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RESEARCH ARTICLE

# Western Safflower Contracting Strategies

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**Abstract**
Safflower grown in the western U.S. is often produced for birdseed mixes. Increasing demand for birdseed products, combined with regional drought, has shrunk western safflower availability. To satisfy the growing demand, processors may look to contracting strategies to incentivize production. We compare expected risk and corresponding certainty equivalents both from the processor and producer viewpoints under various contracting mechanisms and risk aversion levels. Results suggest that contracts containing a combination of lump sum acreage payments and fixed price performance payments would incentivize producer adoption of safflower while maintaining processor profitability and limiting the risk exposure of both parties.

**Keywords:** Agribusiness; contracting mechanisms; marketing; oilseed; risk management

**JEL classifications:** Q13; M10; C6

## 1. Introduction

Between 2003 and 2022, domestic safflower seed prices increased by 142% (USDA, 2023). High prices, coupled with growing world demand for safflower products suggest a bullish outlook for producer profitability (Mordor Intelligence, 2023). Despite the price and demand increases, domestic safflower production has languished behind disappearance, reducing domestic stocks of safflower seed, and disrupting the growth of a potentially lucrative agricultural supply chain. In thin agricultural markets that rely on producer-processor contracting, contract structure has been shown to be a key factor in determining farmer's willingness to grow a particular crop (Hoque et al., 2015; Kliebenstein and Scott, 1975; McCarty and Sesmero, 2021; Wilson and Dahl, 2015; Yang et al., 2016). We explore the problem of anemic domestic safflower production through the lens of agricultural contracts. Specifically, we compare the risk exposure and certainty equivalents for both safflower growers and processors under various contracting arrangements to evaluate the feasibility of increasing domestic safflower supply through contracting.

Safflower is an oilseed crop primarily produced in the western Great Plains due to its compatibility with cereal grain production and harvesting equipment (Berglund et al., 2007). Varieties grown in that region are harvested mainly for seeds high in safflower oil and oleic acid that are processed and used in cooking oil, human nutrition, and other health and beauty products (Bergman and Kandel, 2019; Berglund et al., 2007). Safflower is also grown in the region of Montana, Idaho, and Utah for birdseed mixes due to the region's arid climate,[1] which yields a crisp, white seed that is highly favorable in the birdseed market (Emongor et al., 2017; Godfrey, 2022). Due to the regional differences in price risk, yield risk, and the end-of-use for safflower, this study focuses on the Montana, Idaho, and Utah region.

[1]California also has significant safflower production, yet the growing conditions are markedly different compared to the region of Montana, Idaho, and Utah. This study focuses on the intermountain region of Idaho and Utah.

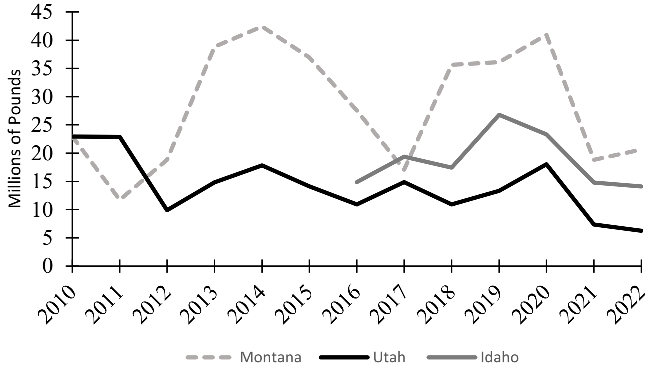


**Figure 1.** Montana, Utah, and Idaho historical safflower seed production.

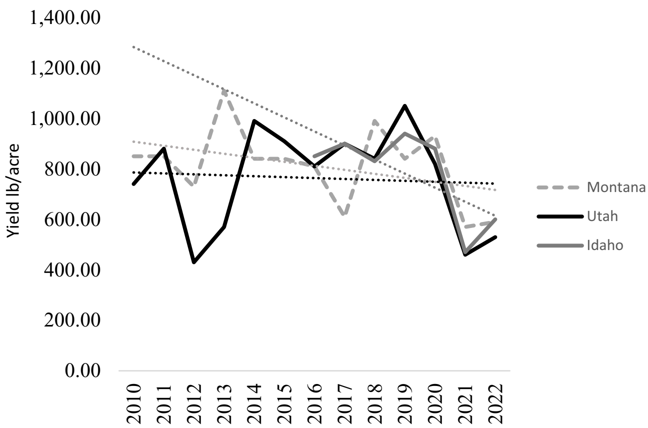


**Figure 2.** Montana, Utah, and Idaho historical safflower seed yield.

Combined production has fallen in Montana, Idaho, and Utah from 53.4 million pounds of raw safflower in 2016 to 41.0 million pounds in 2022 (Fig. 1) (USDA NASS, 2023).[2] A portion of this decrease in production can be attributed to decreased yields perhaps largely resulting from drought. Figure 2 depicts yields declining over the three-state average from 943 lbs./acre in 2019 to only 573 lbs./acre in 2022 (USDA, NASS, 2023). The total production in the region was also negatively impacted by decreased acres planted from 99,500 acres in 2020 to 87,000 acres in 2023 as shown in Fig. 3. (USDA, NASS, 2023). This decrease in acres planted may have largely been spurred on as competing crop prices (wheat and barley) increased at a greater rate over this period as compared to safflower seed. From 2019 through 2022 the safflower seed price increased approximately 71 percent on average across Montana, Idaho, and Utah, whereas wheat and barley prices increased 81 and 91 percent, respectively (USDA, NASS 2023). This presumably increased the opportunity cost of safflower seed production and put pressure on producers to switch production to competing crops.

Oilseed processors in the region have routinely relied on contracts to ensure procurement of seed to meet demand (Pace et al., 2015). More recently, processors have faced growing competition for safflower by a maturing spot market (Godfrey, 2022). This increase in competition for inputs combined with decreasing safflower output has processors in the region

[2]Observations for Idaho only start in 2016 as that was the first date available in the NASS quick stats database.

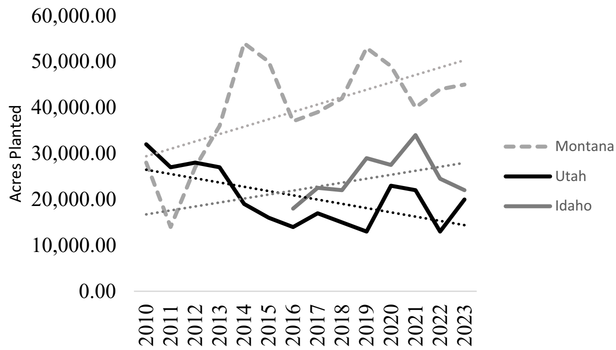


**Figure 3.** Montana, Utah, and Idaho historical safflower seed acres planted.

concerned they may not be able to acquire sufficient safflower seed to capitalize on increasing demand in the birdseed market (Godfrey, 2022).

Many producers remain skeptical of the economic feasibility of replacing traditional, familiar enterprises with safflower (Godfrey, 2022). Safflower has historically provided relatively thin margins compared with other small grains produced in the western states (Pace et al., 2019). War between Russia and Ukraine has heavily disrupted the safflower supply chain (Bankova, Dutta, and Ovaska, 2022). Ukraine and Russia jointly exported approximately 96,000 tons of safflower seed in 2020 (Wamucii 2023a, 2023b). The war has also led to U.S. producers experiencing increased costs for fertilizer manufactured in Eastern Europe (Arndt et al., 2023). Persistent drought has plagued the western states in recent years (U.S. Drought Monitor, 2023) and producers have been forced to rethink crop rotations focusing on allocating water to high-value crops. These events have pushed raw safflower seed prices in the U.S. to unprecedented levels above $600/ton (USDA, NASS, 2023).

To capitalize on these conditions, processors in the region of Montana, Idaho and Utah must consider strategies to entice more dedicated safflower production. The objective of this study is to compare the expected financial implications and risk exposure of various contract mechanisms to incentivize safflower producer participation in the western states region of Idaho and Utah. A financial simulation analysis of expected profit is conducted for four contracting scenarios: 1) spot market price, 2) fixed price, 3) indexed price, and 4) combination lump sum acreage payment with a fixed price. The results are evaluated from both the producer and processor perspectives with both sets of results objectively ranked through sensitivity analysis over the risk aversion level. Findings suggest that the combination lump sum acreage payment with a fixed price contract mechanism is expected to result in the highest average profit for producers with the lowest level of volatility. While this contract mechanism is expected to result in decreased profitability for processors, the sensitivity analysis suggests it is a compelling option considering the goal of regional processors to increase producer adoption of safflower.

### *1.1. Relevant literature*

The proportion of agricultural products being sold through contracting has increased over time. MacDonald et al. (2004) found that the use of production and marketing contracts increased to cover 24% more of the value of U.S. agricultural production in 2004 as compared to 1969. In their USDA, ERS report they concluded that the spot market struggles to offer precise price signals for products aligned with emerging consumer demands and thus predicted a growing reliance on vertical coordination, facilitated by contracts and ownership, as a response to this challenge. Thus, if this trend holds, the emerging consumer demands in the safflower market may necessitate increased use of contracting.

There has been significant research in evaluating contracting strategies within grain production including durum wheat, canola, corn, soybeans, and barley (Wilson and Dahl, 2011, 2014, 2015; Martin and Hope, 1984; Pritchett et al., 2004; Sogn, Vollmers, and Baatz, 1981; Turner, 2018).

Turner (2018), evaluated pre-harvest contracting strategies within corn production to determine whether it is possible to enhance farm returns by marketing within the pre-harvest window over simply selling in the harvest-time cash market. The contracting strategies evaluated included both forward and futures-based contracts. Parametric testing results suggested that pre-harvest strategies did not enhance returns above harvest returns suggesting that futures markets and related forward markets are efficient at pricing corn and that no economic advantage is gained from contracting in the pre-harvest window. However, nonparametric results did lend some support to several of the pre-harvest contracting strategies. If safflower producers are efficient at setting forward contract prices, then we would not expect to see any significant difference in expected returns between forward and spot market contracts. For this reason, we not only include forward and spot market contracts but also consider the use of lump sum payments to incentivize producer adoption of safflower and shift the expected return.

Wilson and Dahl (2015) provide a broad survey of contract terms used in grain contracting as well as illustrate issues that arise when contracting with grain growers (durum wheat and malting barley). They demonstrate how price increases post-contracting can induce producers to breach the contract and sell on the spot market. They also demonstrate how contract provisions can be added to help ensure compliance. The concern of breach of contract is mitigated in the safflower market as this is a thin market with relatively few processors. Producers who breach a contract will likely find it difficult to procure additional contracts for future production periods.

Wilson and Dahl (2011) and (2014) provide analyses of alternative contracting strategies in Durum wheat and canola, respectively. Using various pricing features and contract terms such as no contract, fixed price with and without act of God provisions, pricing floors/ceilings, and an oil premium contract (in the case of canola), the authors analyzed these pricing mechanisms in terms of risk and return to producers using a sensitivity analysis across a range of assumed risk aversion levels. The authors suggest that contracting of these crops has become increasingly important as they have greater risks than competing crops and do not have access to traditional risk management alternatives. Wilson and Dahl (2011) suggest that a similar empirical analysis could be applied to additional crops sharing these characteristics such as white corn, malting barley, field peas, lentils, sunflower etc.

Safflower is another such crop with higher risks compared to competing crops and no access to traditional risk management activities. Our study follows similar methodology as Wilson and Dahl (2011, 2014) and adds to the literature by examining contracting strategies within safflower production to evaluate expected profit, risk exposure, and certainty equivalents. Based upon previous research exploring the impact of contracting on farmer's willingness to grow a crop in a thin market we suspect that provisions reducing farmer exposure to price or production risk will be important factors in incentivizing safflower adoption (Hoque et al, 2015; Kliebenstein and Scott, 1975, Wilson and Dahl, 2015). However, the degree to which various contracting provisions will enhance the attractiveness of safflower adoption remains to be tested.

## 2. Data and methods

Stochastically determined expected profit functions are developed for each contract type to evaluate how various payment mechanisms influence the total risk profile for producers and processors of safflower. The profit functions incorporate the dynamic elements of safflower production by simulating price uncertainty, cost fluctuations, and crop yield predictions that more accurately reflect the relationship between the price received by farmers and the overall riskiness of the enterprise.

**Table 1.** Safflower quality deductions

| Total Dockage[1] | Cleaning Charge ($/ton) | Moisture | Discount ($/ton) |
|---|---|---|---|
| 0.00–5% | $0.00 | 8.0–9.0% | $0.00 |
| 5.1–6% | $8.00 | 9.1–10% | $6.00 |
| 6.1–10% | $10.00 | 10.1–11% | $12.00 |
| 10.1–12% | $12.00 | 11.1–12% | $18.00 |
| 12.1–15% | $15.00 | 12.1–13% | $24.00 |
| 15.1–17% | $18.00 | Any seed exceeding 13% moisture will only be accepted by negotiation. | |
| 17.1–19% | $22.00 | | |
| 19.1–21% | $25.00 | | |
| 21.1–22% | $28.00 | | |

Note: All charges are against gross inbound weights and deductions are charged as $/ton.
Values were estimated from discussions with an owner of a Utah/Idaho oilseed processor (Godfrey, 2022).
[1]Seed includes additional grains, sprouts, or other contaminates.

It is assumed that yields, costs, and other influencing factors are not significantly impacted by entering a contract. Arouna, Michler, and Lokossou (2021) and Casaburi et al. (2014) both attempted to identify the relationship between agricultural productivity and contract farming, but both focused on farm systems in scenarios outside of the United States. We assume productivity for safflower seed production is more correlated with producer characteristics than payment mechanisms for the contracts considered. Specifically, moral hazard is not likely to be a chief concern for safflower. Important attributes such as moisture content can be easily measured and incentivized through quality adjustment payments, which are embedded in all proposed contracts. Other unobserved actions that would affect yield are minor for safflower (e.g., not applying fertilizer) and it is assumed that the performance payments present within all considered contract structures are sufficient to ensure that the marginal benefits associated with higher yields are higher than the marginal costs of following best management practices. Therefore, this model implements the same stochastic costs and yields *ceteris paribus* across all contract types such that marginal changes in risk or expected profit can be specifically attributed to the payment mechanism itself and not secondary effects on effort.

Safflower seed contracted and shipped to the processor often must comply with the moisture and dockage requirements such as those outlined in Table 1. Using a quality scale to monitor moisture and dock material within the incoming safflower loads reduces the amount of waste and cost at the processing plant. Raw seed with high moisture levels, excessive dirt, or dockage must undergo drying and cleaning procedures before the seed is ready for processing. The seed prices are routinely discounted by processors to cover these added costs.

### 2.1. Payment mechanisms

Four payment mechanisms are selected for comparison of expected profit and risk for both the producer and processor. The four contract payment mechanisms are 1) spot market price, 2) fixed price, 3) indexed price, and 4) combination lump sum and fixed price payment (CLS_FP) and are defined in the following sections.

#### 2.1.1. Spot market

Spot markets sell commodities for immediate delivery and cash settlements. Choosing the spot market over a production contract exposes producers to downside price risk and processors to downside input cost risk.

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*2.1.2. Fixed price*

The fixed price performance mechanism is often referred to as a marketing forward contract. It is used frequently in oilseed markets where the processor and the producer agree upon a price per unit at the beginning of the production year. Fixed price contracts are popular as they remove downside producer price risks and reduce downside processor input cost risk. However, significant market price changes can render contracts untenable for one party. In times of low market prices, the processor may find a strong motivation to cancel or break the contract, whereas the situation is reversed for the producer when market prices rise.

*2.1.3. Indexed-price performance payment*

Safflower does not have a futures market which can hinder price discovery. Using an indexed price, one can easily estimate safflower prices given a historical average or standardized price indexed against a commodity with more information transparency. For this contract mechanism, safflower prices are indexed against wheat prices. Producers in the West adopting safflower would likely be replacing dryland wheat production. Thus, using wheat prices as an index for safflower prices in this region is appropriate as wheat could be taken as the opportunity cost of production of safflower.

*2.1.4. Combination lump sum and fixed price payment*

Within this mechanism, rather than determining revenue solely as the product of price and quantity (P × Q), a lump sum payment is paid on a per-acre basis for a portion of anticipated production. Whether dispensed as an establishment or annual payment, this mechanism ensures revenue for the producer irrespective of the field's production. Its appeal is evident when low safflower acreage poses a threat to sufficient raw safflower seed quantity entering the mill. Acreage payments also encourage oilseed production by motivating farmers, previously unfamiliar with safflower, with a guaranteed income percentage. This arrangement mitigates both price and a portion of yield risk for the producer, transferring them to the processor. While the processor assumes additional risk, notably due to the moral hazard from nonperformance-tied acreage payments, lump sum payments may effectively drive safflower adoption among producers.

To minimize moral hazard while still incentivizing producer adoption of safflower, for this analysis the lump sum mechanism pays only 10 percent of expected ending value as a fixed acreage payment using an assumed yield upon contract signing with the balance paid at harvest using the actual observed yield and a pre-negotiated fixed price.

### 2.2. Producer payoff functions

The expected profit per acre over one marketing year for producers under the spot market price mechanism is defined as

$$E\left(\pi_{SP\_prod}\right) = \left(P - Mf - Df\right) * Y - TC \tag{1}$$

where $P$ is the safflower spot price per ton, $Mf$ is the moisture fee ($/ton) deducted for raw safflower with high moisture content that is received at the processor facility, $Df$ is the dockage fee ($/ton) deducted for raw safflower dockage, other seed, and dirt content in raw safflower received at the processor facility, $Y$ is the yield (tons/acre), and $TC$ is the total cost ($/acre).

Within equation (1) all variables are allowed to vary stochastically. The stochastic safflower price ($P$) variable is specified to follow a geometric Brownian motion (random walk) process as in

$$p_t = p_{t-1} + \alpha p_{t-1} dt + \sigma p_{t-1} dz \tag{2}$$

where $p_t$, is the safflower price at time $t$, $\alpha$ is the yearly drift rate as a percentage of yearly changes in price, dt denotes change in time (since this is yearly data it simplifies to 1), $\sigma$ denotes the standard deviation of price change (as a percent), $dz = \epsilon_t \sqrt{dt}$ where $\in_t$ is a normally distributed variable with mean 0 and standard deviation of 1 and $\sqrt{dt}$ simplifies to one over the time period considered.

The stochastic safflower price variable specified in equation 1 relies on historical safflower price data for Idaho and Utah (USDA, NASS, 2023) for years 2011–2022.[3] The safflower prices were adjusted for inflation using the Consumer Price Index (CPI) with a base year of 2022 (U.S. BLS, 2023). The drift rate was determined to not be statistically different from 0 at the 10% significance level thus the assumed drift rate was 0%. Last year's price ($P_{t\text{-}1}$) is assumed to be equal to the average 2022 Utah/Idaho price of $612/ton to align with the cost distributions for 2022.

The distribution for the yield ($Y$) variable is fit to historical safflower yield data for Idaho, Utah, and Montana (USDA, NASS, 2023). Research has demonstrated greater variability among crop yields at lower relative levels of data aggregation (Gerlt, Thompson, and Miller, 2014). Thus, we would expect state-level yields to have less variability than county-level yields and for county-level yields to exhibit less variability than farm-level yields. Our objectives center around estimating profitability at the producer level suggesting the use of farm-level yields to appropriately reflect risk. However, as safflower is a thin market, farm-level yield data is unobtainable. Therefore, state-level data for Idaho (2016–2022) and Utah (2011–2022) is combined with county-level data for Montana (2001–2016) to form the yield series.[4] Inclusion of the Montana county-level yield data serves two purposes, 1) it adds a greater number of observations to fit the distribution and 2) it adds lower level of data aggregation presumably increasing the variability as compared to a state-level only yield series. The Montana yield average is within 0.014 tons/acre of the combined Utah and Idaho yield series suggesting the combined series average would not be inappropriately shifted away from the Utah/Idaho mean with inclusion of the Montana county-level data. A normal distribution is selected for yield ($Y$) through minimization of the AIC with an average of 0.40 tons/acre and a standard deviation of 0.11 tons/acre. The yield distribution is also truncated ($0.12 \geq Y \leq 0.91$ tons/acre) with the minimum and maximum values set at 20% below and above the observed minimum and maximum values, respectively. Yield and prices are often inversely correlated within agricultural commodities. The strength of the correlation, however, depends on the timeframe analyzed as well as other supply and demand factors including relevant farm policy (Paulson and Babcock, 2008). Additionally, farm-level yield-price correlations have been shown to be much weaker as compared to aggregate yield-price correlations (Finger, 2012). To account for the correlation between price and yield while recognizing the assumed decreased strength of correlation when modeling risk at the farm-level we set a modest correlation of $r = -0.1$ between our price and yield variables.

The moisture and dockage fee variables each rely on triangle distributions with parameters taken from Table 1. The moisture fee is set with a minimum and most likely value of $0/ton and a maximum of $24/ton (Table 1). The dockage fee is set with a minimum and most likely value of $0/ton and a maximum of $28/ton. (Table 1). The total cost variable $TC$ is the summation of all assumed costs both variable and fixed. Individual costs are taken from a Utah State University Extension crop budget (Pace et al., 2019) adjusted for inflation to 2022 real values using the CPI (see Appendix Figure A1). Each budget line item is initially modeled stochastically as a triangular distribution with the most likely value taken as given and the minimum and maximum values taken as 50 percent variation around the most likely value. The distributions used within the simulation are described more fully in Table A1 of the appendix.

[3]Note that price data for Idaho was only available back to 2016 while the full range (2011–2022) was available and used for Utah.

[4]See Appendix Table A2 for simulation results of a sensitivity analysis around the assumed variance of the yield variable. This sensitivity analysis demonstrates the effects on the simulated profits when accounting for possible increased yield variance at the farm-level as compared to the aggregate-level (county and state).

The expected profit for the fixed price performance mechanism for the producer is calculated as in equation (1) while holding price constant at the mean of \$612/ton. The indexed-price performance mechanism expected profit for the producer is calculated as in equation (1) with the price variable replaced with the wheat-indexed safflower price calculated as

$$P_{indexed} = \left( P_{fixed} * \frac{P_w}{\overline{P_w}} \right) \tag{3}$$

where $P_{fixed}$ is the fixed safflower price (\$612/ton) used in the fixed contract mechanism, $P_w$ is the expected price of wheat taken as independent draws from a trianlgular distribution fit to historical (2000–2022) U.S. real wheat prices (USDA, NASS, 2023) and correlated with the safflower price variable with $r = 0.35$. The wheat price distribution is set with a minimum and most likely value of \$145.59/ton and a maximum value of \$391.10/ton. $\overline{P_w}$ is the historical average real wheat price (\$226.75/ton).

The expected profit for the combination lump sum and fixed price mechanism for the producer is defined as

$$E(\pi_{Combo_{prod}}) = (P_{fixed} - Mf - Df) * Y * V_{\%} + \theta\left((P_{fixed} - Mf - Df) * (Y - \overline{Y}) * F_{\%}\right) - TC + A$$
$$\text{when } Y > \overline{Y} \text{ then } \theta = 1 \text{ and when } Y \leq \overline{Y} \text{ then } \theta = 0 \tag{4}$$

where $\overline{Y}$ is average yield (0.40 tons/acre), $A$ is the fixed acreage payment calculated as $A = (P_{fixed} * \overline{Y} * F_{\%})$ where $F_{\%}$ and $V_{\%}$ are the assumed propotions of acreage that are fixed for the lump sum acreage payment or variable to be paid post-harvest according to actual production repectively. $F_{\%}$ and $V_{\%}$ are assumed to be 10 and 90%, respectively, for this analysis. Note that equation (4) allows for producers to secure 10% of assumed production at the historical average yield even when the actual yield at harvest falls below this level. However, equation (4) allows for producers to be compensated (through the $\theta$ multiplier) in times when the actual yield achieved is above the historical average. Thus, this contract mechanism transfers all downside price risk and portion of downside yield risk from the producer to the processor while still retaining upside yield risk for the producer.

### *2.3. Processor payoff functions*

Processor expected profits by contract mechanism are defined as returns in dollars per ton of safflower. It is assumed that the processing facility and accompanying machinery have already been established, and no initial investment is included as costs. The expected profit per ton for processors under the spot market mechanism is defined as

$$E(\pi_{SP\_proc}) = Pps - (P - Mf - Df) - TOC \tag{5}$$

where $Pps$ is the price received (\$/ton) for processed safflower from wholesalers and retailers, $TOC$ is the total operating cost (\$/ton) of processing safflower at the mill, and all other variables are as outlined in equation (1). $Pps$ follows a triangular distribution with a min \$800, a max of \$1200, and a most likely value of \$1000/ton. The parameters of this distribution are set with approximately 20 percent volatility around an assumed approximation of the Idaho/Utah price received. $TOC$ follows a triangular distribution with a minimum of \$125, a maximum of \$375, and a most likely value of \$250/ton set with approximately 50 percent volatility around an assumed approximation of the Idaho/Utah total operating cost. Data for both $Pps$ and $TOC$ are not available publicly, therefore, the parameters for those distributions were set after author interview with a manager of a large processor in the Idaho/Utah region (Godfrey, 2022).

**Table 2.** Simulation output statistics: producer and processor expected profit distributions under four contract mechanisms

| | Producer Distributions ($/Acre) | | | | Processor Distributions ($/Ton) | | | |
|---|---|---|---|---|---|---|---|---|
| Statistic | Spot Market | Fixed Price | Indexed Price | Combo Lump Sum | Spot Market | Fixed Price | Indexed Price | Combo Lump Sum |
| Mean | $26.58 | $27.48 | $27.77 | $30.60 | $155.33 | $155.33 | $155.34 | $143.75 |
| S.D.[1] | $73.90 | $65.29 | $92.55 | $62.32 | $138.59 | $96.78 | $182.56 | $98.40 |
| Prob. $\pi < 0$[2] | 38.3% | 34.2% | 43.9% | 32.3% | 13.4% | 5.4% | 20.8% | 7.2% |
| Minimum | −$177.78 | −$161.70 | −$172.77 | −$144.58 | −$440.29 | −$158.85 | −$454.22 | −$193.20 |
| Maximum | $399.60 | $291.02 | $424.97 | $291.75 | $692.16 | $437.42 | $636.68 | $432.19 |
| Skewness | 0.370 | 0.091 | 0.752 | 0.205 | −0.004 | 0.021 | −0.336 | 0.003 |
| Kurtosis | 3.14 | 2.85 | 3.57 | 2.89 | 2.91 | 2.57 | 2.69 | 2.63 |
| 1%[3] | −$123.50 | −$117.98 | −$133.85 | −$103.47 | −$163.90 | −$58.22 | −$292.88 | −$75.14 |
| 5%[4] | −$87.13 | −$79.99 | −$100.40 | −$69.03 | −$71.62 | −$3.05 | −$168.13 | −$18.06 |
| 10%[5] | −$65.09 | −$57.44 | −$78.50 | −$49.17 | −$21.61 | $28.22 | −$98.02 | $14.94 |

[1]Standard deviation.
[2]Indicates the probability that the expected profit is less than $0.
[3]Lowest 1st percentile value of expected profit.
[4]Lowest 5th percentile value of expected profit.
[5]Lowest 10th percentile value of expected profit.

The expected profit for the fixed price performance mechanism for the processor is calculated as in equation (5) with the safflower price paid to producers fixed ($P_{fixed} = \$612/\text{ton}$). Similarly, the expected profit for the processor under the indexed-price performance mechanism is calculated as in equation (5) with the safflower price paid to producers updated to the wheat-indexed price ($P_{indexed}$) defined in equation (2).

The expected profit for the processor under the combo lump sum and fixed price mechanism (CLS_FP) is calculated as

$$E(\pi_{CLS\_FP}) = Pps - \left(\left(P_{fixed} - Mf - Df\right) * V_{\%}\right) - \theta \frac{\left(\left(P_{fixed} - Mf - Df\right) * \left(Y - \overline{Y}\right) * F_{\%}\right)}{Y} - TOC - \frac{A}{Y} \quad \text{when } Y > \overline{Y} \text{ then } \theta = 1 \text{ and when } Y \leq \overline{Y} \text{ then } \theta = 0 \tag{6}$$

where all variables are as previously defined.

## 3. Results

The expected profit from both the producer and processor perspectives under all four contract mechanisms were simulated over 10,000 iterations using Palisade's @Risk Decision Tools Suite 7.6 (2019). A summary of the simulation results is contained in Table 2 with the simulated cumulative density function graphs for producers and processers contained in Figures 4 and 5, respectively.

As seen in Table 2, expected profit was highest for the producer under the CLS_FP mechanism at $30.60/acre. This mechanism also displayed the lowest variability with a standard deviation of $62.32/acre. This result stems from this mechanism's ability to transfer downside price and a portion of yield risk while allowing for producers to capitalize when increased yields are realized.

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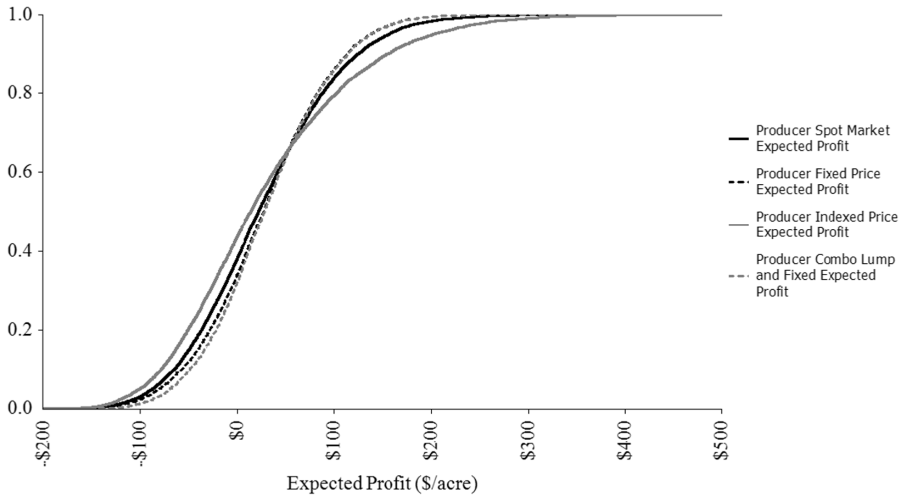


**Figure 4.** Producer expected profit $/acre cumulative distribution functions under four contract mechanisms.

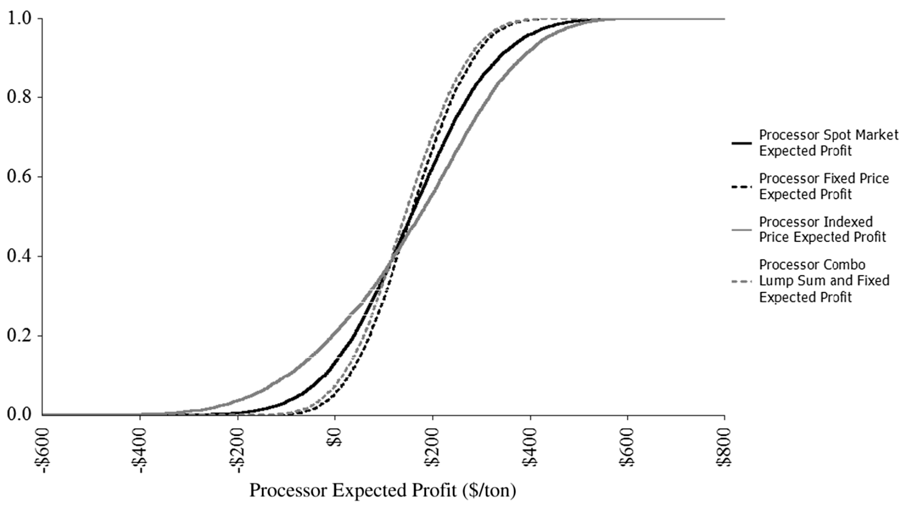


**Figure 5.** Processor expected profit $/ton cumulative distribution functions under four contract mechanisms.

Additionally, as currently designed, this mechanism would be associated with increased expected profits as the lump sum payment assumes no dockage or moisture discount.

As would be expected, the other three mechanisms resulted in similar mean values for expected profit as these contracts were essentially mean-preserving while allowing for differing levels of risk. Variability was greatest for the wheat indexed-price mechanism followed by the spot and fixed price mechanisms, respectively. This suggests that the volatility within wheat prices is comparatively greater than the volatility within safflower prices. Thus, while the indexed-price contract could aid both producers and processors in price discovery, it would come with the tradeoff of increased expected volatility. The increased volatility around the wheat-indexed contract results in a flatter CDF (Fig. 4) as compared to the other contract mechanisms. This points to the larger tails within the distribution for returns expected with the wheat-indexed contract and suggests increased probability of lower lows as well as higher highs.

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The results also indicate a significant probability of profit less than \$0/acre for producers regardless of contract mechanism. This probability is lowest with the CLS_FP mechanism at 32.3% and highest with the indexed-price mechanism at 43.9%. This large probability of negative returns likely acts as a deterrent for safflower adoption among producers in the area. Of course, the results are based on assumed cost distributions that would likely vary considerably between individual producers.

The processor expected profit (\$/ton) was similar and highest under the spot, fixed, and indexed-price mechanisms at approximately \$155/ton. Among those three mechanisms, the fixed price mechanism would be associated with decreased variability with a standard deviation of \$96.78/ton. Having the ability to fix price effectively reduces the processor expected profit variability (standard deviation) by approximately 30 and 47% relative to the spot and indexed-price mechanisms, respectively. The fixed price mechanism is an excellent option to protect the processor from unexpectedly high prices, meaning that downside risk is secured. This mechanism comes with the tradeoff of eliminating potential upside risk as well. This is evidenced by the spot market contract having a maximum value of approximately \$255/ton more than the fixed price mechanism. The CLS_FP mechanism is expected to result in decreased profit of approximately \$12/ton as compared to the other three mechanism but with a relatively low standard deviation of \$98.40/ton—comparable to the fixed price mechanism (\$96.78/ton).

The ranking according to expected mean profit as well as standard deviation for producers would suggest the CLS_FP mechanism would be preferred for risk neutral to risk adverse producers. Similarly, for the processor the fixed price mechanism would be preferred as it has the highest average mean and lowest standard deviation of expected profit. Ranking a set of risky alternatives can be straightforward when the decision maker is assumed to be risk averse and both the average and standard deviation of an alternative are superior to all other alternatives. However, when allowing for varying levels of risk appetite among the decision maker the objective ranking process becomes less clear. We first consider stochastic dominance. The CDFs in Figures 4 and 5 suggest that there is no first order stochastic dominance among contract mechanisms for producers or processors (intersecting CDFs). The lack of first order stochastic dominance is similar to the findings of Wilson and Dahl (2011) and (2014) when evaluating contracting strategies within durum wheat and canola, respectively. To aid in objectively ranking the contract mechanisms a ranking according to certainty equivalents can be desirable as the associated risk premiums could help reconcile the preference discrepancy between producers and processors.

A sensitivity analysis over the assumed risk aversion is conducted to provide an objective ranking of the contract mechanisms while considering differing risk appetites of potential producers and processors. This type of analysis is sometimes referred to as stochastic efficiency with respect to a function (Hardaker et al., 2004). It is a method of stochastic dominance with respect to a function (SDRF) that allows for ranking of a set of risky alternatives in terms of their expected certainty equivalents (CE) for a specified range of attitudes to risk. A CE represents the dollar amount necessary to make the decision maker indifferent between accepting/forgoing a certain risky alternative. This sensitivity analysis over the assumed risk aversion allows for simultaneous comparison of each alternative producing a smaller efficient set than the traditional pairwise comparison of SDRF (Hardaker et al., 2004). We assume a negative exponential utility function as suggested by Hardaker et al. (2004), in part, for its practical CARA (constant absolute risk aversion) property. The sensitivity analysis could be applied assuming any utility function for which the inverse function can be calculated, however, McCarl (1990) demonstrated that the CARA function yields similar results as other utility functions over small risk aversion intervals making it a suitable selection for this study.

The absolute risk aversion coefficient (ARAC) represents a decision maker's degree of risk aversion. Risk aversion can be classified as 1) risk averse (ARAC $>0$), 2) risk neutral (ARAC $= 0$), or 3) risk preferring (ARAC $<0$). This analysis evaluates CE values for all contract mechanisms with the assumed decision maker ranging from risk neutral (ARAC $= 0$) to relatively risk averse

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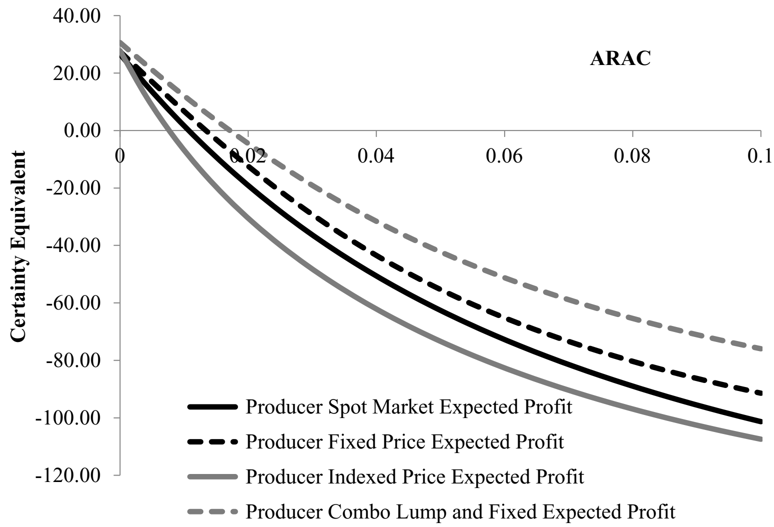


**Figure 6.** Sensitivity analysis over the risk aversion level under a negative exponential utility function for safflower producer expected profit ($/acre) by contracting mechanism.

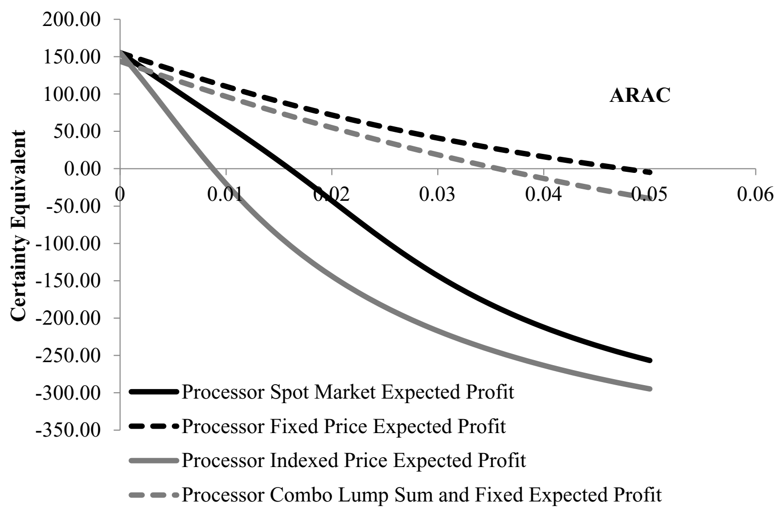


**Figure 7.** Sensitivity analysis over the risk aversion level under a negative exponential utility function for safflower processor expected profit ($/ton) by contracting mechanism.

(ARAC = 0.1). We chose not to conduct the analysis for any level of risk aversion <0 (risk preferring/seeking) as we assume producers/processors are generally not risk seekers as suggested by the literature (Bar-Shira et al., 1997; Feuz et al., 1995). The results of the sensitivity analyses for producers and processors are displayed in Figures 6 and 7, respectively.

Through examination of Fig. 6, the efficient set for producers is determined to include only the CLS_FP mechanism. Additionally, for any producer with an assumed ARAC >0.0167, CE values for all mechanisms are less than $0 suggesting that producers beyond this relatively low level of risk aversion would require compensation equal to the absolute value of the CE in order for the producer to agree to grow safflower under that mechanism.

Through examination of Fig. 7, the efficient set for processors is determined to include only the fixed price mechanism for all ARAC >0. Taken collectively, the sensitivity analysis results from the producer and processor perspectives provide no clear collectively favored contract mechanism. This naturally occurs as both producers and processors are assumed to be profit maximizers while also seeking to mitigate risk. Yet, consider the goal of western safflower processors – secure necessary supply from producers to satisfy increasing demand while remaining profitable. If processors intend to incentivize producer adoption of safflower, then some concession must be given by processors in favor of the producers. The processor sensitivity analysis results (Fig. 7) suggest that the certainty equivalents for the CLS_FP mechanism are very similar to the fixed price mechanism throughout the range of ARAC evaluated. The risk premium for the CLS_FP mechanism relative to the fixed price mechanism averages −$17.10/ton for ARAC >0 and <0.0354. This suggests that processors would only require approximately $17/ton in compensation to be indifferent when considering adopting the combo lump sum/fixed price contract mechanism as compared to the fixed price mechanism. This $17/ton risk premium is only 2.8% of the assumed average market price ($612/ton). This relatively small risk premium may be worth accepting as processors consider the goal of incentivizing producer adoption of safflower production.

No prior studies have undertaken a comparative static analysis to compare the desirability of various producer-processor safflower seed contract arrangements. To contextualize these results, we compare them with reported marketing arrangements for safflower (Bergman and Kandel, 2019; Godfrey, 2022; Herdrich, 2001; Pace et al., 2015) and with comparative static analyses for contracting other thin market annual crops (Wilson and Dahl, 2011; Wilson and Dahl, 2014). While all reported safflower marketing arrangements included fixed price performance payments and adjustments for oil content, none specified provisions for lump sum payments. Studies leveraging comparative static analysis to compare producer-processor desirability of various contractual forms for durum wheat (Wilson and Dahl, 2011) and canola (Wilson and Dahl, 2014) found that securing a fixed price performance at planting can be an effective tool in facilitating successful transactions between producers and processors, although neither consider a provision for lump sum payments within the analysis. Concerns about inducing moral hazard with a CLS_FP mechanism may exist, but when weighed against producer reputational risk and the likelihood of contract renewal in subsequent years, this risk appears minimal so long as the lump sum provision of the CLS_FP is relatively small.

## 4. Conclusion

This study aimed to identify contractual payment mechanisms likely to support a successful transaction between safflower growers and processors within the region of Utah and Idaho. It did so by estimating the volatilities and associated certainty equivalents for producers and processors across various contract structures and risk aversion characteristics. When raw and refined safflower seed trade at average prices experienced over the past decade the possibility of a successful transaction is small when one considers risk aversion. Tight safflower margins, interact with risk to make all but the most risk neutral farmers unwilling to adopt safflower when selling at spot price. However, the potential solution space expands for both parties when safflower price risk is reduced. It further expands for the farmer when their yield risk is reduced through the addition of a lump sum acreage payment as part of a fixed price contract “the combination contract”.

The combination contract successfully mitigates price risk while also providing insurance against a portion of yield risk for the producer. This results in greatly reduced overall risk while providing the highest expected mean return to the producer thus incentivizing safflower adoption.

This mechanism is expected to result in reduced profitability for the processor. However, comparatively low average risk premiums of −$17.10/ton relative to the fixed price mechanism across the relevant range of risk appetite may indicate the reduction in profit is acceptable to help incentivize producer adoption of safflower. This is especially true when one considers how much tighter the farmer's participation constraint is than the processors.

This study compared four largely mean-preserving contract structures that presented unique levels of risk exposure to both parties and calculated the effect it would have on adoption decisions. The results of this should be taken as a qualitative ranking of the four considered contract types as opposed to a solution to an optimization exercise. Factors such as optimal payment level and the outcomes associated with all possible payment combinations were abstracted away from to focus on the impact of different payment structure types on supporting transactions between producers and processors. Additionally, this work was applied to counties and states within the Intermountain West. Economic or agronomic factors outside of this region, or on a farm basis, may be different and thus require different contract structures.

Challenging economic and climate conditions have western safflower processors searching for innovative ways to secure a steady supply of quality raw safflower seed to their facilities. Preplant agricultural contracts have historically been used in the safflower industry but contract mechanisms that are empirically tested and theoretically supported are becoming more critical in the current agricultural environment. Factors contributing to increased instability for safflower processors include reduced global seed supply and increased production costs from war-torn Eastern Europe, climate change and constricting water availability, as well as urban creep and the loss of productive acreage for which crop competition is intense. If these trends continue, they will add further risk into safflower production making successful transactions even more difficult, and further increasing the importance of limiting price risk through contracting. It is also worth considering that under historical prices, processors have a wider solution set than farmers for a successful transaction, so in many years it may be worth paying farmer's a small premium to ensure safflower seed is acquired.

Additional contract mechanisms could be analyzed including hedging contracts tied to grain futures and fixed spread contracts based on grain futures. Various provisions within the contract mechanisms could also be investigated such as including the mechanisms with and without act of God clauses and exploring price floors or ceilings. Additionally, future work could consider quantitatively modeling additional contractual constraints likely to be important in safflower seed transactions to enable the problem to be solved as an optimization exercise. This would allow for the comparison of an infinite amount of payment mechanism combinations which could lead to a pareto-improving contract structure between the producer and processor. This study evaluated four contract mechanisms and provided a springboard for further investigation into pricing schemes within the safflower industry. As there is yet little research within safflower contracting, this simulated analysis can be a beneficial starting point for developing and refining risk management strategies for safflower production in the Intermountain West.

**Data availability statement.** The data that support the findings of this study are available from the corresponding author, [RF], upon reasonable request.

**Author contributions.** Conceptualization, J.P. R.F., and T.M.; Investigation, J.P. R.F., and T.M.; Methodology, J.P. R.F., and T.M.; Formal Analysis, J.P. R.F., and T.M.; Project administration, R.F. and T.M.; Data Curation, J.P. R.F., and T.M.; Supervision, R.F. and T.M.; Writing – Original Draft, J.P. R.F., and T.M.; Writing – Review and Editing, J.P. R.F., and T.M.

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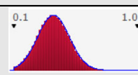
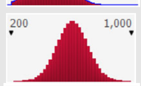
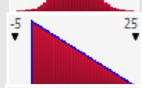
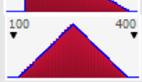
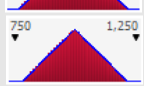
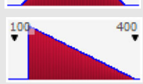
## Appendix

**Table A1.** Summary of assumed distributions for simulation of expected profit for producers and processors of safflower

| Variable Name | Notation[1] | Graph | Minimum | Mean | Maximum |
|---|---|---|---|---|---|
| Yield[2] | Y |   | 0.12 | 0.40 | 0.84 |
| Real Safflower Price3 | P |   | $240.04 | $612.00 | $981.82 |
| Moisture Fee | Mf |   | $0.00 | $8.00 | $23.83 |
| Dockage Fee | Df |   | $0.00 | $9.33 | $27.83 |
| Processor Operating Cost | TOC |   | $126.42 | $250.00 | $374.35 |
| Price Received for Processed Seed | Pps |   | $802.59 | $1,000.00 | $1,199.12 |
| Real Wheat Price | Pw |   | $145.60 | $227.43 | $388.94 |

[1]Notation as defined in equations outlined in the main text
[2]Safflower Yield correlated with Real Safflower Price (r=-0.10)
[3]Real Safflower Price correlated with Real Wheat Price (r=0.35)

**Table A2.** Simulation output statistics for yield sensitivity analysis[1]: producer and processor expected profit distributions under four contract mechanisms

| | Producer Distributions ($/Acre) | | | | Processor Distributions ($/Ton) | | | |
|---|---|---|---|---|---|---|---|---|
| Statistic | Spot Market | Fixed Price | Indexed Price | Combo Lump Sum | Spot Market | Fixed Price | Indexed Price | Combo Lump Sum |
| Mean | $28.82 | $29.87 | $30.20 | $33.33 | $155.33 | $155.33 | $155.34 | $141.60 |
| S.D.[2] | $83.09 | $75.68 | $101.09 | $72.37 | $138.59 | $96.78 | $182.56 | $99.16 |
| Prob. $\pi < 0$[3] | 39.0% | 35.8% | 43.5% | 34.2% | 13.4% | 5.4% | 20.8% | 7.8% |
| Minimum | −$182.49 | −$162.53 | −$181.06 | −$146.20 | −$440.29 | −$158.85 | −$454.22 | −$201.86 |
| Maximum | $448.78 | $325.28 | $470.17 | $326.01 | $692.16 | $437.42 | $636.68 | $432.19 |
| Skewness | 0.428 | 0.180 | 0.795 | 0.289 | −0.004 | 0.021 | −0.336 | −0.007 |
| Kurtosis | 3.14 | 2.77 | 3.69 | 2.84 | 2.91 | 2.57 | 2.69 | 2.65 |
| 1%[4] | −$131.48 | −$127.27 | −$142.68 | −$112.01 | −$163.90 | −$58.22 | −$292.88 | −$78.30 |
| 5%[5] | −$97.74 | −$92.98 | −$109.33 | −$80.54 | −$71.62 | −$3.05 | −$168.13 | −$22.10 |
| 10%[6] | −$74.60 | −$69.04 | −$85.73 | −$59.26 | −$21.61 | $28.22 | −$98.02 | $12.00 |

[1]The sensitivity analysis increases the variance of the assumed yield distribution by 20% to account for presumed increases in yield variability when modeling farm-level yield data as compared to aggregate-yield data.
[2]Standard Deviation.
[3]Indicates the probability that the expected profit is less than $0.
[4]Lowest 1st percentile value of expected profit.
[5]Lowest 5th percentile value of expected profit.
[6]Lowest 10th percentile value of expected profit.

The results in Table A2 demonstrate the impact of increasing the variance around the assumed yield distribution by 20 percent as compared to the results in Table 2. This sensitivity analysis around the yield distribution variance demonstrates the impact for a presumed increase in variance that may arise when modeling yields using farm-level data (unavailable for this study) as compared to aggregate-level (state or county) yield data as demonstrated by Gerlt, Thompson, and Miller (2014). The results align with expectations as those contracts susceptible to yield risk display increased volatility with increased minimum and maximum values expected. The general comparative results among the contract mechanisms and associated implications as discussed in the results section are unchanged within this sensitivity analysis, adding robustness to our findings.

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| **Deterministic Costs of Non-Irrigated Safflower** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Northern Utah | | Quantity per acre | Unit | Price per Unit | Value per Acre | Sub Total | Total |
| **Inputs and Services** | | | | | | | |
| Fertilizer | | | | | | | |
| | 46-0-0 Urea | 40 | Units | $0.64 | $25.64 | | |
| | Application | 1 | Acre | $5.72 | $5.72 | | |
| Herbicides | | | | | | | |
| | Sonalan (ethalfluralin) | 2 | Pints | $10.06 | $20.12 | | |
| | Application | 1 | Acre | $5.72 | $5.72 | | |
| Seed | | 18 | Lbs. | $0.39 | $7.01 | | |
| Labor | | 1 | Acre | $9.80 | $9.80 | | |
| Crop Insurance (NAP) | | | | | $1.43 | | |
| **Subtotal Inputs and Services** | | | | | | $75.45 | |
| **Field Operations** | | Times | Unit | Per Unit | Acre | | |
| | Fall Chisel Plow | 1 | Acre | $12.59 | $12.59 | | |
| | Spring Chisel Plow | 1 | Acre | $12.59 | $12.59 | | |
| | Planting | 1 | Acre | $13.74 | $13.74 | | |
| | Harvesting | 1 | Acre | $28.62 | $28.62 | | |
| | Hauling | 1150 | Lbs. | $0.01 | $13.16 | | |
| **Subtotal Field Operations Cost** | | | | | | $80.70 | |
| **Interest on Operating Capital** | | Rate | Term | Principle | | | |
| | | 5% | 0.5 | $152.02 | | $3.80 | |
| **Total Input, Service and Field Operation Costs** | | | | | | | $159.95 |
| **Overhead** | | | | | | | |
| | Accounting, Liability Insurance, Vehicle Cost, Office Expense | | | | $11.45 | | |
| | Cash Lease for Land (includes propery tax) | | | | $40.07 | | |
| **Total Overhead** | | | | | | | $51.51 |
| **Total Costs** | | | | | | | $211.46 |

**Figure A1.** Safflower Cost Budget for Non-Irrigated Safflower taken from Pace et al. (2019) adjusted for inflation using the consumer price index with a base year of 2022.

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