The Need for Optimal Incentives in Popcorn Contracts under Uncertainty

by

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Abstract

This study derives an optimal risk sharing contract, by maximizing the total joint certainty equivalent for a popcorn processor and popcorn farmer. The processor induces effort by establishing a quality premium that encourages farmer effort level. Thus, the quality of the popcorn is influenced to some degree by the farmer's effort level. An empirical application using contract data shows that effort level is a decreasing function of the farmer's relative risk aversion coefficient holding the processor's relative risk aversion constant. Consequently, as the effort level decreases so does the premium paid for usable popcorn, which in turn decreases both parties' expected profits.

Introduction

Due to the prevalence of quality mismatches, popcorn processors have found that traditional spot markets are a less efficient means of transaction than contracting. A popcorn processor has very specific product requirements regarding shape, color, and kernel size (Purdue News, 2003; Ehmke, oral communication, 2003). Furthermore, a popcorn processor demands popcorn with quality traits that are different from the traditional dent corn used by a feed mill or food processor. If these desired quality attributes are not present in the delivered popcorn, the processor will be forced to cull the popcorn that does not meet specifications or when possible undertake costly procedures to correct the defects. For example, if the moisture content on the delivered popcorn is too high, the processor can dry the popcorn to a desired level. If the delivered popcorn contains a large percentage of foreign material, the processor may purchase additional popcorn from the market to cover the shortfall and meet production requirements. Both activities create an additional cost to the processor when undertaken.

Problem Statement

Popcorn contracts in their current forms rely on various bonus and penalty schemes in an attempt to provide signals to the farmers on the need for a consistently high quality product. Farmers who choose to enter these contracts may receive incentives associated with producing popcorn that embodies the desired quality characteristics, but only if they exert the necessary effort. The outcomes of the farmer's effort to meet contract specifications are uncertain and the effort is costly to the farmer. In essence, the net benefits from effort are uncertain, which causes farmers to provide insufficient effort to produce the desired popcorn.

As the popcorn sector continues to evolve toward a consumer-driven industry, it will be increasingly important to pursue effective compensation and motivation of those farmers who deliver popcorn with the necessary quality attributes. Popcorn processors must institute proper incentives to reward those farmers who enter into popcorn contracts. These incentives must compensate a farmer for their effort level given the uncertainty associated with the risky payoffs of the contract.

By using a risk sharing contract, the processor is able to specify the type of inputs and crop management practices the farmer uses, which provides influence over the quality and quantity of the popcorn produced. In addition, a popcorn processor must provide a premium price structure to compensate the farmer for facing the additional risk of growing popcorn over traditional dent. A processor attempts to set premium prices at the minimum levels necessary to encourage the farmer's entrance into the production contract and consequently producing the desired popcorn attributes.

Objectives

The objective of this research is to determine a risk sharing production contract between the farmer and the popcorn processor. The risk sharing contract utilizes incentives to compensate the farmer for the effort in producing popcorn with different quality attributes. The production contract, if efficient, maximizes the sum (total) of the farmer's and processor's certainty equivalent (Milgrom and Roberts, 1992). The certainty equivalent is defined as the amount of certain income that a risk averse individual would be willing to accept in lieu of a project with an uncertain income. The farmer has the ability to influence the moisture and cleanliness attributes of the popcorn through his management effort. For example, the farmer is able to influence the moisture content by harvesting the popcorn at the correct moisture content. The cleanliness of the delivered product is influenced by spraying properly to prevent infestation and calibrating equipment correctly. A risk sharing contract incorporates a premium associated with the amount of usable popcorn that the farmer can affect with his management effort. This incentive payment, or premium, is specified in the terms of the contract between the farmer and the processor.

Results from this research are an attempt to provide a framework that allows popcorn processors and farmers to determine the optimal incentive payment in risky production contracts through the maximization of the total joint certainty equivalent. Although the performance measures are unique to the popcorn industry, this study addresses critical factors related to contracting, which apply to other agricultural industries.

Contract design

As mentioned previously, the popcorn contract contains a predetermined revenue portion and a premium associated with the quality characteristics of the popcorn. The predetermined revenue portion is based on the means of historical yields and prices. The quantity of usable popcorn, a function of the quality characteristics, determines the premium paid. Upon delivery of the product, the processor takes samples of the product and determines the amount of usable popcorn by grading the percentage foreign and moisture content. Foreign matter and moisture are specified as percentages of the total quantity delivered and stored. Foreign materials are undesirable for the following reasons: they cannot be used in production of the retail good, they use valuable storage space, and they increase the overall processing cost of the delivered popcorn. Excess moisture in the delivered popcorn can be managed by drying, but the processor incurs a cost for drying the popcorn. For these reasons, farmers are paid incentives that induce effort to produce the minimum level of foreign material (i.e., cleanliness) and desired moisture content (i.e., dry matter content).

Literature Review

Three schools of thought have influenced the theory of production contracts in agricultural economics, namely: the transaction cost school (Coase 1937), agency theory school (Alchian and Demsetz 1972, Mahoney 1992, and McDonald, 1984), and the risk sharing school. The risk sharing literature relies upon transaction cost and agency theory, and further these schools by studying the economic impact of contracting when the parties are risk averse. In most cases, however, it is assumed that the agent is risk averse and the principal risk neutral. Once the parties have signed the contract, there is reduced incentive for the agent to perform an action that is costly to undertake and difficult for the principal to observe. It is in the principal's best interest if the agent carries out these actions so that the preferred outcome can be realized. To combat this problem, incentive clauses are included in contracts to induce the agent to perform the unobservable but costly actions that lead to the desired outcome for the principal. By introducing incentive clauses into contracts, the principal now bears more risk than if uncertainty would not exist.

Kawasaki and McMillan (1987) tested the theory of risk sharing with data from Japanese manufacturing. Applications of this theory in American agriculture concern mostly test of landlord-tenant relationship and their preferences for cash-rent vs. multi year land rent (Allen and Lueck 2002). Kawasaki and McMillan (1987) tested the theory of risk sharing with data from Japanese manufacturing. Applications of this theory in American agriculture concern mostly test of landlord-tenant relationship and their preferences for cash-rent vs. multi year land rent (Allen and Lueck 2002).

Methodology and Data

This study uses an expected utility framework to solve for the optimal incentive contract, using the farmer's effort and premium levels as decision variables. The methodology draws from the generic risk sharing and incentive contract models from Allen and Lueck (2002), and Milgrom and Roberts (1992). Milgrom and Roberts (1992) argue that the "Value Maximization Principle", maximizing the total joint certainty equivalent, is an appropriate framework to conduct contract analysis. The certainty equivalent is the amount of certain income that a risk averse individual would be willing to accept in lieu of a project with an uncertain outcome. The total joint certainty equivalent will be computed for a number of different risk aversion levels for both the farmer and the processor. The utilization of scenario analysis allows the results of the model to be applicable to a more diverse set of farmers and processors.

Modeling assumptions

Assumptions were made to make the quantitative analysis tractable; however, these assumptions do not take away from the applicability and implications of the model. The first assumption concerns the parties' underlying objective functions. Farmers are modeled as risk averse agents, who maximize expected utility under a mean-variance framework. Kawasaki and McMillan (1987) determine that the firm's attitude towards the risk associated with a single contract is unimportant. It is generally assumed that the principal (processor) is a larger firm than the agent (farmer) is and therefore the risk associated with a single contract can cause large fluctuations in the total profits of the farmer but have little effect on the overall profit of the processor. Milgrom and Roberts (1992), support these results, suggesting that when the principal is a large or medium sized firm, the agent's ability to bear risk is negligible compared to the principal. It is important to note that the popcorn processor may be risk averse if the operation is closely held by few owners and/or if a single agent provides a large portion of the principals input.

Furthermore, Kawasaki and McMillan (1987) conclude that the agent (farmer) employs contracts in order to let the principal (processor) absorb some of the risk associated with input production. Since farmers dislike having their incomes dependent upon randomness that is outside of their control, contracts offer a mechanism to reduce risk associated with the production of popcorn by shifting the burden of risk bearing to the processor. This occurs because the cost of bearing risk is generally relatively less for the processor than for the farmer. (Milgrom and Roberts, 1992)

Farm-economics literature frequently applies the mean-variance approach for modeling decisions related to uncertainty in production and marketing (e.g., see Coyle (1999); Myers and Thompson (1989)). The main advantage of the mean-variance approach is that it serves as an approximation to the behavior of an expected utility maximizing agent because his objectives can be viewed as a first order Taylor series expansion of any underlying utility function.

Secondly, farmers face a quality risk wherein quality includes two dimensions, foreign matter (i.e. cleanliness), and dry matter content of the popcorn (i.e. the moisture level of the popcorn upon delivery). Inputs related to the biological production process are treated as constant and assumed to be outside the control of the farmer. Thus, popcorn is produced with a homogeneous production technology, whereas the quality of the popcorn is determined by the farmer's management effort.

Moreover, it is assumed that the farmer's managerial effort level affects both foreign matter and dry matter simultaneously. Instead of using an hourly estimate of invested farm time, the maximum effort level is normalized to unity for an acre. Additionally, it is assumed that quality risk is additive, which means that the relative risk level decreases at higher production levels.

The third assumption of the model concerns scheduling of farm activities. Crop delivery is assumed to occur at harvest time so that storage cost can be ignored. The unit of study is normalized to a one-acre lot of land on which the farmer produces popcorn under contract.

Finally, the contract is designed so that the initial payment is based on an average historical yield multiplied by an average historical price (i.e., it is invariant to quality risk). The premium on the other hand, is solely based on the quantity of usable popcorn for the popcorn processor as based on the percentage of foreign matter and moisture content. The farmer is able to influence these parameters via his management effort. The quality of the popcorn is a linear function of the farmer's level of effort.

The Farmer's Optimization problem

As stated in the previous section, the decision variable for the farmer is the level of management effort, which affects the cleanliness and dry matter of the delivered popcorn. The quantity of usable popcorn is determined by the following production function:

(1) $$z_t = y_t \cdot b_1 \cdot b_2 \cdot e_t + \tilde{x}_t \,,$$

where z_t is pounds of usable popcorn at year t, y_t the popcorn acre yield in pounds, b_1 the deterministic cleanliness transformation factor: the minimum amount of foreign matter expected with an effort level of 1 is 2% e.g. b_1 *=1-.02=.98*. Moreover, b_2 is the deterministic dry matter transformation factor: with a moisture level of at least 12%, b_2 *=1-.12=.88*). It should be noted that popcorn could be delivered "too dry": however, we assume that the processor does not receive popcorn that is too dry because it is suboptimal for the farmer to deliver popcorn that falls below the minimum moisture content. The effort level is bounded, $e_t \in [0,1]$, where the maximum level of effort is normalized to unity. When e=1, the farmer maximizes his effort and deliver the total quantity of usable popcorn delivered. However, maximizing the total physical product is not equivalent to maximum total profits. Finally $\tilde{x}_t$ is an unobservable stochastic error term that is uncorrelated with the farmer's effort level. The error term reflects uncertainties that are outside of the farmer's control, such as weather, disease pressure, soil condition etc.

The error term is assumed to have a mean of zero and a finite variance. The expected quantity of usable popcorn (in pounds) can be expressed as (the time subscript is dropped for notational convenience):

(2) $$E[z] = y \cdot b_1 \cdot b_2 \cdot e \,,$$

in addition, the variance of the quantity of usable popcorn is:

(3) $$Var[z] = s_x^2 \,.$$

That is, at an effort level of one, the processor can expect that the usable quantity of popcorn dependents on this year's yield subject to the stochastic error that also reflects the effect of variability in foreign material and moisture level on useable popcorn.

The farmer maximizes expected utility associated with his profit:

$$\underbrace{Max}_{e}\, E[U(p_F)] = E[p_F] - \frac{r_F}{2} Var[p_F], \quad (4)$$

where $E[p_F]$ the expected profit, or expected value of profit is, $Var[p_F]$ is the variance of profit, and r_F is the farmer's level of absolute risk aversion. The last expression in the objective function; $\frac{r_F}{2} Var[p_F]$, can be interpreted as the farmer's risk premium.

The farmer's profit is:

$$p_{farm} = Revenue_{farm} - Cost_{farm}, \quad (5)$$

where the farmer's revenue is defined as:

$$Revenue_{farm} = p' + r \cdot z = p' + r \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}], \quad (6)$$

where, p' is the predetermined amount that the processor pays the farmer when initiating the contract. The parameter *r* is a per pound premium on useable popcorn, and the final term in equation 6 is the total premium. The costs of other inputs that are not related to the effort, or the management level, are included in p'. Note that *p'* is a non-stochastic economic transfer to the farmer, which is uncorrelated with the farmer's effort level.

There is a cost associated with effort because it is unpleasant and forgoes the opportunity to undertake other activities. The cost function is a function of management effort and quantity of usable popcorn. Milgrom and Roberts (1992) suggest that the farmer's marginal cost of effort should be rising, i.e., the cost of effort is increasing at an increasing rate. The farmer’s cost function is quadratically increasing in effort level, according to:

$$(7) \qquad Cost_{farm} = w_M \cdot e^2 \cdot z = w_M \cdot e^2 \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}],$$

where w_M is the cost per pound of useable popcorn associated with effort. It should be noted that varying the cost function, as long as it exhibits the aforementioned characteristics, is a useful tool for scenario analysis, since there are currently no reliable estimates of a popcorn farmer’s true cost function of effort.

Consequently, the profit function for the farmer is:

$$(8) \qquad p_F = p' + r \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}] - w_M \cdot e^2 \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}],$$

in addition, the expected profit for the farmer is:

$$(9) \qquad E[p_F] = p' + r \cdot [y \cdot b_1 \cdot b_2 \cdot e] - w_M \cdot e^2 \cdot [y \cdot b_1 \cdot b_2 \cdot e],$$

the variance of profit:

$$(10) \qquad Var[p_F] = [r - w_M \cdot e^2]^2 \cdot s_x^2 .$$

Therefore, the farmer has expected mean-variance utility is:

$$(11) \qquad \underbrace{Max}_{e}\, E[U(p_F)] = p' + (r - w_M \cdot e^2) \cdot [y \cdot b_1 \cdot b_2 \cdot e] - \frac{r_F}{2}[r - w_M \cdot e^2]^2 \cdot s_x^2 ,$$

and simplifying, we get:

Thus, the certainty equivalent consists of three parts: expected profits, the absolute level of risk aversion r, and the variance of profit. The product of the latter two terms is defined as the risk premium, or alternatively the transaction cost of the project (Milgrom and Roberts, 1992). In the case where r is zero the farmer is risk neutral, and the farmer is not able to increase his utility by risk sharing with other risk neutral agents.

As the farmer's relative risk coefficient increases, the farmer's certainty equivalent decreases. Hence, the farmer is able to increase his utility by shifting his risks to the processor.

The Popcorn Processor's Optimization Problem

The popcorn processor maximizes the expected utility of profits:

(12) $$\underbrace{Max}_{r}\, E\left[U\left(p_P\right)\right] = E\left[p_P\right].$$

The processor's decision variable is the level of premium for rewarding the farmer's effort level. Thus, the desired quantities and quality traits of the contracted popcorn are indirectly determined through the manager's influence on the biological process.

The profit for the processor is:

(13) $$p_{Processor} = Revenue - InputCost - ProcCost,$$

where the processor's revenue is defined as:

(14) $$Revenue = P_P \cdot \tilde{z} = P_P \cdot \left[y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}\right],$$

where P_p is the deterministic price for marketed processed popcorn in dollars per pound.

Total cost consists of two parts: the cost of acquiring the inputs and the cost of processing the corn into popcorn (in dollars per pound).

(15) $$InputCost_{Processor} = p' + r \cdot z = p' + r \cdot \left[y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}\right],$$

where the cost of acquiring the inputs are represented by the predetermined contract price plus the premium *r* (e.g. equal to the farmer's revenue).

The cost of processing the popcorn is defined as:

(16) $$ProcCost_{Processor} = C_P \cdot z = C_P \cdot \left[y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}\right],$$

where C_P is the cost per pound of processing the popcorn.

Consequently, the processor's profit is:

(17) $$\tilde{p}_P = P_P \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}] - p' - r \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}] - C_P \cdot [y \cdot b_1 \cdot b_2 \cdot e + \tilde{x}].$$

Therefore, the expected profit is:

(18) $$E[p_P] = (P_P - r - C_P) \cdot [y \cdot b_1 \cdot b_2 \cdot e] - p'.$$

The variance of profit is

(19) $$Var\ [p_P] = [P_P - r - C_P]^2 \cdot s_x^2.$$

Therefore, the processor has expected mean-variance utility of:

(20) $$\underbrace{Max}_{r}\ E[U(p_P)] = (P_P - r - C_P) \cdot [y \cdot b_1 \cdot b_2 \cdot e] - p' - \frac{r_p}{2}[P_P - r - C_P]^2 \cdot s_x^2.$$

Thus, the certainty equivalent for the processor also consists of expected profits, the absolute level of risk aversion r, and the variance of profit. As with the farmer, the product of the latter two terms in the above equation is defined as the risk premium for the processor. As the processor's relative risk coefficient increases, the processor's certainty equivalent decreases. When this situation occurs, the processor is able to increase utility by risk sharing with the contracted party.

The total certainty equivalent maximizes the farmer's and the processor's utility jointly. Since the farmer's revenue and the processor's input cost are the same, the certainty equivalent maximizes the total net margin of producing, processing, and selling popcorn, minus the farmer's and processor's variance of income times their respective levels of risk aversion:

(21) $$\underbrace{Max}_{e} CE = E[U(p_P)] + E[U(p_F)] = E[p_P] + E[p_F] - \frac{r_F}{2} Var[p_F] - \frac{r_P}{2} Var[p_P],$$

$$\underbrace{Max}_{e}\, CE = U[E[U(p_P)]]^{-1} + U[E[U(p_F)]]^{-1} = E[p_P] - \frac{r_P}{2} Var[p_P] + E[p_F] - \frac{r_F}{2} Var[p_F]$$

where the expressions $r_F \cdot Var[p_F]/2$ and $r_P \cdot Var[p_P]/2$ can be interpreted as the transaction cost associated with the contract: i.e., for higher levels of variance or risk aversion, the farmer is willing to give up relatively more profits to enter the popcorn contract. When both the farmer and the processor are, risk neutral, i.e. r equals zero, no risk premium exists.

Upon expanding the above expression, the following is obtained:

(22) $$\underbrace{Max}_{e} CE = (P_P - C_P - w_M \cdot e^2) \cdot [y \cdot b_1 \cdot b_2 \cdot e] - \frac{r_F}{2}[r - w_M \cdot e^2]^2 \cdot s_x^2 - \frac{r_p}{2}[P_P - r - C_P]^2 \cdot s_x^2 .$$

Moreover, the incentive constraint requires that the marginal benefit equals the marginal cost of effort:

(23) $$\frac{\partial E[r \cdot \tilde{z}]}{\partial e} = \frac{\partial E[C(e, \tilde{z})]}{\partial e},$$

this is equal to

(24) $$r \cdot y \cdot b_1 \cdot b_2 = 3 \cdot w_M \cdot e^2 \cdot y \cdot b_1 \cdot b_2 .$$

This study proceeds by optimizing the certainty equivalent given in (*22*), subject to the incentive constraint in (*24*).

Results

Optimal results are derived for thirty-six scenarios and are depicted in Tables 1 and 2 in the appendix. The relative risk aversion coefficient for the farmer is varied from 0 to 5 for each of the six levels of relative risk aversion for the processor. When the both the processor and the farmer are assumed to be risk neutral, no risk sharing occurs. In addition, any time the farmer is risk neutral he will provide a full effort level regardless of the risk aversion level of the processor. This phenomenon occurs because the farmer is unconcerned with the uncertainty about the quality of useable popcorn. The premium per usable pound of popcorn is 12 cents.

When the farmer is slightly risk averse, r is equal to one or two, then the farmer provides an effort level of 100% and 99%, respectively. It should be noted that as the processor's relative level of risk aversion increases, the farmer's effort level rises. For example, when the processor exhibits a relative risk aversion level of 1, the farmer provides an effort level of 99% but when the processor has a relative level of risk aversion of 5, the farm provides an effort level of 1. The transaction cost (risk premium) associated with the contract for the farmer increases from $0 to $66 and $132 per acre as r increases from 0 to 1 and 2 respectively. The premium decreases to 11.8 cents per usable pound of popcorn, when the processor exhibits low levels of risk aversion but with an increasing processor's risk aversion level, it increases again to 12 cents per usable pound of popcorn.

When the farmer is moderately risk averse (r relative risk aversion level of 3), the farmer's effort level falls to approximately 90% in the case of a low processors' risk aversion level. As the processor's risk aversion level increases, the farmer's effort level rises. When the processor's risk aversion is 5, the farmer's effort level has increased to 93%. The same pattern exists for the incentives paid to the farmer, ranging from a minimum of 9.7 cents to 10.4 cents per usable pound of popcorn with increasing risk aversion of the processor. The farmer's risk premium continues to rise, ranging from

$131 per acre with a processor's relative risk aversion level of 0, to $150 per acre in the case of a processor's relative risk aversion level of 5.

As the farmer becomes highly risk averse, corresponding to a relative risk aversion level of 4 or 5, effort begins to decline rather dramatically to a low of 0.79 at r of 5 for the farmer and r of 0 for the processor. As with both the moderate and low levels of risk aversion, the incentive paid to the farmer exhibits the same trend with respect to the processor's risk aversion level. Figure 1 in the appendix provides a graphical example of these results.

The aforementioned results allow the following result to be reached: the farmer's effort level and the premium (incentive) structure decrease as the level of the farmer's risk aversion increases when holding the processor's risk aversion level constant. In addition, by examining Table 1 and Figure 2, it can be determined that the farmer's certainty equivalent exhibits the same pattern. It is declining as the farmers risk aversion increases while the processor risk aversion is held constant. In addition, as the processor becomes more risk averse, the farmer's certainty equivalent begins to decline, when holding the level of risk aversion for the farmer constant. For example, when r equal 4 for the farmer and 0 for the processor, the farmer's certainty equivalent is $19.85, but when the processor's r increases to 5 the farmer's certainty equivalent falls to $16. However, this is not the case for the processor's certainty equivalent. It actually rises when the farmer's risk aversion level is between 0 and 3. At a relative risk aversion level of 3 the processor's certainty equivalent reaches a maximum, and it then begins to decline when r equals 4 or 5 for the farmer.

An analytical exposition can explain the fact that while the level of risk aversion increases, the effort level and the incentive intensity decrease, whereas the risk premium increases to a certain level (until r equals approx. 3), and then decreases. The incentive constraint, re-expressed in terms of the effort level, wage and premium can be simplified to $r/3 = w_M \cdot e^2$, and upon inserting the expression for the effort level in the variance expression $r_F \left[r - w_M \cdot e^2\right]^2 \cdot s_x^2 / 2$, which simplifies to $2 \cdot r_F \cdot r^2 \cdot s_x^2 / 9 > 0$.

Hence, in order to maximize the total certainty equivalent, there is a tradeoff between increasing the farmer's effort, which improves the joint profit, and the premium paid to the farmer to compensate for the higher effort level for a given level of processor's risk aversion. Ceteris paribus, a higher premium strictly increases the transaction cost associated with the contract (i.e. decreases the certainty equivalent, see Figure 3). That is, at high levels of risk aversion, the overall certainty equivalent is low due to a relatively high-risk premium, which reduces the farmer's expected utility. Therefore, the farmer minimizes the variance of profit $2 \cdot r_F \cdot r^2 \cdot s_x^2 / 9$ by decreasing the effort level. In turn, this reduces the processor's profit level. With a relative risk aversion of 5, the farmer chooses to exert an effort level of only .79 and .81 when ρ equals 0 and 5 for the processor respectively. This implies that the farmer has to be compensated with a relatively low premium for usable popcorn: at this level, the processor compensates the farmer's effort by paying only 7.5 and 8 cents per pound given the level of risk aversion exhibited by the processor.

Conclusions

This research provides a robust framework for deriving an incentive based production contract, which maximizes the sum of joint certainty equivalent under various levels of risk aversion by finding the optimal levels of effort and premium. The results show that the effort level is a decreasing function of the farmer's relative risk aversion coefficient, when holding the processor's relative risk aversion coefficient constant. That is to say, the processor and the farmer face a tradeoff at high levels of risk, between effort level, which increases the expected profits and the transaction cost associated with providing the incentives. However, as the processor's relative level of risk aversion increases for a given level of risk aversion by the farmer, he is willing to pay a higher incentive to the farmer to insure that the popcorn delivered has the desired quality attributes. Consequently, as the effort level decreases, so does the premium paid for usable popcorn, which in turn decreases both parties' expected profits. The processor places a high value on this information because he is able to determine the optimal intensity of incentives that he needs to pay the farmer in order to induce the effort for the popcorn desired. If the processor would have the ability to discriminate perfectly in the selection of contracted farmers, he would only choose to contract with those farmers that had a risk aversion level, which would maximize his profit.

Limitations

It is crucial to note that the results of this study rest on a few vital assumptions. One central assumption is the somewhat arbitrarily specification of the production function, in which the farmer has a constant marginal impact on the amount of usable popcorn produced. Conceivably, the farmer's effort does not have a constant marginal impact on the quality traits. Furthermore, it is assumed that the processor monitors only the foreign matter and dry matter; in reality, though the processor might be concerned about additional product characteristics and the coordination of product flows. Nevertheless, the results of this study provide interesting insights, which warrant for further research.

Future extensions

Numerous opportunities exist to expand the methodology and framework used in this paper. A promising extension is to specify the cost functions of the processor and farmer via empirical estimation. Another feasible extension is to determine the correct measurement variable for effort or a proxy for measuring effort. Furthermore, the framework could include coordination of product flows and allow for alternative marketing strategies. Although this model and its performance measures are specific to the popcorn industry, the framework of building risk sharing production contracts using a certainty equivalent framework could be readily applied to other branches of production agriculture.

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Rehber, E. "Vertical Integration in Agriculture and Contract Farming." Working Paper #46, Food Marketing Policy Center, University of Connecticut. May 1998.

Appendix

Table 1: Model Results for the Farmer

Relative Risk Aversion Processor	Relative Risk Aversion Farmer	Total Certainty Equivalent	Incentives	Effort Level	Farmer Expected Value	Farmer Certainty Equivalent	Risk Premium Farmer	Absolute Risk Aversion Farmer
0	0	440.424	0.12	1	250.859	250.859		
0	1	373.511	0.12	1	250.859	183.946	66.913	0.098
0	2	306.697	0.118	0.991	244.309	115.317	128.992	0.196
0	3	253.597	0.097	0.901	186.119	53.936	132.183	0.294
0	4	215.569	0.084	0.838	151.718	19.859	131.858	0.392
0	5	186.299	0.075	0.79	128.855	-1.455	130.31	0.49
1	0	434.249	0.12	1	250.859	250.859		
1	1	367.335	0.12	1	250.859	183.946	66.913	0.098
1	2	300.428	0.119	0.998	249.291	116.626	132.665	0.196
1	3	245.823	0.099	0.907	189.808	53.916	135.892	0.294
1	4	206.741	0.085	0.843	154.608	19.147	135.461	0.392
1	5	176.682	0.076	0.795	131.211	-2.561	133.772	0.49
2	0	428.073	0.12	1	250.859	250.859		
2	1	361.16	0.12	1	250.859	183.946	66.913	0.098
2	2	294.247	0.12	1	250.859	117.032	133.827	0.196
2	3	238.154	0.1	0.913	193.504	53.871	139.633	0.294
2	4	198.007	0.087	0.849	157.511	18.407	139.104	0.392
2	5	167.15	0.077	0.8	133.58	-3.695	137.275	0.49
3	0	421.897	0.12	1	250.859	250.859		
3	1	354.984	0.12	1	250.859	183.946	66.913	0.098
3	2	288.071	0.12	1	250.859	117.032	133.827	0.196
3	3	230.587	0.101	0.919	197.205	53.8	143.405	0.294
3	4	189.366	0.088	0.855	160.424	17.64	142.784	0.392
3	5	157.702	0.078	0.805	135.961	-4.858	140.819	0.49
4	0	415.722	0.12	1	250.859	250.859		
4	1	348.808	0.12	1	250.859	183.946	66.913	0.098
4	2	281.895	0.12	1	250.859	117.032	133.827	0.196
4	3	223.121	0.103	0.925	200.91	53.704	147.206	0.294
4	4	180.816	0.089	0.86	163.347	16.846	146.5	0.392
4	5	148.337	0.079	0.811	138.353	-6.049	144.402	0.49
5	0	409.546	0.12	1	250.859	250.859		
5	1	342.633	0.12	1	250.859	183.946	66.913	0.098
5	2	275.719	0.12	1	250.859	117.032	133.827	0.196
5	3	215.756	0.104	0.931	204.618	53.584	151.034	0.294
5	4	172.358	0.09	0.866	166.278	16.027	150.252	0.392
5	5	139.055	0.08	0.816	140.756	-7.267	148.023	0.49

Table 2: Model Results for the Processor

Relative Risk Aversion Processor	Relative Risk Aversion Farmer	Total Certainty Equivalent	Incentives	Effort Level	Processor Expected Value	Processor Certainty Equivalent	Risk Premium Processor	Absolute Risk Aversion Processor
0	0	440.424	0.12	1	198.839	198.839		
0	1	373.511	0.12	1	198.839	198.839		
0	2	306.697	0.118	0.991	200.401	200.401		
0	3	253.597	0.097	0.901	206.44	206.44		
0	4	215.569	0.084	0.838	201.162	201.162		
0	5	186.299	0.075	0.79	192.326	192.326		
1	0	434.249	0.12	1	198.839	192.663	6.176	0.002
1	1	367.335	0.12	1	198.839	192.663	6.176	0.002
1	2	300.428	0.119	0.998	199.227	193.015	6.212	0.002
1	3	245.823	0.099	0.907	206.549	198.828	7.721	0.002
1	4	206.741	0.085	0.843	201.94	193.159	8.781	0.002
1	5	176.682	0.076	0.795	193.48	183.906	9.574	0.002
2	0	428.073	0.12	1	198.839	186.488	12.351	0.004
2	1	361.16	0.12	1	198.839	186.488	12.351	0.004
2	2	294.247	0.12	1	198.839	186.488	12.351	0.004
2	3	238.154	0.1	0.913	206.582	191.346	15.236	0.004
2	4	198.007	0.087	0.849	202.652	185.277	17.375	0.004
2	5	167.15	0.077	0.8	194.579	175.599	18.98	0.004
3	0	421.897	0.12	1	198.839	180.312	18.527	0.005
3	1	354.984	0.12	1	198.839	180.312	18.527	0.005
3	2	288.071	0.12	1	198.839	180.312	18.527	0.005
3	3	230.587	0.101	0.919	206.541	183.993	22.548	0.005
3	4	189.366	0.088	0.855	203.3	177.515	25.786	0.005
3	5	157.702	0.078	0.805	195.625	167.405	28.219	0.005
4	0	415.722	0.12	1	198.839	174.136	24.703	0.007
4	1	348.808	0.12	1	198.839	174.136	24.703	0.007
4	2	281.895	0.12	1	198.839	174.136	24.703	0.007
4	3	223.121	0.103	0.925	206.427	176.766	29.661	0.007
4	4	180.816	0.089	0.86	203.886	169.871	34.015	0.007
4	5	148.337	0.079	0.811	196.617	159.324	37.293	0.007
5	0	409.546	0.12	1	198.839	167.961	30.878	0.009
5	1	342.633	0.12	1	198.839	167.961	30.878	0.009
5	2	275.719	0.12	1	198.839	167.961	30.878	0.009
5	3	215.756	0.104	0.931	206.243	169.664	36.579	0.009
5	4	172.358	0.09	0.866	204.411	162.345	42.065	0.009
5	5	139.055	0.08	0.816	197.556	151.353	46.203	0.009

Figure 1: Incentive payments and effort level relative to the processor and farmer's relative risk aversion level

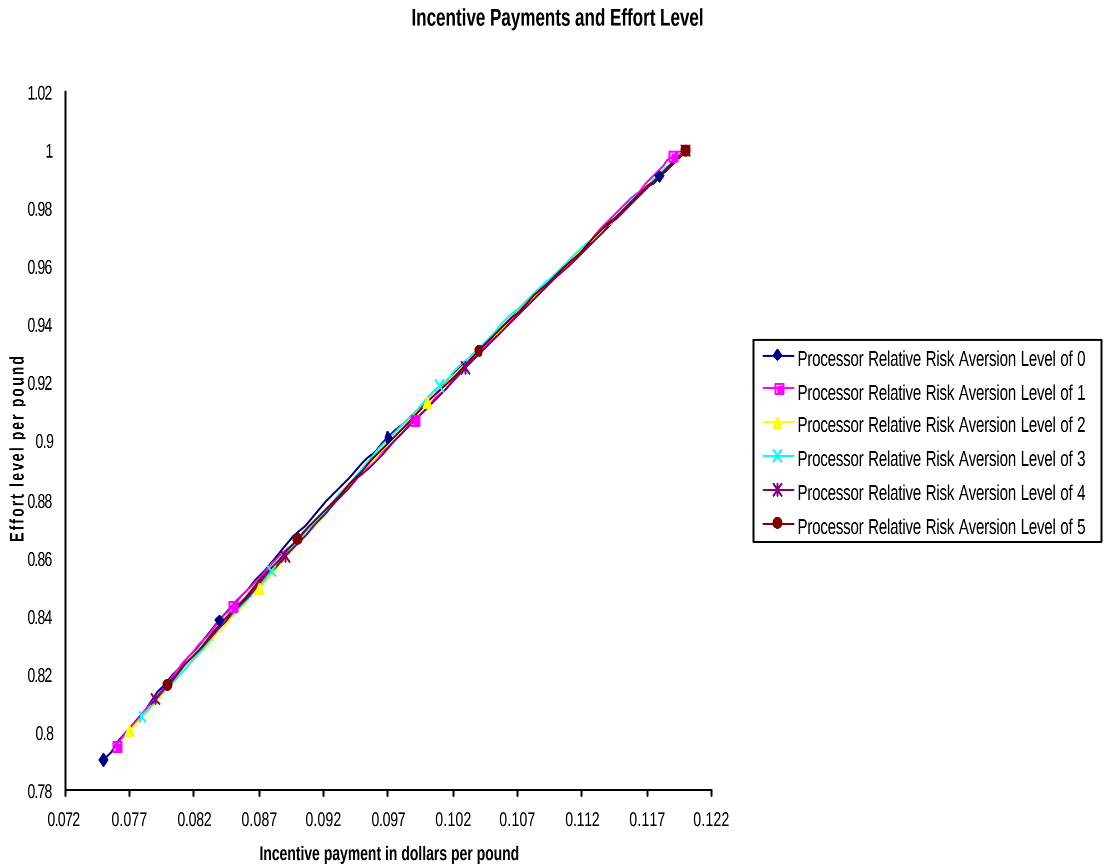

Figure 2: Certainty Equivalents

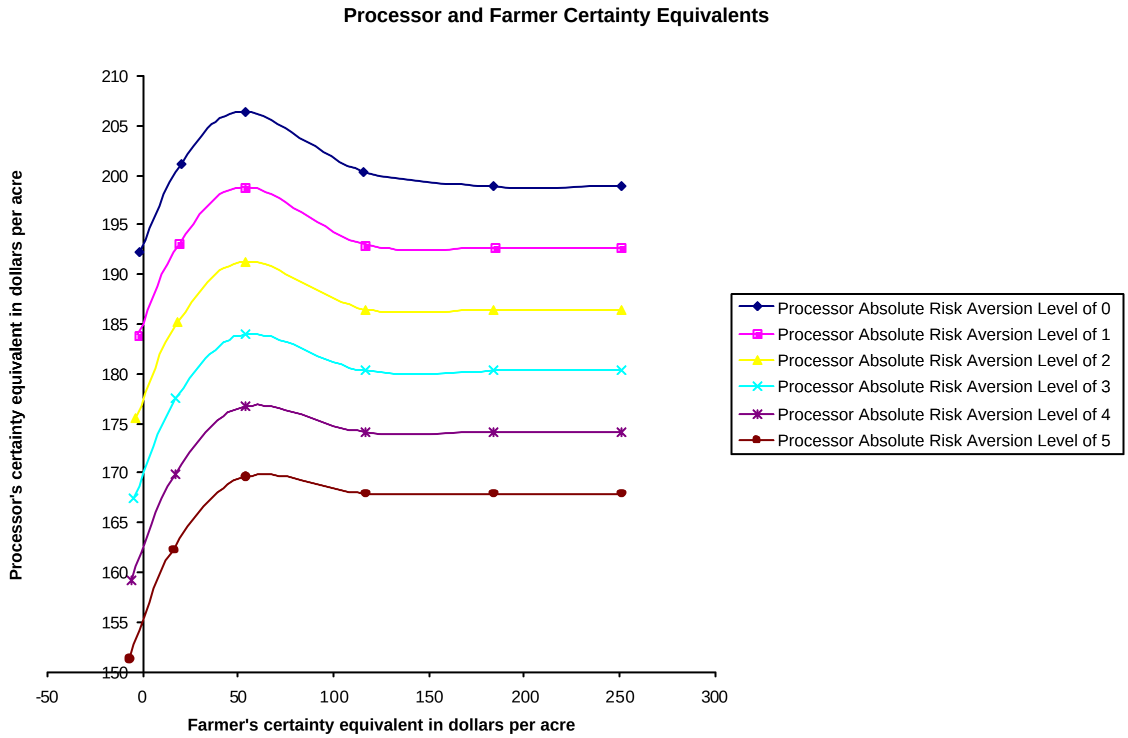

Figure 3: Total Certainty Equivalent and Effort Level