Proceedings of the 1986 Winter Simulation Conference
J. Wilson, J. Henriksen, S. Roberts (eds.)

SIMULATION ANALYSIS OF FINANCIAL RISKS FOR THREE VEGETABLE CROPS IN HAWAII

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ABSTRACT

Historical data on yields, input and output prices of three vegetable crops in Hawaii are analyzed. Appropriate theoretical probability distributions are fitted to these data to capture their randomness for profit simulation. Stochastic dominance analysis is then performed using the simulated profit data to rank the profitability of the three crops. Under the assumption that the producer is risk averse, growing lettuce appears to be more preferable to head cabbage, and head cabbage more preferable to mustard cabbage.
KEYWORDS: Risk Analysis, Simulation, Vegetable, Stochastic Dominance.

1. INTRODUCTION

Financial variability of crop production is largely due to the variations in market prices, input prices, and production yields. Since producers are often faced with the choice of growing one crop versus others, it would be important to identify the financial variability of each crop under consideration in order to maximize net returns. This paper presents an empirical framework to estimate the financial variability of crop production. Three vegetable crops - head cabbage, mustard cabbage, and lettuce are analyzed in the context of the proposed framework to determine the extent of financial risks each exhibits. Stochastic dominance analysis is then performed to identify the rankings of the three crops under various risk preference structures of the producers.

Considerable effort has been devoted to model and measure the relationship between agricultural yield variability and financial risks including contributions by Horowitz (1970), Roumasset (1976), Richardson and Mapp (1976), Richardson and Condra (1981), Blake and Gray (1981), Samples and Leung (1985) among others. This paper extends the analysis to include the effect of variability of input and output prices on financial risks into a simulation model. It also presents the analysis of the simulated output in a stochastic dominance framework. The primary objective of this paper is to demonstrate how simulation may be used to improve managers' ability to make decisions between risky alternatives when information is far from complete.

2. THE METHODOLOGICAL FRAMEWORK

The basic framework centers around the following annual simple cost and return model:

$$P = TR - TC \quad [1]$$

$$TR = p * q \quad [2]$$

$$TC = \sum_i c_i * w_i + FC \quad [3]$$

where P = profit;
TR = total revenue per acre;
TC = total cost per acre;
FC = fixed cost per acre;
p = output price per unit;
q = yield per acre;
c_i = price per unit for input i;
w_i = amount of the ith input needed per acre; and
i = pesticide, fertilizer, herbicide, labor, water.

The model assumes that the producer is price-taker in both the input and output product markets. It also assumes that the amount of inputs needed per acre and fixed cost per acre non-stochastic. In the model, the uncontrollable stochastic variables are yield (q), output price (p), and input prices (c_i). In addition, we assume that yield and output price are not correlated on the grounds that output price would not be affected by individual farm yield. Theoretical probability distributions are fitted to the historical data of these uncontrollable variables. Profit is then simulated using the fitted distribution in the above cost and return model. The simulation is replicated so as to obtain a profit distribution.

Figure 1 shows schematically the basic steps. The simulated profit distributions of several crops are then analyzed using the method of stochastic dominance to determine the crops' relative efficiency ordering under various assumptions of risk preference.

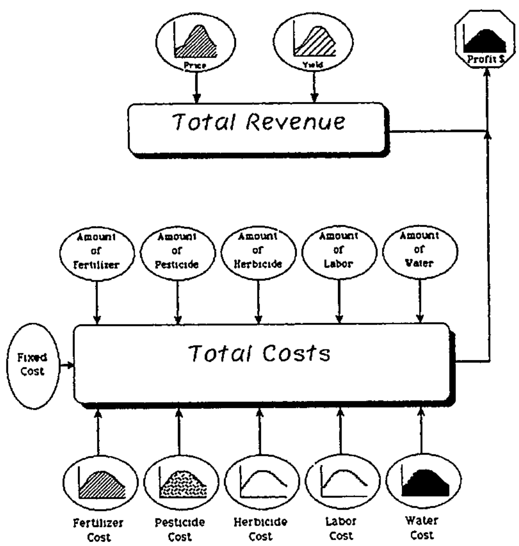

Figure 1: Cost and Return Model Flowchart

3. DATA

Historical data (50 years) of yield and price of three crops (head cabbage, mustard cabbage, and lettuce) on the island of Maui were gathered from the various issues of Statistics of Hawaiian Agriculture published by the Hawaii State Department of Agriculture. Farm wages were also collected from the same source. The historical costs of fertilizers, pesticides, and herbicides were gathered from the Brewer Chemical Company and the Hawaii Agriculture Company. Historical data on water cost was gathered from the Annual Reports of the Maui Board of Water Supply.

The various input quantities for each crop were obtained as averages from cost studies conducted by the Department of Agricultural and Resource Economics, University of Hawaii. These cost studies were conducted for different farms in Omaopio on the island of Maui.

All the price and cost figures were adjusted for inflation using the Honolulu consumer price index (CPI). The adjusted figures are in 1967 dollars.

The yield figures were tested to see if significant trend exist. Both head cabbage and mustard cabbage did not show significant trends in yield. However, lettuce was found to have significant improvement in yields in the last two decades. In order to reflect the true yield variability of lettuce, only the last 20 years of data were used in the following analysis.

4. RESULTS

The historical data collected on yield, output price, and input costs for each of the three crops were fitted to several theoretical probability distributions using the UNIFIT software package (Law and Vincent , 1983). UNIFIT employs a three-activity approach for determining an appropriate distribution for the observed data. These activities are: (1) hypothesize one or more families of distributions which might be appropriate using heuristics such as histograms and sample moments; (2) estimate the parameters for each hypothesized family thereby specifying a number of particular distributions; and (3) determine which of the fitted probability models is the best representation of the data using graphical displays and formal goodness-of -fit tests.

The fitted distribution together with their means and variances are summarized in Table 1 below.

Table 1: Summary of Fitted Distributions

Variables	Fitted Distribution	Mean	Variance
Head Cabbage			
Yield	Lognormal	26.50	17.70
Price	Normal	5.37	0.96
Mustard Cabbage			
Yield	Normal	14.06	9.00
Price	Gamma	11.50	2.01
Lettuce			
Yield	Weibull	14.05	0.23
Price	Normal	10.74	5.04
Input Prices			
Fertilizer	Gamma	13.90	0.96
Pesticide	Normal	19.89	5.38
Herbicide	Gamma	5.01	2.60
Wages	Weibull	2.31	0.89

The distribution for each of the variables were chosen based on economic plausibility and statistical goodness-of-fit.

Profits for each crop are then simulated using the above cost and return model computer-coded in FORTRAN. The simulation experiment was replicated for 50 times, each with 100 random variates for a total of 5,000 simulated profit figures. The rationale for the replications is to allow change of seeds for the random number generation process. The simulated profits for each of the crop are summarized in Table 2 below.

Table 2: Simulated Profit Distributions

Crop	Mean $/acre	Standard Deviation $/acre	Coefficient of Variation	Coefficient of Skewness
Head Cabbage	403	187	0.46	0.93
Mustard Cabbage	288	73	0.25	0.36
Lettuce	413	340	0.82	0.30

As can be seen in Table 2, growing lettuce produces the highest mean profit ($413), followed by head cabbage and mustard cabbage. However, it also has the highest standard deviation with a coefficient of variation of 0.82. All three profit distributions tend to skew slightly to the right as depicted in Figures 2, 3 and 4 and the coefficients of skewness.

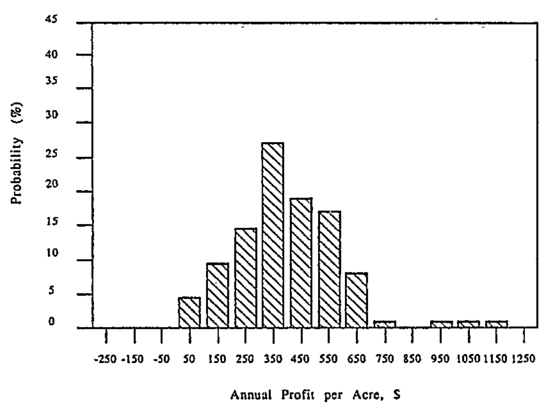

Figure 2: Probability Distribution of Profit for Head Cabbage

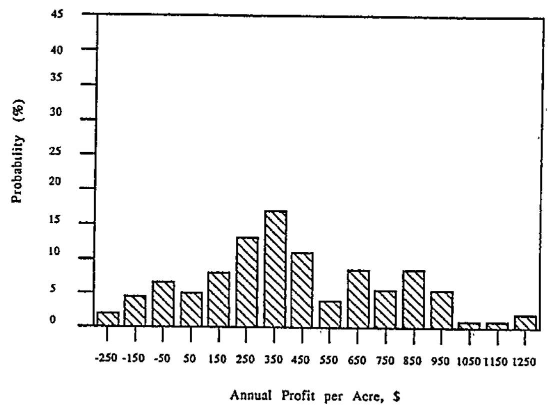

Figure 3: Probability Distribution of Profit for Lettuce

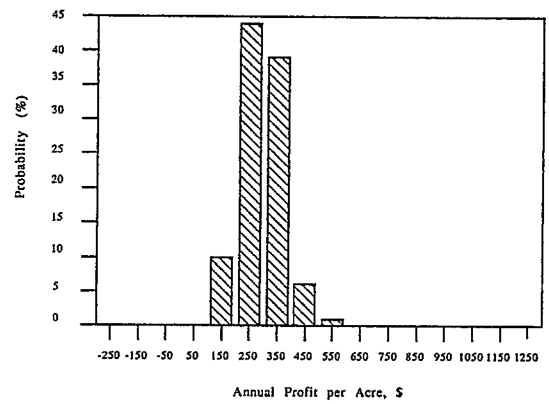

Figure 4: Probability Distribution of Profit for Mustard Cabbage

Table 3 shows the quantile summary of the three simulated profit distributions. This provides a quick synopsis of the profit variability of the three crops. The lower and upper quartiles provide the inter-quartile range which covers 50% of the distribution. For example, Table 3 indicates that 50% of the time profit for head cabbage will lie between $283 and $514. Similarly, the lower and upper octiles provides the range which covers 75% of the distribution. The range and median of each of the distributions are also presented in table 3. It is interesting to note that while the mean profit for growing lettuce is higher than that of head cabbage ($413 vs. $403), the median profit for growing head cabbage is higher than that of lettuce ($387 vs. $353). This is primarily due to the fact that the profit distribution for head cabbage is slightly more skewed to the right than that of lettuce as indicated by the coefficient of skewness (0.93 vs. 0.30).

Table 3: Quantile Summary of the Simulated Profit Distributions ($/acre)

Crop	Median	Range	Quartile	Octile
Head Cabbage	387	14 to 1115	283 to 514	199 to 591
Mustard Cabbage	284	137 to 507	225 to 336	203 to 371
Lettuce	353	-292 to 1291	195 to 662	22 to 862

The above descriptive analysis provides the profiles of the risks of producing each of the three crops. This information can be very useful for producers to base his/her production decision on each crop. While growing lettuce can yield the highest expected (mean) profit, it also has the highest risks as indicated by the high standard deviation. In fact, the simulated profit distribution for lettuce ranges from -$292 to $1291. This appears to reflect the fact that lettuce is very sensitive to water deficiencies and plant diseases as compared to head cabbage and mustard cabbage. Although the mean profit value for mustard cabbage is modest, with a range of $137 to $507, its risk factor as measured by the standard deviation is very low and it always produces a (positive) profit. Mustard cabbage is highly disease resistant and can grow in a wide range of temperatures. It can also be used in processed products. Between the two extremes of lettuce and mustard cabbage, head cabbage is found to yield a higher mean profit than mustard cabbage without the high risk associated with lettuce. Its simulated profit ranges from $40.82 to $1267.85 also assures a no loss situation for the producer.

The simulated profit distributions also provides the basic data for ranking the three crops given the producer's attitude towards risk. The conventional E-V analysis in an expected utility framework is to consider the trade-off between expected value and variance of profits. It is appropriate for a risk averter, particularly if the profits are normally distributed or the decision maker has a quadratic utility function (Anderson et al., 1977). This would require that the profit distributions are symmetrical which is not applicable in the present case where all three profit distributions are skewed to the right.

Stochastic dominance is an alternative methodology in an expected utility framework that does not require the restrictive assumptions of E-V analysis (Anderson et al., 1977). It is not as efficient computationally and does not necessarily produce as small an efficient set as E-V analysis. Stochastic dominance uses the relationships between the cumulative probability distribution functions (CDFs) of alternative plans to identify their relative merits. In comparing two risky alternatives, if one of CDF lies nowhere to the left of the other CDF, then the first alternative is first-degree stochastically dominant. It rests on the assumption that decision makers prefer more profit to less and is appropriate for individuals with all risk attitudes. However, this rule cannot generally provide an absolute ranking. By introducing few more restrictive assumptions on the risk preference of the decision makers, more efficient rules are available to sort out the optimal alternative. If the decision maker prefers more to less and is risk averse, second-degree stochastic efficiency analysis provides another rule for ranking risky alternatives. A prospect is second-degree stochastically dominant over another prospect if the former CDF lies more to the right in terms of differences in area between the CDFs. While higher degrees of stochastic efficiency analysis are available, first- and second-degree analyses are sufficient for the present analysis.

Figure 5 shows the CDFs of the profit distributions of the three crops. As can be seen, none of the CDFs lies entirely to the right. Hence none of the crops is first-degree stochastically dominant over the others. In other words, without knowing the risk attitude of the producer, it is not possible to identify any crop which out-performs the others in terms of maximizing expected utility. It is obvious from Figure 4 that both lettuce and head cabbage are second-degree stochastic dominant over mustard cabbage. However, it is not so clear-cut between head cabbage and lettuce. A detailed calculation of the area between the CDFs of lettuce and head cabbage reveals that lettuce is second-degree stochastic dominant over head cabbage although the difference is very small (670 vs 580). Therefore, given that the producer is risk averse, growing lettuce is slightly preferable to head cabbage, and head cabbage is preferable to mustard cabbage.

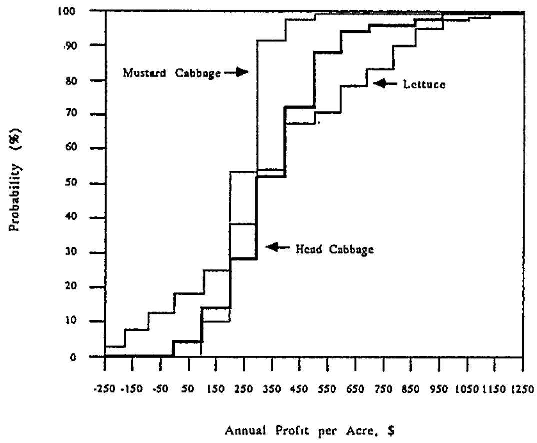

Figure 5: Comparisons of Cumulative Probability Distribution Functions (CDF) of Profits

5. CONCLUDING REMARKS

This paper provides a framework which utilizes the rich information generated from a simulation model for studying risky prospects in the context of stochastic efficiency analysis. While it is often difficult to obtain reliable data for stochastic efficiency analysis, the use of simulation can be very effective in bridging the gap. This is illustrated by the analysis of the three vegetable crops in Hawaii. It should be noted although this present analysis was not performed on the microcomputer, it can easily be adapted to the microcomputer environment. In fact, a microcomputer version of UNIFIT is now available and the simulation analysis can easily be done using any electronic spreadsheet.

The output of this type of analysis can be very useful in extension work and managerial decision making. Many extension personnel have found that producers and other firm managers are more than able to grasp the basic fundamentals of probability. While the mathematical procedures for simulation and efficiency analysis may not be easily understood, the basic concepts do not require a high level of mathematical fluency. Thus, the output may be used as a teaching device to re-enforce probability concepts which managers may find useful. The presentation of simulation in conjunction with efficiency analysis may also lead some managers to view their decisions in a different perspective, which might also be useful. More importantly, those managers who have a firm grasp of the basic concepts may find that such analyses enhances their ability to make decisions between various risky alternatives and more clearly see how their present financial status may affect their decisions.

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