RESEARCH ORIENTATIONS AND THEIR IMPLICATIONS FOR AGRICULTURAL ECONOMISTS

C. B. BAKER*
University of Illinois

Division of agricultural economics research into behavioral vs. policy alternatives is proposed to reduce ambiguities implied by a positive vs. normative division. The thesis is argued with reference to growth of the farm firm. A specific model is proposed. Brief comparisons are provided with alternatives in behavioral and policy applications.

In the pages of this *Journal*, Professor Johnson has indicted a large number of agricultural economists for irrelevance.[1] Many modern farm management researchers have been led, under the protective guise of production economics, to the same sterility that marked latter years of pre-Heady investigators. The earlier researchers centered their work on farm records and emphasized precision in observational processes and accuracy in estimation. Latter day researchers centre their work on model formulations of the farm firm or sub-sectors of the farm firm. They are more cavalier in data use, and often downright opportunistic. Both groups are, Johnson argues, essentially positive in orientation. That is, they concern themselves with "what is" questions. Their avoidance of normative ("what ought to be") questions has led both groups, Johnson concludes, to answering questions no one has asked and avoiding questions that are of substantive concern. Additionally, we might observe, both groups developed, over time, an excessive concern with methods, the final evidence of sterility!

I suggest we take Professor Johnson's criticisms seriously. They surely must have occurred to most of us as we interpreted still another statistically estimated production function[2] or perhaps the results of still another linear programming solution.[3] However, there is a sense of frustration too in Professor Johnson's analysis. The partitioning of the investigational field into positive and normative becomes most nebulous. More important, his conclusions lack definition on prescriptive proposals for research investigators. Instead, we are exhorted to be more useful.

The difference between "positive" and "normative" has been noted by numerous economists with respect to supply response studies.[4] But

* Visiting Fulbright-Hays Scholar, University of Sydney, 1966-67.

[1] Johnson, G. L. Stress on Production Economics. *Aust. J. of Agric. Econ.*, v. 7, no. 1 (June 1963), pp. 12-26.

[2] E.g., Mauldon, R. G. Advice from Estimated Marginal Productivities. *Aust. J. of Agric. Econ.*, v. 7, no. 1 (June 1963), pp. 55-60.

[3] E.g., Musgrave, W. F. Linear Programming—An Evaluation. *Aust. J. of Agric. Econ.*, v. 7, no. 1 (June 1963), pp. 35-41.

the distinction has not always been clear. Often regression models have been called "positive" while linear programming models have been called "normative". Few have demurred in this practice.[5] Sometimes regression is linked with the use of time series data in such a way as to suggest that the data themselves are characteristic of "positive" research. Contrarywise, cross-section data from farm-level surveys, used with linear programming models, sometimes is so characterized as to suggest that the data are especially relevant for "normative" research.

In this paper, I suggest an alternative division of the investigational field that is somewhat more simple and straightforward, in terms familiar to us, and that is perhaps more useful in its implications for relevant research activities. Distinctions made by reference to models or data are at best ambiguous and at worst misleading. The distinction useful in research lies in the orientation of the whole research process, with special emphasis on perception of the problem and formulation of it for research, not in the specific model used in the research. Indeed, either regression models or linear programming models, for example, can and have been used for exploring either "positive" or "normative" questions.

My conclusions are intended to relate to all branches of agricultural economics, though a considerable emphasis is given to research relating to the farm firm. Though much recent literature has centered on problems in estimating supply response, my examples will lie principally in growth properties of the farm firm, and appropriate methods for studying them. I shall argue that the principal research orientations available to agricultural economists can be characterized usefully as behavioral, on the one hand, and policy, on the other. Hence, at the outset it is worthwhile outlining the differences in concept that distinguish these alternatives.

Alternative Research Orientations

As a science, Economics can be given a behavioral orientation. So oriented, the economist's objective in research is *to explain* economically relevant phenomena: individuals or groups in production, consumption and/or exchange. I shall define as "micro", systems that exhibit economic phenomena distinguishable without exchange. In contrast, "macro" systems are defined as those in which exchange occurs within the system.[6] In such a continuum it may be argued that the analysis of a micro unit hardly qualifies as an exercise in *social* science. I deny this argument, suggesting that output from micro research is used in specifying macro models and the micro unit cannot be studied without specification of the macro system of which it is a part. We shall see later that such specifications comprise the central methodological feature of

[4] E.g., Schaller, W. N. Estimating Aggregate Product Supply Relations with Firm-Level Observations, in *Production Economics in Agricultural Research,* AE-4108, Department of Agricultural Economics, University of Illinois, 1966, pp. 97-112.

[5] A notable example of one who has is R. H. Day. See, e.g., his article: Dynamic Coupling, Optimizing and Regional Interdependence. *Jr. of Farm Econ.*, v. 46, no. 2 (May 1964), pp. 442-451.

[6] Professor Boulding even suggests that the field of economics centres on exchange. See Boulding K. E. The Verifiiability of Economic Images, in Krupp, S. R., ed., *The Structure of Economic Science.* Prentice-Hall Inc., Englewood Cliffs, 1966, pp. 129-144.

problem perception and problem formulation in research that is behaviorally oriented.

Economics also can be oriented toward policy objectives. The objective of policy research is *to prescribe* course(s) of action for a decision maker. The typical role of the economist in policy-oriented research is that of adviser and consultant. Hence the prescriptions are conditional: Course(s) of action are prescribed that conform to objective(s) of the decision maker and constraint(s) upon his choices, self-imposed or otherwise. To so characterize the setting of a policy-oriented research problem is not to ignore significant problems in identifying the objective(s) and constraint(s). Indeed substantial research that is behaviorally-oriented often is required before a policy-oriented research problem can be formulated for effective investigation.

"Positive" research is sometimes distinguished from "normative" research on grounds that the former is directed to prediction while the latter is not.[7] One may question this basis for distinction between positive and normative research, since each requires prediction for attainment of its objectives. In any event, I do not suggest prediction as a basis for differentiating behavioral from policy-oriented research. As will be developed below, properties of the predictions can differ somewhat as between the two orientations, but not the requirement that predictions be made.

Methodological Objectives of Research Activities

Activities entailed by the research process are outlined in Table 1. The methodological objectives of each of these broadly conceived research activities are identified in the body of the table. I distinguish between these objectives in accordance with differences in the alternative orientations. The final contribution sought from behavioral research is an improved theory of the system whose behavior is under investigation. The final contribution of policy research is a set of recommendations that would, upon implementation, improve the welfare position

TABLE 1

Methodological Objectives of Research Activities, by Type of Research Orientation

Research activities	Research orientation	
	Behavioral	Policy
Perception of problem	Identity of what is to be explained	Identity of decision maker and his "felt needs"
Formulation for research	Hypotheses on unexplained behavior	Elements of decision model
Characterization of solution	Criteria for test of hypotheses	Terms in which estimates are required
Acquisition of evidence	Data with test-relevant properties	Estimates relevant for recommendations
Use of evidence	Tests of hypotheses	Recommendations

[7] E.g., Schaller, *op. cit.*

of the decision maker whose alternatives are under investigation. Perhaps the distinction between the alternative orientations can best be clarified by examples.

A Behavioral Example

It commonly is observed that farmers appear to use less variable inputs than is implied by the condition that annual marginal cost of input equals annual marginal value product of input. The statement is true for annual inputs, such as fertilizer and operating expenses,[8] as well as for most durable capital items, with the possible exception of certain kinds of machinery. What accounts for the apparent discrepancy between equilibrium values and observed values of variable inputs? Is it a problem in observation? We cannot rule out this possibility with certainty. The means at hand for inferring the relevant marginal quantities are far from perfect. Is it a problem of using the wrong deductive model? Again, we cannot be dogmatic. The behavioral theories of the firm are persuasive in suggestions for non-equilibrating behavior in resource use within the firm, at least in the short run.

However, two hypotheses might account for this phenomenon, both well within the existing theories available in Economics. The first would explain the under use of variable inputs by aversion to risks (actually "uncertainties") associated with use of inputs that must be financed. Kalecki[9] has argued that as the percentage of inputs financed with loans increases relative to all firm inputs, the real cost associated with increased use of inputs increases at an increasing rate. The result is an equilibrium of input use at less than is implied by equating the rate of interest with the marginal value product of financed inputs. The argument is subject to considerable refinement, elaboration, and subdivision. The aversion can take the form of demand for liquidity, for flexibility, or for equity protection (Kalecki's argument). To test the hypothesis requires data related to the farmer's decision-making processes. The acquisition of such data is a most subtle observational problem. Analysis of the data also is demanding.

A second hypothesis suggests that the apparent non-equilibrium use of variable resources rests on the existence of "capital rationing". In this argument, the farmer would use more of variable inputs were it not for the fact that lenders restrict him, at fixed rates of interest, to quantities less than necessary to equate his marginal cost of input with his marginal value product of input. A condition necessary to the existence of "capital rationing" (actually, to be more precise, "loan rationing") is imperfection in the loan market. Otherwise, interest rates would increase for

[8] For example, see Swanson, E. R. *Productivity of Resources on Tenant- and Owner-Operated Farms*, AERR-10, Department of Agricultural Economics, University of Illinois, June 1955; and Baker, C. B., and Irwin, G. D. *Effects of Borrowing from Commercial Lenders on Farm Organization*, Illinois Agricultural Experimental Station Bulletin 671, 1961. Economists do not appear unanimous in concluding that variable inputs are used in quantities less than optimum. For example, see Breimyer, H. F. Why Do Farmers Overinvest? *J. of Farm Econ.*, v. 48, no. 2 (May 1966), pp. 475-477. Dr. Breimyer's observation relates to farmers in aggregate; mine, to farmers as individuals, based on MVP's inferred from budgets and estimated production functions.

[9] Kalecki, M. The Principle of Increasing Risk, in *Essays in the Theory of Economic Fluctuations*. Allen and Unwin Ltd., London, 1939, pp. 95-106.

a given borrower, perhaps as a function of loan quantities, such that marginal cost, including financing cost, would be equated with marginal value product of loan funds. Those who adhere to this hypothesis find ample evidence of such imperfections.

These two hypotheses are contrasted in Figure 1. Interest rate (on the vertical axis) is related to loan quantity (on the horizontal axis) in two functions: a market supply function for loans and a market demand function for loans. At their intersection, the quantity of loans demanded equals the quantity of loans supplied at the (equilibrium) market rate of interest. If the quantity of loans demanded, at a given rate of interest, exceeds the quantity supplied at that rate, one concludes that the effective restraint on resource use is *external* loan rationing. If the quantity of loans demanded is less than the quantity offered at a given rate, one concludes that the effective restraint is *internal* credit rationing—i.e. aversion to uncertainties associated with borrowing.

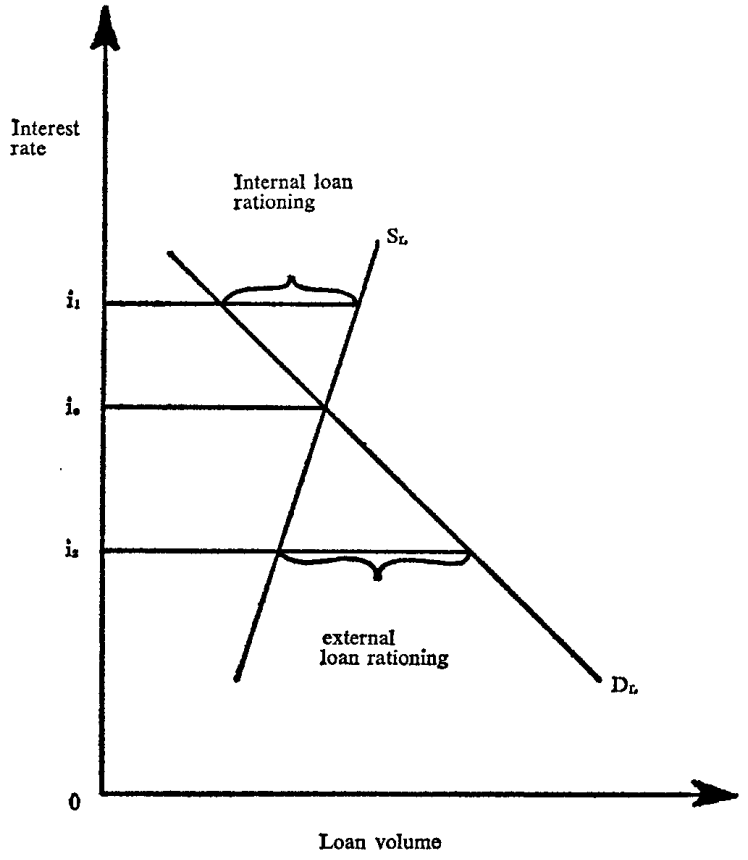

FIG. 1—Equilibrium in use of loan funds.

Actually, there may be strong arguments to suggest that neither hypothesis is as appealing as an alternative and that the relevant phenomena are far more complex. Research at the University of Illinois suggests that primary lenders in the U.S.A. (a) do not vary interest rates in response to loan quantity or quality, at least over substantial ranges of either,

and (b) do vary credit limits in quantities that accord with risks incurred by them but not necessarily by the borrower. But the farmer is conditioned to anticipate lender behavior, taking it into account in so far as he depends upon the primary lender to finance expansions in the use of resources or, more generally, upon credit as a source of liquidity.

For the lender, a loan risk is reduced when proceeds of the loan are used for self-liquidating purposes—i.e. for outlays generating receipts that pay the loan within the maturity period of the loan. The loan risk also is reduced when the proceeds are used to purchase tangible, reclaimable assets.[10] Thus fertilizer ranks high on grounds of self liquidity, but low on grounds of asset-generation; machinery or buildings, just the reverse. On the other hand, feeder cattle rank high in both respects for the lender, though not necessarily so for the borrower. It is not surprising, therefore, to find that feeder cattle are valued highly by lenders and fertilizer relatively low. As a matter of fact, a few bankers were found to actually lower the rate of interest in the specific case of feeder cattle loans, one of the few instances of loan quality being reflected in interest rates.

For the farmer dependent on credit to expand his operation, the implications are clear. Even though fertilizer may possess a higher marginal value product than cattle, he will be inclined to use his credit to finance cattle. If he absorbs all his credit to finance $2,000 worth of fertilizer with a marginal value product of $2, the farmer nets $2,000. But if he can borrow $8,000 for cattle that generate a marginal value product of $1.50, he can net $4,000 despite the lower marginal value product for cattle.[11]

Finally, the cost of borrowing is not completely reflected by the interest cost. There are strong reasons to suppose that the farmer regards unused credit as a more or less liquid reserve with which to protect himself against uncertainties and that the cost of using this reserve increases rapidly as it nears depletion.[12] Thus the reason for "less than optimum" use of variable inputs may well be explained by external loan rationing, but in terms of the farmer's expectation on the restraints imposed upon him by his primary lender(s). Clearly, there are limits to this explanation. Other sources are available to finance variable inputs.[13]

A recent example of behavioral research in farm-firm growth is provided by Gilchrist.[14] He develops a regression model in which total input

[10] Baker and Irwin, *op. cit.*

[11] For an elaboration of this logic, with use of a simple linear programming model, see Irwin, G. D., and Baker, C. B. *Effects of Lender Decisions on Farm Financial Planning*, Illinois Agricultural Experiment Station Bulletin 688, 1962.

[12] For an elaboration of this concept, see Baker, C. B.. Firm Growth, Liquidity Management and Production Choices, in *Production Economics in Agricultural Research*, AE-4108, University of Illinois, 1966, pp. 137-150. The third hypothesis might also suggest an explanation for another phenomenon for which no satisfactory explanation is available: why do firms differ in size by amounts that increase over time instead of decreasing, as implied by the law of comparative advantage?

[13] Rogers, L. F. *Effects of Merchant Credit on Farm Organization.* Unpublished Ph.D. thesis, University of Illinois, 1963.

[14] Gilchrist, V. Projecting Capital Accumulation for the Agricultural Firm-Household. *Candian J. of Agric. Econ.*, v. 14, no. 1 (1966), pp. 50-60.

capital (TC) of the firm in Year *i* is expressed as a function of net income (N), living expense (L) and size of consumption unit in years preceding *i*. Total input capital in Year 1 is the intercept constant. The size of the consumption unit is postulated to grow at a constant annual rate over the projection period. The model assumes all net income not consumed to be invested in the firm, there to yield income at the same rate as preceding capital and capital increments. Constancy also is assumed for N/TC, with respect to increase in TC; and for L/N, with respect to increase in N. He shows how the model can be expanded to take income tax factors into account, as well as such financial strategies as reserves for uncertainty and (to a limited extent) use of credit.

Finally, Gilchrist makes a brief comparison between his model and multiple period linear programming models.[15] He characterizes his own model as "positive" and the multiple period linear programming models as "normative". He compares the alternative approaches in terms of predictive accuracy. There may be some question about the "positive" character of his model as it is opened to take into account the financial strategies he suggests in its applications. The appropriate criterion for his behaviorally-applied model would seem to be the level of explanation attained for growth in TC. For the multiple period linear programming model, the appropriate criterion would seem to be the usefulness of recommendations implied for the decision maker whose choices are modelled in the linear programming characterizations. To *test* a normatively-used model requires answering counter-factual questions following a period of time sufficient to mature effects of a decision based on recommendations.

A Policy-Oriented Example

A policy problem may arise directly from perception that the norm of a decision maker is subscribed to at less than the optimum permitted by the alternatives available to him and constraints on his choice among the alternatives. The problem may find expression on the part of the decision maker himself, in the form of a "felt need". To make the problem operational in terms of research, however, requires the specification of a decision model and therewith, demonstration that a suboptimum choice among alternatives currently exists. Clearly the economist must have an unambiguous description of the decision maker, in terms of a model adapted to needs of the problem.

A decision problem often is subsumed in a "What will be" question. That is, the researcher is given the problem of predicting a future value of a variable representing a phenomenon of relevance to a decision maker.[16] The decision maker cannot be expected always to be explicit

[15] Models cited by Gilchrist are Loftsgaard, L. D., and Heady, E. O. Application of Dynamic Programming Models for Optimum Farm and Home Plans. *J. of Farm Econ.*, v. 41, no. 1 (February 1959), pp. 51-62; and Dean G. W., and Benedictus, M. Di. A Model of Economic Development for Peasant Farms in Southern Italy. *J. of Farm Econ.*, v. 46, no. 2 (May 1964), pp. 295-312.

[16] Many prediction problems, as well as decision problems generally, subsume problems of explanation. Thus it is clear that a model that satisfactorily explains the past behaviour of a variable relevant for the decision maker would likely be useful in predicting future behaviour of the variable. The common objective of a prediction may well be responsible for lack of clarity in distinctions that otherwise seem straightforward between behaviorally-oriented research and policy-oriented research.

on terms in which the prediction is required or articulate in expressing his needs to the economist. Hence, the perceptive investigator will proceed, more or less formally, to the specification of what appears to be the relevant decision model, checking it against observed behavior of the decision maker and using it to imply the data requirements for his research.

A problem urgent for many farmers is choice among financing strategies in organizing, operating and expanding the farm firm. It is a problem peculiarly difficult for the economist to make operational for research. Models of production organization commonly are solved to imply an allocation of resources that equate returns at the margin among (a) labor and (b) physical forms of capital. In such models an investment in a building is compared with the purchase of feeder cattle in terms of marginal value product and annual input costs. However useful they may be in static models of production organization, such terms of comparison are not adequate in problems of firm growth for two reasons: (a) they ignore the value of liquidity in countering the effects of uncertain expectations; and (b) they ignore the differential effects of alternate physical forms of capital upon "credit" and, hence, upon financing strategies available to the decision-maker.

For a large class of events uncertain for the individual, insurance provides a cost-minimizing method of attaining liquidity. The liquidity thus produced has limited utility. It exists only in the form of a contingency reserve. *If* the event occurs, *then* the reserve can be drawn upon subject to the terms that indemnify insurable interests in described attributes of the insured, property or otherwise. It is clear from outlays on insurance that these reserves provide a payoff that is far from negligible. It is worthwhile to note, however, that insurance reserves are limited in terms of availability to the insured and in terms of class events for which it is possible to insure. Hence, other forms of reserves, less limited in access and more general in their payoff utility, are desirable and vital to a firm's growth.

Assets provide potential liquidity through sale. Clearly, some assets provide more liquidity than others, in this sense, as a percentage of their balance sheet value. Also, assets provide liquidity through credit they generate for the farmer. Results from behaviorally-oriented research that suggest variation among assets in this attribute have already been noted. I define credit as a resource available to the decision maker. It can be exchanged for a loan through sale of a security. Or it can be held in reserve. A credit reserve, like the contingency reserve provided by insurance, does not appear in a balance sheet. Its size and structure depend on evaluations made by lenders available to the decision maker. The evaluation has been found to vary by asset structure and location of farm,[17] by type of lender,[18] and by sequence of borrowing activities and debt obligations.[19] It is plausible to assume that an individual's credit depends on many other factors as well—personal characteristics,

[17] Baker and Irwin, *op. cit.*

[18] Rogers, *op. cit.*

[19] Neuman, D. F. *Effects of Non-Real Estate Loan Policy of Primary Lenders on the Organization of Farms in East-Central Illinois.* Unpublished Ph.D. thesis, University of Illinois, 1962.

level and structure of income, etc. I will confine discussion, however, to asset and debt structure.

I have outlined elsewhere[20] the effects of credit use on production choices in a firm dependent on external funds. In use of variable resources, optimizing conditions include finance costs and liquidity costs as well as input prices. Both finance and liquidity costs increase marginal cost of input and hence reduce the optimal use level of the credit-financed input. Indeed, there are strong reasons to expect that liquidity costs are an accelerating function of credit-financed inputs.

By X_1 and X_2 I identify two variable inputs financed to produce a given output of product Y. The inputs are combined optimally when the marginal rate at which X_2 substitutes for X_1 equals the ratio of price of X_1 to price of X_2. However, the optimum combination may shift when credit effects are taken into account. Evidence already cited supports the hypothesis that credit is absorbed at rates that vary by type of loan: low for loans that are self-liquidating and whose proceeds are used for chattel assets; high for non-self-liquidating and non-asset-generating loans; medium otherwise. Since credit is absorbed at rates that differ among inputs, liquidity also is affected differently by type of input. It follows, therefore, that if credit has a non-zero value in reserve, the optimum combination of inputs is effected by credit use that shifts the combination of X_1 and X_2 to favour use of those inputs whose financing involves least loss of liquidity.

A similar analysis can be made of resource allocation among enterprises in a farm firm where choices are constrained by credit limits. In the absence of such constraints, it can be shown that products Y_1 and Y_2 are produced in a combination that maximizes returns above variable costs when their marginal rate of substitution,

$$(1) \qquad MRS_{Y_2 \text{ for } Y_1} = (P_2 - C_2)/(P_1 - C_1),$$

where P_1 and P_2 are prices of Y_1 and Y_2 respectively, and C_1 and C_2 are marginal costs, with respect to output, of inputs specific to the production of Y_1 and Y_2, respectively.

Evidence already cited, however, suggests that agricultural lenders are not indifferent among farm enterprises in fixing loan limits. Predictably, they tend, *ceteris paribus*, to favour those enterprises that exhibit relatively high rates of capital turnover and in which a relatively high proportion of inputs are chattel assets. For example, a cattle-feeding enterprise is favoured over dairying and over cash crop production. That is, loans to finance cattle absorb least credit per dollar borrowed. Thus if credit has a positive value in reserve, it must be taken into account

$$(2) \qquad MRS_{Y_2 \text{ for } Y_1} = (P_2 - C_2 \pm L_2)/(P_1 - C_1 \pm L_2), \qquad ..$$

where L_1 and L_2 are liquidity values from credit generated by output from Y_1 and Y_2, respectively.

Thus, to study the full range of choices in production, marketing, and financial organization requires a model capable of accounting for costs of liquidity loss and gains from increased liquidity. What is needed is

[20] Baker, C. B. Limited Capital as a Restraint on Agricultural Development, in *Economic Deveopment of Agriculture*, Iowa State University Press, 1965, pp. 118-131.

a model that (a) incorporates the necessary production, consumption, marketing, and financing relations, (b) is adaptable to variation in input, and (c) generates measurable output in terms relevant to the decision maker's questions on growth and liquidity alternatives. Several general alternatives are available: simulation,[21] dynamic programming,[22] recursive linear programming,[23] and multiple period linear programming.[24]

Substantial arguments can be made and have been presented to favour any of these generalized models. Simulation models can incorporate a rich variety of relationships and inputs and generate a proliferation of outcome measures, a valuable property in problems in growth. They are particularly adapted to policy-oriented research, where detail often is essential for prescriptive relevance, and empirical generalization is perhaps of lesser importance. With modern computers to reduce costs of obtaining solutions, and an investigator who is resourceful and patient, simulation models may yet prove useful in research designed to investigate alternative strategies in bringing about growth of the farm firm.

Where optimizing is important, dynamic programming is a more relevant choice. For the problem at hand, the leading methodological problem is to construct a model that will generate output in terms of all variables obviously relevant in growth of an organization as complex as that of a firm. The problem is empirically different from that of optimizing replacement of a tractor or a dairy cow. The problems that can be handled are necessarily small in terms of decision variables. They also are demanding in terms of problem formulation, if decision-relevance is retained.

In recursive linear programming models the optimization of organization in period $t + 1$ is made to depend upon outcomes from the organization (optimum) in period t. But the optimum organization in t is independent of the organization in $t + 1$. Moreover, it is easy to bound the allowable change, in selected variables, between t and $t + 1$. This property has been cited as being especially useful in "positively" oriented research.[25] Indeed, this would seem to be the case, though the more important the "adjustment coefficients" become in recursive models, the more behavior there is in the system that remains unexplained, however useful such models may be made in terms of prediction.

Despite persuasive arguments that can be made for the alternatives, I propose use of a linear programming model with periods that are mutually dependent, instead of one-way dependent, as is the case with

[21] Halter, A. N., and Dean, G. W. Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to a Large-Scale Ranch. *Jr. of Farm Econ.*, v. 47, no. 3 (August 1965), pp. 557-573.

[22] Burt, O. Operations Research Techniques in Farm Management: Potential Contribution. *Jr. of Farm Econ.*, v. 47, no. 5 (December 1965), pp. 1418-1426.

[23] Day, R. H. *Recursive Programming and Production Response.* North Holland Publishing Co., Amsterdam, The Netherlands, 1963.

[24] Loftsgaard and Heady, *op. cit.* More recent examples are provided by Cowling, K. G., and Baker, C. B. A Polyperiod Model for Estimating the Supply of Milk. *Agric. Econ. Research*, v. 15, no. 1 (1963), pp. 1-14; and Dean and Di Benedictus, *op. cit.*

[25] Day, R. H. On Aggregating Linear Programming Models of Production. *Jr. of Farm Econ.*, v. 45, no. 4 (November 1963), pp. 797-813.

the recursive models. Justification is that the logic of mutual dependency better accords with the needs of policy-oriented objectives. Moreover, it is useful to construct a model richer in its output structure than can be pragmatically accommodated in a dynamic programming model, but perhaps retaining some of the rigour from optimizing conditions that would be lost in a simulation model.

A Proposed Model[26]

An outline for N periods is provided in Table 2. Processes activated in Period 1 depend on outcomes expected from processes active in Period 2, ... N, and vice versa. The variable, Z, is perhaps best conceived as a "value of plan". It is comprised essentially of cash contributions in each of the periods, less the cost in each period to produce and borrow, less the interest cost from the debt as it is repaid or transferred between periods, as allowed by debt contracts, plus the value of unused assets at the end of Period N, and less the value of unpaid debts at the end of Period N. Final values[27] of assets and debts are discounted at $1/(1+i)^n$. Their values at intermediate points in time are reflected in cash flows through time. Cash is divided between "Use Cash", available for use within periods, and "Cash", a row used in accounting for cash transactions that occur on the last day of the period indicated, including transfers to the next period.

Constraints

The entire choice set is constrained by an initial supply of (a) capital in selected (durable) categories, (b) labor, (c) cash and (d) credit. In keeping with the purpose of the model, all but labor are stated in terms of dollars' worth of services available in the specified period. Additions through purchase, less subtractions through sale and use, modify the initial stock as it is transferred to Period 2. Labor is newly specified in each period. So is credit. However, credit is modified by incoming stocks of capital resources, inventories of crops and livestock, and cash, as well as by producing, marketing and financing processes activated in preceding periods. The firm starts with a loan balance of zero. Debt obligations actually contracted are allowed to be transferred between periods, subject to terms of the debt contracts. Inventories of crops and livestock are generated by production processes and can be sold in Period t or transferred, at specified storage costs, to Period $t+1$.

Finally, a minimum level of income is specified for household use in each period. In the model outlined in Table 2, this level is determined exogenously in each period. After the minimum has been reached, the cash surplus of the period, if any, is transferred to the following period. A modification might be advisable. The minimum income requirement in Period $t+1$ can be modified by level of income earned in Period t by introducing a fractional coefficient in the transfer column in Period t

[26] Material in this section is drawn largely from Baker, 1966, *op. cit.*, though some modifications have been introduced.

[27] K. D. Cocks has demonstrated that to maximize the investment pay-off at the end of the planning period is equivalent to maximizing the sum of annual pay-offs when the end-of-period pay-off consists in the surplus accumulated through the years of the planning period. See his Capital Accumulation and Hicksian Models. *Farm Econ.*, v. 10, no. 11 (1965), pp. 458-465.

TABLE 2

An N-period Growth Model of the Farm Firm

		Period 1					Transfer		Transfer to Period 2			
	Z =	− c							−c(1+i)			
Row No.	P_j:	Produce	Buy	Sell	Borrow	Repay	Cash	Income	Capital	Loan Bal.	Inventory	Cash
1.1	Capital	a	−a	a					a			
1.2	Labor	a	−a									
1.3	Use Cash	a	a	−a	−1	(1+i)	1					
1.4	Cash						−1	1				1
1.5	Credit	a	−a	a	a	−a						
1.6	Loan Bal.				−1	1				1		
1.7	Crops	−a		a							a	
1.8	Livestock	−a		a							a	
1.9	Income							1				
2.1	Capital								−a			
2.2	Labor											
2.3	Use Cash											−1
2.4	Cash											
2.5	Credit	a	−a	a	a	−a			−a	a	−a	−a
2.6	Loan Bal.									−(1+i)		
2.7	Crops										−a	
2.8	Livestock										−a	
2.9	Income											
..	....											
N.1	Capital											
N.2	Labor											
N.3	Use Cash											
N.4	Cash											
N.5	Credit	a	−a	a	a	−a						
N.6	Loan Bal.											
N.7	Crops											
N.8	Livestock											
N.9	Income											

TABLE 2 (concluded)

		Period N					Transfer		Transfer to Z						
	Z =	— c							$a(1+i)^{-n}$	$a(1+i)^{-n}$	$a(1+i)^{-n}$	$(1+i)^{-n}$	$a(1+i)^{-n}$	= maximum	
Row No.	P_j:	Produce	Buy	Sell	Borrow	Repay	Cash	Income	Capital	Loan Bal.	Inventory	Cash	Credit	Restrictn.	
1.1	Capital													≤	b
1.2	Labor													≤	b
1.3	Use Cash													≤	b
1.4	Cash													=	0
1.5	Credit													≤	b
1.6	Loan Bal.													=	0
1.7	Crops													=	0
1.8	Livestock													=	0
1.9	Income													=	b
2.1	Capital													≤	0
2.2	Labor													≤	b
2.3	Use Cash													≤	0
2.4	Cash													=	0
2.5	Credit													≤	b
2.6	Loan Bal.													=	0
2.7	Crops													=	0
2.8	Livestock													=	0
2.9	Income													=	b
..	....													.	...
N.1	Capital	a	—a	a					a					≤	0
N.2	Labor	a	—a											≤	c
N.3	Use Cash	a	a	—a	—1	(1+i)	1							≤	0
N.4	Cash						—1	1				1		=	0
N.5	Credit		—a	a	a	—a							a	≤	b
N.6	Loan Bal.				—1	1				a				=	0
N.7	Crops	—a									a			=	0
N.8	Livestock	—a									a			=	0
N.9	Income							1						=	b

and in the row "Income", in Period $t + 1$. The coefficient would accord with the decision maker's marginal propensity to consume.

Any or all of the row quantities could be distributed seasonally within each year. Also, differentiations are necessary to sort the resources into quality classes. For example, "Capital" would divide into such categories as land, buildings, machinery and livestock, since these are categories in which it would be relevant to reflect growth of the firm. Labor could be sorted into skill or other groupings to reflect changes over time. Both credit and loan balance would need to be differentiated to reflect institutional variations and contractual differences among borrowing alternatives open to the farmer.

Crop and livestock inventories could remain aggregates, structured by given proportions in production. Alternatively, they could be differentiated if one desires to enrich the model with more explicit choices in production and/or marketing. I suggest caution, however, in making such modifications. In problems of growth, detail in finance may be more important than detail in production and marketing choices. For widely differing alternatives in production and marketing, it might be preferable to specify alternative models, thus providing a basis for choice by comparing their solutions in the presence of growth-relevant financial alternatives.

Processes

The model generates a solution that describes a firm in joint equilibrium with respect to time as well as production, marketing and finance. To activate production processes requires use of a complement of resource services from capital assets in proportions taken as given. The production organization of the farm is treated broadly, leaving model space available to explore financial alternatives. But it is necessary to leave at least limited production alternatives open and to allow for growth by alternatives in assets as well as in finance.

Capital and labor resources are added in "buy" vectors, wherein cash is used and credit generated, as well. Cash is obtained from sale of capital resources or from crop and livestock inventories. Labor sales also could be introduced. As assets are sold, credit is reduced at rates reflected in rows that describe relevant credit quantities. Use Cash can be obtained in exchange for credit (borrowing) as well as from sales. Borrowing reduces credit and generates a loan balance that must be serviced. An interest rate, i, is added to the dollar specified in "Repay", or alternatively, to the dollar of loan balance transferred to the next period. Repayment is provided as an alternative that must be used, if the loan contract so specifies, or that may be used as an alternative to transfer of unpaid debt to the next period (or season, if seasonal distributions are specified).

Finally, cash is transferred to income in each period to satisfy the minimum income specification. Any surplus of cash is transferred to Use Cash of the succeeding period. The coefficient in the income row is positive, indicating that it reduces the requirement imposed in the amount of b in the right hand side element of this row. Periods between 1 and N simply repeat the alternatives shown for Period 1, unless there is reason to introduce variations in alternatives.

In the interperiod processes, I already have indicated the purpose of

vectors that transfer loan balances unpaid at the end of the previous period. Capital resources also are transferred between periods. Relative sizes of a_{ij} will account for depreciation that occurs from use rates of capital resources in the period in which the transfer occurs. Too, I already have indicated the alternative of transferring inventories of crops and livestock between periods. Whether it is profitable to do so depends on the demand for cash in the originating period compared with the following period, the cost of storage, and the value of credit generated in the following period, the last factor also being influenced by alternative means of generating credit.

Finally, a special set of vectors is necessary to allow for the termination of any model of finite term, if the "value of plan" is to take account of asset and debt accumulations generated by the model. The first set of vectors reflects value remaining at the end of Period N of the categories of capital resources. Since the plan is to be evaluated at t_0, the asset values are shown in Z at a discount. The same logic applies to any debt that remains unpaid, and hence, represents a claim against the value of the plan at the end of Period N. The discount rate can vary among the various asset and debt categories if there is reason to introduce a variation relevant for the decision maker.

Any crop or livestock inventories that remain unsold likewise contribute to the value of the plan. As the model now is specified, the value of crops and livestock could as well be liquidated, the proceeds combined with Period N transfers to Z. However, there may be reason to leave a separate vector, introducing parameter variations to study effects of possible variations in the value of inventories if transferred to the period beyond the end of the model.

A final vector, "Credit", is introduced with a similar possible use. When the model is terminated at N, it may be argued that any further credit that might transfer, in association with the transfer of credit-generating resources, is of no relevance. This is so with respect to any allocation problems and financing problems within the model period. However, the logic used earlier to suggest the value of a reserve in the form of credit appears to apply equally here. Hence, the credit vector is included. Again parameter variation could be used to determine the sensitivity of solution elements to varied assumptions on the value of credit. Should the model generate a final position that is essentially debt-free, it might be argued that increments to credit would be relatively low in value. This might be useful information for the decision maker.

Research Applications

To apply the proposed model in behavioral research requires identification of circumstances in which processes and constraints specified in a quantitative version of the model accord with those of real-world farm firms. Then one imposes a set of expectations on outcome alternatives, solving the model for an optimum in accordance with the quantity postulated to be maximized or minimized. Solution elements (e.g. activity levels of processes in the optimum solution) are then compared with decisions made by farmers assumed to be characterized in the model. The better the match, the better the explanation provided by the model of farmer behavior.

It is clear that in a model as complex as the one proposed, the

problems of specifying a population of farmers homogeneous in constraint and process *identity*, to say nothing of level, is substantial. It is considerably reduced, however, by centering the specification of alternatives on financial choices, and measuring most relevant quantities in monetary terms.

Common applications of linear programming models do not generate error estimates for quantities in solution output. This elementary feature of linear programming solutions creates considerable problems in that data with test-relevant properties are not provided by the analysis. The problem can be reduced, if not resolved, by examining results from solutions obtained from parameter variations in the linear programming model[28] and by recourse to "ersatz" error estimates drawn directly from sampled populations.[29] While the latter may be less than completely satisfactory, they may be preferable to the alternative assumption that elements in the solution of linear programming models are error-free.

Policy applications of the proposed model are much more straightforward. Indeed, most relevant comments already have been made. In at least a loose sense, we can conceive of a "decision space" with dimensions in terms of time (lengths of run), phenomenal extent (range of decisions) and phenomenal intensity (details per decision). These dimensions are suggested to indicate the need to specify, in a given decision model, the limits that bound the problem to be investigated. Without such a specification, the problem is boundless. The relevant point is that bounds exist in any soluble problem, but are implicit without specific indication.

I have suggested favoring detail in financial specification in contrast with that in production and marketing. Clearly this is a question that must be answered with reference to a particular decision maker—or a particular set of decision makers. The same is true of time in the problem specification. For given size of model, the larger the number of time periods the less detail can be provided within each time period. Either of these problems, as well as that of phenomenal intensity vs. extensity, can be modified by skill of the investigator in the specification of the model. The principal point here is that in a policy orientation, the objective is to include elements in such way that solutions reveal the basis for recommendations in terms useful for the decision maker.

A word might be added with respect to the Gilchrist model, in so far as its features are described in the brief journal article cited above. Centered on regression methods, a procedure is provided for obtaining relevant error estimates. Thus behavioral applications are facilitated, at least superficially. However, to apply the model in policy research introduces severe problems, several of which Gilchrist notes himself. Choices in production allocations are ignored in the model. So long as it retains its "positive" characteristics, it would seem that the same is true for financial strategies he suggests for investigation with the model.

[28] Some basis for judgement as well as procedural suggestions are provided in Hartley, H. O., Total Supply Functions Estimated from Farm Surveys, paper presented at NCR-4 Conference on *Problems in Estimating and Aggregating Regional Supply Response Estimates*, Chicago, March 1962.

[29] For an example of this procedure, see Fruin, J. E., Baker, C. B., and West, V. I. Consequences of Acreage Adjustment on Cornbelt Farms. *Jr. of Farm Econ.*, v. 42, no. 4 (November 1960), pp. 905-909.

Indeed, the model he proposes is necessarily limited to alternatives that have been available and to past choices made in the population of farmers sampled for parameter estimates. No model, regression, linear programming or other, provides the magic by which test-relevant data are generated for hypotheses on events that have not yet occurred.