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

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Abstract

USDA designed Livestock Risk Protection (LRP) as a product 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 take-up, 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 examine linkages between LRP subsidies and trading volumes in corresponding options markets, and show that LRP crowds in, rather than crowds out, derivatives trading. We exploit the arbitrage requirement of near-concurrent increases in options open interest (OI) and subsidies to estimate that livestock producers may have harvested $164 million, or 22%, of federal LRP subsidies between 2015 and 2024.

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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 take-up, and livestock insurance take-up 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 can 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) are likely to 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,

[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).

2023, 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 presents several significant 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

[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.

a substantial beneficial interest in the insured are prohibited from offsetting coverage for the purpose of 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 near-concurrent increases in options open interest (OI) to quantify potential subsidy capture. Our results indicate marked increases in options open interest following subsidy expansions, and offer evidence that LRP crowds in, rather than crowds out, livestock commodity options trading. Disaggregated analysis by trader type and option sentiment reveals patterns consistent with targeted arbitrage in certain markets, especially feeder cattle and–to a lesser extent–lean hogs.

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 dollars 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

Figure 1: LRP Liability by Commodity, 2005-2025

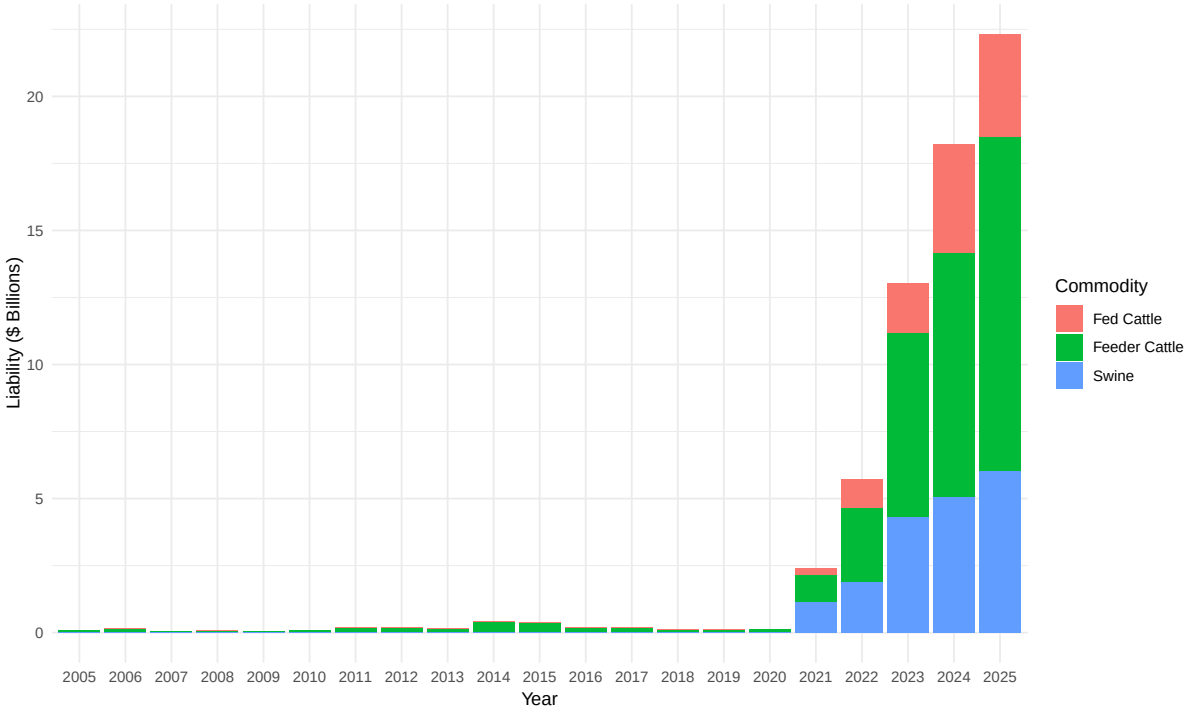
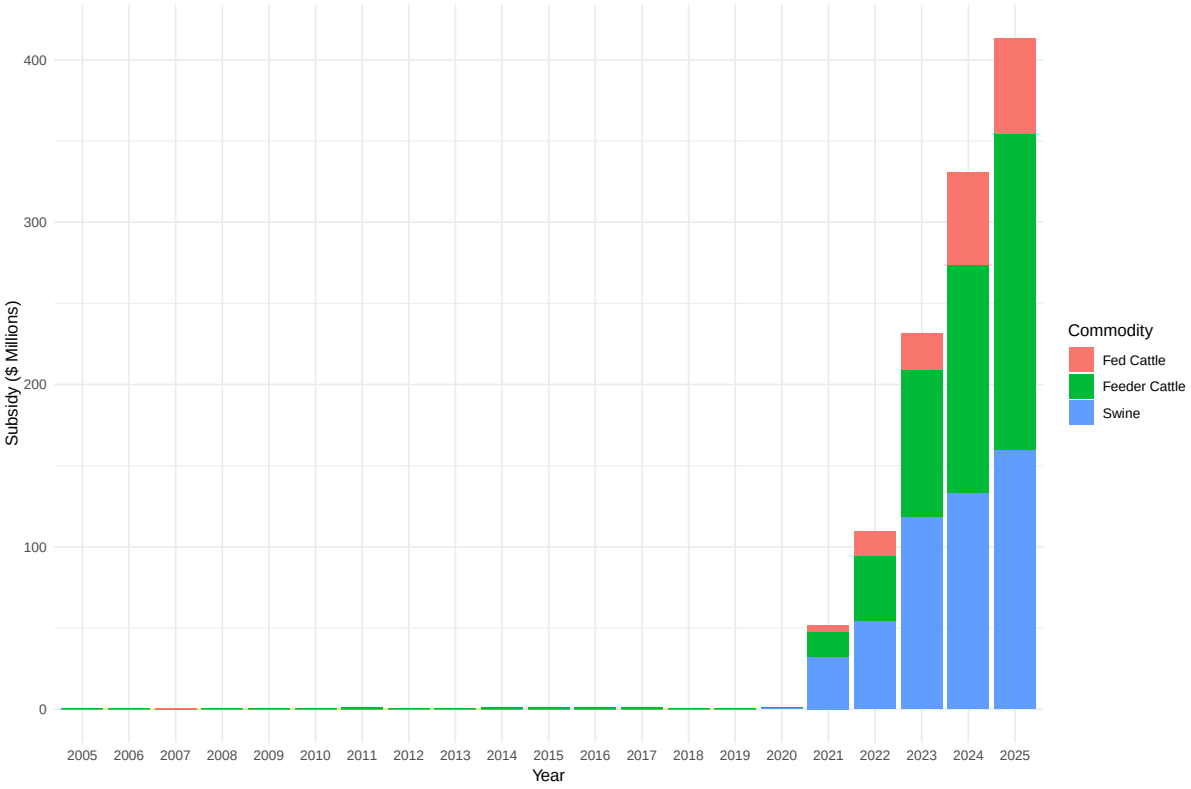


Figure 2: LRP Premium Subsidies by Commodity, 2005-2025



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 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.

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

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

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 2025. 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

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

Figure 3: LRP Loss Ratios, 2005-2025



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.

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 take-up (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, pur-

chasing subsidized price insurance (i.e., LRP), buying a market put option, conducting a clean subsidy 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.

[7] For example, the payoff for a long put option with strike $P(t) = F(t,T)$ is $\max(P(T), P(t))$; it 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 $\kappa = (\pi - 1)/(2\pi) \approx 0.1817$. Restricting prices to only the upper half of the normal distribution therefore reduces the variance of the long put option to only about one-fifth 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:

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

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

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

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:

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

The certainty equivalent is:

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

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:

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

And the certainty equivalent is:

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

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 $\mathrm{Var}[P(T)] = V_I + V_b + 2\rho\sqrt{V_I V_b}$. 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:

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

The certainty equivalent is:

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

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:

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

Expected wealth is:

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

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:

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

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	$\mathbf{Var}(W_T)$	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 advan-

tage 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:

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

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.

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 options open interest (OI) by matching studying whether its fluctuations change after rises in LRP subsidy levels.

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 wish to compare producers' short put, or bullish, option OI levels with LRP subsidy levels.

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 wish to compare producers' short call options, or bearish, OI levels with subsidy levels.

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. Polcies 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 subsidy rates (Boyer and Griffith, 2023a): pre-July 2019 (regime 1), July 2019-June 2020 (regime 2), and post-July 2020 (regime 3). 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 3. 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.[15] 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).

[15] 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

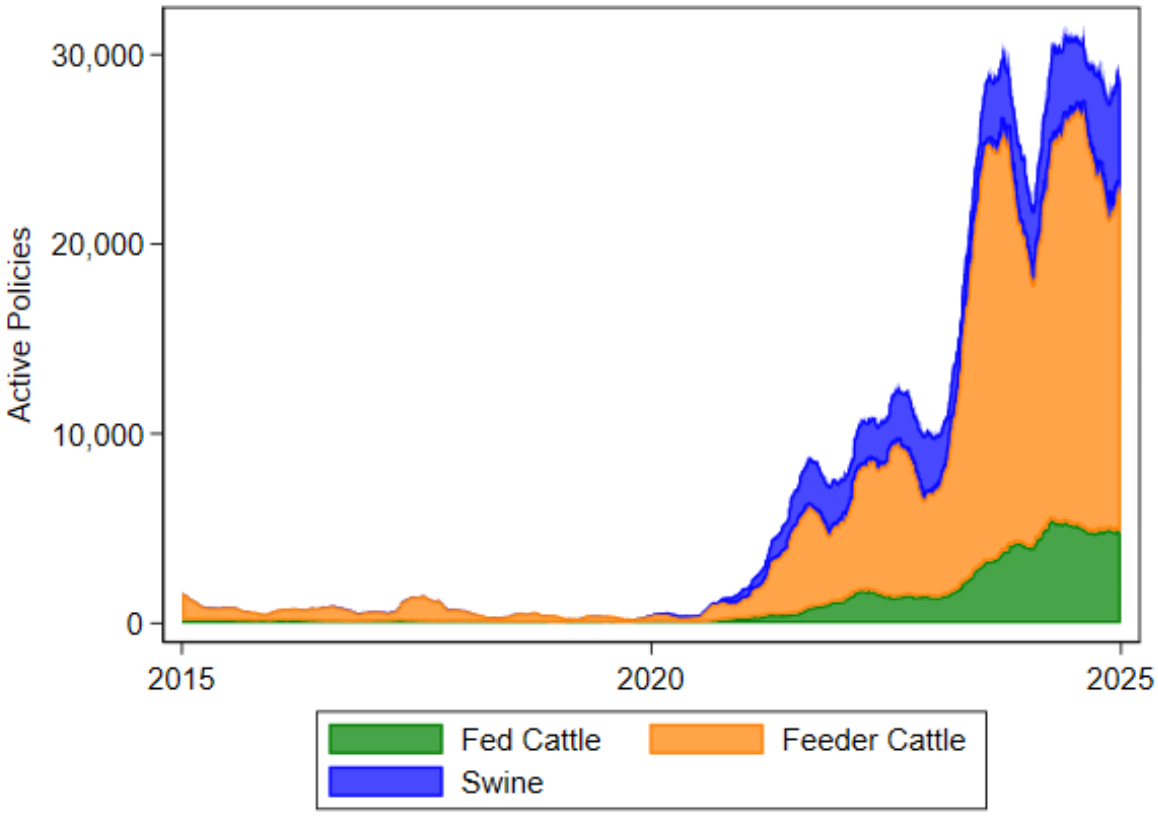
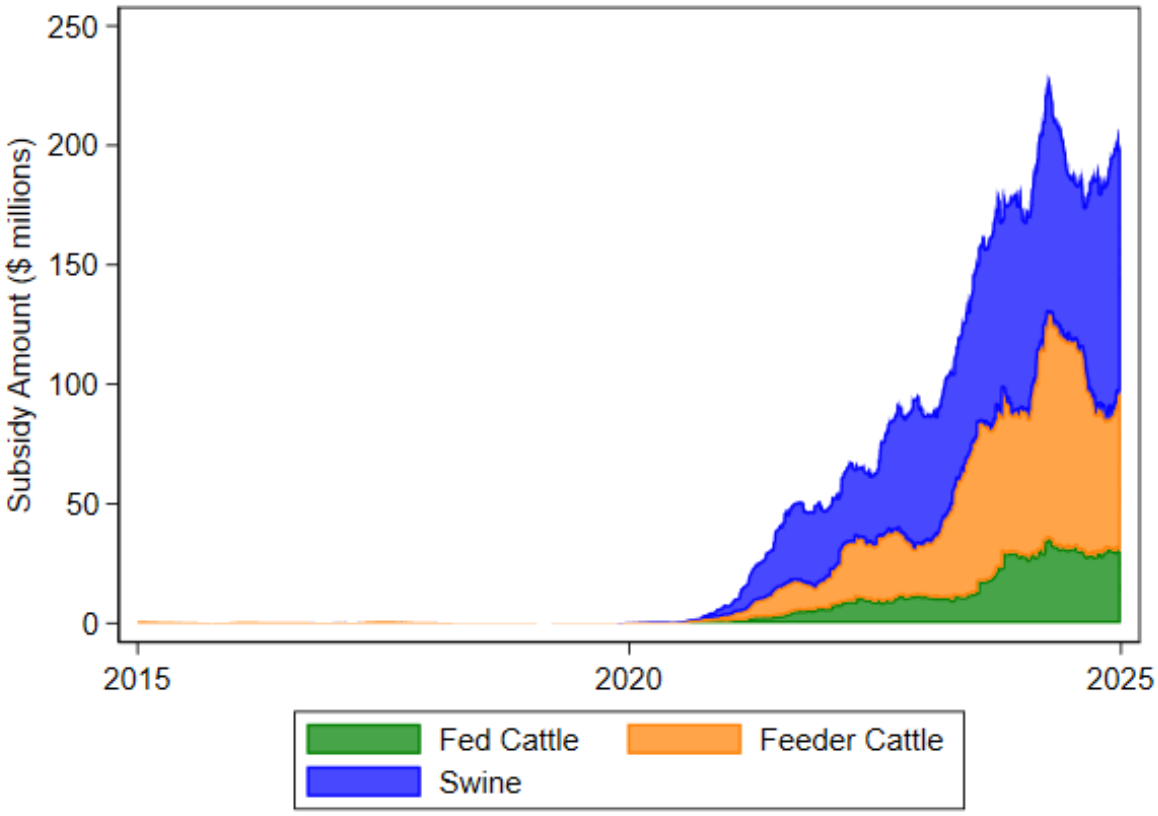


Figure 5: LRP Subsidies by Livestock Commodity, 2015-2024



4.2 Empirical Approach

Our objective is to understand the causal relationship between LRP policy takeup and derivatives market trading; this will yield insight into the crowding in/out regularity, as well as help establish the extent and magnitude of any arbitrage that may take place. Our identification strategy relies on near-concurrent increases in options open interest and LRP subsidies, since that is a necessary condition for arbitrage. LRP subsidies are paid by the federal government and rise when producers take out polices, so we model open interest as a function of them. This assumes that subsidies are exogenous to trading activity, after controlling for underlying futures price changes and the VIX.

As shown in table 4 many of the variables we consider, including all the subsidies in Figure 4, are non-stationary. Others, like some of the open interest variables and the VIX index, are stationary. Traditional models like vector error correction (VECM) require all variables to be of the same order of integration and require pre-testing for cointegration across multiple equations (which can introduce uncertainty and errors from those preliminary tests). In contrast, autoregressive distributed lag (ARDL) models are particularly useful in cases where data have different orders of integration, and do not need explicit pre-testing of each variable's integration order. Rather, ARDL uses a bounds testing procedure to check for a long-run relationship (cointegration) between the modeled variables directly within a single-equation framework, making it more flexible and robust.

We therefore estimate the effects of LRP subsidies on commodity i options open interest for trader type j using an approach that incorporates ARDL. When expressed in its error-correction form, the model separates short-run dynamics from the (potential) long-run equilibrium, similar to a VECM but simplified to one equation per dependent variable. This helps interpret how the dependent variable adjusts over time: the error-correction term pulls the system back to equilibrium after shocks, while lagged differences capture immediate responses. For each commodity in our analysis, we conduct Pesaran et al.'s bounds test of the relationship between its options open interest and active LRP subsidy levels, including controls (2001).[16] If the test confirms cointegration, we use this ARDL specification for analysis; otherwise, we fall back to a purely differenced model without the long-run component, in order to avoid spurious relationship between trending variables.

To select the appropriate model, we apply the following procedure. We first attempt to fit an ARDL for each commodity-open interest combination, allowing up to four lags for the dependent variable ($\Delta y_{i,j,t}$, representing the short-run change in the log OI), and independent variables. The error-correction

[16] Open interest types we model include the commodity's overall level, as well as the bullish or bearish positions held by both the category of traders CFTC associates with producers (as well as merchants, processors, and users) and non-reporting traders.

Table 4: Stationarity Test Results (Augmented Dickey-Fuller)

Commodity	Variable	p-value	Conclusion
Feeder Cattle	Active Subsidy	0.9926	Non-stationary
	Futures Price	0.8223	Non-stationary
	Non-Reporting Bearish	0.0126	Stationary
	Non-Reporting Bullish	0.0007	Stationary
	Producer Bearish OI	0.2248	Non-stationary
	Producer Bullish OI	0.0276	Stationary
	Total OI	0.0560	Non-stationary
Lean Hogs	Active Subsidy	0.8560	Non-stationary
	Futures Price	0.0062	Stationary
	Non-Reporting Bearish	0.0394	Stationary
	Non-Reporting Bullish	0.0002	Stationary
	Producer Bearish OI	0.2809	Non-stationary
	Producer Bullish OI	0.0369	Stationary
	Total OI	0.0026	Stationary
Live Cattle	Active Subsidy	0.9908	Non-stationary
	Futures Price	0.7333	Non-stationary
	Non-Reporting Bearish	0.0003	Stationary
	Non-Reporting Bullish	0.0000	Stationary
	Producer Bearish OI	0.1925	Non-stationary
	Producer Bullish OI	0.0125	Stationary
	Total OI	0.0009	Stationary
Exogenous	VIX Index	0.0000	Stationary

Notes: All tests include a single lag; p<0.05 is evidence in favor of stationarity. Dash indicates missing or invalid test results.

form of the ARDL is:

$$\Delta y_{i,j,t} = \alpha(y_{i,j,t-1} - \theta' Z_{i,t-1}) + \sum_{k=1}^{p-1} \mu_k \Delta y_{i,j,t-k} + \sum_{l=0}^{q-1} \delta_l' \Delta Z_{i,t-l} + \sum_{h=0}^{2} \lambda_h R_{h,t} + \varepsilon_{i,t}, \tag{4.1}$$

where $\alpha(y_{i,j,t-1} - \theta' Z_{i,t-1})$ is the error-correction component such that α is the adjustment coefficient (typically negative, indicating how quickly deviations from the long-run equilibrium are corrected),[17] and the expression $y_{i,j,t-1} - \theta' Z_{i,t-1}$ measures the previous period's deviation from the long-run relationship. The vector $Z_{i,t-1}$ includes the lagged log subsidies interacted with regime dummies for different subsidy periods as well as lagged controls. The vector θ represents long-run coefficients, or the the equilibrium elasticities. The term $\sum_{k=1}^{p-1} \mu_k \Delta y_{i,j,t-k}$ captures the short-run autoregressive effects from past changes in OI on itself while $\sum_{l=0}^{q-1} \delta_k' \Delta Z_{i,t-k}$ includes the contemporaneous and lagged short-run effects on OI of changes in regime-specific subsidies and controls. Equation 4.1 also includes regime dummies $R_{h,t}$ to account for fixed effects across policy periods and the error term $\varepsilon_{i,t}$. All standard errors

[17] An adjustment coefficient value of -0.5 is interpreted to mean that 50% of the disequilibrium is corrected each period)

are robust to potential hetroskedasticity and autocorrelation standard errors (Newey and West, 1987).

We then conduct the bounds test which generates an F-statistic on the joint significance of the lagged levels and a t-statistic on α; if both reject the null of no cointegration at the 5% level, we confirm a long-run relationship and proceed with ARDL. Otherwise, we estimate a differenced model without the error-correction term:

$$\Delta y_{i,j,t} = \sum_{m=0}^{r} \xi_m' \Delta W_{i,t-m} + \sum_{n=1}^{s} \phi_n \Delta y_{i,j,t-n} + \sum_{h=0}^{2} \lambda_h R_{h,t} + \nu_{i,t}, \tag{4.2}$$

where $\Delta W_{i,t-m}$ includes the contemporaneous and lagged differenced log subsidies (interacted with regime dummies), differenced controls, and the regime dummies $R_{h,t}$ themselves, with four lags. This is essentially a finite distributed lag model in differences, estimated using Newey-West standard errors to handle autocorrelation; it focuses solely on short-run dynamics without assuming a long-run equilibrium (1987).

4.2.1 Recovering Elasticities

We use the results from equation 4.1 or equation 4.2 to construct elasticities for the percentage change in commodity options OI for a 1% change in active LRP policy subsidies. By construction the elasticities are regime-specific. For the commodity/OI pairs that pass the bounds test and are fitted to ARDL models, we calculate—if they exist—short-run elasticities (β_{SR}) from the sum of the statistically significant, relevant δ_l coefficients on the subsidy terms for each regime $\beta_{SR} = \delta_0 + \delta_1$, combining the contemporaneous effect and a single lag.[18] This represents the immediate response of OI to subsidy changes. In addition, the long-run relationship θ in equation 4.1 indicates the regime-specific equilibrium OI response (β_{LR}) to a sustained subsidy increase. Again, assuming that the OI and LRP subsidy increases must occur within a two-week window to be candidates for arbitrage capture, we calculate the total elasticity (β_{TOT}) as the short-run effect plus the partial adjustment toward the long-run over two periods: $\beta_{TOT} = \beta_{SR} + (1 - (1+\alpha)^2) \cdot \beta_{LR}$. The term $(1 - (1+\alpha)^2)$ approximates the cumulative correction to the long-run relationship after two weeks. We rely on the two-week window to focus attention on rapid, detectable responses to subsidy fluctuations and avoid over-interpreting distant lags that might reflect other factors, although we acknowledged this is an empirical assumption. If the ARDL model has no significant short-run subsidy lags, then the elasticity calculation collapses to the long-run adjustment $\beta_{TOT} = (1 - (1+\alpha)^2) \cdot \beta_{LR}$

[18] CFTC data are aggregated weekly, and it may be that the policy and options trades are not perfectly simultaneous.

If the bounds test fails for a commodity/OI pair, we estimate the differenced model in equation 4.2; it has no long-run component, so the elasticity (β_{CUM}) is simply the sum of the relevant ξ_m coefficients on the differenced subsidy terms for each regime. All coefficient and standard error combinations are computed via the delta method.

4.2.2 Estimating Subsidy Capture

To estimate the percentage of subsidies captured through arbitrage, we combine the elasticities we estimate with the knowledge that subsidies can only be captured when they increase. We focus on weeks where subsidies rise from $t-1$ to t. For each commodity-open interest pair with significant positive combined elasticities β_{TOT} at the 5% level, we compute the implied extra OI attributable to the observed subsidy increase. Negative elasticities are excluded, as capture requires concurrent rises in both subsidies and OI, consistent with subsidy harvesting behavior. Then we determine the share of the subsidy increase that could have been captured, given the weight equivalents represented by the rise in OI and the LRP subsidies.

First we calculate any extra OI implied by the subsidy by multiplying the weekly percentage subsidy increase by β_{TOT} and lagged OI. Next, we convert this extra OI into weight equivalents using contract sizes (400 cwt for live cattle and lean hogs, 500 cwt for feeder cattle), and compare that rise to the actual change in insured weight under LRP policies to derive the share of the subsidy rise "harvested" by producers. Then we calculate the harvested amount as this share times the subsidy increase. Finally, we aggregate the harvested amounts and total subsidy increases across all trader types and options sentiments within each regime, yielding a cumulative capture percentage: (total arbitraged / total subsidy increases).

4.2.3 Limitations

Data availability subjects us to two limitations. First, although our model predictions draw attention to the effect of subsidies on livestock producer behavior, the CFTC lumps many other market participants (merchants, processors, and users) into the same classification shared by producers. As long as their behavior isn't correlated with producers' LRP-oriented trades, other trader types will only serve to add measurement error that, through attenuation bias, confounds our ability to identify how subsidies affect trading (and arbitrage) behavior. However, to be classified traders need to be sufficiently large. CFTC regulations (Commission, 2025) require traders with, as of the close of trading each day, at least 50 futures-equivalent positions in Feeder Cattle, or 100 positions in Live Cattle or Lean Hogs to self-report.

Producers (as well as any other kinds of traders) who do not carry positions that large appear in the COT report as non-reporting traders. We include them in the analysis because it is likely to include a sizeable share of producers who trade derivatives; note that this measurement error issue will apply to that group, too.

A second limitation we face is that the COT OI data only permit us to classify options positions as either bearish or bullish. We cannot differentiate whether different trader groups are purchasing or writing calls versus puts. Moreover, because options data can be combined with futures and spot positions to generate synthetic strategies (through put-call parity), we cannot conclude that additional bearish or bullish options trading on the part of producers is necessarily very risky and counter to the aims of the LRP program. Indeed, we are unable to differentiate whether producers are combing options trades with LRP to effect true, riskless arbitrage, or trade for cash the downside protection that LRP was intended to offer. As a result, any subsidy harvesting we estimate should not necessarily be attached to a risky behavior.

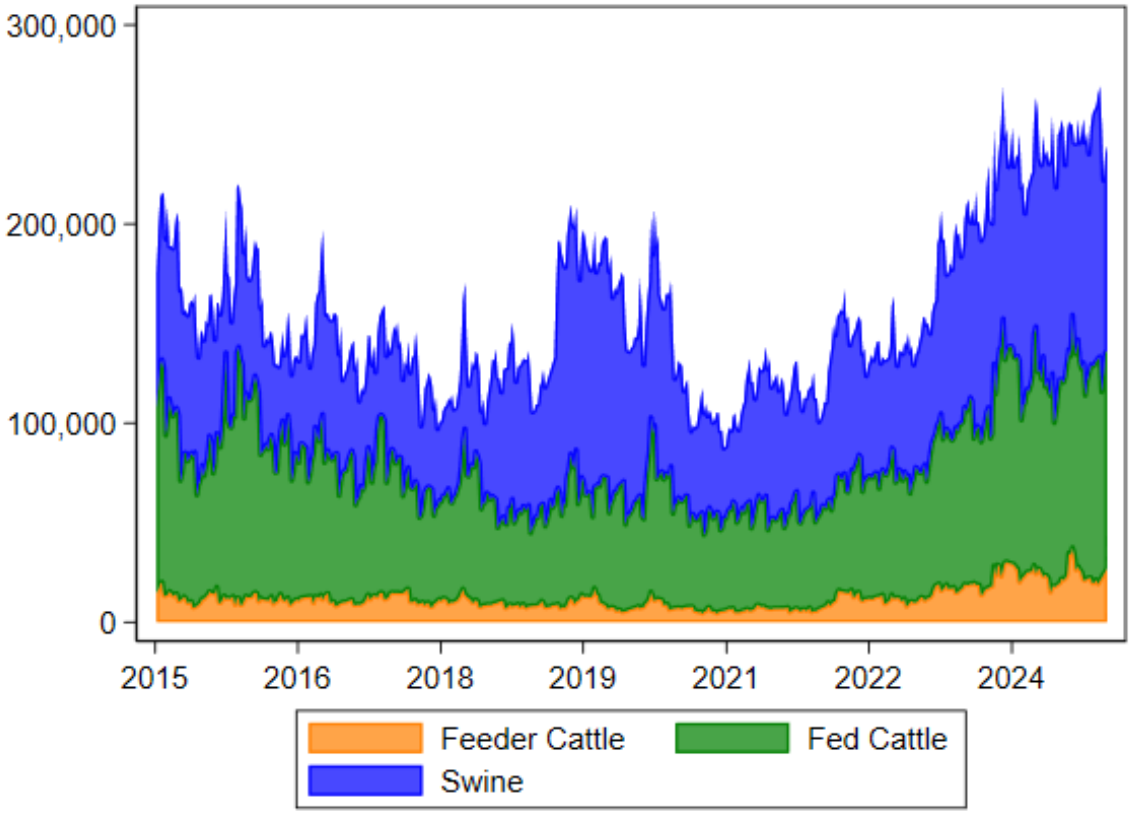
5 Results

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 (crowding out). Conversely, subsidy harvesting—either clean (short calls) or dirty (short puts)—could increase OI by prompting additional writing activity. Figure 6 displays the weekly OI in livestock options contracts for fed cattle, feeder cattle, and swine from 2015 through mid-2025. 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 the 2019 LRP subsidy rate changes, 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 (regime 1), OI began to rise noticeably—especially in swine. The upward trend is even more noticeable just after subsidy increases in July 2020 (regime 2). 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 suggests a possible link between LRP subsidy expansions and heightened activity in the corresponding options markets, raising the question of whether subsidies affected options trading. Indeed the spikes in OI following subsidy changes appear to favor the possibility of crowding in, a

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



necessary condition for subsidy harvesting, although the OI data alone does not distinguish between mechanisms or trader types.

5.2 Subsidy Effects on Overall Options Open Interest

Table 5 presents the elasticity relationship we measure between LRP subsidies for a given type of livestock and open interest in the relevant options market. They are interpreted as the expected percent increase in options open interest resulting from a one percent increase in the federal subsidy paid on active LRP policies, controlling for changes in futures prices and the VIX. The former control is important because the CFTC options position data are delta-adjusted, so they change with the change in underlying futures prices; the latter control represents marketwide uncertainty, so may itself lead to simultaneous rises in LRP and options trading.

Table 5: Elasticities of Total Options Open Interest to Subsidies

Commodity	Jan 2015–Jun 2019	Jul 2019–Jun 2020	Jul 2021–Dec 2024
Feeder Cattle	0.473*** (0.089)	0.446*** (0.105)	0.523*** (0.088)
Lean Hogs	-0.009 (0.015)	-0.015 (0.011)	0.037*** (0.013)
Live Cattle	0.056*** (0.021)	-0.018 (0.039)	0.028* (0.016)

Notes: Elasticities are estimated from the preferred model using Newey-West standard errors with up to 4 lags. Standard errors are in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

No elasticity values in table 6 are negative and significant, indicating that according to our analysis LRP subsidies *do not* crowd out overall options trading. Rather, the reverse may be true at least in some cases. Feeder cattle elasticities are highly significant and positive across regimes; the coefficients are indistinguishable, statistically. They indicate that a one percent rise in the federal subsidy paid to the producers of feeder cattle is associated with about a half-percent rise in the overall feeder cattle market open interest. This result aligns with both figures 5 and 6, where after policy changes in 2021 feeder cattle takes up a dominant share of the subsequent federal subsidies under the program, while its options market open interest more than doubles. Likewise, lean hogs and live cattle options market trading may be crowded in by LRP subsidies—especially in the most recent subsidy regime—although the elasticity values are less than one-tenth as large and not significant at the 5% level, in the case of live cattle.

In the context of our model, the findings in table 6 could indicate that LRP subsidies induced producers of feeder cattle, fed cattle, and swine engage in arbitrage trading, especially since mid-2021. However, it may instead be the case that the extraordinary rise in LRP take-up promoted additional hedging by producer counterparties, AIPs and the reinsurance companies they transact with. Additional trading behavior by these firms, who take on risk by writing and insuring livestock policies, may instead explain the elasticities in table 6. However, aggregate OI masks heterogeneity by trader type and option sentiment (bullish vs. bearish). We examine them next, to establish more evidence in support of

potential arbitrage transactions.

5.3 Subsidy Effects on Producers' and Non-Reporting Traders' Options Positions

LRP is targeted at producers, so we estimate IRFs for the effects of subsidies on the options held by the CFTC's producer/merchant/processor/user category in the COT data. CFTC-reported options 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.

Table 6: Elasticities of Producer-Held Options Open Interest to Subsidies

Commodity	Sentiment	Jan 2015–Jun 2019	Jul 2019–Jun 2020	Jul 2021–Dec 2024
Feeder Cattle	Bearish	0.556*** (0.130)	0.719*** (0.155)	0.549*** (0.128)
	Bullish	0.113** (0.054)	-0.142 (0.133)	0.081*** (0.031)
Lean Hogs	Bearish	0.004 (0.011)	-0.019*** (0.004)	0.052 (0.060)
	Bullish	-0.026 (0.018)	-0.012 (0.013)	0.032** (0.015)
Live Cattle	Bearish	0.050*** (0.017)	0.008 (0.031)	0.009 (0.012)
	Bullish	-0.001 (0.027)	-0.044 (0.057)	0.009 (0.022)

Notes: Elasticities are estimated from the preferred model using Newey-West standard errors with up to 4 lags. Standard errors are in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

Notably, table 6 resembles table 5 in both magnitude and sign, across commodities. Once again, most of the feeder cattle elasticities are highly significant and positive, and statistically similar across regimes—indicating that LRP subsidies lead to near-term rises in producer-held options open interest. Lean hogs and live cattle market OI are again less-robustly related to LRP subsidies for the livestock underlying those contracts. We note that all elasticities in hte last regime, with the largest subsidy expenditures, are positive even for these other commodities, although are generally not significant. Yet unlike table 5 the results in table 6 are trader-specific; they are free of the AIP and reinsurance firms that might account for the crowding-in effects observed in table 5.[19] As a result, they better represent possible arbitrage behavior on the part of LRP policy holders although that because the classification system combines, e.g., producers and processors, our analysis faces measurement error and attenuation bias. On the other hand, the negative elasticity for lean hogs OI relative to the subsidy for the period July 2019 - June 2020 cannot be interpreted as supporting of arbitrage behavior—at least during that period, for that commodity. A necessary condition for the arbitrage is that *both* OI and the subsidy must

[19]CFTC would likely classify counterparty firms as either swap dealers or other reporting traders.

increase around the same time.

To interpret the sentiment-oriented results in the table, recall that bearish implies writing calls and potentially clean subsidy harvesting; bullish implies writing puts and perhaps dirty subsidy harvesting. According to table 6, feeder cattle producers may have engaged in both types of arbitrage behavior, while lean hogs (fed cattle) producers engaged in dirty (clean) arbitrage trades of their own. Although, for these other commodities any arbitrage trading was likely lower-intensity relative to the federal subsidies, since the elasticities are far smaller.

Similar patterns are exhibited by non-reporting traders in table 7. Feeder cattle OI held by smaller producers, like cow-calf operations, is most obviously affected by changes in LRP subsidies. Nearly all the elasticities we measure for that livestock type, across regimes and sentiment orientation, are positive and highly statistically significant. No other small producer elasticities in the table are positive and significant; one is negative, bearish lean hogs options trading between July 2019 - June 2020. As above, we interpret this result to indicate that the necessary condition for swine producer clean subsidy harvesting did not exist at that time.

Table 7: Elasticities of Non-Reporting Trader's Options Open Interest to Subsidies

Commodity	Sentiment	Jan 2015–Jun 2019	Jul 2019–Jun 2020	Jul 2021–Dec 2024
Feeder Cattle	Bearish	0.435*** (0.062)	0.495*** (0.072)	0.429*** (0.060)
	Bullish	0.013 (0.031)	0.149** (0.075)	0.079*** (0.019)
Lean Hogs	Bearish	0.009 (0.014)	-0.013*** (0.004)	0.093 (0.107)
	Bullish	0.010 (0.022)	-0.002 (0.008)	0.079 (0.091)
Live Cattle	Bearish	0.017 (0.012)	0.034 (0.024)	0.007 (0.009)
	Bullish	0.020 (0.019)	-0.039 (0.040)	0.015 (0.016)

Notes: Elasticities are estimated from the preferred model using Newey-West standard errors with up to 4 lags. Standard errors are in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

5.4 Estimating the Harvested Subsidies

To quantify the extent of possible subsidy harvesting, we apply the elasticities estimated above to calculate the additional, near-concurrent increases in options open interest (OI). Since subsidy capture can only occur at policy outset we focus on weeks where subsidies rise; similarly, arbitrage requires that OI increases too, so we exclude commodity-sentiment pairs with negative or insignificant elasticities. We convert the extra weekly OI implied by subsidy increase to weight equivalents using CME contract sizes (500 cwt for feeder cattle, 400 cwt for live cattle and lean hogs) and compare this to the actual increase in insured weight under LRP to derive the potentially captured share of the subsidy rise. These

amounts are then aggregated across trader types (producers and non-reporting) and sentiments (bearish and bullish) within each regime, capped at 100% to avoid overestimation. Note that since early-regime (before 2021) subsidy levels were much lower—recall 4—a full capture implies a very small arbitrage value.

Table 8 presents the implied capture percentages by commodity and regime. Unsurprisingly, feeder cattle exhibits the most consistent and substantial arbitrage target across all regimes, reaching 100% before July 2021 and 62.75% afetrwards. Subsidy capture in lean hogs amounts to 9.04% in the latest regime, while live cattle is confined to 100% in the pre-2019 period. These patterns align with the stronger elasticities observed for feeder cattle, suggesting more pronounced arbitrage in that market. Multiplying these percentages against the RMA's summary of business data, by livestock type, generates the implied subsidy captured through arbitrage trades shown in table 9. They sum to $164.2 million from 2015-2024, and are clustered in feeder cattle and, to a lesser extent, swine.

Table 8: Implied Subsidy Capture Percentages

Commodity	Jan 2015–Jun 2019	Jul 2019–Jun 2020	Jul 2021–Dec 2024
Feeder Cattle	100%	100%	62.75%
Lean Hogs	—	—	9.04%
Live Cattle	100%	—	—

Notes: Percentages represent the sum of producer and non-reporting trader capture across Bearish and Bullish option types, capped at 100%. Only significant regimes ($|t| > 1.96$) are included.

Table 9: Implied Subsidy Capture

Commodity	Jan 2015–Jun 2019	Jul 2019–Jun 2020	Jul 2021–Dec 2024
Feeder Cattle	$3.4 million	$0.2 million	$135.6 million
Lean Hogs	—	—	$24.5 million
Live Cattle	$0.5 million	—	—

Notes: Amounts in the table are calculated as capture percentage multiplied by total LRP subsidies for that subsidy regime and livestock type. Only significant regimes ($|t| > 1.96$) are included.

6 Conclusions

Rapid take-up of LRP following policy changes and subsidy increases in 2019 and 2020 raises concerns about rising actual 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 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 marked increases post-subsidy regimes, particularly for feeder cattle and swine, suggesting a potential link with (and crowding in effect of) LRP.

Taking our model to data, we exploit the requirement of near-simultaneous increase in both OI and LRP subsidies to conduct an arbitrage trade. The elasticity results confirm that crowding in effect across commodities, but especially for feeder cattle. When we disaggregate by trader type and option sentiment, some notable patterns emerge: subsidy increases coincide with more rapid increases in options open interest held by producers and non-reporting (smaller producer) traders in feeder cattle (both bearish and bullish) and to a lesser extent producer-held lean hogs (bullish). These findings align with model predictions about both types of subsidy harvesting among feeder cattle producers, and dirty subsidy harvesting in lean hogs. We use our elasticities to estimate that producers captured about $164 million, or 22%, of the $729 million in federal subsidies paid to support the LRP program from 2015-2024.

From a policy perspective, our findings highlight inefficiencies of subsidized livestock insurance. Subsidy harvests are a rent transfer from taxpayers, but a costly one due to the administrative burdens ans overhead costs it places on USDA and AIPs, and ultimately taxpayers. Recent changes in LRP terms expressly prohibit options trading that could generate dirty subsidy harvests, but clean versions are still possible. Beyond eroding taxpayer value, designing insurance policies that leave open the possibility of these types of arbitrage trades could potentially harm derivatives market integrity by distorting liquidity or perceived sentiment.

A key limitation in our work is our reliance on CFTC data that classifies producers into more aggregated trader groups, which likely introduces measurement error into our analysis. CFTC's options data also lumps certain kinds of calls and puts together, obscuring specific option-type responses critical to distinguishing clean from dirty subsidy harvesting. Going forward, we intend to access disaggregated call and put data to provide more clarity into the effects of LRP subsidies on options markets.

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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:

$$\mathrm{Var}[\max(Z,0)] = \frac{1}{2} - \delta^2 = \frac{1}{2} - \frac{1}{2\pi} = \frac{\pi - 1}{2\pi} = \kappa \approx 0.1817.$$

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:

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

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, $c_A \geq \pi_{\text{fair}}$, 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 at $I(\tau)$, yielding a payoff of $Q \cdot (P(t) - I(\tau))$. This position is held until T, settling for $Q \cdot (I(T) - I(\tau))$. Combined with the long spot position $Q \cdot (I(T) + b(T))$ and subsidized insurance (paying $\max(P(t) - I(T), 0)$), the total wealth is:

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

Simplifying (noting that $I(T) + (P(t) - I(\tau)) + (I(T) - I(\tau)) = P(t) + I(T)$ and combining with the insurance payoff):

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

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

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

For $I(T) \geq P(t)$, $\max(I(T),P(t)) = I(T)$, so $\max(I(T),P(t)) - I(T) = 0$, and wealth is:

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

Thus, wealth simplifies to:

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

since $\theta = \pi_{\text{fair}} - s$ and $c_A \approx \pi_{\text{fair}}$ (assuming a small early exercise premium). Expected wealth is:

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

matching the European case, as early exercise does not bias $\mathbb{E}[I(T)] = F(t,T)$. However, the interim futures position introduces additional volatility from $I(T) - I(\tau)$, increasing variance beyond basis risk ($Q^2 V_b$). The variance is approximately:

$$\text{Var}[W_{h_c}] \approx Q^2 \left[V_b + \text{Var}[I(T) - I(\tau) \mid \tau < T] \cdot \Pr(\text{early exercise})\right],$$

where $\text{Var}[I(T) - I(\tau)]$ depends on the time to expiration and volatility.

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 $I(\tau)$, settling for $I(T) - I(\tau)$. Total wealth is:

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

Simplifying:

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

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

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

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

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

Thus, wealth simplifies to:

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

with expected wealth:

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

The higher put premium ($\phi_A > \pi_{\text{fair}}$) slightly increases expected wealth, but early exercise adds volatility from $I(T) - I(\tau)$, yielding:

$$\text{Var}[W_{h_d}] \approx Q^2 \left[V_I + V_b + 2\rho\sqrt{V_I V_b} + \text{Var}[I(T) - I(\tau) \mid \tau < T] \cdot \Pr(\text{early exercise}) \right].$$

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.