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Alternative Analyses of Farm Growth*

By Roger P. Strickland, Jr.

Four strategies for farm growth are analyzed and compared on the basis of ownership, equity, and productive capacity achieved, and on the basis of resistance to adversity. The primary tool of analysis was a model utilizing a stochastic simulator interfaced with both *ex ante* and *ex post* linear programming routines. The performance of the growth strategies differed markedly with respect to the various indicators. It appeared that little was gained from using a stochastic model rather than a deterministic one.

Keywords: Farm growth; Linear programming; Simulation.

A number of studies of farm firm growth, involving a variety of models and techniques, have recently been reported (3, 4, 5, 8, 9, 10). Much has been learned from these studies, but the results have often been conflicting and difficult to interpret, and the appropriateness of the alternative models requires further analysis. This study combines two techniques—simulation and linear programming—to model a southern Michigan dairy farm for the purposes of studying firm growth.

Alternative means to monitor growth include the measurement of inputs, assets or net worth, and output (1, 7, 11). None of the three has received universal acceptance. Inputs have qualitative variations that are difficult to discern with any degree of accuracy at a point in time or over time. Human agents and inputs that did not enter the market during the production period are examples. Inputs that are not acquired via the market during each production period also create problems of valuation. This is particularly true for services of real estate, valuation of which is often arbitrary.

Boussard (2) has a particularly interesting and scholarly treatise dealing with maximization of the firm's net worth at the end of the planning horizon, assuming a linear consumption function. However, factors such as the relation of family maturation and income level to the operator's marginal propensity to consume, the future development of new products, and reactions to national economic conditions must be weighed before accepting a linear consumption function.

Value of output is the measure of firm size used in this study. Value of output can be measured with relative accuracy and ease. Value of output reflects management input at all levels, including both production and marketing systems. It reflects the combined effects of exogenous forces and counteractions by management: A management input that can be detected in a comparative analysis. Value of output does not reflect the decline or accumulation of resource ownership, but ownership is a measure of wealth, not size.

To yield information of value, any model utilized in a growth study must possess several characteristics: (1) It must ensure continuity of operation from one production period to the next; (2) it must permit the approximation of relationships establishing the levels of endogenous variables to an acceptable degree, and effecting changes in these variables; and (3) it must include the more critical decision points and the major decision alternatives.¹

The following analysis is based on a model consisting of a stochastic simulator interfaced with both an *ex ante* linear programming (LP) routine and an *ex post* LP routine, yielding a total of three different plans for each production period. Due to differences in assumptions regarding the state of knowledge, comparisons of plans permit analysis of managerial decisions.

The three plans are sets of production decisions and are determined as follows:

(a) *Ex ante LP plan*. Activity levels are determined by LP maximization of expected profits using mean values of stochastic variables. Profits are calculated using mean values of stochastic variables.

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¹ The terminology used is intentionally nonspecific because what is critical or major depends upon objectives and resources available to achieve the objectives.

(b) *Simulation plan.* Activity levels are based on representative production practices of southern Michigan dairy farmers. The effects of exogenous factors manifested through yields and prices are stochastically determined using probability functions in conjunction with a random number generator. Profits are calculated with randomly generated values of stochastic variables. Expected profits are also derived using the mean values of stochastic variables.

(c) *Ex post LP plan.* Activity levels are determined by LP maximization of profits using the randomly generated values of stochastic variables obtained for the simulation plan. Profits are calculated with the randomly generated values.

The stochastic simulator is the means for reflecting real world uncertainty.² The effects of uncertainty are ignored by a conventional LP model, which could be a serious weakness in a firm growth study if the farm operator is averse to high-risk situations. Also, LP models require modification if the operator seeks to achieve several objectives simultaneously without necessarily maximizing any one. The LP algorithm does provide a relatively efficient vehicle for analyzing a problem with respect to a single criterion. A variety of useful information may be obtained through the use of alternative objective functions and constraints, assuming such results are interpreted judiciously.

Simulation models are typically complex, with decision rules, discrete relationships, nonlinear functions, and multiple objectives. Consequently, interpretations with regard to any one objective are generally difficult, and costs of construction and operation rise rapidly as the number of objectives increases.

In this study, the simulator was the model's core, providing continuity of operation through the maintenance of inventory and capital accounts; effecting managerial decisions regarding the production mix, technology levels, and resource acquisition; and establishing the current conditions of the stochastic elements. Linear programming was utilized to derive two production plans specific to the current production period: the ex ante plan based on expectations³ and the ex post plan

based on the outcome of the stochastic elements, that is, perfect knowledge via hindsight.⁴

The ex ante LP derived production plan reflects the results of maximizing expected profits when uncertainty is disregarded. The ex post optimal production plan establishes a norm against which the performance of the other plans can be measured.

The simulator used in this study is a computerized farm firm model. Its components and relationships were designed to represent those that existed for southern Michigan farms during the study period. It contains land, livestock, and machinery purchasing activities with alternative financing arrangements. Numerous crop and livestock enterprises may be combined to meet the user's desires, with several technology levels available for each. Services of inputs, including land and labor, may also be purchased. Bookkeeping features maintain inventory records and capital accounts and compute enterprise profitability, depreciation, and net worth. The simulator automatically purchases replacement machinery within the guidelines established by the operator.

Price and yields are stochastic variables. Frequency or probability distributions for the variables are based on historical data. The possible outcomes of the random number generator are arranged in a similar distribution so that the number generated is associated with a value for the variable. When adverse conditions are simulated, unfavorable values are arbitrarily drawn from the extreme part of the probability distribution.

The LP models solve for production plans only, given a package of resources without regard to how they were acquired. The resource package in both LP plans is identical to that of the simulator. The price and yields of the ex post LP are also identical to those of the simulator, while the ex ante LP includes mean values for the prices and yields.

Procedure

The initial set of firm characteristics is simulated over a 10-year period under eight different managerial-strategy situations. The eight situations consist of two levels of managerial ability under each of four growth strategies. The two levels of managerial ability are hypothesized to be the above average and the exceptional (upper 5 percent). The four growth strategies consist of a vertical strategy (fixed land base) and three lateral strategies. Under the lateral strategies land is acquired by renting, land contract, or mortgage.

²Uncertainty is to be construed as imperfect knowledge of both the possible outcomes and the associated probabilities of occurrence from a specific, but yet to occur, set of conditions. Needless to say, the definition of the probability function is a crucial step in the construction of a stochastic model. The included probability functions, consisting of both commodity production and marketing conditions, were based on conditions existing in Michigan. A random number generator was the determinant of the specific value for a function.

³The weighted means of the probability functions were used.

⁴For information on the procedure for interfacing FORTRAN programs with the IBM LP package, see (13).

In the simulations, an ex ante LP solution is first obtained for each period using the mean values for the stochastic variables. Second, a set of decisions designed to represent the rather rigid cropping patterns of southern Michigan dairy farmers is simulated under stochastic conditions. Third, an ex post LP solution is derived using the perfect knowledge that exists through hindsight. This procedure is repeated in simulating each of the 10 years of operation.

Acquisition of cows and land is made in years 1, 6, and 10. Purchasing at intervals is considered to be more realistic than annual purchases. It gives firms a period of adjustment and possibly permits sufficient capital to be accumulated so that sizable quantities of land could be purchased at once. This is consistent with the typical pattern of expansion by absorbing existing operations. After each purchase year, as a separate phase of the analysis, each firm is subjected to 5 years of adverse conditions to gain an indication of the risk associated with each strategy.

Information Provided

Information covering three aspects of managerial decisions for firm growth is generated. First, the losses in potential income, relative to the maximum,⁵ are partitioned into (1) that due to decisions known to be non-optimal relative to the information available at the time⁶ and (2) that due to the stochastic elements in exogenous forces. Second, the level of growth achieved by each management-strategy situation over a 10-year period is simulated. Third, the vulnerability of each situation under adverse conditions is assessed. The length of time each management level or growth strategy is able to survive bankruptcy in its several situations is used as a gauge of its vulnerability, relative to the alternatives.

An annual loss, computed as the amount by which the maximum net income possible (ex post LP) exceeds the realized net income (simulator), occurs each year unless all random factors are correctly anticipated, either by chance or by foresight. Thus, the loss is always greater than, or equal to, zero. Similarly, that component of the loss due to incorrect decisions is always greater than, or equal to, zero; that is, nonoptimal decisions almost always result in losses.⁷ In contrast, the

⁵The income to be had from correctly anticipating the exogenous factors.

⁶Optimality is used with reference to maximizing current net income. It is a benchmark indicating the net income sacrificed in bringing other objectives into the decision.

⁷Given that the respective probability functions are the best information available at decision time, optimal decision sets would be those based on weighted mean value, that is, over time, expectations would be for the highest average value for the objective.

effect of the stochastic elements may be positive, zero, or negative. A positive effect indicates that the occurring stochastic conditions favor the simulation plan: The loss expected from not following the ex ante optimal plan (incorrect decision) will be at least partially offset. An exact offsetting is possible but improbable. Otherwise, the loss expected from incorrect decisions will be aggravated.

The total loss is computed as the net income for the ex post optimal plan less the net income for the simulation plan. To get the incorrect decision component of the loss, the expected net income from the simulation plan is subtracted from the expected net income from the ex ante optimal plan.⁸ The remaining component of the loss, that due to the stochastic elements, has two components: (1) The effect on the plan put into operation, and (2) the effect on the optimal plan. The former is computed as the difference between income expected and income realized from the simulation plan. The latter is the difference between the incomes of the ex ante optimal plan and the ex post optimal plan. It may be calculated simply by subtracting the incorrect decision component of the loss from the total loss. In either case, it may be positive, zero, or negative.

At this point, it is probably worthwhile to reemphasize the fact that annual net income is not the only objective to be considered in managing a firm bent on achieving growth. But the deviation of the income realized from the maximum is an indicator of some "costs" associated with the inclusion of additional objectives.

Results

When income lost through non-income-maximizing decisions over a 10-year period is partitioned into that due to incorrect decisions and that due to stochastic elements, the partitioning produces some interesting comparisons. For the eight managerial-strategy situations, the proportion due to "incorrect" decisions ranges from 79 percent to 91 percent, with an average of 87 percent weighted over all eight situations. Part of the income lost is knowingly foregone in deference to other objectives and part may result from erroneous decisions by farm managers, who perhaps had insufficient information.

To illustrate, a year-by-year breakdown is presented in table 1 for one of the eight managerial-strategy situations. This one combined the exceptional level of management and the acquisition of land by mortgage,

⁸Expected net incomes are based on the weighted means of probability functions.

one of three lateral growth strategies. The fact that the effect of the stochastic elements is negative in a majority of the cases in table 1 should come as no surprise. The stochastic elements relating to the enterprises in the selected decision set must be the most favorable relative to all the other possible decision sets if the stochastic elements are to favor the set of decisions put into operation.

The results of this study pertaining to the relative strengths of the strategies in achieving growth and in withstanding adverse conditions are briefly summarized in table 2. Ownership, equity, and productive capacity are taken as three measures of size and thus of growth achieved. These measures are indicated by assets, net worth, and gross income, respectively.

Table 1.—Annual loss from nonoptimal solution: Total and amounts attributable to incorrect decisions and stochastic elements

Year	Annual loss	Incorrect decisions	Stochastic elements
1	-\$3,602	-\$2,389	-\$1,213
2	-1,676	-2,046	+370
3	-4,013	-3,067	-946
4	-3,465	-2,607	-858
5	-2,902	-3,297	+395
6	-3,600	-4,504	+904
7	-5,856	-4,497	-1,359
8	-5,268	-4,148	-1,120
9	-6,611	-5,605	-1,006
10	-5,359	-4,347	-1,012
Total	42,352	36,507	5,845
Percent	100	86.2	13.8

Conclusions

This analysis resulted in consequential findings in two important areas. One is in relation to the relative strengths and weaknesses of four common growth strategies. The second deals with an evaluation of the merits of a stochastic model as opposed to a deterministic model.

The analysis of the four types of strategies is divided into two parts: (1) What are the relative potentials for growth of the four strategies, and (2) what are their relative strengths under adverse conditions? The conclusion is that no single strategy is superior to the other three under both tests.

Expanding laterally by means of a land contract arrangement turned out to be the best all-around strategy. It captures the leadership position in achieving growth and demonstrates substantial strength in withstanding adverse conditions.

Purchasing land under a contract offers certain advantages to farmers if such an arrangement is available. With the small downpayment requirements, the contract offers the potential either to acquire control of additional land or to release additional funds for other uses. The land contract does, however, present the imprudent operator with a means to financial ruin through too much indebtedness. With reasonable use, it offers the opportunity to acquire additional resources beyond what could be purchased with larger down payments required in mortgaging. This consideration can be particularly important in the case of assets subject to capital gains.

The vertical strategy is the most resilient in the face of adversity but is more restrictive than two of the other

Table 2.—Summary comparison of strategies^a

Item	10-year growth			5-year resistance ^b	Annual net cash income
	Ownership	Equity	Productive capacity		
Vertical	—	+	—	++	0
Renting	—	+	++	--	0
Land contract	++	++	+	+	++
Mortgage	+	++	+	+	+

^aThis table represents a set of qualitative judgments on the part of the author regarding the relative positions of the strategies under certain specified measures. A mark of (++) is given to the top-ranked strategy and the other three are assigned one of the following marks: (+), (0), (-), or (--) according to their position in relation to the one with the highest rank. There were two managerial-strategy situations involving above average and exceptional management available for evaluating each strategy. Exceptional management exhibited superior performance under each measure but the above results hold equally for both types of management.

^bResistance to bankruptcy under conditions of adversity.

strategies in achieving growth. Expansion by renting land under a long-term contract is the weakest strategy, considering both factors. Firms adopting this strategy are always the first to succumb to adverse conditions. The success of the strategy necessitates the maintenance of a substantial cash flow and adverse conditions reduce the cash flow.

The attempt to compare the growth potential of alternative growth strategies is not original. On the other hand, evaluation of the ability of firms operating under a particular strategy to withstand adverse conditions has not often been made. The study indicates that there is definitely a wide variation among strategies with regard to this characteristic, and it would appear that this aspect would deserve a great deal of consideration from an operator planning to commit large sums of money to growth. This is a particularly important finding in view of several possibilities now facing commercial farmers: (1) Future technological innovations could result in substantial outward shifts in the supply curve for agricultural commodities, (2) the development of substitutes is an ever-present threat, and (3) drastic change in Government policy is a possibility constantly facing agriculture. Any of these three factors, and perhaps others, could put agricultural producers in a difficult position for a long time as part of an adjustment process that would very likely see a number of operations fail. Operators planning to invest several hundred thousand dollars should be made aware of the variations in the risk associated with the different strategies.

The partitioning of the income loss from decisions that were nonoptimal in an ex post sense has implications for both dairy farmers and economic researchers. Given a bundle of assets and a set of production decisions, variations in stochastic elements generally had very little impact on the growth of a southern Michigan dairy farm during a 1-year period. Also, the net effect of stochastic elements over a longer period was small, as the offsetting effects among enterprises and among years tended to cancel out.

The fact that the net effect of stochastic elements was inconsequential—that is, the effect was similar to using means in a deterministic model—is not surprising, given the diversity of the dairy operation. Even with diversity limited to milk, hay, and several types of grain, adverse production or marketing conditions in one commodity were typically offset by more favorable conditions soon thereafter, if not in the same calendar year.

In retrospect, it appears that little was gained from using a stochastic model as opposed to a deterministic one. This is not to say that knowledge concerning the

dispersion and probability of occurrence for exogenous forces is not important. These two types of information are invaluable to the success of both the firm and an analysis of its operation. But computer resources could have been utilized more efficiently by using predetermined sets of exogenous forces to test the particular hypotheses under study. The value of the frequency distributions would be in the design stage when the sets of exogenous forces were selected.

Admittedly, the impact of exogenous forces is likely to become more pronounced as the degree of diversity in the firm's operations diminishes, but a stochastic model will not necessarily permit a better analysis. Analysis based on probability distributions requires that either some minimum number of values be drawn from the distribution or that the probability of occurrence be considered in the analysis. For future research, consideration should be given to limiting the use of probability or frequency distributions to the design and analysis stages in a project. Not only may more efficient use be made of computer resources in conducting the analysis, but considerable savings may result from constructing deterministic models as opposed to stochastic models.

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