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Abstract

Dairy farmers often rank the benefits from a secure market as a major reason for belonging to a milk-marketing cooperative. As yet, no methodology has been developed to value market security offered by a cooperative. This paper presents such a methodology by developing a willingness-to-pay measure.

Dairy Farmer's Valuation of Market Security Offered by Milk Marketing Cooperatives

A cooperative is an economic institution by which autonomous economic units can jointly carry on activities common to their individual economic pursuits. Many dairy farmers belong to milk marketing cooperatives which allow them to take advantage of economies of scale in milk marketing, integrate forward into milk packaging and processing, and increase their bargaining power. Further, the presence of an assured market is often cited by dairy farmers as being the most common reason for cooperative membership (Jensen).

A loss of market access to a dairy farmer who has large capital investments in illiquid assets can be financially devastating. A dairy farmer is particularly vulnerable to short-term opportunistic behavior of milk handlers, because production costs are sunk at the time of the transaction and milk is highly perishable (Staatz). Provision of secure and long-term access to output markets is a main advantage of the cooperative over an investor-owned milk handler who does not offer a guaranteed market to the same degree as a cooperative. A recent national survey of milk marketers reported that 95% of the surveyed cooperatives guaranteed a market for their dairy farmers versus 51% of the investor-owned processors. Both the Processors and Grade A dairy farmers rated market guarantees as being very important. These results were consistent with an early study where 87% of the cooperative cheese plants surveyed guaranteed a daily market for farmers' milk, versus only 76% of the non-cooperative firms (Schrader, et al. and Babb).

In times of milk surplus, an investor-owned handler often "cherry picks". In this practice, producers who are small, inconveniently located, or have other non-profitable characteristics are dropped as customers. Besides cherry picking, an investor-owned handler may go out of business, leaving all its former customers without a milk market. Since most individual farmers do not have the storage capacity for their milk, a farmer that does not have a market will have to dump milk until a new market is obtained. Cooperatives also go out of business on occasion but the member-controlled nature of the business allows members to know in advance about the difficulties, allowing them to find other outlets for their milk. Some investor-owned handlers who are going bankrupt continue to collect milk and farmers are not informed until their checks are returned for insufficient funds or the bankruptcy is announced.

Despite the acceptance of market security as a primary cooperative benefit, the economic value of it "defies quantification" (Mengel). This paper develops the theoretical framework for quantifying the value of market security by utilizing a willingness to accept (or pay) measure.

Background

While an investor-owned handler farmer (IHF) is more likely to lose a market, an IHF often receives a higher price (Jensen). Thus, the range of expected incomes facing an IHF will probably be greater than that of a farmer cooperative member (FCM). The theoretical value of market security must then be related to the difference between the income probability distribution that the farmer would face as a FCM versus an IHF.

Consider two hypothetical dairy farmers who are located adjacent to one other. Their scale is approximately the same, as is their management and labor input. The income distributions from being a FCM or an IHF for each farmer are essentially identical. Each farmer makes the choice between being a FCM or an IHF based on the same set of distributions. Yet one farmer may choose the cooperative and the other the investor-owned handler due to differences in individual risk preferences. The farmer who is more risk averse will give more weight to income variance differences than the less risk averse farmer.

A measure for the value of a secure market must therefore incorporate risk preferences in the evaluation of alternative income distributions. Several techniques are available in the literature to rank income distributions. First and second degree stochastic dominance are commonly used although they rarely result in complete orderings of distributions (King and Robison). Elicited utility functions are also used as ordering criteria. While these will result in exact orderings, the practical difficulties in obtaining complete and accurate utility functions make the results sensitive to errors. Stochastic dominance with respect to a function (SDWRF) provides an intermediate option.

Theoretical Framework

SDWRF utilizes the Pratt-Arrow absolute risk aversion coefficient. This coefficient is defined as $r(x)=-u''(x)/u'(x)$ where x in this case is income and u is a von Neumann-Morgenstern utility function. A value of $r=0$ represents an individual with constant marginal utility of income and absolute risk neutrality. This individual would choose between two income distributions based only on expected income. The coefficient is positive for all risk averse decision makers (declining marginal utility of income) and a higher value indicates a greater degree of risk aversion.

SDWRF requires only the assumption that the farmer's absolute risk aversion coefficient is within an upper and lower bound. The effectiveness of SDWRF depends upon the width of the intervals being used. Several researchers

(Wilson and Eidman; King and Robison; Tauer) have researched feasible upper and lower bounds for ordering different income distributions. Raskin and Cochran, however, have demonstrated the sensitivity of marginal utility to risk coefficients and suggested that the intervals utilized by previous work (King and Robison, Tauer) may have been too wide. The intervals used in the simulations presented in this paper are based on the implications of Raskin and Cochran's paper.

Much literature relates to SDWRF but of particular interest is previous work by Bosch and Eidman who used SDWRF to choose between an income distribution with and without information. They then estimated an amount which would make the two distributions stochastically equal. This is relevant because market security can be viewed as a similar problem. The amount that would make the farmer indifferent between the income distribution from a relatively guaranteed market and that from a more uncertain market is a measure of the value of market security.

Consider a farmer choosing between two income distributions each with five possible outcomes. Distribution C is associated with a farmer marketing through a cooperative and distribution H is associated with an investor-owned handler. The hypothetical distributions, with each outcome having an equal probability of occurrence, are

Cooperative Distribution (C)	Independent Handler Distribution (H)
22,000	18,000
24,000	22,000
24,000	25,000
25,000	27,000
26,000	28,000

The expected value of each income distribution is $24,500, a risk neutral individual (r=0) would be indifferent between the two distributions and market security would have no value to this individual. However, the standard deviation for C is $1,483 and for H it is $4,062. The hypothetical distributions have equal expected values to isolate the variance-reducing effect of a secure market.

Define the cumulative distribution function (CDF) of distribution C as C(x) and the CDF of distribution H as H(x). Following Meyer, the solution procedure for ordering income distributions using SDWRF identifies the utility function which minimizes:

$$\int_{-\infty}^{\infty} [H(x)-C(x)]u'(x)dx \qquad (1)$$

subject to

$$r_1 \leq -u''(x)/u'(x) \leq r_2. \qquad (2)$$

If (1) is positive for a given set of decision makers, then members of this set unanimously prefer C(x) to H(x). If (1) is zero, then neither distribution is unanimously preferred since an individual in the set of decision makers is indifferent between the distributions. If (1) is negative, C(x) is not unanimously preferred to H(x) and a new equation

$$\int_{-\infty}^{\infty} [C(x)-H(x)]u'(x)dx \qquad (3)$$

is minimized subject to the same constraint. If (3) is positive, then H(x) is unanimously preferred to C(x) for all decision makers with absolute risk coefficients in the interval $[r_1,r_2]$. If (3) is negative, then SDWRF can not order the distributions.

Meyer developed an optimal control methodology for ordering distributions using SDWRF. His theorem states

$$r = \begin{cases} r_1 \text{ if } \int_{-\infty}^{\infty} [H(x)-C(x)]u'(x)dx<0 \\ r_2 \text{ if } \int_{-\infty}^{\infty} [H(x)-C(x)]u'(x)dx>0. \end{cases}$$

For example, consider a farmer facing the distributions presented above whose risk coefficient is within the closed interval of r_1=0.00005 and r_2=0.0001. To solve the optimal control problem set up by Meyer, a negative exponential form of utility, $u(x)=-e^{-rx}$ can be assumed. This provides constant upper and lower bounds on r along with u(1)=0. The function [H(x)-C(x)] is illustrated in Figure 1. The solution procedure works backwards from the right-hand side of Figure 1. Since the objective function has a value of 0 above \$28,000, the upper limit of integration becomes \$28,000. An intermediate value of the objective function is calculated each time the value of [H(x)-C(x)] changes. According to Meyer's theorem, the control value is initially 0.00005. The first interval of integration is \$27,000 to \$28,000. The value of the objective function over this range is

$$\int_{27,000}^{28,000} [H(x)-C(x)]u'(x)dx \qquad (4)$$

$$= \int_{27,000}^{28,000} (-1/5)(0.00005)e^{-0.00005x}dx$$

$$= -0.002529.$$

Since this value is negative, the control value remains at 0.00005. The integral from $26,000 to $27,000 is -0.005317 and the integral from $24,000 to $26,000 is -0.005732. The intermediate value of the objective function from $24,000 to $28,000 is -0.013578.

The final non-zero interval of [H(x)-C(x)] is $19,000 to $24,000 The intermediate value of the objective function over this range is 0.021075. Since this is greater in absolute value than -0.013578, the control value will change somewhere between $19,000 and $24,000. Iterations indicate the objective function changes sign at approximately $19,935. Thus, 0.0001 is the control value from $19,935 to $19,000. The intermediate value of the objective function integrated over this interval is 0.002670. Since the value of the minimized objective function is positive, H(x) is preferred to C(x) by all decision makers whose risk aversion coefficient is always between 0.00005 and 0.0001. Further, the utility function which minimizes the objective function is defined by:

$$r = \begin{cases} 0.00005 \text{ when } x \geq \$19{,}935 \\ 0.0001 \text{ when } x < \$19{,}935. \end{cases} \quad (5)$$

Willingness to Accept (or Pay)

The amount a risk averse farmer is willing to accept as compensation for facing a more risky distribution is a measure of market security. A farmer paid the willingness to accept (WTA) amount is hypothetically indifferent between marketing through an independent handler (and receiving the WTA amount) and belonging to a cooperative.

When the value of (1) is zero, an individual in the relevant risk aversion coefficient range is indifferent between the two distributions. WTA is calculated as the amount of money added to each possible outcome in distribution H such that the overall value of the objective function becomes zero. When the value of (1) is zero, a value for (3) must also be calculated. When the value of (3) is also zero, an individual in the relevant risk coefficient range is indifferent between the two distributions. Estimates of WTA can be obtained by solving for ε_1 and ε_2 in the following:

$$\int_{-\infty}^{\infty} [C(x)-(H(x)+\varepsilon_1)]u'(x)dx=0 \tag{6}$$

$$\int_{-\infty}^{\infty} [(H(x)+\varepsilon_2)-C(x)]u'(x)dx=0. \tag{7}$$

Rewrite (6) and (7) as follows

$$\int_{-\infty}^{\infty} [C(x)]u'(x)dx - \int_{-\infty}^{\infty} [(H(x)+\varepsilon_1)]u'(x)dx = 0 \tag{8}$$

$$\int_{-\infty}^{\infty} [(H(x)+\varepsilon_2)]u'(x)dx - \int_{-\infty}^{\infty} [C(x)]u'(x)dx = 0. \tag{9}$$

Note that (8) and (9) are differences between the expected utilities of the two distributions. These equations can also be written as

$$\int_{-\infty}^{\infty} [c(x)]u(x)dx - \int_{-\infty}^{\infty} [(h(x)+\varepsilon_1)]u(x)dx = 0 \tag{10}$$

$$\int_{-\infty}^{\infty} [(h(x)+\varepsilon_2)]u(x)dx - \int_{-\infty}^{\infty} [c(x)]u(x)dx = 0 \tag{11}$$

where h(x) and c(x) are probability density functions.

The income probability distributions presented in the previous example are discrete. (10) and (11) can be written in discrete form as:

$$\sum_{j=1}^{m} [c(x_j)]U(x_j) - \sum_{i=1}^{n} [(h(x_i)+\varepsilon_1)]U(x_i) = 0 \qquad (12)$$

$$\sum_{i=1}^{n} [(h(x_i)+\varepsilon_2)]U(x_i) - \sum_{j=1}^{m} [c(x_j)]U(x_j) = 0. \qquad (13)$$

In the example m=n but the WTA expression is developed for the general case of $m \neq n$.

By assuming the negative exponential form of the utility function, (12) can be rewritten as

$$\sum_{j=1}^{m} [1/m][-e^{-rx_j}] - \sum_{i=1}^{n} [1/n][-e^{-r(x_i+\varepsilon_1)}] = 0 \qquad (14)$$

and solving for ε_1

$$\varepsilon_1 = (-1/r) * LN \left\{ \frac{(\sum_{j=1}^{m} -e^{-rx_j})(n)}{(\sum_{i=1}^{n} -e^{-rx_i})(m)} \right\} \qquad (15)$$

A similar expression defines ε_2 except that the other bound on the risk coefficient would be used. Thus, two estimates for willingness to accept are obtained by this procedure.

The validity of (15) is contingent on the value of the objective function not changing sign and thus the same control value being used. If this is not the case, the simplified form presented in (15) could not be used and (10) and (11) would be solved by iterating the WTA value until equality holds.

Equation (15) is used to obtain WTA values for the simulation. First, r is 0.00005 and calculations yield a value of $235 for WTA. Using a r value of 0.0001, a value of $476 is obtained. The lower bound value of r gives the lower estimate of WTA and the upper bound value of r results in the higher estimate of WTA.

The sensitivity of WTA is explored by defining different intervals of risk coefficients. The schedule below shows that the WTA estimates become relatively significant when r is in the range of values used by previous researchers (Tauer; King and Robison):

Risk Coefficient Interval	Low Estimate of WTA	High Estimate of WTA
0.00001 to 0.00003	$46	$139
0.00003 to 0.00005	$139	$235
0.00005 to 0.0001	$235	$476
0.0001 to 0.0002	$476	$953
0.0002 to 0.0003	$953	$1388
0.0003 to 0.0005	$1388	$2050
0.0005 to 0.001	$2050	$2760

Conclusions

Past research has documented that dairy farmers consider the benefit of a secure market as the primary reason for belonging to a dairy marketing cooperative. This paper presents the first methodology for quantifying the value of market security to an individual farmer.

The income distribution associated with belonging to a cooperative is considered to have a lower variance than the income distribution of a farmer selling to an investor-owned handler. A farmer makes the choice between the cooperative and the investor-owned handler based on individual risk preferences. Farmers with a greater degree of risk aversion are more likely to prefer cooperative membership. The benefit of market security can be calculated as the amount that would have paid to the farmer to be indifferent between selling to an investor-owned handler and to a cooperative. The WTA amount can be calculated by employing Meyer's technique for choosing between two stochastic functions. Stochastic dominance with respect to a function can be used to first rank income distributions and to then derive the amount that a farmer would accept to be indifferent between distributions.

An example was presented where market security was calculated for two distributions with equal expected values but different variances. A conservative interval on the absolute risk coefficient of 0.00005 to 0.0001 was used to derive estimates of $235 and $476 for WTA. Further investigation indicates that higher risk coefficient ranges result in more significant WTA amounts.

Further research is needed to estimate actual income distributions resulting from marketing milk through a cooperative versus an investor-owned handler. The methodology presented above could then be used to obtain actual estimates of the benefit of market security of milk marketing cooperatives.

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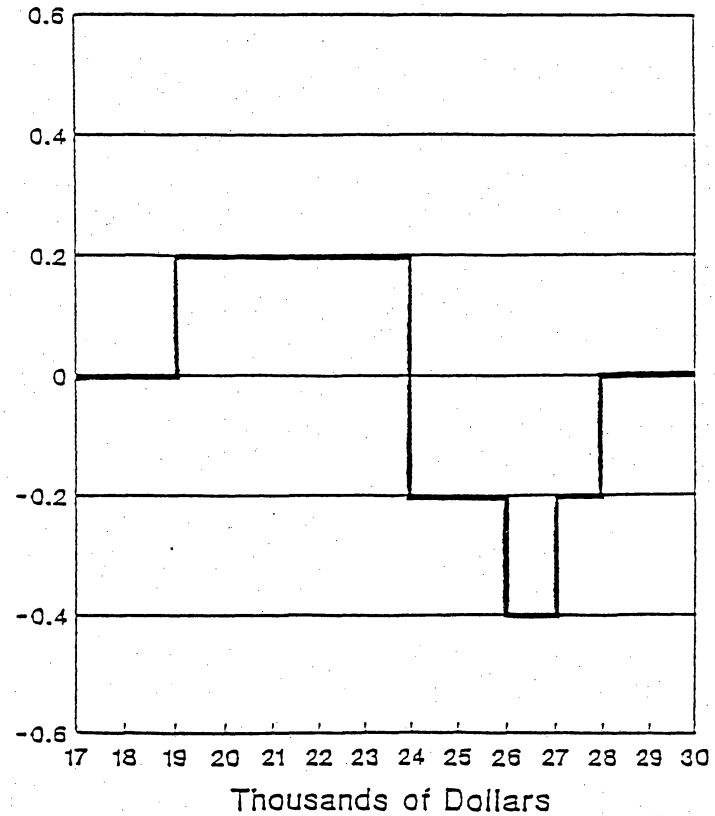

Figure 1. H(x)-C(x)