092	2.324
p-value	0.500	0.788	0.762	0.127
R^2	0.695	0.574	0.440	0.543
Observations	469	469	469	469

Notes: All regressions are estimated at the weekly frequency, and are estimated with heteroskedasticity- and autocorrelation-robust (HAC) standard errors using a Bartlett kernel with a bandwidth of 12 weeks. Controls include prices for livestock, corn, and soybeans as well as their first differences; implied volatilities for all those series and their differences, as well; the VIX, the tbill rate, their differences, and a time trend. IV specifications use the subsidy generosity schedule and its squared value as instruments. The table includes results for the preferred IV model—2SLS or LIML—depending on first stage fit. Significance levels: *p<0.10, **p<0.05, ***p<0.01.
Source: Authors' calculations based on USDA-RMA LRP policy microdata and CME options open-interest series.

positive and significant, but once market fundamentals are included, several flip signs. In the IV specification, only one elasticity—producer-held bullish OI——remains statistically significant at negative 0.04%. This indicates that as LRP takeup increases exogenously through subsidy generosity, swine producer use of bullish options tends to fall. This lack of positive and significant IV elasticities for Swine matches the overall OI findings in table 4: during the period analyzed, higher subsidy generosity did not crowd producers into additional options positions, but rather may have crowded them out.

Across commodities, several consistent patterns emerge. First, instruments tend to produce good first stage results, permitting robust causal inference on the linkages between LRP takeup and producer option activity. Second, we identify two statistically significant elasticities for bearish positions (long puts or short calls), consistent with clean subsidy-harvesting behavior that does not eliminate the risk protection structure of LRP itself, but instead permits the producer to fully insulate from price risk. Only one significant causal elasticity—in Feeder Cattle—suggests dirty subsidy harvesting that run counter to

Table 5c: Elasticity of Trader-Type Options Open Interest to LRP Takeup—Swine

	Producers Bearish	*Producers Bullish*	*Non-reporting Bearish*	*Non-reporting Bullish*
OLS				
Log New LRP Weight	0.020***	0.047***	−0.013***	0.007***
p-value	0.000	0.000	0.000	0.003
OLS with Controls				
Log New LRP Weight	−0.012**	−0.005	−0.025***	−0.011**
p-value	0.026	0.317	0.000	0.019
Instrumental Variables with Controls				
Log New LRP Weight	−0.217	−0.041**	0.027	0.064
p-value	0.787	0.016	0.625	0.411
Model	2SLS	2SLS	2SLS	2SLS
First-stage KP LM statistic	30.067	30.067	30.067	30.067
p-value	0.000	0.000	0.000	0.000
KP Wald F statistic	28.918	28.918	28.918	28.918
Cragg–Donald Wald F	63.100	63.100	63.100	63.100
Stock–Yogo Weak ID test [10%]	19.93	19.93	19.93	19.93
Sargan/Hansen test	2.345	5.169	0.148	10.130
p-value	0.126	0.023	0.701	0.001
R^2	0.511	0.691	0.223	0.299
Observations	469	469	469	469

Notes: All regressions are estimated at the weekly frequency, and are estimated with heteroskedasticity- and autocorrelation-robust (HAC) standard errors using a Bartlett kernel with a bandwidth of 12 weeks. Controls include prices for livestock, corn, and soybeans as well as their first differences; implied volatilities for all those series and their differences, as well; the VIX, the tbill rate, their differences, and a time trend. IV specifications use the subsidy generosity schedule and its squared value as instruments. The table includes results for the preferred IV model—2SLS or LIML—depending on first stage fit. Significance levels: *p<0.10, **p<0.05, ***p<0.01.
Source: Authors' calculations based on USDA-RMA LRP policy microdata and CME options open-interest series.

the LRP program's risk protection aims. Finally, the economic magnitudes for any of our IV elasticities are small. While LRP subsidies clearly invite LRP participation, any resulting distortions in options markets are limited in scale.

Overall, the available evidence indicates that LRP participation and derivatives activity are jointly determined by risk and liquidity conditions but that the causal effect of policy generosity is narrowly concentrated and consistent with rational hedging responses. Producers appear to adjust their derivative portfolios in ways that reinforce the downside protection provided by subsidized insurance rather than amplify speculative exposure. This interpretation provides a behavioral foundation for the subsidy-capture analysis that follows.

5.4 Quantifying the Harvested Subsidies

To quantify the magnitude of potential subsidy harvesting, we apply the IV elasticities estimated above to the instrument-predicted change in LRP-insured weight $\widehat{W}_{i,t}^{IV}$, and translate it into the implied OI change according to the procedure described in section 4.2.1 and interpret this quantity as the likely arbitraged weight. We form 95% CIs for each estimate by applying the same procedure to the confidence bounds produced by the original IV elasticities.

Table 6 displays our estimates of subsidy capture. By construction, they are consistent with the sign and significance patterns in the trader-type IV elasticities. Yet, the magnitudes depart a bit. While two IV elasticities for Fed Cattle in table 5a are significant (and have a larger sum at the mean), compared to just one for Feeder Cattle in table 5b, the latter displays a larger arbitrage value in table 6. This is consistent with the fact that Feeder Cattle producers were much more active in using LRP, insuring more than twice as much hundredweight and securing over three times as many subsidy dollars ($311.9 million to Feeder Cattle producers, but just $94.36 million to Fed Cattle producers). Because no IV elasticities in table 5c are significant and positive, we lack sufficient evidence under our identification strategy to link swine producers with subsidy harvesting behavior.[21]

As shown in the table, we find that Fed Cattle producers used simultaneous derivatives transactions to capture about $2.7 million (95% CI: $1.2-$4.2 million) of LRP subsidies from 2015-2024, while Feeder Cattle producers arbitraged $9.8 million (95% CI: $2.3-$17.2 million). Summing across commodities in table 6 yields $12.5 million in implied captured subsidies over 2015–2024, at the mean (95% CI: $3.5-$21.41 million). Total LRP subsidies in cattle markets over the same horizon are $406.3 million, so our point estimate corresponds to a 3.1 percent capture rate, with an uncertainty band implied by the reported confidence intervals of about 0.9 to 5.3 percent. Notably, most of the subsidy harvesting is concentrated in bearish options, which is consistent with a clean subsidy harvest whereby producers insulate themselves from risk entirely. We estimate that only about $1.6 million in subsidy capture was accomplished with the bullish options necessary to effect a dirty subsidy harvest that removes the protections against adverse price risk intended under LRP.

Our estimates in table 6 are likely biased downward for two reasons. First, the CFTC trader categories used to identify these effects are broad, and aggregation across heterogeneous participants introduces measurement error in reported positions. Such misclassification attenuates the estimated elasticities that form the basis of the capture calculation, biasing them toward zero and reducing the implied

[21] An absence of significant subsidy capture in swine markets aligns with the overall OI results, where the IV effect is negative and significant, indicating that LRP subsidies crowding out rather than crowd traders into options markets.

subsidy values. Second, because the CFTC reports *delta-adjusted* option positions, measured open interest moves mechanically with changes in the underlying futures price. To prevent this automatic revaluation from being mistaken for behavioral trading, all elasticity regressions include both the level and the first difference of the corresponding futures price. These controls absorb most of the covariance between delta-adjusted positions and price movements, so that the remaining variation identified by the subsidy instruments reflects genuine trading activity rather than shifts in option moneyness. However, when we convert those estimated (moneyness-purged) open-interest responses into physical weight equivalents, we use standard CME contract sizes and treat the delta-adjusted positions as if each unit represented a full contract. Because delta-adjusted measures typically understate the number of full contracts represented in the market, this mapping converts the smallest plausible measure of contract change into arbitraged LRP-insured weight, thereby understating the true scale of contract-equivalent subsidy capture.

Table 6: Implied Subsidy Capture (in Millions)

			Bullish			*Bearish*			*Total*		
	LRP cwt	LRP Subsidies	Arbitraged	Low CI	High CI	Arbitraged	Low CI	High CI	Arbitraged	Low CI	High CI
Fed Cattle	41.67	$94.36	$1.57	$0.60	$2.52	$1.11	$0.55	$1.67	$2.68	$1.15	$4.20
Feeder Cattle	104.55	$311.90	—	—	—	$9.81	$2.31	$17.21	$9.81	$2.31	$17.21
Swine	105.94	$241.67	—	—	—	—	—	—	—	—	—

Notes: Arbitraged values represent an estimate of the implied subsidy dollars captured via arbitrage through simultaneous LRP takeup and options writing. Confidence intervals are estimated as 95% confidence interval bounds based on standard errors from IV elasticity estimates. Blank cells (—) indicate no statistically significant arbitrage detected.
Source: Authors' calculations based on USDA-RMA LRP policy microdata and CME options open-interest series.

6 Conclusions

Rapid takeup of LRP following policy changes and subsidy increases in 2019 and 2020 raises concerns about spiking taxpayer costs (Glauber, 2022; Belasco, 2025). In addition, the design of the price-based policy—when similar market-based instruments are available—also presents the possibility of unintended market consequences, including the potential for subsidy harvesting by using offsetting options trades to effect arbitrage. We provide a theoretical framework to demonstrate how subsidized LRP, akin to a put option, leaves open the door to different types of subsidy harvests: one that locks in today's price plus the subsidy via short calls, eliminating risk but capping upside, and another that uses short puts to capture the subsidy while retaining full price exposure, undermining risk management objectives. In either case, subsidy capture creates an externality, since it is done far less efficiently than a simple direct payment, relying on the administration of an entire insurance program and the AIP network.

Our model predicts that subsidizing LRP could have indeterminate effects on derivatives markets, possibly crowding out or crowding in options trading—depending on the risk tolerance and wealth objectives of livestock producers—with implications for derivatives market liquidity and price discovery. Empirically, trends in options open interest (OI) show increases as subsidies were paid out, particularly for feeder cattle and swine, suggesting a potential link with (and crowding in effect of) LRP.

Taking our model to data, we use the requirement of simultaneous increase in both options OI and LRP takeup to conduct an arbitrage trade to identify, through an instrumental variables approach that exploits the government-set subsidy schedule to isolate exogenous LRP demand, the elasticity of options trading to policy takeup. We show that LRP crowded out derivatives trading by swine producers, possibly by leading them to substitute cheaper insurance for the same protection that had been previously available through market options trading. Although we were unable to estimate any significant overall cattle options market effects caused LRP takeup, this could be confounded by the possibility that counterparties like AIPs use options to lay off some of the risk they take on by writing additional LRP policies to producers.

In addition, we find that LRP subsidies encouraged measurable subsidy harvesting in cattle markets: applying the trader- and sentiment-specific elasticities to observed changes in insured weight and option open interest implies roughly \$12.5 million (95% CI: \$3.5m–\$21.4m) of subsidy capture out of \$406.3 million paid to fed and feeder cattle policyholders from 2015-2024. Most of this capture—about \$10.9 million—is tied to bearish options positions (e.g., short calls) of fed cattle producers and feeder cattle non-reporting traders, consistent with clean harvesting that preserves downside protection while locking in the subsidy. A smaller $1.6 million is linked to bullish positions of non-reporting fed cattle traders, consistent with dirty subsidy harvesting that removes downside protections, counter to LRP program goals. Our IV results fail to establish evidence of subsidy capture among swine producers. Overall, the magnitudes we estimate are modest but informative: they quantify subsidy-driven trading in cattle markets, primarily reflecting risk-reducing behavior.

From a policy perspective, these findings highlight an inefficiency inherent in subsidized livestock price insurance. Establishing a policy program so similar to existing market derivatives left the door open to unintended subsidy capture behavior, possibly counter to the program's objectives. A modest but measurable share of federal LRP outlays were likely arbitraged rather than used for risk management, as intended. Such activity represents a rent transfer from taxpayers—and a costly one—given the administrative overhead of running the insurance and reinsurance system required to deliver those payments. Recent program amendments now prohibit offsetting options positions intended to generate dirty subsidy harvests, but clean arbitrage remains possible. In any case, systematic subsidy harvesting reveals that even well-intended insurance design can unintentionally interact with derivatives markets, distorting liquidity and even weaken the program's overall effectiveness at protecting producers.

References

Baker, D. (2023). White Paper on Subsidy Harvesting. White paper, CIH.

Baker, D. (2024). Livestock Price Insurance – the Do's and the Don'ts. White paper, CIH.

Barua, S. (2024). Risk Preferences Impact on Cattle Producers' Use of Price Risk Management. Master's thesis, University of Tennessee.

Belasco, E. J. (2025). The public cost, private gains, and budgetary implications of federal livestock and forage insurance expansion. Report, American Enterprise Institute (AEI).

Boyer, C. N., K. L. DeLong, A. P. Griffith, and C. C. Martinez (2024). Factors influencing United States cattle producers use of livestock risk protection. *Agricultural Economics 55*(4), 677–689.

Boyer, C. N. and A. P. Griffith (2023a). Livestock risk protection subsidies changes on producer premiums. *Agricultural Finance Review 83*(2), 201–210.

Boyer, C. N. and A. P. Griffith (2023b). Subsidy Rate Changes on Livestock Risk Protection for Feeder Cattle. *Journal of Agricultural and Resource Economics 48*(1), 31–45.

Carrico, J. (2024). Risk management tool may cause cattle market price fluctuations. `https://www.dtnpf.com/agriculture/web/ag/news/article/2024/02/01/lrp-affecting-cattle-market`. Progressive Farmer, accessed July 11, 2025.

Feuz, R. (2025). Evaluation of pricing within livestock risk protection insurance and the associated vulnerability towards subsidy harvesting. Poster, 2025. 2025 AAEA and WAEA Joint Annual Meeting, July 27 - 29, 2025, Denver, Colorado.

Glauber, J. W. (2022). The US Animal Insurance Program: Rapid Expansion at a Growing Cost to Taxpayers. Report, American Enterprise Institute.

Goodwin, B. K. and V. H. Smith (2013). What harm is done by subsidizing crop insurance? *American Journal of Agricultural Economics 95*(2), 489–497.

Goodwin, B. K., M. L. Vandeveer, and J. L. Deal (2004). An empirical analysis of acreage effects of participation in the federal crop insurance program. *American Journal of Agricultural Economics 86*(4), 1058–1077.

Haviland, L. B. and R. Feuz (2025). Enhancing Decision Making in Livestock Risk Protection Insurance: Insights into Optimal LRP Contract Selection. *Journal of Agricultural and Resource Economics 50*(2), 221–239.

Hill, S. (2015). Exploring producer perceptions for cattle price and animal performance in the stocker industry. Master's thesis, Kansas State University.

Horowitz, J. K. and E. Lichtenberg (1993). Insurance, moral hazard, and chemical use in agriculture. *American Journal of Agricultural Economics 75*(4), 926–935.

McKendree, M. G., G. T. Tonsor, and L. L. Schulz (2021). Management of multiple sources of risk in livestock production. *Journal of Agricultural and Applied Economics 53*(1), 75–93.

Merritt, M. G., A. P. Griffith, C. N. Boyer, and K. E. Lewis (2017). Probability of receiving an indemnity payment from feeder cattle livestock risk protection insurance. *Journal of Agricultural and Applied Economics 49*(3), 363–381.

Risk Management Agency (2026). Livestock Risk Protection (LRP) Handbook.

Rosch, S. (2021). Federal Crop Insurance: A Primer. Report R46686, Congressional Research Service.

Rosch, S. (2022). Farm Bill Primer: Federal Crop Insurance Program. In Focus IF12201, Congressional Research Service.

Young, C. E., M. L. Vandeveer, and R. D. Schnepf (2001). Production and price impacts of US crop insurance programs. *American Journal of Agricultural Economics 83*(5), 1196–1203.

Yu, J., A. Smith, and D. A. Sumner (2018). Effects of crop insurance premium subsidies on crop acreage. *American Journal of Agricultural Economics 100*(1), 91–114.

Yu, J. and D. A. Sumner (2018). Effects of subsidized crop insurance on crop choices. *Agricultural Economics 49*(4), 533–545.

A Appendix: The Clean Subsidy Harvest Locks in a Fixed Price at t

As we show in the text, the clean subsidy harvest strategy combines a subsidized, synthetic long put option with a short call option to provide the producer with a deterministic net price, given some assumptions. To demonstrate that in the text we perform the following simplification:

$$P_T + \max(P_t - P_T, 0) - \max(P_T - P_t, 0) = P_t \tag{A.1}$$

To verify this, consider two cases based on the terminal spot price P_T.

Case 1: $P_T < P_t$: The insurance policy pays off at $\max(P_t - P_T, 0) = P_t - P_T$, while the call expires worthless $\max(P_T - P_t, 0) = 0$. As a result:

$$P_T + (P_t - P_T) - 0 = P_t \tag{A.2}$$

Case 2: $P_T \geq P_t$: The insurance policy does not pay because the livestock price is too high $\max(P_t - P_T, 0) = 0$; on the other hand the producer must settle the call option and pay the holder $\max(P_T - P_t, 0) = P_T - P_t$. In this case:

$$P_T + 0 - (P_T - P_t) = P_t \tag{A.3}$$

No matter which outcome as t approaches T, the net price is deterministic. This subsidy harvest locks in a fixed sale price of P_t.

B Wealth Variance is Lower Under a Long Put than When Unprotected

Assume that $P(T) \sim N(F(t,T), \sigma_T^2)$ and $P(t) = F(t,T)$, with an at-the-money strike. The protected price is $\max(P(T), P(t)) = P(t) + \max(P(T) - P(t), 0)$. Begin by normalizing so that $Z = \frac{P(T)-P(t)}{\sigma_T} \sim N(0,1)$. Then, re-stating:

$$\max(P(T), P(t)) = P(t) + \sigma_T \max(Z, 0).$$

The variance is now:

$$\text{Var}[\max(P(T), P(t))] = \sigma_T^2 \text{Var}[\max(Z, 0)].$$

Where:

$$\text{Var}[\max(Z,0)] = \mathbb{E}[\max(Z,0)^2] - (\mathbb{E}[\max(Z,0)])^2.$$

To compute this, note that the first term:

$$\mathbb{E}[\max(Z,0)] = \int_0^\infty z \cdot \frac{1}{\sqrt{2\pi}} e^{-z^2/2} dz = \frac{1}{\sqrt{2\pi}} = \delta \approx 0.3989.$$

While the second term:

$$\mathbb{E}[\max(Z,0)^2] = \int_0^\infty z^2 \cdot \frac{1}{\sqrt{2\pi}} e^{-z^2/2} dz = \frac{1}{2},$$

since the full $\mathbb{E}[Z^2] = 1$, and symmetry gives half for $z > 0$. Thus:

$$\mathrm{Var}[\max(Z,0)] = \frac{1}{2} - \delta^2 = \frac{1}{2} - \frac{1}{2\pi} = \frac{\pi - 1}{2\pi} = \kappa \approx 0.34085.$$

Since $\kappa = \frac{\pi-1}{2\pi} < 1$ (as $\pi \approx 3.1416$, $\pi - 1 < 2\pi$), we have:

$$\mathrm{Var}[\max(P(T), P(t))] = \kappa\sigma_T^2 < \sigma_T^2 = \mathrm{Var}[P(T)].$$

The inequality holds because the price floor censors downside fluctuations, reducing variability while retaining only upside deviations.

C Impact of American Options versus European Options

In our model, we assume that markets trade European options, exercisable only at maturity T, to simplify the derivation of closed-form payoffs and certainty equivalents. However, livestock options traded at the Chicago Mercantile Exchange (CME) are American, allowing exercise at any time up to and including T. In this appendix we derive the mathematical and practical implications of American options for producer wealth and certainty equivalents under subsidy harvesting strategies, and we explain how the possibility of early exercise alters the model's intuition, particularly for risk-averse producers.

For an American put option with strike price $P(t)$, the value at time t is given by the supremum over all stopping times $\tau \leq T$:

$$\phi_A = \sup_{\tau \leq T} \mathbb{E}[e^{-r(\tau - t)} \max(P(t) - I(\tau), 0)],$$

where $I(t)$ is the futures price process, r is the risk-free rate, and the expectation is taken under a risk-neutral measure. This value, determined via dynamic programming or a partial differential equation with a free boundary, includes an early exercise premium, making it strictly greater than its European counterpart ($\phi_A > \pi_{\text{fair}} = \delta\sigma_T$). Early exercise is optimal when the futures price falls significantly below the strike ($I(\tau) < P(t)$), as the holder captures the intrinsic value ($P(t) - I(\tau)$) and earns interest on the proceeds.

Similarly, for an American call option on a futures contract with strike $P(t)$, the value is:

$$c_A = \sup_{\tau \le T} \mathbb{E}[e^{-r(\tau - t)} \max(I(\tau) - P(t), 0)].$$

Unlike stock options, where early exercise of calls is typically suboptimal for non-dividend-paying assets, early exercise of an American call on a futures contract can be optimal if the futures price rises significantly above the strike ($I(\tau) > P(t)$). This occurs when the intrinsic value exceeds the remaining time value, particularly near expiration or when interest rates are high, as the holder can lock in the gain ($I(\tau) - P(t)$) and invest the proceeds. Thus, $c_A \ge \pi_{\text{fair}}$, with the premium depending on market conditions (e.g., volatility, time to expiration, interest rates).

C.1 The Clean Subsidy Harvest (h_c)

In the clean subsidy harvest, the producer writes an American call option and purchases subsidized insurance (akin to a long put). If the call is exercised early at $\tau < T$ when $I(\tau) > P(t)$, the producer receives the strike price $P(t)$ but must deliver a short futures position initiated at $I(\tau)$. The immediate cash flow from assignment is $Q \cdot [P(t) - I(\tau)]$, and the subsequent mark-to-market change from τ to T is $Q \cdot [I(\tau) - I(T)]$. The total futures-related cash flow therefore simplifies to $Q \cdot [P(t) - I(T)]$, exactly as if the call had been exercised at maturity.

Combining this with the long spot position $Q \cdot [I(T) + b(T)]$ and the subsidized insurance (paying $\max(P(t) - I(T), 0)$), total wealth at T is:

$$W_{h_c} = Q \cdot \left[I(T) + b(T) + \max(P(t) - I(T), 0) + (P(t) - I(T)) - \theta + c_A - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1) \right].$$

Simplifying (the $I(T)$ terms within $I(T) + (P(t) - I(T))$ cancel, leaving a constant $P(t)$ term):

$$W_{h_c} = Q \cdot \left[P(t) + b(T) + \max(P(t) - I(T), 0) - \theta + c_A - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1) \right].$$

For $I(T) < P(t)$, $\max(P(t) - I(T), 0) = P(t) - I(T)$, so:

$$W_{h_c} = Q \cdot \left[2P(t) - I(T) + b(T) - \theta + c_A - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1) \right].$$

For $I(T) \geq P(t)$, $\max(P(t)-I(T),0) = 0$, giving:

$$W_{h_c} = Q \cdot \left[P(t) + b(T) - \theta + c_A - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1)\right].$$

Using $\theta = \pi_{\text{fair}} - s$ and $c_A \approx \pi_{\text{fair}}$ (assuming a small early exercise premium), wealth simplifies to:

$$W_{h_c} = \begin{cases} Q \cdot \left[2P(t) - I(T) + b(T) + s - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1)\right], & I(T) < P(t), \\ Q \cdot \left[P(t) + b(T) + s - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1)\right], & I(T) \geq P(t). \end{cases}$$

Expected wealth is therefore:

$$\mathbb{E}[W_{h_c}] = Q \cdot \left[P(t) + s - 2\tau - m_{\text{call}}(e^{r\Delta t} - 1) + \mu_b\right],$$

since $\theta = \pi_{\text{fair}} - s$ and $c_A \approx \pi_{\text{fair}}$ (assuming a small early-exercise premium). Because the futures-related cash flows simplify to $Q[P(t) - I(T)]$, early exercise does not change expected wealth relative to the European case—— it only alters the *timing* of cash flows, not their terminal sum. In a frictionless setting, early exercise does not affect terminal variance: the combined spot and futures positions yield a deterministic payoff in $I(T)$, so the only remaining risk is basis variation. Hence,

$$\text{Var}[W_{h_c}] \approx Q^2 V_b.$$

On the other hand, for risk-averse producers subject to liquidity or margin constraints, the interim cash flow $Q[P(t) - I(\tau)]$ introduces *path variance*—greater volatility in wealth over time even though terminal wealth is unchanged.

C.2 Dirty Subsidy Harvest (h_d)

In the dirty subsidy harvest, the producer writes an American *put* option. If exercised early at $\tau < T$ when $I(\tau) < P(t)$, the producer pays $P(t) - I(\tau)$ and takes a long futures position at $I(\tau)$, which then settles for $Q[I(T) - I(\tau)]$ at maturity. The net futures-related cash flow again simplifies to $Q[I(T) - P(t)]$, exactly as if exercised at maturity. Total wealth is:

$$W_{h_d} = Q \cdot \left[I(T) + b(T) + \max(P(t) - I(T), 0) - \theta + \phi_A - (P(t) - I(T)) - 2\tau - m_{\text{put}}(e^{r\Delta t} - 1)\right].$$

Simplifying, the futures cash flows reduce to $Q[I(T)-P(t)]$, so

$$W_{h_d} = Q\cdot\left[I(T)+b(T)+\max(P(t)-I(T),0)-(P(t)-I(T))+\phi_A-\theta-2\tau-m_{\text{put}}(e^{r\Delta t}-1)\right].$$

Case-wise:

$$W_{h_d} = \begin{cases} Q\left[I(T)+b(T)-\theta+\phi_A-2\tau-m_{\text{put}}(e^{r\Delta t}-1)\right], & I(T)<P(t), \\ Q\left[I(T)+b(T)-P(t)+\phi_A-\theta-2\tau-m_{\text{put}}(e^{r\Delta t}-1)\right], & I(T)\geq P(t). \end{cases}$$

Using $\theta=\pi_{\text{fair}}-s$ and $\phi_A>\pi_{\text{fair}}$, expected wealth becomes:

$$\mathbb{E}[W_{h_d}] = Q\cdot\left[F(t,T)+s-2\tau-m_{\text{put}}(e^{r\Delta t}-1)+\mu_b\right].$$

As with the clean subsidy harvest case, early exercise affects only timing, not the terminal distribution, of wealth. The higher put premium ($\phi_A>\pi_{\text{fair}}$) slightly increases expected wealth but does not change variance in a frictionless environment:

$$\text{Var}[W_{h_d}] \approx Q^2\left[V_I+V_b+2\rho\sqrt{V_I V_b}\right].$$

Adding liquidity or funding frictions could still translate interim position changes into perceived volatility through cash-flow timing effects.

C.3 Implications for Producer Strategy

American calls and puts on futures can be exercised early. For calls (used to conduct a clean arbitrage), exercise occurs if $I(\tau)>P(t)$ and the intrinsic value exceeds time value, depending on price movements, volatility, and interest rates; for puts (used to conduct a dirty arbitrage), exercise occurs if $I(\tau)<P(t)$. This potential for early exercise introduces interim futures positions, adding volatility beyond basis risk and index (underlying asset) risk, reducing the certainty equivalents of both strategies, particularly for risk-averse producers. It narrows the certainty equivalent gap with subsidized insurance (e.g., $\text{CE}_{h_c}-\text{CE}_i$ decreases). Practically, the possibility of early exercise requires that producers actively manage options positions over the life of the arbitrage, involving complex transactions and cash flow disruptions, making subsidy harvesting less appealing compared to standalone insurance.

For risk-averse producers, American options make subsidy harvesting riskier, tilting preferences toward subsidized insurance, especially if early exercise probabilities are high. Bullish producers might favor the dirty subsidy harvest for the higher put premium, but the added risk may deter participation.