A Theory of Subsidy Harvesting in Livestock Price Insurance

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Abstract

USDA designed the Livestock Risk Protection (LRP) program to help producers insure against declining prices for fed cattle, feeder cattle, and swine. Prices in derivatives markets determine program indemnities, making LRP policies similar to put options. Beginning in 2019, USDA made several changes to the program to encourage producer takeup, including increased premium subsidies. We introduce a theoretical model to show that subsidizing LRP premiums invites producers to "subsidy harvest," i.e. 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 provide. The subsidy harvest is a pure rent and costlier than a direct payment because it requires administrative oversight and federally-subsidized delivery through approved insurance providers. According to the model, the government's premium subsidy leads producers to favor LRP-oriented strategies over market options alone, while their choice to offset actual risk protection using options depends on individual risk tolerance and wealth objectives.

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1 Introduction

Since 1938, the U.S. government has offered 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 in liability (Rosch, 2022). FCIP 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 and unexpected declines in commodity prices, FCIP premiums 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 and shares in their underwriting risk 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.) 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 futures prices over a period of coverage; participation is encouraged through premium subsidies.

Prior to 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, participation in livestock insurance programs 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, as of this writing, currently accounts for almost 31 million head, $16 billion in liability, and $295 million in subsidies—compared to 2018 figures of 343,000 head, liabilities of $176 million, and subsidies under one million dollars (Boyer and Griffith, 2023a).

Rapid increases in LRP takeup, and participation in livestock insurance more broadly, have drawn scrutiny from market observers and policymakers. While higher subsidy rates and other recent changes successfully 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 whether increased LRP participation affects futures market trading and prices (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, lowering trading volume (Glauber, 2022; Belasco, 2025). Reduced commercial interest in a commodity futures market can have significant negative consequences, including harming its price discovery function (Working, 1953; Peck, 1985).

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

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

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

Carrico, 2024).

Since LRP works like a long put option, the producer can conceivably lock in a payoff equal to the terminal value of the livestock under the LRP policy plus the subsidy, less transaction costs and the opportunity cost of necessary margin account funds in the interim, by purchasing a LRP contract and writing a look-alike market put option. Alternatively, although unremarked upon up to now,[3] the producer can instead combine an LRP policy with a 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 via the sale of look-alike options tied to USDA insurance products can present several problems for the viability of the FCIP's livestock insurance portfolio. First, producers may take on additional risk, contravening the statutory purpose of livestock insurance as a risk management tool: a dirty subsidy harvest totally eliminates the downside protection afforded by LRP. Moreover, writing options requires margin maintenance, so producers need access to cash or credit to preserve the margin as positions are marked to market each day until options contract expiry. Second, clean subsidy harvesting caps the upside. It offers producers only the ability to earn at most the current livestock price plus the policy subsidy, reducing potential producer returns. 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). The revised provisions define 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." The insured (and anyone with a substantial beneficial interest in the insured) are now prohibited from offsetting coverage for the purpose of subsidy capture. RMA provisions further identify specific presumptive trading patterns, including opening a short put near the SCE window and certain call-plus-futures structures that jointly replicate selling a put option; the agency also noted it can access brokerage records to investigate suspected violations. Similar changes were made to DRP and LGM insurance policies. While changes in policy provisions are an explicit recognition of the potential for subsidy harvesting, the theoretical and empirical literature on the potential arbitrage

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

relationship between LRP and derivatives markets is thin (Boyer and Griffith, 2023b; Feuz, 2025).

We develop a theoretical framework for livestock risk management under uncertainty in the presence of subsidized insurance for prices. The model predicts that strategies involving subsidized insurance dominate unhedged behavior and market put options alone. Based on their risk tolerance and wealth objectives, producers behaving optimally will 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. We compare their theoretical performance under a variety of assumptions; our results suggest important considerations for the design of subsidized insurance on prices from derivatives markets.

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

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

Figure 1: LRP Liability by Commodity, 2005-2024

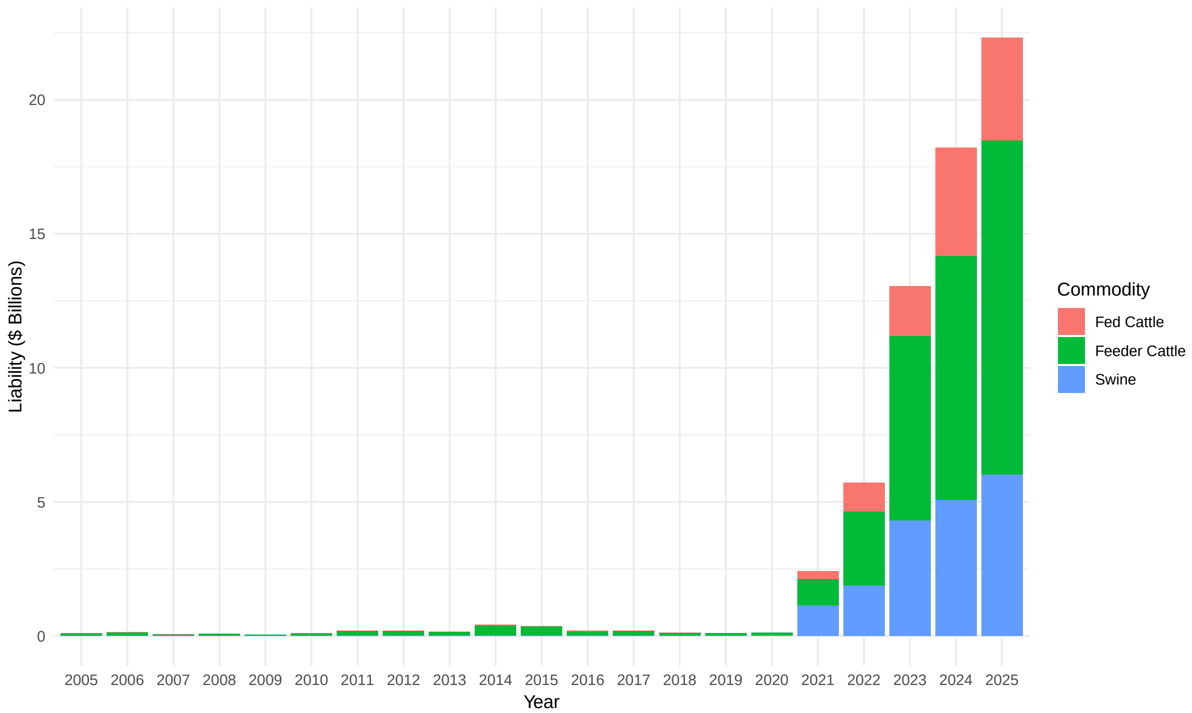
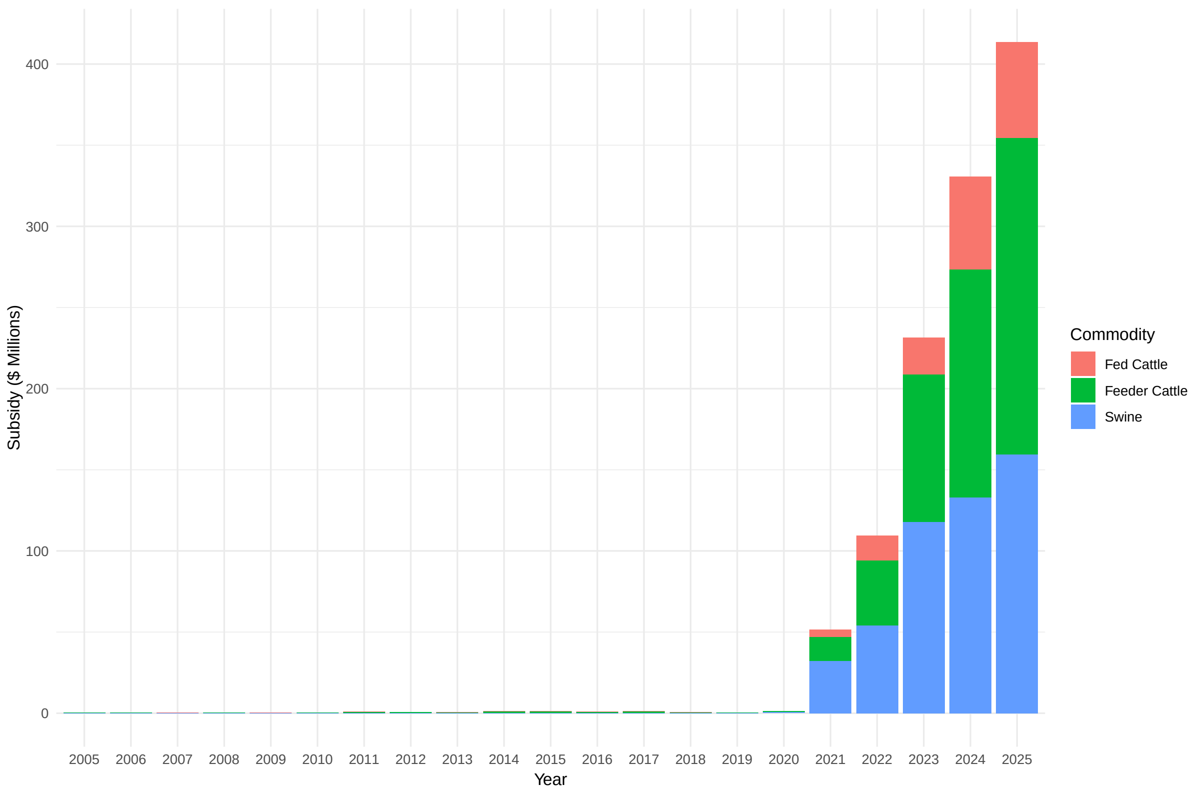


Figure 2: LRP Premium Subsidies by Commodity, 2005-2024



pounds) and do not include Brahman or dairy breeds. Price adjustment factors are intended to account for differences between steer prices in the CME contract and prices of other types and weights of cattle. The price adjustment factors are used in calculating expected ending values and actual ending values. For instance, type 2 steers (6.0 - 10.0 cwt) are the closest to the type of cattle included in the CME contract or index and therefore have a price adjustment factor of 100%, i.e. the price used in calculating the expected and actual ending values is simply the price for the CME contract or index.

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

Table 1: Available Insurance Periods by Commodity

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

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

Figure 3: LRP Loss Ratios, 2005-2024

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

actual ending value is less than the coverage price, a loss is realized. Otherwise, there is no indemnity. Figure 3 shows loss ratios (total losses over total premiums) for LRP between 2005 and 2024. The total loss ratio is based on the premium remitted to the insurer, whereas the producer loss ratio is based on the producer-paid premiums. If the premiums on the policies are actuarially fair, then the loss ratio should average 100% over a long period of time. The loss ratio indicates good performance, which might be expected, given that there is limited potential for moral hazard or adverse selection under LRP (Boyer et al., 2024; Merritt et al., 2017; Haviland and Feuz, 2025).

Two crucial inputs to equation 2.1, which link LRP to the derivatives markets, are the expected ending value and the actual ending value. The expected ending value is published each day by RMA,[4] whereas expected ending values are not publicly available but 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).

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

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

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

2.1 Related Literature

Our work connects to several strands of the literature, including the effects of subsidized crop insurance on producer behavior and market outcomes. Horowitz and Lichtenberg (1993) showed that subsidized insurance could induce moral hazard by encouraging production on marginal land. Young et al. (2001) and Goodwin et al. (2004) studied the effects of insurance subsidies on acreage decisions and found that subsidies modestly increased planted area. More recently, Yu et al. (2018) and Yu and Sumner (2018) examined how the design of insurance products interacts with producer risk preferences and commodity market conditions. Goodwin and Smith (2013) documented that rising subsidies on the crop side of the FCIP's book of business were associated with increased liability—much like the pattern we now observe in livestock insurance.

In contrast to crops, the behavioral effects of subsidizing livestock price insurance have received comparatively little attention. Yet, the concern that government-subsidized insurance could crowd out private risk management is long-standing. Glauber (2022) raised this possibility for livestock insurance specifically, noting that LRP's design as a subsidized put-option substitute creates a direct channel for substitution. Belasco (2025) examined the potential for livestock insurance to reduce commercial participation in commodity futures markets, with implications for price discovery and market liquidity.

Rapid growth of livestock insurance is recent, so the related literature is thin. What little LRP research has been conducted mainly focuses on the impact of changes to the subsidy structure on premiums (Boyer and Griffith, 2023a) or factors affecting takeup (Boyer and Griffith, 2023b; Boyer et al., 2024). A study by Merritt et al. (2017) examined the likelihood that producers would receive indemnities for feeder cattle under different insurance periods, while Haviland and Feuz (2025) conducted a similar assessment for all types of livestock. Baker (2023) and Baker (2024) discuss the arbitrage potential for subsidy harvesting in trade publications. On the question of subsidy harvesting specifically, Feuz (2025) and Zhang et al. (2026) offer empirical treatments of the extent of subsidy capture using LRP policies.

Our contribution, in the form of a theoretical framework, demonstrates that subsidized instruments can create arbitrage opportunities when they share features with market assets. In the LRP setting the insurance product mimics closely a traded derivative, the subsidy is large and well-defined, and the offsetting trade is straightforward for any producer with access to a commodity brokerage account. The institutional details described above—in particular, the tight link between LRP policy parameters and futures-market prices, the availability of matching options contracts, and the structure of premium subsidies—are what make subsidy harvesting feasible. The model we develop in the next section formalizes this relationship and derives the conditions under which rational producers would choose to harvest the subsidy rather than use LRP purely for risk management.

3 A Model of Livestock Producer Decisions with Subsidized Insurance

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

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

$\phi = \pi_{\text{fair}}$,[5] 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 $\kappa < 1$.[6] 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.

Our assumption that $P(T)$ follows a normal distribution amounts to a Bachelier model for futures prices, which we adopt for tractability.[7] We price options as $\pi_{\text{fair}} = \mathbb{E}[\max(P(t) - P(T), 0)]$, which assumes zero risk premia so that the physical and pricing measures coincide and the risk-free rate is negligible for option valuation purposes. When we later introduce a positive risk-free rate r in the relaxed case, it enters only through the opportunity cost of margin, not through option pricing—consistent with our simplification. Finally, we set the strike equal to the current futures price (that is, we focus on at-the-money options) for expositional clarity. For strikes below the futures price—as when an LRP coverage level is less than 100%—the constants δ and κ become functions of moneyness, but the qualitative rankings among strategies are unchanged.

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.

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:

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

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

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

[7] The normal model allows closed-form expressions for δ and κ that clarify the economic intuition. Our qualitative results—the dominance rankings among strategies and the role of the subsidy in driving them—extend to standard option-pricing setups that impose, e.g., lognormality.

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. 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:

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

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:

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

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

3.3.2 Subsidized Insurance (i)

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

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

Expected wealth is:[8]

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

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

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

And the certainty equivalent is:

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

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

[8] 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:[9]

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

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:[10]

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

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

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

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

[10] 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,[11] 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

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

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

3.5.1 Unhedged Sale (u)

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

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

Expected wealth includes the expected basis:

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

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

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

The certainty equivalent is:

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

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

3.5.2 Subsidized Insurance (i)

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

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

Expected wealth accounts for transaction costs and the expected basis:[12]

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

Variance includes basis risk, accounting for correlation:[13]

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

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:

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

[12]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.

[13]This is a linear covariance approximation. The true covariance between the censored index price $\max(I(T), P(t))$ and the basis $b(T)$ does not decompose as $\rho\sqrt{\kappa V_I \cdot V_b}$ because censoring is a nonlinear operation. We adopt this approximation for tractability; it does not drive the main comparative statics, which depend on the variance differences $(1-\kappa)V_I$ across strategies. Setting $\rho = 0$ eliminates the approximation entirely and preserves all qualitative rankings.

Variance matches the insurance strategy:

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

The certainty equivalent is:

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

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:

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

Expected wealth reflects frictions and the expected basis:

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

Variance arises only from basis risk:

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

The certainty equivalent is:

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

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

3.5.5 Dirty Subsidy Harvest (h_d)

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

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

Expected wealth is:

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

Variance includes both index and basis risk:

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

The certainty equivalent is:

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

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

3.6 Comparing Strategies under Relaxed Assumptions

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

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

Table 3: Summary of strategies under relaxed assumptions.

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

The wealth difference includes frictions:

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

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

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

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

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

The wealth difference reflects the subsidy:

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

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

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

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

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

The clean subsidy harvest incurs additional costs:

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

On the other hand, its variance is lower:

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

The certainty equivalent difference is:

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

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

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

The subsidy harvest again faces additional costs:

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

It likely also suffers from more wealth variance:

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

The certainty equivalent difference is:

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

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:

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

The certainty equivalent difference is:

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

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.

4 Numerical Illustration

To make the model's predictions more concrete, we calibrate an example using parameters representative of a typical feeder cattle producer. Suppose the producer raises $Q = 62$ head of feeder cattle with a target weight of 8 cwt per head, implying a total quantity of approximately 500 cwt—the equivalent of one CME feeder cattle futures contract. Recent futures prices and price volatility for the related futures contract were around $F(t,T) = \$260$/cwt and $\sigma_T = \$20$/cwt over a 26-week insurance period ($\Delta t = 0.5$ years), respectively. Assume that the producer selects the 100% coverage level, which carries a 35% premium subsidy. Under these assumptions, the actuarially fair premium is $\pi_{\text{fair}} = \delta \sigma_T \approx \$7.98$/cwt, the per-unit subsidy is $s \approx \$2.79$/cwt, and the producer-paid insurance premium is then $\theta \approx \$5.19$/cwt.

For the relaxed case, we set basis at $\mu_b = -\$3$/cwt (reflecting transportation discounts faced by producers), and its standard deviation $\sqrt{V_b} = \$3$/cwt, the cash-futures price correlation $\rho = 0.8$, transaction cost $\tau = \$0.40$/cwt per trade, margin requirement $m = \$12$/cwt, and a risk-free rate of $r = 0.045$. The opportunity cost tied to margining is therefore $m(e^{r\Delta t} - 1) \approx \$0.27$/cwt. The producer's total livestock value is approximately \$130,000, implying that the net subsidy after transaction and margin costs for a clean subsidy harvest is approximately \$860. That is small relative to the total value of the livestock, but it is sufficient to shift certainty equivalent rankings depending on risk preferences because it is accompanied by a large reduction in variance.

We generate certainty equivalents using relative risk aversion R, which is more interpretable across wealth levels than the absolute coefficient γ. The two are related by $\gamma = R/W$, where W is a reference wealth level (here, the expected wealth of the unhedged position). We apply risk-aversion rates for γ to represent three different producer types: one who is risk-averse ($R = 3$),[14] one who is risk-neutral ($R = 0$), and a third who is (symmetrically) risk-seeking ($R = -3$). The latter is motivated by the fact that subsidy harvesters may choose to trade risk protection for returns; producers who perceive themselves as having informational advantages may behave on the margin as if they were risk-seeking.

Table 4 reports the expected wealth, wealth standard deviation, and certainty equivalents associated with each strategy across three different producers, classified by their risk-preference: risk-averse ($R = 3$), risk-neutral ($R = 0$), and risk-seeking ($R = -3$). Several features are worth noting. In the frictionless case (Panel A), the clean subsidy harvest delivers the highest certainty equivalent for risk-averse producers, confirming the model's prediction. By conducting the clean subsidy harvest the risk-averse producer effectively secures an arbitrage trade—capturing the full subsidy while eliminating all price risk—generating a certainty equivalent equal to his expected wealth. By contrast, the dirty subsidy harvest dominates for risk-seeking producers: it delivers the same expected wealth as the clean subsidy harvest but retains the full variance of the unhedged position—offering the chance to earn additional returns. For the risk-neutral producer, with $R = 0$, all three subsidy-capturing strategies (subsidized insurance, the clean subsidy harvest, and the dirty subsidy harvest) are tied; each produces the same

[14]This level of risk-aversion is consistent with those commonly estimated in the literature (Hardaker et al., 2004; Moschini and Hennessy, 2001).

Table 4: Numerical illustration: strategy comparison for a feeder cattle producer (single contract).

			Certainty Equivalent ($)		
Strategy	**E[W] ($)**	**SD(W) ($)**	$R=3$	$R=0$	$R=-3$
Panel A: Illustrative case (no frictions)					
Unhedged (u)	130,000	10,000	128,846	130,000	131,154
Subsidized Insurance (i)	131,396	5,840	131,003	**131,396**	131,790
Market Put (p)	130,000	5,840	129,607	130,000	130,393
Clean Subsidy Harvest (h_c)	131,396	0	**131,396**	**131,396**	131,396
Dirty Subsidy Harvest (h_d)	131,396	10,000	130,243	**131,396**	**132,550**
Panel B: Relaxed case (with frictions)					
Unhedged (u)	128,500	11,236	127,026	128,500	129,974
Subsidized Insurance (i)	129,697	7,097	129,109	**129,697**	130,284
Market Put (p)	128,300	7,097	127,712	128,300	128,888
Clean Subsidy Harvest (h_c)	129,360	1,500	**129,334**	129,360	129,386
Dirty Subsidy Harvest (h_d)	129,360	11,236	127,886	129,360	**130,834**

Notes: We use the following parameters to generate the expected wealth, its standard deviation, and the certainty equivalents of the producer strategies: $Q = 500$ cwt (one CME feeder cattle contract, ≈62 head), $F(t,T) = \$260$/cwt, $\sigma_T = \$20$/cwt, $\delta \approx 0.399$, $\kappa \approx 0.341$, $s = \$2.79$/cwt. Relaxed case adds: $\mu_b = -\$3$/cwt, $\sqrt{V_b} = \$3$/cwt, $\rho = 0.8$, $\tau = \$0.40$/cwt, $m = \$12$/cwt, $r = 0.045$, $\Delta t = 0.5$ years. Transaction costs (τ per trade) apply to every market transaction: purchasing LRP, buying a market put, or writing an option. Subsidized insurance and the market put each involve one trade; the clean and dirty subsidy harvests each involve two (purchasing LRP plus writing an option). Margin costs apply only to written options (the clean and dirty subsidy harvests). Bold entries indicate the dominant strategy within each panel and risk-preference column. Certainty equivalents computed as $\text{CE} = \mathbb{E}[W] - (R/2W)\text{Var}[W]$, where R is relative risk aversion and W is reference wealth of the unhedged strategy. All values in the table are rounded to the nearest dollar.

expected wealth and CE, given that risk-neutral producers are indifferent to variance.

Panel B introduces frictions for each strategy, and although they attenuate the magnitude of CE differences, the strategy ordering is generally maintained across risk preferences after accounting for added costs. In the relaxed case, the clean subsidy harvest remains the dominant strategy for the risk-averse producer, though its CE premium over subsidized insurance shrinks from \$393 to \$225 as transaction and margin costs erode part of the subsidy. The dirty subsidy harvest still dominates for risk-seeking producers in Panel B, but its certainty equivalent now exceeds subsidized insurance by just \$549. This is because it now incurs the additional transaction and margin costs of writing the offsetting put—reducing its expected wealth below the subsidized insurance choice by \$337. For risk-neutral producers, adding frictions leads subsidized insurance to strictly dominate: insurance avoids the cost of the exchange trades, which are required by both types of subsidy harvests.

Another key results is that in both panels strategies that involve subsidized insurance always dominate the CE produced by the unhedged and market put option. A producer who would otherwise go unhedged can strictly improve, with or without the introduction of frictions, by purchasing the subsidized insurance even without conducting a subsidy harvest. Similarly, the subsidy drives a wedge between subsidized insurance and the market put option that no level of risk preference can close. According to both the model and our numerical example, some form of subsidized insurance is optimal for producers with every risk-preference type. As a result, subsidizing livestock insurance may crowd out the trading of market options by livestock producers, unless it also invites subsidy harvesting behavior.

5 Conclusions

Rapid takeup of LRP following policy changes and subsidy increases in 2019 and 2020 raises concerns about spiking taxpayer costs (Glauber, 2022; Belasco, 2025). In addition, the design of the price-based insurance policy—when similar market-based instruments are available—presents the possibility of unintended market consequences, including the potential for subsidy harvesting by using offsetting options trades to effect arbitrage. We provide a theoretical framework to demonstrate how subsidized LRP, which mimics a market 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 (in a world without frictions) 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.

From a policy perspective, these findings highlight an inefficiency inherent in subsidized livestock price insurance. By establishing a policy program so similar to existing market derivatives USDA left the door open to unintended subsidy capture behavior, possibly counter to the program's objectives of reducing producer revenue risk. Such activity, conducted via taking offsetting positions in the options markets, represents a rent transfer from taxpayers—and a costly one—given the administrative overhead of running the insurance and reinsurance system required to deliver those payments. Recent program amendments now prohibit offsetting positions intended to generate subsidy harvests and identify specific presumptive trading patterns (Risk Management Agency, 2026). These presumptions explicitly cover short put positions and certain call-plus-futures structures, but their scope with respect to a standalone short call—the basis of the clean subsidy harvest—is less clear. Moreover, enforcing a ban on offsetting positions requires RMA or AIPs to monitor producers' derivatives market activity, a task that is difficult when brokerage accounts are held at separate institutions from the insurance provider.

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. Observable patterns consistent with subsidy harvesting would include increased open interest in livestock options coinciding with LRP enrollment periods, particularly in contracts whose maturities align with common insurance periods. Empirical investigation of these patterns and the magnitude of subsidy harvesting in practice is left for future research.

The broader lesson that emerges from recent LRP experience, however, is that when a government program subsidizes an instrument that closely replicates a privately-traded derivative, the subsidy itself becomes the object of optimization rather than the risk management it was intended to support. This observation applies beyond livestock insurance to any setting in which subsidized insurance or guarantee programs overlap with liquid derivatives markets. Program designers should consider whether any arbitrage opportunities may be produced, and if so, if they undermine the program's goals. If so, simpler transfer mechanisms—such as direct payments—could be employed achieve the same distributional objectives at lower taxpayer cost.

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Appendix

A 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:

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

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

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

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 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 early-exercise 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 may include an early exercise premium, implying $\phi_A \geq \pi_{\text{fair}}$. American puts on futures can possess an early-exercise premium and may be exercised prior to maturity when sufficiently in the money and the value to holding them is low.

On the other hand, for an American call option on a futures contract with strike $P(t)$, early exercise is *not* optimal in frictionless arbitrage settings. Because the underlying futures contract is marked to market daily with no upfront cost, exercising a call early provides no additional interest advantage on the intrinsic value. Thus, American calls on futures equal their European counterparts, $c_A = \pi_{\text{fair}}$, with no early exercise premium. Nevertheless, call option writers may face assignment if the option purchaser exercises suboptimally (or for operational reasons), affecting the timing of cash flows but not terminal payoffs.

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). Although early exercise of the call is suboptimal for a rational holder and therefore unlikely, assignment may still occur in practice. If the call is exercised early at $\tau < T$, the producer takes the associated futures position and experiences interim cash flows due to mark-to-market settlement. The resulting futures-related cash flows from assignment to maturity simplify to $Q[P(t) - I(T)]$, exactly as if the call had been exercised at maturity.

As shown in Appendix A, combining subsidized insurance with the written call collapses exposure to the futures price, leaving terminal wealth approximately deterministic apart from basis and cost terms. Early assignment therefore does not change expected wealth or terminal variance relative to the European case—it only alters the *timing* of cash flows and introduces potential margin or liquidity pressures prior to maturity. In a frictionless setting, the remaining uncertainty is basis variation:

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

For risk-averse producers subject to liquidity or margin constraints, interim cash flows can generate somewhat greater volatility in wealth over time even though terminal wealth is unchanged.

C.2 Dirty Subsidy Harvest (h_d)

In the dirty subsidy harvest, the producer writes an American *put* option. If exercised early at $\tau < T$, the producer takes the associated futures position and experiences interim cash flows from settlement. The net futures-related cash flow from assignment to maturity simplifies to $Q[I(T) - P(t)]$, exactly as if exercised at maturity. Total wealth is therefore:

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

Simplifying,

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

Using $\theta = \pi_{\text{fair}} - s$ and $\phi_A \approx \pi_{\text{fair}}$ (with a possible small early-exercise premium), expected wealth becomes:

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

Early exercise is a distinct possibility faced by the producer who employs the dirty subsidy harvest, but only as it affects the timing, not the terminal distribution, of his wealth. Indeed, the possibility of early exercise of American put options may increase their premium and therefore a producer's expected wealth, but it does not materially change variance in a frictionless environment:

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

Adding liquidity or financing frictions can translate interim position changes into perceived volatility through cash-flow timing effects.

C.3 Implications for Producer Strategy

American options on futures allow early exercise, but this is generally relevant only for puts, not calls. As a result the dirty subsidy harvest faces greater potential for early assignment than the clean strategy. When early exercise occurs, it introduces interim futures positions and associated cash-flow adjustments, particularly affecting risk-averse or liquidity-constrained producers. These frictions may reduce certainty equivalents for subsidy harvesting strategies relative to subsidized insurance alone (e.g., the gap $\text{CE}_{h_c} - \text{CE}_i$ narrows), even though terminal payoffs remain largely unchanged.

For financially constrained or highly risk-averse producers, the liquidity and margin implications of American options may tilt their preference toward subsidized insurance rather than active arbitrage strategies. On the margin, the added interim risk and operational complexity can deter participation in especially dirty subsidy harvesting.