Economics of Firm Growth: GP-2 Seminar

W. R. Bailey
J. R. Martin
O. Walker
B. Johnson

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Economics of Firm Growth

GP-2 Seminar June 14-16, 1965
Sylvan Lake, South Dakota

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AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE UNIVERSITY
BROOKINGS, SOUTH DAKOTA
GP-2 SEMINAR ON ECONOMICS OF FIRM GROWTH
June 14-16, 1965
Sylvan Lake, South Dakota

Attendance

Orlan Buller  Kansas State University
Larry J. Connor  Michigan State University
(formerly ERS, Oklahoma)
Roy E. Hatch  ERS, Texas A and M University
Rex D. Helfinstine  South Dakota State University
Clarence W. Jensen  Montana State University
Stan Johnson  University of Missouri
(formerly University of Connecticut)
H. H. Kramer  Director, Nebraska Agricultural Experiment Station
(formerly Director, Purdue University Agricultural Experiment Station)
Ken R. Krause  South Dakota State University
W. F. Lagrone  ERS, University of Nebraska
L. D. Loftsgard  North Dakota State University
J. R. Martin  ERS, College Station, Texas
R. A. Pearse  University of Missouri (Visiting Fellow)
Ulf Renborg  Agricultural College of Sweden, Uppsala, Sweden
Melvin D. Skold  Kansas State University
(formerly Colorado State University)
K. R. Tefertiller  University of Florida
(formerly Texas A and M University)
Odell L. Walker  Oklahoma State University
Robert Eddleman  University of Florida
(formerly Texas A&M University)
PREFACE

Published here are the three major papers presented at a seminar on economics of firm growth. The seminar, sponsored by the Great Plains Technical Research Committee No. 2, became international with the attendance of Prof. Ulf Renborg from the Agricultural College of Sweden, Uppsala. Prof. Renborg, who has important accomplishments in the subject of firm growth, was able to accept the Committee's invitation. He contributed a major paper and led the post-seminar critique.

Purpose of the seminar was to explore. After 5 years of fruitful research, the regional project had been recently revised around the dynamic concept of firm growth. Committee members would soon be developing their contributing projects. We needed to give structure to the problem of firm growth and to explore the more urgent and more promising questions for research.

The idea for the seminar had originated earlier when a subcommittee first met to consider revision of the regional project. That meeting itself resembled a seminar except for the absence of prepared papers. We did have extensive notes, which I planned to use in a report summarizing the research findings of the regional project. The findings had indicated that in the Plains those product enterprises having the greatest year-to-year variability also returned by far the most income. Furthermore, any schemes to reduce variability would likewise reduce net farm income. Instead of seeking strategies to reduce variability, it seemed better for the firm to "live with" a considerable degree of variability, but adopt strategies to dampen the adverse effect of low yield years, and adopt other strategies to exploit the opportune
Incomes from the "bumper crop." Instead of spending the unexpected income on consumption goods, or using it to acquire more rapid equity in present resources, the firm could use it to engage additional productive resources, and achieve firm growth. Another alternative of course would be investment in nonfarm activities.

Firm growth has at least three aspects of interest to the researcher. First, growth can be a goal in itself especially for the small or newly established firm, but also for other firms. Thus, the researcher is interested in developing managerial strategies a firm could use to achieve business growth. Secondly, firm growth can be a managerial strategy to combat risk and uncertainty. As the farm grows larger it may become less vulnerable to such hazards. Thirdly, and partly because of the first two aspects, the dynamics of growing firms is a more realistic setting in which to study resource allocation, production response, and other management problems. For example our committee might find in a theory of firm growth an explanation of why Great Plains farmers generally have expanded their specialized grain enterprises instead of adopting livestock feeding enterprises, as farmers had done in the Corn Belt. Many agriculturalists had expected farm feeding of livestock to emerge as the Plains' economy matured.

Our revised regional project GP-2 encompasses all three aspects of firm growth. The general objective is to learn how farm businesses can become established, survive and grow in the Great Plains environment. This objective breaks down into four parts: (1) the ways in which beginning farmers can establish a business, (2) the long-run organizational strategies for economic growth, (3) the operational,
or year-to-year tactics to achieve economic survival in periods of stress, and (4) an evaluation of alternative combinations of organization strategies and operational tactics with respect to firm growth and survival.

Professor Kenneth Tefertiller (then Texas) arranged for the seminar topics, the papers and the discussion. It was decided not to have formal discussants in view of the small number of seminar participants. At the conclusion of the seminar the committee voted to have the major papers reproduced and bound for limited distribution with no attempt to summarize the very extensive informal discussion.

Warren R. Bailey
Chairman (1965)
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
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<tr>
<td>Operational Gaming and Simulation as Research and Educational Tools in the Great Plains - Odell Walker, Oklahoma State University</td>
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<td>Swedish Experiments in Planning for Economic Growth of Agricultural Firms - Ulf Renborg, Bertil Johnson and Earling Skoglosa, Agricultural College of Sweden</td>
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<tr>
<td>What's Ahead in GP-2 - Warren R. Bailey, USDA (ERS)</td>
<td>143</td>
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</table>
CONCEPTUAL ASPECTS AND PROBLEMS IN FORMULATING FIRM GROWTH RESEARCH

By

J. Rod Martin

There are many problems associated with firm growth research and few specific research approaches to those problems. Real progress in formulating growth problems and in advancing knowledge of firm growth will be forthcoming only after a great deal of time and effort has been spent in working to solve these problems. However, growth research must be undertaken now, for many important adjustment problems in agriculture can undoubtedly be effectively attacked through firm growth research.

Dynamic Nature of the Problem

The traditional static theory of the firm has been very useful in dealing with many microeconomic problems. The very nature of growth and capital accumulation problems, however, renders static theory somewhat unrealistic. A brief review of literature reveals similar but at the same time somewhat different concepts of economic dynamics.

Samuelson's concept of dynamics is best summarized in his own words:

1In part, this paper reports some of the preliminary findings of research being conducted at Oklahoma State University. Dr. James S. Plaxico, Oklahoma State University, should be recognized for his guidance and direction of this study. The opinions expressed in this paper are those of the author and do not necessarily represent those of the Economic Research Service or the United States Department of Agriculture. Helpful suggestions and relevant discussion points by my colleagues Kenneth R. Tefertiller, Texas A&M University, and Stanley R. Johnson, University of Missouri, are acknowledged.

2Agricultural Economist, Farm Production Economics Division, Economic Research Service, U. S. Department of Agriculture, stationed at Texas A&M University, College Station, Texas.
Statics concerns itself with the simultaneous and instantaneous or timeless determination of economic variables by mutually interdependent relations.... It is the essence of dynamics that economic variables at different points of time are functionally related;.... It is important to note that each such dynamic system generates its own behavior over time,... This feature of self-generating development over time is the crux of every dynamic process.³

Most economists are familiar with Hick's dynamic model:

Outputs of different dates are to be regarded as different outputs; inputs of different dates are to be regarded as different inputs; and beyond that there is only one little difference.⁴

The "one little difference" to which Hicks refers is the concept of discounted future costs and receipts. This concept produces a dynamic model where the same commodity in different periods is treated as different commodities.

Baumol classifies the Hicks approach as statics involving time rather than dynamics. He explains that in the model phenomena are not considered in their relation to preceding and succeeding events; and if the process of change does not concern us, we can consider the situation at a given moment. The moment may be dated, but the analysis of it can be static. Baumol's concept of economic dynamics emphasizes the structural aspects of dynamics: "Economic dynamics is the study of economic phenomena in relation to preceding and succeeding event."⁵

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Harrod also emphasizes the changing structural relationship in economic dynamics. He points out that in economic statics certain fundamental conditions are taken as given, and these known conditions determine the values of certain unknowns. In dynamics, however, the fundamental conditions will themselves be changing, and the unknown in the equations to be solved will not be specific magnitudes per time period but increases or decreases in the magnitudes per time period.⁶

While economists may detect distinct differences among eminent economists with respect to concepts of economic dynamics, the layman would be struck with the high degree of similarities. The general agreement and, perhaps, a precise definition is given by the statement, "...how the various variables move through time..."⁷

Baumol discusses the six classifications of dynamic systems as proposed by Samuelson.⁸ These classifications are relevant because they tend to delineate the types of problems on which we do research. The classifications are summarized as follows:

1. Static and stationary. This refers to an economy where no change is taking place. (The method of analysis is such that the passage of time is not considered.)
2. Static and historical. This refers to a case where changes are taking place but only as a result of noneconomic causes. (Changes in output may occur as a result of bad weather.)
3. Dynamical and causal. This is a type of system where, given the initial facts, there is sufficient information to predict what will happen in the future. (The structure of the system is given and determines the conditions at a later time period.)

4. Dynamical and historical. This includes a system where the course of economic events is only partially influenced by noneconomic factors. (This might be a system where the business cycle occurs as a result of both changes in investment and variations in the weather.)

5. Stochastic and nonhistorical. This is a system where changes occur as a result of economic random or chance happenings where probability theory may be used in an analysis.

6. Stochastic and historical. This is a system where changes occur as a result of noneconomic random happenings.

Although all research problems cannot be placed in specific categories, an attempt should be made to place them within the proper framework of analysis; otherwise, the complexity will be overwhelming. Samuelson recognizes a definite limitation to economic dynamics in general. He points out that it is so flexible a method that there are dangers involved in its use. The number of conceivable models is literally infinite, and a lifetime may be spent in exploring possibilities.\(^9\) "The overwhelmingly complex economic life of our society cannot be analyzed in one fell-swoop -- where shall we begin?"\(^10\) An answer to this question is given by Saaty. He discusses the problem of restricting an analysis to fewer variables than can actually be found in the real world; he defends this "suboptimization" as follows:

Suboptimization is a case of optimization for one phase of an operation, without taking into consideration every factor which has a bearing on the problem....For example, in optimizing performance in a given naval operation, one does not have to consider the entire set of objectives of the Navy....Although a true optimum is not obtained, it at least provides a rational technique for approaching the optimum. This procedure is necessary because of economic

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\(^9\)Ibid, p. 373.

and practical consideration, and the difficulty which one encounters....In most practical cases suboptimization is the only resort to solving a problem.\textsuperscript{11}

The Capital Accumulation Process

A precise and complete definition of the growth and capital accumulation process is the moot question for GP-2 research. Much research will be needed to answer this question in its entirety. Some insight into the growth and capital accumulation process may be gained by looking at what actually occurs with respect to a given firm.

As an example, assume that some productive firm has only one productive activity that may be utilized to generate capital. This activity (Table 1) has total capital requirements of $21.00, including an investment requirement of $11.00 (in land, machinery, or what have you) which must be made before the activity can be utilized or activated. Operating capital requirements are $10.00 each production period. Gross sales are $30.00 and net returns $20.00. In the example, operating capital is equal to costs in order to simplify the presentation. The net returns of the activity are returns to all resources used in production. The model (without any reference to objectives or a criterion function) is illustrated in Table 2.

The level of owned capital at the beginning of the first production period is $20.00. The investment required is in some scarce resource, and as a result of some limitation only one unit of the investment can be purchased during the first production period. It is necessary to treat capital investment as a separate activity because one unit of investment capital

Table I. Requirements and Returns for One Unit of the Productive Activity Used to Describe Capital Accumulation

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
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</thead>
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<tr>
<td>Type of capital requirement:</td>
<td></td>
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<tr>
<td>Capital investment 1/</td>
<td>11.00</td>
</tr>
<tr>
<td>Operating capital</td>
<td>10.00</td>
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<tr>
<td>Total capital required</td>
<td>21.00</td>
</tr>
<tr>
<td>Gross sales</td>
<td>30.00</td>
</tr>
<tr>
<td>Net returns 2/</td>
<td>20.00</td>
</tr>
</tbody>
</table>

1/ A requirement such as land, buildings, etc., necessary in order to produce through the productive activity.

2/ Net returns to all owned resources equal to gross sales minus operating capital (assumes only owned capital is used).
Table 2. Illustration of the Capital Accumulation Process Through Several Production Periods, Utilizing the Productive Activity Described in Table 1, $20.00 of Owned Starting Capital and $1.00 Borrowed Capital

<table>
<thead>
<tr>
<th>Production period</th>
<th>Unused capital</th>
<th>Borrowed capital</th>
<th>Net returns</th>
<th>Capital invested</th>
<th>Net capital generated</th>
<th>Reinvestment capital</th>
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<tr>
<td>t₁</td>
<td>0</td>
<td>+20.00</td>
<td>0</td>
<td>+1.00</td>
<td>-11.00</td>
<td>-10.00</td>
</tr>
<tr>
<td>t₂</td>
<td>18.94</td>
<td>0</td>
<td>0</td>
<td>-1.06</td>
<td>+30.00</td>
<td>-10.00</td>
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<tr>
<td>t₃</td>
<td>38.94</td>
<td>+18.94</td>
<td>0</td>
<td>+30.00</td>
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<td>t₄</td>
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<td>t₆</td>
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<td>+77.94</td>
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<td>+60.00</td>
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<table>
<thead>
<tr>
<th>Time</th>
<th>Capital requirements and returns of the activities by production periods</th>
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<tr>
<td></td>
<td>t₁</td>
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<td>-------------------------</td>
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<tr>
<td>Production period</td>
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<tr>
<td>t₁</td>
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<tr>
<td>t₂</td>
<td>18.94</td>
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<td>t₃</td>
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<td>t₄</td>
<td>37.94</td>
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<td>t₅</td>
<td>77.94</td>
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<tr>
<td>t₆</td>
<td>137.94</td>
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</table>

Net returns = 139.94
Capital invested = 22.00
Net capital generated = 117.94
Net capital generated = Net returns - Capital Investments (139.94 - 22.00 = 117.94).
Reinvestment capital = Net capital generated + Starting owned capital (117.94 + 20.00 = 137.94).

1/ Unused capital from the preceding production period.
2/ Investment as required for the productive activity (table 1).
allows one unit of the productive activity to be operated in the current and all subsequent time periods. Operating capital, however, is required each time one unit of the productive activity is operated. The additional equations and restrictions necessary to make a growth model operational are not shown in the example. Only the capital equations are illustrated. In the model, requirements and returns are on an annual basis, and one production period is defined as 1 year.

In the first production period, since one unit of investment is made, one unit of the productive activity can be utilized. Total capital requirements are $21.00; and since only $20.00 of owned capital is available, $1.00 must be borrowed so that $21.00 is available during the first production period. The productive activity of production period $t_1$ adds $30.00 to capital in the next production period, but $1.00 principal, plus $0.60 interest, is paid for the $1.00 borrowed for operations in $t_1$. Since only one unit of investment was acquired in $t_1$, only one unit of the productive activity is operated during period $t_2$ which has operating capital requirements of $10.00. Total capital requirements for period $t_2$ equal $11.06$. Therefore, $18.94 of the $30.00 added by the productive activity of period $t_1$ is unused during production period $t_2$. This unused capital is assumed to be transferred and available for use in production period $t_3$. The process continues.

In period $t_4$, it becomes possible to make an additional capital investment. This makes it possible to produce two units of the productive activity. Total capital requirements during $t_4$, then, are $11.00 for one unit of investment, plus $20.00 operating capital for two units of the pro-
ductive activity. Finally, at the end of the fifth production period $137.04 of owned capital is available.

The net returns through the five production periods are $139.94; capital investment is $22.00; and a total of $128.94 of capital is generated ("net capital generated" in Table 2). Two useful equations can be developed from this simple example:

\[ \text{NCG} = \Sigma \text{NR} - \Sigma \text{CW} \]  

and

\[ \text{RC} = \text{NCG} - \text{SOC} \]  

Where NCG represents net capital generated, NR represents net returns, CW, capital withdrawals, RC, reinvestment capital, and SOC refers to the level of starting owned capital. Capital withdrawals may be further defined as:

\[ \Sigma \text{CW} = \Sigma I + \Sigma C + \Sigma T_x \]  

Where I represents capital investments (such as land, etc.), C represents consumption, and \( T_x \), income taxes. Equation (2) can become:

\[ \text{RC} = \Sigma \text{NR} - \Sigma I - \Sigma C - \Sigma T_x + \text{SOC} \]  

Since SOC is a constant, it may be ignored if it is assumed that some form of this equation will be maximized. A relevant question is what is to be maximized? Reinvestment capital, capital investments, and consumption may be items that increase satisfaction. Therefore, one criterion might be:

\[ \text{Max.} \text{ RC} + \Sigma I + \Sigma C = \Sigma \text{NR} - \Sigma T_x + \text{SOC} \]  

and the criterion function may be:

\[ \text{Max.} \Sigma \text{NR} - \Sigma T_x \]

The relevant question now becomes: Will this criterion maximize the growth
process? The answer depends upon how growth is measured. Should it be measured mostly in terms of reinvestment capital, capital investments, or consumption?

The point of these equations and discussion is to illustrate that in a growth framework all capital flows over time must be accounted for. The conventional measures of costs and returns become somewhat less useful in the capital accumulation process. In determining the structure of the model, costs are important only to the extent that they require capital to be withdrawn from the capital generating stream. High input costs associated with small capital withdrawals (such as harvesting costs) become a minor consideration, but small costs associated with large capital withdrawals (land purchases for example) become very significant. Returns are important in the growth process only to the extent that they represent net increases in resources (for example, net increases in liquid capital levels which may be used to purchase any resource). In a static framework, small costs associated with large capital requirements increase net returns compared to higher costs and lower capital requirements. However, in a capital accumulation framework, the higher net returns may not be compatible with maximum growth rates.

Framework for a Growth Problem

Many factors other than the transfer of capital through time are relevant to the growth process. So many factors are involved that it may be desirable to establish some framework for discussion. Table 3, a growth
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<th>loan</th>
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<td>Fixed cost</td>
<td>dol.</td>
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<td>Net returns</td>
<td>dol.</td>
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<tr>
<td>Reinv. capt.</td>
<td>dol.</td>
<td>6,106</td>
<td>242.00</td>
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Subsequent time periods

Objective function (net returns) 24.97 -2.00 -282.96 -12.00 -1.00 -.06 -73.22 -.34 0.0 0.0 .04 0.0
model presented within a linear programming framework, provides such a framework. It is not intended to imply that this is the growth model. It is also not intended to imply that techniques other than linear programming are irrelevant with respect to growth research. The framework is appropriate since it incorporates all the important aspects of the problem, including resources, their use and development, alternatives by which resources may be developed or used over time, criteria or objectives to be fulfilled by the solution to the problem, and a structural framework relating the component parts of the problem.

The model depicts the situation of an established farm firm, a 426-acre owner-operated farm including a complement of equipment and livestock. The complement of equipment is adequate for a size of operation up to 700 acres of land. Additional equipment must be purchased if the total acres operated exceed this level. In the event that expansion, in terms of acres operated, occurs above the starting size of 426 acres, additional livestock must be purchased. The level of family labor available is 1,900 hours, and additional labor may be hired at the going wage rate. Annual fixed or overhead costs must be met; these costs increase if the total operation exceeds 700 acres. In addition, a minimum capital withdrawal equal to $3,000, plus 25 per cent of the annual net returns is required, which is assumed to be used for family consumption. The starting level of owned capital is $6,106. Additional operating capital may be borrowed up to a level equal to 50 per cent of the unmortgaged value of owned land. Additional land may be operated through renting or purchase. Land may be purchased on a cash basis or through a 33-year amortized real estate loan which requires a mortgage on owned land.
The model, including only the activities of the first production period (first year) and their relationship to the second period with resource and restriction levels through the first two production periods, is shown in Table 3. This model is utilized in a study of capital accumulation and the growth process of the farms, conducted at Oklahoma State University. The results of this study will be reported in a manuscript under preparation, "Polyperiod Analysis of Capital Accumulation and Growth Process of Farm Firms, Low Rolling Plains of Southwestern Oklahoma." Some of the preliminary results from this study will be reported in later sections of this paper.

The starting situation and the operation activity (column 2, Table 3) were determined by linear programming computations. The purpose of the linear program problem was to derive the minimum land requirements and optimum combination of enterprises to obtain a $3,000 return to operator labor and management for a specific resource situation. The enterprise combination and requirements on a per acre basis were used to represent the operating activity used in the model.

The operating activity may be looked upon as an aggregation of enterprise activities. Any farm operation, accumulation of capital, or expansion of the land base must utilize this operating activity. Therefore, the combination of enterprises is predetermined and not to be solved as a specific part of the growth problem. No costs or capital charges are included for the use of owned resources. This is a necessary and realistic accounting

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procedure because returns to owned factors are used indiscriminately in the growth or capital accumulation process.

In the example, nine operational restrictions were considered to be relevant in each time period. The net returns equation is an accounting row used in connection with the "consume" activity (column 2, Table 3). The alternative activities allow resources to be expanded if they can be profitably used in the growth process.

The annual requirements for the operating activity include 1 acre of land, 3.14 man-hours of labor, $18.11 of capital, one unit of equipment, and one unit of investment in livestock and livestock equipment (column 2, Table 3). The net capital generated on an annual basis is $24.97. The coefficient of - $24.97, therefore, appears in the reinvestment capital row of the operating activity. A coefficient of - $24.97 also appears in the reinvestment capital row of production period 2.

The function of all coefficients in the reinvestment capital rows is to accumulate the amount of net capital generated. As an example, if $1.00 of capital is generated during or through the first production period, the amount of owned capital available at the end of the first production period is the $100 generated, plus the amount of capital owned at the beginning of the first production period. With $6,106 of owned capital available at the beginning of the first production period, $6,106 plus $100 or $6,206 would be available at the end of production period 1 (this is the purpose of the $6,106 coefficient in column 1 of the reinvestment capital row). With respect to the reinvestment capital row of production period 2, the amount of owned capital available is any capital generated during production period 2, plus the amount of owned capital available at
the beginning of production period 2 (which, as noted above, was $100 plus $6,106 or $6,206). Therefore, the coefficients in the reinvestment capital rows of production periods subsequent to the ones where the activities originate are only accounting procedures.

Renting land is assumed to be an annual activity (column 5, Table 3), and any number of acres may be rented during any production period independent of any other period. The purchase of an acre of land adds an acre of land to the land resource of the time period in which it is purchased and also makes the same acre available in all subsequent time periods. The market value of land is assumed to be $240 per acre, plus a $2.00 land transfer fee unless otherwise specified. Therefore, the cash land buy activity (column 3, Table 3) has annual capital requirements of $242. The collateral resource, which is used to obtain credit, is based upon the value of owned land. Therefore, buying land on a cash basis adds a value of $240 to the collateral resource. In terms of net returns, the cost of buying land on a cash basis is the transfer fee only because investments in resources such as land are requirements and in effect become income through inventory changes. However, in terms of net capital generated or reinvestment capital, (the reinvestment capital row of the production period) $242 is withdrawn from the capital stream as a result of the land purchase (see equation 4 above).

The alternative method of purchasing land, a real estate loan with payments amortized over a 33-year period (column 4, Table 3), requires equal annual installment payments. Part of the annual installment is applied to interest payments at 5 1/2 per cent and the balance of the installment is payment of principal.
Each installment payment is $16.05, which is the operating capital requirement for this land purchasing activity in each production period. In production period 1, $13.31 is deducted from net returns by the activity. This is the amount of interest paid through the first production period if land is purchased through this activity. Notice that the deduction from net returns in production period 2 is less than $13.31. This results because, as equal installment payments are made, the amount applied toward principal becomes greater and the interest payments become less. Since the loan is amortized over a 33-year period, deductions against operating capital, net returns, and reinvestment capital (net capital generated) are made in each subsequent production period. With respect to the reinvestment capital coefficients for this activity, the amount withdrawn from the capital stream in each production period is $16.05 which is annual installment payment. The coefficient in the reinvestment capital row of production period 2 is $32.10. Half of this results from the accounting procedure explained above, and the other $16.05 is the capital withdrawal associated with the activity during the second production period.

Much less than the current market price of farmland can be borrowed under existing mortgage lending practices: that is, the mortgage value of the land being purchased is only a fraction of the market value. However, it is common practice for farm mortgage lenders to finance an amount equal to the entire purchase price of the land if the buyer has additional owned land to offer as security. The amortized land buying activity involves this type of real estate loan. It requires that owned land be used to secure the real estate loan. The collateral requirements for this type of land buying activity is measured in terms of the current per acre market price.
of land ($240 per acre). The collateral or mortgage value of the land being purchased is assumed to be 46 per cent of its market value ($110.42). The real estate loan for the purchase of 1 acre ($242), less the mortgage value of the land being purchased ($110.42), leaves $131.58 of additional security needed to meet the security requirements of the loan. Land already owned by the farm operator is assumed to have the same per acre mortgage value as the land being purchased ($110.42 per acre). Therefore, the $131.58 additional security requirements necessitate that more than an acre of owned land be mortgaged to secure a real estate loan for the land buy activity. In terms of the market value of the land, this is equal to $285.53 required at the time the land is purchased. The security requirements for land purchased through an amortized loan at a given time decreases in subsequent years. Security requirements decrease because annual principal payments are made which, in effect, decrease the mortgage security outstanding. The principal payments represent a form of capital accumulation.

The assumed level of family labor available (1,900 hours) and the starting level of owned capital ($6,106) are arbitrary selections. The starting level of owned capital, in this case, was assumed to be gross sales forthcoming from the 426-acre farm, minus enterprise operating costs, overhead and machinery depreciation costs, and a family level of living expense. The starting level of collateral for purposes of obtaining real estate loans and borrowing operating capital is equal to the market value of owned land. The collateral level available at the beginning of the first production period is also available in subsequent time periods if it is not used to secure real estate credit in an earlier time period. However, the collateral level available or used in any time period can be greater or
less than the level of the preceding production period, depending upon
the amount of land previously purchased (collateral value of land purchased
or being purchased) and the level of real estate credit extended.

It is assumed that the level of operating capital that may be borrowed
annually is equal to 50 per cent of the market value of unmortgaged owned
land. The model is constructed to insure the maximum amount of flexibility.
For example, resource costs or capital requirements may be easily varied,
collateral requirements changed, etc.

The buy equipment activity included in each time period (column 8,
Table 3) is required to account for additional equipment purchases and
increasing overhead costs incurred when the farm size increases beyond
700 acres of total land. The required additional equipment purchase for
each acre of land operated above 700 acres is assumed to be equal to the
minimum average investment in equipment when the operation is 700 acres
($6.55). It is also assumed that the additional equipment is purchased
through a 5-year amortized loan with annual installment payments equal to
$1.55. An annual depreciation or maintenance cost of $1.15 would be
associated with each additional unit (on a per acre basis) of equipment
purchased. With the increase in overhead costs included in the buy equip­
ment activity, the annual capital requirements are $3.95 (the total of
$1.55, $1.15, and $1.25). However, the total costs for the production
period would not include the capital investment. Therefore, the reduction
in net returns would be the total interest paid in purchasing the equipment,
$0.39 plus the annual charges for equipment depreciation ($1.15) and over­
head costs ($1.25) which total $2.40. Purchasing equipment during any pro­
duction period makes the equipment available in subsequent periods; however,
capital requirements in subsequent periods are equal to annual machinery
depreciation, $1.15 plus increased overhead costs, $1.25, (column 9, Table
3).

The buy livestock activity (column 10, Table 3) is formulated to pro­
vide for operation expansion. The average required per acre investment --
if operations are expanded -- is $5.26. An investment in any production
period makes the capital investment available in subsequent periods. The
capital investment is not a charge against farm costs. Therefore, such an
investment is withdrawn from the capital stream but does not deduct from
net returns.

Normally, some proportion of the annual returns from farm operations
is spent or consumed in such a way that the expenditures do not represent
reinvestment per se into the farm business. These expenditures may be
considered a family living expense. For this reason, an annual capital
withdrawal is written into the program model. This restriction specifies
that $3,000 plus 25 per cent of the net returns be generated through farm
operations and withdrawn from the capital stream annually. In addition to
the $3,000 constant, a fixed cost of $1,532 is withdrawn as capital expendi­
tures for overhead and machinery depreciation costs. The fixed cost activity
(column 10, Table 3) is required to withdraw this capital in each production
period. The activity is forced into each production period to the required
level. Capital withdrawals of $3,000 and fixed costs of $1,532 total
$4,532; this amount is the level of fixed cost requirement in each production
period. There is no farm cost associated with the $3,000 capital with­
drawal; however, the $1,532 overhead and machinery depreciation cost are
annual farm cash cost. Net returns are reduced by $0.34 for each unit of
the fixed cost activity which is forced to a level of $4,532 to account for the $1,532 total fixed cost in each production period.

Since the consumption function or capital withdrawal without reinvestment into the firm is assumed to be $3,000 plus 25 per cent of the net returns, the consumption of 25 per cent of net returns activity (column 11, Table 3) is included in the model. The save capital activity (column 12, Table 3) is included so that any savings (owned capital not used in the farm business during any production period) may receive interest or returns.

The objective function shown in Table 3 assumes that net returns are to be maximized. The -$282.96 coefficient in the objective function of the amortized loan land buy activity (column 4, Table 3) is the total amount of interest paid (on a per acre basis) over the 30-year planning period in the event land is purchased this way during the first production period. The objective function coefficient of the buy equipment activity (column 8, Table 3) includes the small amount of interest paid for purchasing equipment, but it also includes the depreciation and increased overhead charge for the 30-year planning period (on a per acre basis) in the event the size of operation exceeds 700 acres during the first production period. All other objective function coefficients are self explanatory.

Formulation Problems

There are many limitations with respect to this model. However, with the above firm growth framework, it is possible to discuss formulating problems in their proper context.

Starting Firm Situation

The starting situation for any specific analysis will, of course, depend
upon the problem to which the research is directed. Most likely some typical situation or situations would be selected for a given type of farm or farming area. For more basis research problems a linear program solution, as is the case above, might be a relevant starting place. A conceivable starting situation might also be a farm operator with the ability to operate a farm and nothing else. In this case, someone's equity would have to be made available in order that land, machinery, and other inputs might be purchased for farm operation. Perhaps an advantage of a "dynamic" or growth situation is that, as the growth process unfolds, the situation at certain stages or points of time may represent different starting situations at the present time.

Growth vs. Decision Model

The model presented above is a growth model rather than a decision model with respect to the organization of farm enterprises. The organization of enterprises is assumed to remain in constant relationships as growth occurs. The effect of this type of assumption should be evaluated, for it seems logical that a growth model should also be a decision model. Also, certain problems might require a decision model rather than a growth model. However, it is felt that the advantages of such a simplifying assumption compensate for the loss of generality. This type of simplifying assumption may have much promise when working with problems in farming areas where a high degree of specialized operations exist. In such areas, the opportunity costs of not producing a specific organization of crops and livestock suited to the area are quite high. Even if several types of organizations, perhaps with quite different capital requirements, are relevant, several aggregated activities could be included in the model rather than a wide range of individual enterprise activities which complicate
the model and computing procedures.

Relevant Criterion Functions

The problem in an economic model of what shall be the quantity to maximize or what shall be the criterion function is not a new one. It would seem that this problem might become even more complicated in a growth model. However, the problem of selecting a relevant criterion function for a growth situation may not be a formidable one. The model presented above, which depicts a 30-year planning horizon, was utilized to analyze the effect of criterion functions or management strategies on the growth process. Identical results with respect to growth and capital accumulation occurred as the following criterion functions were satisfied:

1. Maximize the present value of net returns (6 per cent discount rate),
2. Maximize discounted value of gross sales (6 per cent discount rate),
3. Maximize undiscounted value of net returns,
4. Maximize the level of owned capital at the end of the planning horizon,
5. Maximize the level of land operated in the last production period,
6. Maximize the level of land operated throughout the planning horizon.

A criterion function of maximizing the present value of consumption (6 per cent discount rate) resulted in very similar growth process. Only the last production period was different, and the difference resulted from the way in which the problem was formulated.

A criterion function of maximizing land investments resulted in a slower rate of growth than the above objectives because maximum net returns resulted from a policy of renting land only. Although the average cost of purchasing land (interest payments over the 30-year planning horizon) was less than
renting, the total capital outlays for purchasing land (interest payments plus principal payments) was higher and, therefore, resulted in slower growth rates and lower total net returns. However, with this objective function, the optimum policy was achieved through renting land during the first half of the 30-year planning period (the same policy that occurred with respect to the other criterion functions). Land purchases then took place towards the end of the planning period.

These results indicate that the structure of the firm with respect to resource restrictions, alternative methods of expanding resource levels, consumption requirements or capital withdrawals, etc., are most important with respect to capital accumulation over time. The implications are that the environment within which farm operations occur tend to overwhelm specific operator objectives whether they be to maximize returns, sales, farm size, owned capital or reinvestment capital, or even consumption. Any of these objectives, criteria, or choice indicators tend to maximize capital accumulation. Since there is but one maximum rate, these objectives result in the same conditions. The structure of the system is the important factor. Different objectives result in the same growth rates for the same structural relationships of the firm. But different structural relationships result in very different growth rates.

**Capital Levels and Capital Rationing**

The problem of what shall be the starting level of owned capital is not unlike the problem of what shall be the starting size of firm. However, the matter of credit use and capital rationing is probably more relevant because so many farm operators have most of their wealth tied up in assets other than liquid capital.

Capital rationing, in terms of limiting the level of borrowed capital,
is restrictive on the growth process, but large differences in capital rationing may result in relatively small differences in growth rates. Referring again to the Oklahoma study, when borrowed capital was restricted to half of its original level (from 50 per cent of the unmortgaged value of owned land to 25 per cent), the growth process decreased within the 30-year period by about 20 per cent, both in terms of land operated and net returns. Reducing the level of borrowed capital again by one-half or to one-fourth of its original level (to 12.5 per cent of the unmortgaged owned land value) reduced growth by about one-third its original level. When capital use was restricted to owned capital only, starting with a level of $6,106, the minimum specified level of consumption, $3,000 annually, could not be met during the first 5-year period. In fact, capital was generated for a period of 10 years before enough capital was available to operate all owned land, 426 acres. However, the growth rate increased quite rapidly during the last half of the 30-year planning period. The differences in the level of borrowed capital, on an annual basis, for the different capital rationing levels were $51,120, $25,560, and $12,780. Over the 30-year planning period the total amount of these differences were quite substantial.

In considering capital use and capital rationing levels, the model used in any growth study should probably be structured in such a way to depict the actual credit restrictions imposed by credit institutions on the firm under investigation. The matter of internal capital rationing may then be approached by varying credit restrictions downward. More will be said about this matter later. In formulating a growth model it is important that collateral or security be treated as a resource. This is a resource which should be utilized the same as other farm resources.
Considerable value may be lost if the resource is not utilized. This is a point that economists tend to overlook probably because we think, or at least analyze, too much in a static framework.

**Capital Withdrawals**

Establishing the relevant levels of capital withdrawals in a growth model or with respect to growth research appears to be one of the more difficult formulation problems. Capital withdrawals here refers to items such as consumption (assuming that firm-household relationship is relevant) and income taxes. This represents capital that is created through the operation of the firm which is not reinvested into the firm. In the study cited above the effect of higher consumption levels or capital withdrawals on the growth process was very significant. When consumption levels were increased from a minimum of $3,000 annually to $3,000 plus 25 per cent of the net returns, the growth process was reduced by about 56 per cent of its original level in terms of maximum acres operated and by about 39 per cent in terms of the present value of net returns. A consumption function equal to $3,000 plus 50 per cent of the value of net returns reduced capital accumulation and growth further to about 61 per cent of its original level in terms of the present value of net returns. A consumption function of $3,000 plus 75 per cent of the net returns reduced capital accumulation further to 75 per cent of its original level.

Higher levels of propensity to consume increase consumption levels in the early part of the growth period, but they restrict capital accumulation and result in lower consumption levels during the later years. With a propensity to consume not less than 75 per cent of the net returns, each year the growth process was restricted to such an extent that total consump-
tion over the 30-year period were less than consumption, when the propensity to consume was limited to 50 and 25 per cent. A propensity to consume of 75 per cent came close to effecting a non-growth situation.

Another problem entirely, but one that represents the importance of capital withdrawals, is the difference in growth rate that occurred when additional land was purchased rather than rented. In the above analysis, land could be rented at a cost of $12.00 per acre which required a capital withdrawal of $12.00. Land could be purchased on an amortized basis at an average cost, which is interest payment (see the criterion function coefficient, Table 3), much less than $12.00 per acre. However, the total capital withdrawal, which includes interest payment plus principal payment, is about $16.00 per acre. The difference in terms of capital withdrawals ($4.00 per acre) would amount to $2,000 on an annual basis if 500 acres of additional land were acquired. Under conditions of constant farm size, greater net returns would be associated with payments to purchase land (assuming other returns and costs are constant). In a growth situation, however, renting land, with lower capital requirements and higher costs, resulted in maximum returns over time because lower capital withdrawals allowed the firm to grow larger and increased the volume of operations.

The matter of capital withdrawals for income taxes is not difficult because we know what tax structures are like. The proper level of consumption is a more difficult problem. One way to handle family consumption would be to break up the firm-family relationship and pay the operator a specific salary. This would be convenient, but would it be realistic?

The importance of capital withdrawals has implications with respect to criteria and choice indicators. Where capital withdrawals are signifi-
cantly different from costs, an objective of maximizing returns may not result in maximum capital accumulation. Under these conditions, a better criterion may be one that maximizes reinvestment capital.

**Risk and Uncertainty**

Research efforts should be directed towards evaluating credit use, resource investments, and capital withdrawals in the growth process within an environment of risk and uncertainty. The circumstances surrounding the use of these items are such that they may only be evaluated properly within this framework. Accordingly, it is important that methods of introducing risk and uncertainty into dynamic analyses be found. Stan R. Johnson will show us an effective way of introducing the stochastic process in a linear program model such as the one presented above. We can all appreciate the doors that will be opened when we can assign probabilities to the growth process.

**Changes in Technology and Prices**

The growth process is undoubtedly influenced by changes in technology and prices. This is a difficult problem to deal with. Even though the model presented above leaves much to be desired, useful information about the growth process can be gained simply by varying the cost (capital withdrawal requirements) of inputs over time. The same is true with respect to product prices and technology. Although little is known about the future with respect to specific changes in technology, general relationships between technological innovations, prices, and capital requirements are known or at least can be simulated. Simulating probable or possible changes over time could establish probable minimum and maximum growth rates over time. The divergence of these growth rates over time might
help to establish a relevant planning horizon. A more sophisticated model, which included the stochastic process, could give us a great deal of useful information.

Planning Horizon

The problem of what the relevant planning horizon is with respect to a growth situation is a difficult one, because it is not unrelated to other difficult factors such as risk and uncertainty, changes in technology and prices, resource ratios, and perhaps the growth rate itself. Due to the great uncertainty of events and actions in the distant future, there is a tendency to emphasize the present and the years immediately ahead. However, the nature and characteristic of different types of inputs should dictate generally the relevant planning horizon. A new and refreshing approach to the problem is that the relevant planning horizon should be solved for rather than arbitrarily selected. Until a new approach is developed that solves for the optimal planning period, there is a need to test the economic importance of varying the length of the planning period. This can be easily done (with enough computer time) with only minor modification of our existing tools.

Competition and Disequilibrium

At some stage of our growth research, we must deal with the problem of competition among firms and disequilibrium. This problem is too important to disregard. It is very convenient to assume pure competition, but capital accumulation and firm growth suggest a situation other than equilibrium. Arrow presents a strong thesis that individual firms, at disequilibrium, are in the position of monopolists with respect to an imperfect elasticity
of demand for their product. The aggregate aspects of growing firms must be considered. It is common knowledge that farm firms are growing both in product output and physical size. Also, land is not available for firm growth without competition from many firms for the use of land and other resources. Associated with this are the formidable institutional problems evolving from land ownership and the land market. Varying the price of land resources would tend to account for or give us some idea of the effect of competition and, to some extent, the institutional problems among farm operators for farm resources. These problems are of such importance that analyses should be undertaken to deal specifically with them and to investigate every facet of them.

Use of All Techniques Applicable

Although much has been said and written about capital accumulation and the growth process, few studies have attempted to analyze growth problems on a firm basis. We can, in the short run, merely hope to scratch the surface in this very important area of research. A better knowledge of the growth process is compatible with a better understanding of farm adjustments in general. The limitations tend to be overwhelming, but progress is made only by doing something.

Linear programming is a convenient framework for the growth model for it has all the components of a growth situation. However, the use of all

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techniques in addition to and in combination with linear programming is relevant to growth research. The number of useful techniques and approaches are limited only by our imagination.

In view of the many limitations and lack of knowledge, growth research will involve arbitrary selections of important variables with respect to the capital accumulation process. This approach will be subject to criticism. However, critics should bear in mind that the arbitrary selections are as a process of simulation and should not be interpreted as value judgments indicating what ought to be. Problems relating to the capital accumulation process are much too complicated to be solved straightforwardly by the deductive process. The process may be approximated through a simulation technique which has met with much success in other scientific fields and probably holds much promise in the social sciences.

The Perfect Model for Growth Research

With this background material, it is now possible to contemplate the perfect model for growth research. It is a "hybrid" between several existing techniques. The model deals with random income generating variables and expected values in a stochastic process. It automatically considers different planning horizons for different types of inputs, and the model generates its own aggregation weights in order to compensate for changes in technology and prices.

The timeliness of firm growth research brings to mind several elderly men who were always sitting around a pot-bellied stove in deep East Texas.
There appeared to be not a care among them, for they sat rocking and whittling away day by day. The store's faithful old grandfather clock began to strike. It struck 13 times. One of the men got up, brushed himself off, straightened his chair and said, "I'm going home; it's never been this late before."
Impatience, dissatisfaction and distrust of purely static models as guides for analyzing farm decision problems in the Great Plains are evident in the fact that G.P. 2 exists and in past activities of the committee.\footnote{Great Plains Committee No. 2 was established in 1958 by the Great Plains Research Council. The title of the regional project initiated at that time is "Organizing and Operating Dryland Farms in the Plains to Meet Variable and Changing Economic Condition."} Major emphasis of the committee has been on generating data describing the levels and variability of yields, prices and returns from individual enterprises. However, little has been done toward utilizing these data in a framework which depicts the decision environment of Great Plains Farmers. Objectives of gaming and simulation activities, characteristics of such models for Great Plains problems, and examples of research and educational uses are presented in this paper. The objective is to provide ideas for Great Plains economics research suited to the environment in which decisions are made.

Model building is not a new concept in economics research. Thus, a shift from considering broadly defined and primarily static models
of firm behavior to more detailed, dynamic models or simulators does not require specific emphasis. The two procedures considered are simulation and operational gaming. In operational gaming, a player makes periodic decisions and responses through time within a simulated economic problem environment. Interaction of the human element, the player, with problem components is emphasized. Simulation is a process of experimentation with a model to determine effects of different decisions by observing the distribution and level of results over time resulting from each initial decision. The initial decision specifies a fixed strategy or set of strategies over time. Thus, the human input is predetermined in simulation. In a broad sense, operational gaming could be thought of as simulation in which the human element is part of the simulation. Gaming tends to emphasize education and research on the human factor in decision making and simulation tests results of alternative choices. Beyond these points, a fine line of distinction between the two processes is neither necessary nor particularly desirable.

**Gaming and Simulation Objectives**

The foremost decision in planning and using a simulator is not whether it will be manual or machine computed, ultra-real life or abstract, etc., but what it will, should or can be designed to do. Success of the exercise depends on defining attainable and worthwhile purposes or objectives. These objectives guide construction and administration of the process.

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2/ The model capable of quantification and application in both gaming and simulation is referred to as a simulator.
General educational objectives of operational gaming are to develop abilities to (a) abstract, organize and use information from a complex decision environment, (b) forecast and plan, and (c) combine the role of generalist and specialist. More specific applied objectives might be to teach facts (e.g. potential levels and variability of yields or prices), illustrate principles (e.g. maximize returns to scarce resources), demonstrate critical points in annual or long run financing, show effects of initial resource position and environment on firm growth opportunities, provide experience in maintaining and using records and accounts, and, afford examples of applications for economic choice guides in a real-world environment.

Objectives of research utilizing simulation have been to describe results of different operational strategies and to order the strategies according to outcomes, given possible objectives of a decision maker. Decision problems considered have contained time dynamics, deterministic changes in technology, technical production relationships and prices, and stochastic elements. Initial strategy choices can be guided by principles and concepts relating to diversification, flexibility, reserves, insurance, the firm-household complex and institutional constraints. Many problems which have or can be attacked are too complex for conventional (static) analytical tools.

The possibilities of using operational gaming in human and management input research have not been fully assessed. Use of the model to study the decision process, identify managerial objectives, test effects of training in economics and technical agriculture,

relate farm management research results to farmer's knowledge, and attempt to measure managerial ability appears to be a distinct opportunity. The fact that operational gaming is a pleasant experience to most participants might be exploited in obtaining information on a wide range of psychological and philosophical attributes.

**Building the Simulator**

The objectives provide the general guide for design and should determine the level of management, kinds of decisions, economic conditions, periods simulated, knowledge situation assumed, and computational method. In the simple game discussed here (Appendix A), we will assume the following teaching objectives:

1. Develop abilities for analyzing income obtainable from different livestock enterprises.
2. Prepare the student for instruction on sources of variability in returns and costs and use of strategies such as diversification.
3. Illustrate problems of firm growth with uncertain income and a low initial capital position.
4. Teach procedures for evaluating and attaining multiple firm objectives under resource and personal constraints.
5. Provide elementary farm management experience using a simple model with as much verisimilitude as possible.

Gaming forces careful preparation. If we approached each class lesson as systematically (and spent as much time), all teaching would be vastly improved.
For a classroom or extension meeting, hand calculation may be the only alternative. Elaborate computer games are not the objective, but a means of attaining objectives. However, the objective of familiarizing students with computer capabilities surely is relevant to educational needs. As beginners, we probably should build our models as simply as possible and increase the complexity only as necessary as we add additional economic concepts and objectives.

The Mathematical Model

The game requires decisions on the number of steers and hogs to produce. Two-hundred acres of corn are produced for feed or sale. Corn appears out of place in a game for the Great Plains. However, in an educational game, use of enterprises somewhat foreign to the participants avoids attempts to translate data used in the game into general facts. The objectives here relate to concepts rather than empirical facts about particular enterprises.

Formally, the production or returns functions for each enterprise are as follow:

CORN:

\[ C_{ij} = \bar{Y}_C + Sy_C X_i + b_i (T_j - T_0), \]

where:

- \( C_{ij} \) = corn yield under the \( i^{th} \) production condition and in the \( j^{th} \) decision period;
- \( \bar{Y}_C \) = average corn yield;
- \( Sy_C \) = Standard deviation of corn yield; and,
- \( X_i \) = A standard normal deviate within a specified range, representing a set of conditions leading to yields varying about the means.
b₁ = A trend coefficient for corn yield over time.
T = Time (j = 1---N). Thus, (Tⱼ - T₀) provides a period count
(by years) for use in adjusting yield through time.

The corn equation is written generally enough that it is adaptable
to a computer routine. In a computer routine, X would be drawn ran-
domly from an appropriate distribution. In this game, b₁ = 0, only
three Xᵢ are considered, Vᵢ = 50, Sᵢ = 12.5. The probabilities for
Xᵢ are P (-2) = .25, P (0) = .5 and P (2) = .25. Other probabilities
(distributions) could be used and effects of fertilizer strategies
added. The function reduces to a simple description for game admin-
istration. Possible corn yields are 25, 50, and 75 bu. per acre with
probabilities of .25, .50, and .25, respectively.

Corn can be sold for $1.00 per bushel, if not fed. Additional
corn can be purchased for $1.20 per bushel. Annual cash production
costs for corn are $15 per acre ($3,000 per year).

STEERS:

(2) \[ R_{SI} = P_{SSI} G_i + (P_{SSI} - P_{SBI}) \bar{W} - V_i, \]
where:
\[ R_{SI} \] = return per steer under \( i \)th production and economic condition;
\[ G_i \] = Gain under the \( i \)th condition;
\[ P_{SSI} \] = Selling price of steers under the \( i \)th condition;
\[ P_{SBI} \] = Buying price of steers under the \( i \)th condition;
\[ \bar{W} \] = Initial weight of steers purchased (assumed constant); and,
\[ V_i \] = Other cash production costs under the \( i \)th condition.

The return is the residual after cash costs are paid, following
procedure used in partial budgeting and linear programming. One or
a combination of different \( P_{sb1} \), \( P_{ss1} \), \( G_i \), and \( V_i \) can cause a variation in \( R_{s1} \). The function indicates data needed to build realistic games and identifies research gaps. Hopefully, past work of G.P. 2 will provide some of the data.

Each variable in the steer equation should be further specified. For example, the form of \( P_{sbj} \) might be:

\[
(3) \quad P_{sb} = \bar{P}_s I_s + X_i S_s (\bar{P}_s I_s) + b_2 (T_j - T_0)
\]

where:

- \( \bar{P}_s \) = long term average steer price;
- \( I_s \) = seasonal index for steers for the month purchased;
- \( S_s \) = standard deviation of the seasonal index for steer prices;
- \( X_i \) = standard normal deviate with a specified range; and,
- \( b_2 \) = a trend coefficient for steer prices.

Again, a variety of distributions could be used. Correlations between variables, conditional probabilities, joint probabilities, cycles and specific sequences could be included to increase realism and teach additional concepts. The form of \( V_i \) will be particularly important. Effects of individual animal performance, quality of hired labor, management, disease, transportation problems, and even stocking rates could be handled within the equation for \( V_i \).

For the manual game, all data are summarized into three outcomes, $25/Steer, $50/Steer, and $75/Steer with probabilities of .25, .50, and .25, respectively. Steers require 40 bushels of corn per head. Buildings and equipment are available for 100 steers per year but pasture available will handle 200 steers. To expand steers, investments in buildings and equipment would cost $40 per head.
HOGS:

The hog returns function is similar to that for steers. Returns per litter and probabilities are: \( P(\$140) = .10 \), \( P(\$150) = .80 \), and \( P(\$160) = .10 \). Thus, hogs are depicted as a more stable source of income than steers. Hogs require 120 bushels of corn per litter. Labor limits hogs to 50 litters. No hog facilities are available but can be added for \$100 per litter.

Other Data and Conditions

For simplicity, additions to steer and hog facilities must be paid out of returns in the year added. No additional operating costs are included explicitly. However, the \( V_i \) in each livestock function could be assumed to include a charge for equipment maintenance and depreciation. Alternatively, a building and equipment cost function easily could be constructed to include a more usual loan amortization procedure.

Decisions on numbers of steers and hogs must be made before corn yields or livestock returns are known. Steer numbers can be varied in 25 steer units and hog numbers can be varied in five litter units. The latter restrictions facilitate hand calculation, but could be attributed to lumpy hog and steer equipment purchases.

Managerial Objectives

The objective of the manager of the farm is (1) to maximize net worth, subject to (2) survival in the short run. To survive,
mulated profits cannot drop below -$5000. Family living expenses of $5,000 must be paid each year along with $3,000 for corn production and $1,000 non-deferrable overhead farm expenses. Thus, a total of $9,000 plus corn purchases and building and equipment investments must be subtracted from receipts. The remainder is the quantity to be maximized over the period simulated. The value of new buildings and equipment is added to accumulated returns to compute gain in net worth at the end of the period simulated.

**Game Administration**

The briefing for game play should include a statement of objectives, a problem orientation, an explanation of forms used, and some practice in carrying out requirements of the game. The potential value of the exercise can be lost immediately if procedures and data are not understood. If possible, materials should be handed out well in advance of play. Experiences of the authors to date suggest that a traditional farm management budgeting or linear programming exercise should precede the game so that participants are thoroughly familiar with the economic relationships involved. The challenges of identifying the role of specific economic concepts in guiding play of a game and providing experience in applying concepts studied in lecture sessions will be as instructive to teachers as to students.

The briefing lays the foundation for attaining objectives. For example, one objective of the game discussed here is to prepare...
students in an advanced farm management class at Oklahoma State University for class discussions on variability of costs and returns. A smooth transition is desired from using normal or average enterprise budgets in whole farm budgeting exercises to recognition of potential variation in yields, inputs, costs and returns and consideration of planning strategies under imperfect knowledge. The intent is to add such knowledge without destroying confidence in appropriate uses of "normal or average" concepts in farm planning.

During the briefing, the mathematical model for the game can be used to introduce most of the relevant concepts. In addition, the game provides a familiar reference for later discussions. For example, average corn yield, $\overline{Y}_C$, in Equation (1) is easily identified as the normal crop yield used in enterprise budgets. Using the probabilities of $X_i$, it is verified as the expected yield over time, excluding trend. Other terms in Equation (1) introduce two sources of yield variability or change. The set of natural conditions leading to variation of $Y_C$ and summarized in $X$ should be discussed. The trend term introduces an analysis of yield changes over time.

Equation (2) emphasizes that gain ($G_i$), difference between selling and purchase price ($P_{ss_i} - P_{ss_i}$), and other cash costs ($V_i$) are key factors affecting returns. Given the assumed levels of corn price and production cost, the relationship of allowable livestock price margins to the price level can be illustrated. Price seasonality, variations in seasonality and trends also are introduced in
Equation (2). As indicated earlier, opportunities for analyzing variation in $V_1$ are extensive.

The amount of orientation depends on objectives of the game. If one objective is to test performance of the players, less guidance would be given. Similarly, if data used are only examples of relationships, less emphasis on factual content is required than would be the case when empirical facts are to be taught. One criticism of games tried at O.S.U. is welcomed by us—"other important relationships should have been included such as..." Such a comment indicates the interest and thought stimulated in the game. Unless we have led a participant to expect too much, he will recognize opportunities to add other environmental conditions with no serious damage to the game activity.

**Educational Opportunities - A Summary**

The model building phase of operational gaming is a major contributor to education of the teacher, research worker and student. The model provides a way to stimulate interest and approach realism, while teaching principles of management and economic organization. Building a simulator requires disciplined development and application of a variety of facts and concepts. Many decision problems under imperfect knowledge cannot be adequately considered, much less solved, without intensive attention to model building.

The university classroom is ideally suited to use of operational gaming. The game provides a way to critique student performance in applying knowledge concerning planning under uncertainty.
We hope to use the tool in the Oklahoma State University High School Farm Management Contest. Simple games can be used to illustrate modern management principles to audiences such as civic clubs. Extension applications will undoubtedly stimulate interest. However, many extension classes need preparation in theoretical areas before the "game" becomes much more than a game. Even in very simple games, the mechanics of computations can rapidly overshadow objectives, analysis of data and application of planning principles. Thus, tables should be provided to reduce the computational burden.

Research Opportunities

Research is stimulated and facilitated by the farm simulator. Examples of research suggested by the game discussed here are: (a) generate data for constructing the returns equations for steers and hogs (e.g. input, gain and price relationships, correlations, joint distributions and variance); (b) compare alternative strategies for obtaining firm growth; and, (c) estimate minimum levels of resources required for firm survival and growth. In each case cited, the need for data or knowledge is discovered as a result of attempting to build and play the game.

The following traditional analysis of the decision problem posed in the sample game illustrates potential research contributions of the simulation technique. The average corn yield-livestock relationship is $10,000 = 40S + 120H$, $S =$ Steers and $H =$ Hogs. Average returns for steers are $50-$40 = $10.00 with owned corn and $2.00 with purchased corn. Returns are $30 and $6.00 for hogs.
Thus, returns per unit of corn are equal. If we assume that depreciation on facilities is included in the annual cash cost, the long-term solution would be to have 200 steers and 50 litters of hogs. Capital for additional facilities would be $9,000 and returns above cash, overhead and living costs would be $3,700.

This result is very similar to the linear programming results we publish. Simulation illustrates that this result may be of little value to a farmer who must accumulate capital to reach the plan under constraints specified in the game. We could add to our traditional analysis by specifying the range of returns from the optimum (-$7,800 to $15,000) and alternative plans. Another common approach, is to specify optimum plans for different conditions. However, we can say little about how the farmer chooses a plan. Impacts of high or low enterprise returns or yields cannot be analyzed without examining many possible sets of returns over time.

Research with the sample simulator can answer a number of questions ignored by the static analysis. For example, what would happen if the farmer planned for the lowest corn yield and fed as many hogs as possible with that amount of corn? The research procedure for answering that question would be to repetitively play that strategy over a number of decision periods and samples of conditions and evaluate the results. Other questions are: What if the farmer (a) plans for the highest corn yield, (b) jumps immediately to the optimum long-run plan, or (c) mixes hogs and steers in various ways? What level of accumulated capital is necessary to
withstand possible events? Questions relating to the largely underdeveloped area of firm growth are numerous. For example, how many years would be required to reach the 200 steer - 50 litter level, given alternative strategies, different conditions and the initial capital position?

The game and simulations analysis also might be used to investigate the acceptance and understanding of farm management research. It might explain divergence between our L.P. answers and plans observed in operation. If this divergence is primarily a time lag, simulation might provide knowledge needed to shorten the time lag.

Analysis oriented to studying management (human interaction within the simulator) earlier was mentioned as a possibility. Do experience, educational background, age, family or real life equity affect the way participants play the game? What types of individuals are most successful in playing? Do economics, business, animal science, or agricultural economics backgrounds affect understanding and performance? Do professional gamblers, misers, conservatives, liberals, etc. play differently? Is learning accelerated by use of the game? Are there rational strategies for play (decision making) not perceived in economic theory? Problems of experimentation with simulators to answer these questions are numerous, but, hopefully, surmountable.

Conclusions

The following tentative conclusions or hypotheses are advanced
for consideration.

(1) Management games build student interest. However, success in teaching managerial principles depends on the skill of the game builder and administrator. The game must have well defined objectives.

(2) The simulator is a valuable model and training device for the researcher and educator. It forces investigation of the decision environment during business growth and through time. It identifies important decision alternatives. Through games, specialists in a variety of fields may find a common ground.

(3) Actual experience in building and experimenting with games rather than inheriting a computer game and blindly using it is needed, given the present state of knowledge and development.

(4) Simulation research on effects of alternative strategies for a dynamic environment will be productive in the Great Plains.

(5) Simulation or operational gaming may afford a fresh, productive technique for management input research.

(6) Farm management research such as G.P. 2 as conducted in the past is needed to provide the data for building simulators.
Appendix A

Oklahoma Farm Management Decision Game No. 11

1. You are owner-operator of a 200-acre farm. The only crop that you can grow is corn. The average yield is 50 bushels per acre, varying from 25 to 75 bushels. The probabilities of various yields are: 25 bushels - .25, 50 bushels - .50, 75 bushels - .25. Corn not fed to livestock is sold at $1.00 per bushel. If livestock requirements exceed production of corn, corn must be bought at $1.20 per bushel.

2. You have buildings and equipment for 100 steers per year but pasture for 200 steers. Steers require 40 bushels of corn per unit. To expand steers, investments in buildings and equipment would cost $40 per head. Net returns and the probabilities of various net returns from steers are: $25 - .25, $50 - .50, $75 - .25.

3. A hog activity can be added by investing $100 in buildings and equipment per litter. Hogs require 120 bushels of corn per litter. Labor limits hogs to 50 litters. Net returns and probabilities of returns are $140 - .10, $150 -.80, $160 - .10.

4. Decisions on number of hogs and steers must be made before yields or livestock prices are determined. The number can be varied each year in 25 steer units or 5 litter units. Investments to expand livestock must be made out of profits.

5. Production costs for corn are $3,000. Other overhead farm costs are $1,000 and family living expenses are $5,000. Hence, a minimum of $9,000 must be earned each year. The remaining earnings are profits.

6. The objectives are: (1) Maximize net worth, subject to (2) survival in the short run. To survive, accumulated profits cannot drop below -$5,000. (New facilities are added to net worth at the end of the simulation period.)
# Data for Computations

**Total Corn Production**

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**Corn required**

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<td><strong>Summary:</strong></td>
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<tr>
<td>Fixed Cost and Family Living Expenses</td>
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<td><strong>Net Annual Return:</strong></td>
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<td><strong>Accumulated Return:</strong></td>
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* New facilities are a function of steer and hog decisions.
† Add corn sales or subtract corn purchases.
SWEDISH EXPERIMENTS IN PLANNING FOR ECONOMIC GROWTH OF AGRICULTURAL FIRMS 1/

By

Ulf Renborg 2/

INTRODUCTION

The Swedish work in this field has its roots in a ten year interest in planning problems of the individual agricultural firm. During the last two or three years our interest has focused more consciously on the obstacles to profitable growth of firms and on planning for their long-run economic growth.

We have had four starting points when intensifying our studies in this direction: (1) an awareness of our poor knowledge of the growth problems of the agricultural firm, (2) the practical experience that large farms are generally more profitable than small ones and the knowledge that not only size itself but also the growth process per se affords economic advantages, 3/ (3) the fact that if he wants to be successful on a fulltime basis the farmer will have to increase his input of capital progressively over time; this prediction is based on neo-classical marginal analysis and on the fact that economic progress generally lowers capital/labor price ratios, thus favoring substitution of capital for labor, and (4) the unsatisfactory way

1/Research work reported in this paper is the preliminary information of a project under way at the Department of Agricultural Economics at the Agricultural College of Sweden in Uppsala, Sweden. The project uses a team approach under the chairmanship of the author. Other participants are agr. lic. Bertil Johnson, agronom Erling Skoglosa and agronom Rolf Olsson.

2/Professor, Department of Agricultural Economics, Agricultural College, Uppsala, Sweden.

in which our planning methods are today used in practical planning on the micro level--as a rule the practical planning is aimed more at finding the best possible plan within now available resources than at the more important goal of building up a plan which gives the best possible basis for future development or growth.

Our Swedish experiments can be divided into four groups:

(1) Studies directed toward identifying the factors which hamper the growth of individual agricultural firms. These problems have been analyzed on a preliminary basis in a regional study involving planning for ten pilot farms in northern Sweden in 1956-60 and on a country-wide basis in a study on ways of increasing the efficiency of Swedish agriculture published in 1963. More intense studies of this problem were started in the spring of 1964 with a number of student papers based on field work in two different parishes in middle Sweden. Further, two master's theses on this problem are under way.

(2) A systematic search for relevant planning models, which has been going on this winter (1964/65) and has resulted in a list of literature.

(3) The construction of a work sequence for practical planning for growth of the agricultural firm. A preliminary version

of such a work sequence is appended to this paper, as a basis for discussion.

(4) Planning experiments involving practical testing of proposed work sequences. As yet only one experiment of this type has been carried through.

In this paper I will discuss our work up till now under three headings: Growth problems of the agricultural firm, Proposed planning models, Work sequence for practical planning. We are in our work focusing the interest on long-run planning for growth, for those cases where the farmer is aiming at a full-time job on the farm. Our studies do not deal with farmers who are unwilling to expand or with part-time farmers.

GROWTH PROBLEMS OF THE INDIVIDUAL AGRICULTURAL FIRM

At this preliminary stage the growth problems of the individual agricultural firm can be summarized under five headings: (1) The goals the farmer has for his economic activity, (2) The acquisition of monetary capital (or funds) necessary for growth, (3) The acquisition of farm land, (4) The increasing risk and uncertainty connected with the growth process, (5) The farmer's lack of knowledge.

These problems will be dealt with here insofar as we think it possible for the farmer or the planner to take them into account. Other measures which might be taken by the public or another group in society to make the growth problems easier to solve, will not be dealt with. Examples of other measures are the easing of credit
facilities for growth, changes in institutional patterns to increase the supply of agricultural land, credit plans for easing liquidity problems of growing firms, greater funds for schools and extension service to increase the knowledge of the farmers, etc.

**Problems Related to the Goals of the Farmer**

In our work, we regard it to be a fact that the goals of farmers generally are not clearly expressed. It is therefore difficult to get clear and concise answers as to the more relevant goals. We also think that the goals set by farmers are in fact multiple. This means that a naive profit maximizing model is a poor description of an agricultural firm.

Another assumption is that the goals held by farmers more often are of the type "want to be full-time farmer," "want to earn a reasonable income" than of the extreme economic-man type "wish to earn as much money as I can with my ability even if this means that I have to quit farming." Many farmers accept considerably lower incomes than other groups before they cease farming.

Still another relevant observation is that goals often include elements which a priori exclude some production branches ("don't like pigs," "hate sheep," etc.) and that farmers seldom aim at expansion.

Within the set of goals held by some Swedish farmers is the aim of being "free from debt" when they retire or at least press down the debts as much as possible before that time. Obviously this can be an important obstacle to growth.
As meaningful planning is impossible without a clear concept of the goals to be reached, the planner may encounter difficult problems in the important first step of fixing relevant goals. We have in our models held to the following three points:

1. That some goals must be established although it is difficult to relate them to those held by the farmer. These initial goals can be revised during the course of the planning but they must always be specified to begin with.

2. That we cannot at each planning moment ask the farmer for the goals he holds. We have to build up a normative planning system consciously aiming at the growth of the firm and guaranteeing as far as possible the minimum growth needed to maintain or increase the capacity of the firm, so that the long-run income goal of the farmer can be achieved. At least we want to be able to inform the farmer about the growth rate and the long-run income obtainable over a specified planning period.

3. That a number of goals often have to be fulfilled at the same time. The various elements of this set can be directly related to the growth problems to be dealt with here and/or to specific goals held by the farmer irrespective of the growth aspect of planning.

Problems Related to the Acquisition of Funds Necessary for Growth

In the Swedish setting three important problems can be related to this aspect of the growth of farms. Provided that capital can
be borrowed at some price the three problems are:

1. The farmer does not always have the debt free liquid funds necessary to start a farm on a good basis for future development. The minimum amount of equity capital of course differs between countries, price situations and type of farms.

2. Because growth of firms is a continuing process, the total amount of capital necessary increases over time. Then the growth process must include the generation—within the firm itself or from outside sources—of capital, which can be successively reinvested in the farm. This is necessary to make it possible for the farm to pay at any future point in time an income comparable to the steadily rising income of persons working in other sectors of the economy.

3. Unwillingness of many farmers to increase their relative indebtedness can be a serious drag on the increase of farm size. The existence of this obstacle has to be ascertained in all planning for growth.

Problems Related to the Often Necessary Acquisition of Land for Growth

The lack of land in the market is very often an important obstacle to growth in the Swedish setting. The high demand for additional land is based on its high marginal product and on speculation in rising land values. At the same time the market supply of land is low either due to the fact that land, especially close to big cities, is looked
upon as a good investment although not used at all for the time being, or due to the fact that many old farmers with low alternative value on their labor remain on too small farms and thus withhold land from the market. In Sweden the acquisition of land is also complicated because farms are often so small that several must be added together to get a reasonable size. As neighboring farms are rarely put on the market at the same time the growth of acreage is often costly as the successive adding of farms requires successive adjustment.

Satisfactory solutions are difficult to find for the farmer willing to expand his acreage. From the individual farmer's point of view it is only possible either to move immediately to a larger farm or to investigate his neighborhood as to when neighboring farms may be put on the market. Until they are available, he can only increase his preparedness to buy land if and when this is put on the market in the indefinite future.

Problems Related to the Increasing Risk and Uncertainty Connected With Firm Growth

Increasing size of farms often means an increase in the absolute value of the yearly variations in gross income due to price and yield variations. If the growth is financed through borrowed money, which requires yearly redemption and interest payments, these variations in gross income have increasing effects on the family income which is an ever smaller part of the gross income. This then means that planning for growth must include a close watching of the liquidity of the firm. Otherwise the growth process may be blocked by sudden drops in gross income.
Problems Related to Lack of Knowledge

Lack of knowledge on adjustment and growth problems and on relevant production possibilities can seriously hamper the growth of individual firms. However, in the individual case the only possibility is to adjust the long-run plans for growth to the level of knowledge which the farmer can be expected to reach during the planning period and to remember that increase of knowledge always costs money. Even after acquiring this knowledge there will remain the lack of knowledge just mentioned.
Available Models for Long-Run Planning for Growth of the Agricultural Firm

The General Planning Model

We are indebted to Erik Johnsen5/ and Jan Odhnoff6/ for the general model that will be used in our planning procedure. In our interpretation of these authors the general model consists of the following sub-models:

1. A sub-model, M, describing the goals to be fulfilled.
2. The base sub-model, G, including the functioning of the firm, K, and the activities to choose among, A
3. A seeking process, S
4. A process of adaptation of standards, N, related to the goals

The model M describing the goals to be fulfilled will preferably be of the satisficing rather than of the optimizing type. This choice is relevant to the way in which the farmer sees his planning problem and also relevant to the problems involved in the long-run planning of firm growth. The meaning of a satisficing model is given by Herbert Simon: "An alternative is satisfactory if (1) there exists a set of criteria that describes minimally satisfactory alternatives and (2) the alternative in question meets or exceeds all these criteria."7/

5/Johnsen, Erik: Oral communications on studies about to be published.
The base model, G, includes all the knowledge on the firm to be planned. Examples of base models are those used in linear programming or dynamic programming. Other models are possible. In long-run planning for growth it is important that the base model include a specified planning period and that the time element of the model is stressed.

The seeking process, S, will be used to combine the activities A of the base model utilizing the resources specified in, and subject to the constraints set by the model K (the functioning of the firm) and aiming at the fulfillment of the goals included in model M. Examples of seeking processes are the Simplex method for solving linear programming problems, Monte-Carlo Methods, common rules for decision making under uncertainty, etc.

The process of adaptation of standards, N, will be used to check the fulfillment of the goals indicated by model M. If these goals are not reached then activities (A), constraints (K), and finally also the goal standards may be changed. This adaptation of the standards is necessary if there is no solution that fulfills all the goals set. Raising the standards is possible if all the goals are immediately fulfilled and this procedure can go on until no further raise is possible.

This general planning model is usable in a great number of planning problems. Before using it for long-run planning of firm growth it is necessary to fill in the factual material relevant to
the planning problem. Relevant material of this type will be discussed in the following sections. The various sub-models will be discussed in the order just mentioned.

**Goals for Long-Run Planning of Firm Growth (Model M)**

As far as the discussions have brought us hitherto in the Swedish group it seems appropriate to include in model M for this type of planning, criteria such as:

1. A profit standard
2. A capacity standard
3. A liquidity standard
4. A flexibility standard

Each of these standards must be dated and thus related either to some point or to some period in time. If the latter, the time period has to be the relevant planning period. In this section I will indicate proposals for setting these standards.

The **profit standard** may be desired income from labor and capital which the farmer invests in his business. This income should be measured after reduction for taxes. Another possible alternative is the income required for consumption after reduction for taxes and for savings necessary for the growth of the firm. The consumption level is preferably adjusted to the varying size of the family over time. It may be possible to change the standard to a criterion which maximizes profit or consumption.

The **capacity standard** may be measured as a minimum capital requirement per man for each point in time. This standard can be
calculated from general studies on the relationship between capital requirement per man and profit for various types of farm or production branches. An alternative capacity standard may be the rate of growth of capital on the average during the planning period to meet the necessary capital requirement at each point in time during this period. Information on the setting of these standards can be fetched from many sources. The capacity standard is designed to take care of the problems related to acquisition of capital for the long-run growth of the firm. It is important to remember that capital for expansion can be equity or borrowed funds and that equity capital at any point in time consists of capital at an earlier point in time plus capital generated by savings from incomes (negative savings = consumption of capital) plus deliveries from external sources (minus sign = deliveries to external sources) plus capital gains due to inflation (minus sign = loses, for the same reason).

The liquidity standard for each point in time can be expressed as for example the amount of equity capital necessary to counterbalance the income variations due to risk and uncertainty. Careful studies on the input and output streams of the firm may give clues to better measuring rods.

The flexibility standard can be measured on the active side of the balance sheet. It can be expressed for example as a standard

indicating the percentage of total assets which are directly marketable or as a maximum time period within which non-marketable assets have to be paid back under ordinary conditions. The flexibility standard is also related to the increasing risk and uncertainty problem involved in firm growth and to the costs to make readjustments of non-marketable assets.

The Base Model G of the Firm in Long-Run Planning for Growth

Decision on the length of the planning period is an advisable first step in building the base model. The planning period is the period in time between the planning moment and the relevant planning horizon. The starting point for deciding the length of the planning period should include consideration of: (a) the general view of Hicks9/ dynamic model that the profit over some period of years has to be maximized, (b) the possibility shown by Modigliani and Cohen10/ to cut off part of the future by investigating which non-realized events and decisions are relevant to the planning of actions during the first year of the planning period, (c) the subjective judgment of the farmer as to what part of future events and decisions is relevant to the planning of his actions.11/

The elements of the base model are:

1. Resources available at the planning moment for the agricultural firm; for example acreages of farm land and forest, hours

---

2. Structural constraints characterizing the firm to be planned; for example rotation restrictions, intermediate products, etc. These constraints can be related to a single year of the planning period or may tie together years within the planning period.

3. Possible activities to be performed during the planning period. In our case it may be suitable to distinguish between production processes (wheat production, milk production, etc.) and processes inducing growth (additional land, capital, building space, etc).

4. Information on the contributions that each single activity gives to the fulfillment of the goals set forth.

5. The resource requirements of the various activities.

Points (1) and (2) constitute part K of the base model, the functioning of the firm. Points (3), (4) and (5) constitute part A of the base model, the activities to choose among. It is important to note that each element of the model has to be dated, i.e. related to the relevant sub-period of the planning period.

Of special interest in our case are the processes inducing growth. Examples of these processes are: acres of farm land possible to add to the farm during some future year, capital acquired through current savings of running incomes during each single year of the planning period, increases of capital, etc. Both positive and negative additions are of course possible. Of interest in this connection
are the costs entailed in the growth itself. These costs are for example the adjustment costs when the size of the firm is increased and the very often increasing marginal costs of borrowed capital. Both these types of costs have to be weighted against the advantages of the growth.12/

There are of course a great many ways to construct the base model. Four different ways will be given here.

(G1) All relevant sub-periods of the planning period are included in the planning model and the goal standards fulfilled for the whole period looked upon as an entity. All possible alternative growth paths during the planning period should in principle be examined.

(G2) The same as model (1) but with major stress on the first sub-period of the planning period. This is Modigliani and Cohen's approach to the planning procedure. This approach permits us to treat the later sub-periods of the planning period in much less detail than the first sub-period. It also stresses the point that future sub-periods are always subjected to replanning and thus only of interest in so far as they have a bearing on what has to be done during the first sub-period.

(G3) The combination of one short-run plan for the first and one for the last sub-period of the planning period. In

the short-run plan for the last sub-period all expected additions to the available resources through processes initiating growth are included and the best possible anticipations of the relevant planning parameters made. The connections between the two short-run plans and the long-run plan are more loosely indicated. The two plans and their connections form the total long-run plans.

(G4) A short-run plan only for the first sub-period of the planning period combined with an analysis, according to Penrose, of the most profitable growth or expansion directions of the firm. Observe the necessity of fitting the plan to the existing resources and their organization and to include the possible and necessary adjustments and their affects in income and costs.

The alternative ways of building the base model G are illustrated as follows:

(G1)

(G2)

(G3)

(G4)

the planning period

The long-run features of this base model are established through decisions on the length of the planning period, the dating of the

individual elements of the base model and the way in which the model is built up. The growth feature of the model is established in the contributions that individual activities give to such goals as capacity (growth), liquidity and flexibility and also in the growth initiating processes.

The Seeking Process, $S$, for Combination of Activities

These processes can be of various types. It seems convenient to tie them to the alternative ways of building models. If so the following are examples of seeking processes that could be used:

To models of type (G 1) and (G 2):

Dynamic linear programming or dynamic programming (Bellman).

To models of type (G 3):

Traditional one-period linear programming, simulating processes or "program planning" can be used for the short-run and the long-run plans individually. The tying together of plans is essentially a problem of finding all the possible ways of combining alternative short-run and long-run plans.

To models of type (G 4):

Traditional one-period linear programming combined with analysis according to Penrose based on shadow prices and studies of unused resources.

All models can be combined with sensitivity analysis, for example by using criteria for decision making under uncertainty when choosing between alternative growth directions.
All these seeking processes can of course always be exchanged for simpler trial-and-error techniques. This may be the only way out in the practical planning of individual farms especially before electronic computers are more readily available and before the extension service personnel is more prepared than now to use highspeed electronic computers.

The Process of Adaptation of Standards, N

The calculation of alternative plans has to be made stepwise. When a plan has been established, it must be checked to see if the goal standards are met. If so the plan can be accepted and the adaptation process need not be used. If, on the other hand, some goal standards are not reached the adaptation process will be used to make possible changes in activities included in the plan and/or in restrictions in such a direction that goals can better be fulfilled. If after these changes all goals are fulfilled, the plan can be accepted. If the goals are still not fulfilled alternative plans have to be formulated by starting over again. If after some trials, no plan can be found which fulfills all the goals, then modifications also can be made on the goal standards. The planning is going on until the planner thinks that the marginal cost of making new trials is equal to the marginal value of the increase in knowledge of the future organization.

The adaptation process, N, can be mechanized and made fit for solution on electronic computers for problems of reasonable size (Johnsen, Erik; private communications). Of course, trial-and-error
methods can also be used. In this case the calculation of a number of plans and the results as to fulfillment of the goals give important knowledge as to the production possibilities of the firm and can be of value when deciding on the plan to be put in action.

This way of working with a seeking process, S, and an adaptation process, N, is illustrated graphically below. The procedure is an interaction of seeking and checking results against given goals. This procedure goes on until a plan is found which fulfills the goals or adjusted goals. In this the planner and the farmer must cooperate closely.

![Diagram showing the interaction between Goals and Planning](image)

Goals                                      Planning
THE WORK SEQUENCE FOR PRACTICAL LONG-RUN PLANNING FOR GROWTH OF THE AGRICULTURAL FIRM

(A preliminary outline)

Goals

General goals, not possible to quantify:

☐ I intend to keep my farm

☐ as full-time farmer

☐ as part-time farmer

☐ live there but not farm

☐ I may sell the farm

Profit goal

☐ Maximizing income after tax deductions over the planning period

☐ Reach a specified income level after tax deductions:

<table>
<thead>
<tr>
<th>Period of years</th>
<th>_____ to _____</th>
<th>_____ to _____</th>
<th>_____ to _____</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kr/year:</td>
<td></td>
<td></td>
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</tbody>
</table>

Price level: 19....

Capacity or growth goal

☐ Reach at least the following total capital investment (owned and borrowed) per 2000 hours of labor a year:

<table>
<thead>
<tr>
<th>Year:</th>
<th>a)</th>
<th>a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kr/2000 h:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Price level: 19.... a) Status at the planning moment
This means an average yearly growth rate of capital invested per 2000 hours.

Liquidity goal

Owned capital at least the following % of total capital:

<table>
<thead>
<tr>
<th>Year</th>
<th>a)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% owned capital:</td>
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<td></td>
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</tbody>
</table>

a) Status at the planning moment

Flexibility goal

At least the following % of total capital invested in other assets than land and buildings:

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<thead>
<tr>
<th>Year</th>
<th>a)</th>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>% of total capital:</td>
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</tbody>
</table>

a) Status at the planning moment

Other quantifiable goals

The Base Model and Choice of Seeking Process

The planning period covers the years: _____ to _____

Planning moment: ..............................................

Available resources at the planning moment:
<table>
<thead>
<tr>
<th>Capital, owned</th>
<th>Kronor</th>
<th>Costs/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>borrowed previously</td>
<td></td>
<td></td>
</tr>
<tr>
<td>new loans</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Land, farm land</th>
<th>Owned</th>
<th>Rented</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>forest land</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Building space,</th>
<th>Seasons of the year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>insulated</td>
<td>m²</td>
<td></td>
</tr>
<tr>
<td>non insulated</td>
<td>m²</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labor force,</th>
<th>Kronor</th>
<th>Costs/year</th>
</tr>
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<tbody>
<tr>
<td>available hours</td>
<td></td>
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</table>

**Structural constraints**

**Rotation restrictions:**

Max./min. % of farm land in:

<p>| | | | | |</p>
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</thead>
</table>

**Other constraints**

........................................................................

.................
Production processes (pp)

See appendix with processes and necessary technical coefficients.

The coefficients will be calculated for the following years during the planning period:

\[
t_1: \begin{array}{c}
\vdots \\
\vdots \\
\vdots \\
t_n:
\end{array}
\]

Expected major innovations and changes in price relations and in the farmer's knowledge during the planning period:

Growth inducing processes (gp)

Changes (+ and -) in resources expected during the planning period:

<table>
<thead>
<tr>
<th>gp</th>
<th>Process expected introduction during period</th>
<th>Units/period</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Capital, kr</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Necessary savings</td>
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<tr>
<td></td>
<td>Land, hectare</td>
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<tr>
<td></td>
<td>Building space, m²</td>
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<td></td>
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<tr>
<td></td>
<td>Labor hours</td>
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Important alternative growth paths:

Choice of base model and seeking process

☐ Model 1: All relevant sub-periods of the planning period simultaneously planned

☐ Model 2: Model 1 but major interest focused on the first sub-period

Division in sub-periods:

<table>
<thead>
<tr>
<th>Period no</th>
<th>Covers years</th>
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Seeking process:

☐ Dynamic linear programming\(^{14}\)/

☐ Dynamic programming\(^{14}\)/

Intuitively formulated growth paths based on information from the base model + subjective choice made jointly by the farmer and the planner according to the fulfillment of the goals already formulated

☐ Model 3: Planning independently of the first and the last sub-period of the planning period\(^{15}\)/ + indications of possible alternative growth paths between these two sub-periods

\(^{14}\)The use of these techniques requires that one of the goals is expressed as an optimization (max., or min.).

\(^{15}\)A number of alternative plans preferably specialized in various directions have to be established for both sub-periods.
First sub-period covers the years: 

Last sub-period covers the years: 

Seeking process for each sub-period:

- Traditional I-period linear programming
- Simulation technique
- "Program planning"

Seeking process for possible growth paths between alternative plans the two sub-periods:

- Intuitively formulated growth paths based on information from the base model.

Seeking process for the combinations of plans for the first and the last sub-periods and the possible growth paths between the two sub-periods.

- Max. profit over the planning period discounted to the planning moment.
- Subjective choice jointly by the farmer and the planner according to the fulfillment of the goals previously formulated.

Model 4: Planning of the first sub-period only combined with analysis of growth directions according to Penrose

Seeking process: Traditional I-period linear programming

Sensitivity analysis

- No sensitivity analysis (i.e., planning under subjective certainty as to the outcome of future events)
- The planning will be combined with sensitivity analysis:

The use of these techniques requires that one of the goals is expressed as an optimization (max. or min.).
Construction of a game matrix by calculating the outcome of each alternative growth path for a set of future "states of Nature." Application of criteria for choice under uncertainty on this game matrix.

The Adaptation Process (To Be Applied in Connection With Any Seeking Process)

Calculate the first combination of processes \((pp + gp)\) and check the fulfillment of the goals. If the goals are fulfilled the first plan is reached.

If the goals are not fulfilled seek new combinations of processes. Three ways are possible:

1. Exchange processes whereby those processes go out which contribute least and those processes go in which contribute most to the goal or goals not fulfilled.
2. Examine the possibility to change the technical coefficients of the processes in the first combination.
3. Examine the possibility to change the structural constraints of the base model.

If the goals can not be reached in this way try new combinations of processes and work these combinations through again.

If, after many experiments, some goal or goals are still not reached examine the combinations of processes at hand and consult

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16/With one goal expressed as an optimization.

17/As the goals only have to be fulfilled and no optimal criteria are used there may be many combinations of processes that fulfill the goals.
the manager as to the future work: He may accept one of the combinations as his plan or order more experimentation.

The Planning Procedure

Build the relevant base model. Appendix......

Use the relevant seeking processes and the adaptation process to formulate alternative plans. Appendix......

The formulated alternative plans and their goal fulfillment. Appendix......

<table>
<thead>
<tr>
<th>Alternative no:</th>
<th>Sub-periods of the planning period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Resources:

Processes:

Goal fulfillment:

Actions necessary to take during the first sub-period:

(One table of this kind for each alternative)

Result of the sensitivity analysis. Appendix......

Formulation of the alternative "states of Nature":

...........................................................................................................................................

...........................................................................................................................................
Chosen alternatives according to various criteria:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximin (Wald)</td>
<td>.................................................................................................</td>
</tr>
<tr>
<td>Minimax risk (Savage)</td>
<td>.................................................................................................</td>
</tr>
<tr>
<td>Pessimist-optimist (Hurwicz)</td>
<td>.................................................................................................</td>
</tr>
<tr>
<td>( \alpha = 1 ) (pessimist)</td>
<td>.................................................................................................</td>
</tr>
<tr>
<td>( \alpha = 0 ) (optimist)</td>
<td>.................................................................................................</td>
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<tr>
<td>( \alpha = )</td>
<td>.................................................................................................</td>
</tr>
<tr>
<td>Insufficient reason (Laplace)</td>
<td>.................................................................................................</td>
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</tbody>
</table>

The chosen plan and the main reasons why it was chosen:

...........................................................................................................

...........................................................................................................
Firm growth is an area of economic inquiry that has received little of the attention of economists in the past. It has even been suggested that, "Perhaps such a theory (of firm growth) is impossible to construct, unnecessary, trivial, or outside the place of economics proper."¹ In this study an attempt is made to show that all of the above possibilities can be rejected and that in fact the theory of firm growth is a real economic problem and furthermore that it is an economic problem that lends itself to empirical investigation. Since this is an empirical study, the investigation of firm growth is restricted to one firm assumed to be representative of a set of firms that possess a sizable number of the same characteristics. The particular group of farms which are the subject of this study are the dryland farms in the Southern High Plains of Texas.

Aggregate empirical facts that are available for this area suggest that growth is a problem of real consequence for these farm firms. A few of the more pertinent of these facts are:² ³


1. Evidence of "price cost squeeze"
2. Increased capital investment in machinery per farm.
3. Increased technology evidenced in the development of farm machinery suitable to large size farm operations.
4. Average per capita income for farmers is consistently below the national average per capita income.

These and other factors have lead to a general view among agricultural economists that farm firms expecting to remain in business and be in a position to adopt the increased technology of agricultural production must increase in size.4

Noneconomic implications of a continuation of the above conditions are mainly associated with the probable decline in population in this rural area and the repercussions that it is likely to cause. The numerous economic implications associated with increasing firm size appear to fall into three general categories. The first is within the area of economies of size and scale. There are important questions to be answered with respect to the effects, if any, of the increasing or decreasing size of farm firms on the average cost per unit of output. The second implication is associated with the problems of entry. As the size of farm operation that will yield an income comparable with nonfarm alternatives increases it becomes increasingly difficult for beginning farmers to secure the amount of capital necessary for them to have an initial operation of the size that has a reasonable chance of being successful. The third economic implication of a continuation of these conditions is

associated with the problem of increasing firm size or growth. Farm firm growth has for some time been in evidence and is almost certain to continue to occur, yet it has received little or no treatment by Agricultural Economists. Thus, the process of firm growth seems to have a good deal of promise as an area of research.

Up to now no explicit definition of firm growth has been given although it has implicitly been illuded to as an increase in the size of firms.

"The term 'growth' is used in ordinary discourse with two different connotations. It sometimes denotes merely increase in amount; for example, when one speaks of 'growth' in output, exports, sales. At other times, however, it is used in its primary meaning of a process of development, akin to natural biological processes in which an interacting series of internal changes leads to increases in size accompanied by changes in the characteristics of the growing object."\(^5\)

For the analysis to follow, firm growth is defined as an increase in the worth of the firm. The basic reason for choosing increased worth as opposed to increased output as evidence of firm growth is that in the analysis to follow variability of output plays an important role. This in itself precludes output as a stable index of firm size. As an illustration of the definition adopted for growth, suppose that the worth of a firm were \(A\) at the beginning of a particular period of time and that at some subsequent period of time e.g., the \(n\)th period it was \(B\); then firm growth for periods 1 through \(n\) would \(B - A\). Two facts are clear from this simple illustration. The first is that firm growth has only secondary connection with the concepts or standards of size and scale by which firms are examined in traditional economic theory. Concepts

of size and scale are given only of incidental consideration since this analysis is concerned with the process of a firm's moving from one size to another. The existence constant or decreasing long run average cost curves is then just one of the necessary conditions for firms to grow.

Secondly, the illustration demonstrates that firm growth is dynamic in nature. In essence, the fact that a firm must move from one period to another in order to accomplish growth is implicit in the definition.

There is at present some controversy in the economic literature as to what is dynamic and what is static. One of the streams of thought envolved from the concept of economic dynamics as defined by J. R. Hicks. The substance of this concept is contained in the following quotation.

"I call Economic Statics those parts of economic theory where we do not trouble about dating; Economic Dynamics those parts where the quantity must be dated. For example, in economic statics we think of an entrepreneur employing such-and-such quantities of factors and producing by their aid such-and-such quantities of products; but we do not ask when the factors are employed and when the products become ready. In economic dynamics, we do ask such questions; and we even pay special attention to the way changes in these dates affect the relations between factors and products." 6

Essentially, Hicks suggests that the dating of the variables and dynamic analysis are one and the same. Another somewhat more precise definition of static and dynamic analyses is suggested by Samuelson. Central to the system of classifications that

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Samuelson has set down his formulation that was borrowed from Ragnar Frisch:

"A system is dynamical if its behavior over time is determined by functional equations in which variables are different point of time" are involved in an "essential" way..."Attention is called to the fact that variables at different points of time must enter into the problem in an essential way"...and Samuelson concludes that: "Unless, therefore, we reserve the designation dynamics for systems which involve economically significant variables at different points of time in an irremovable way, we shall find that no nondynamic system exists."\(^7\)

Samuelson proceeds to prescribe some six all inclusive divisions into which all economic analyses must fall.\(^8\)

Generally, the economic literature concerning the definitions of static and dynamic systems or models is characterized by the diversity and incompatibility of the two above quotations on the subject. Perhaps the literature has been left in this rather untidy state due to the relative rarity of concentration on analyses that involve the movement of economic variables over time—especially within the micro framework. An alternative conceptualization of the two states (Static and Dynamic) and intermediate positions is advanced here as a basis for positing the nature of this analysis. First define a static situation as one in which all of the variables are stationary. Let another state be defined as purely dynamic. Suppose for operational simplicity that these two points define a spectrum. Then, at one end would lie the purely static type of analysis, i.e., a completely timeless comparison of equilibria; and


\[^8\]Ibid, pp. 314 and 135.
at the other end the completely dynamic analysis, i.e., one in which all variables are functions of time in an irreversible way. Most empirical analyses have some stationary variables and some time related variables and thus lie in the intermediate area someplace between the two extremes. Models of this type shall be defined as non-static to denote their mixed character. Exact placing of a mixed model along the static-dynamic spectrum is difficult and usually arguable since non-static models can differ in the number of interaction allowed between variables, and the like. The model presented in this analysis is significantly non-static, it is of linear form, it is stochastic, and the variables are dated with time subscripts.

The fact that time must be included in the study of firm growth is the source of a host of further problems that are involved in its empirical analysis. The major difficulty that appears in the multiperiod analysis necessary for studying firm growth is that something must be assumed or postulated about the environment within which firms move through time. Should it be assumed that the firm functions in an environment that is characterized (1) by perfect knowledge of the outcomes of various decisions over successive periods in the model, (2) by a knowledge of the exact probability distributions of the outcomes of various decision variables for each period, or (3) by no knowledge at all of the expected outcomes of various decision variables for any period? Imperfect knowledge or the problem sometimes identified with the terms risk and uncertainty is quite relevant
to firm growth. If growth is to be meaningfully analyzed imperfect
knowledge must be handled in a manner that will result in definitions
that avail themselves to empirical analysis. In establishing the
related definitions that are applied here, the work of Frank Knight
on this subject is used as a point of departure.

"Taking, the, the classification point of view, we shall
find the following simple scheme for separating three different
types of probability situation:

1. 'A priori' probability.
2. Statistical probability.
3. Estimates."

The first and second of the above classifications of probability
have come to be designated by the somewhat ambiguous term "risk"
in economic writings. The third classification has come to be
called "uncertainty." Knight suggested that:

"It is this third type of probability or uncertainty
which has been neglected in economic theory...It is this
pure uncertainty which by preventing the theoretically
perfect outworking of the tendencies of competition gives
the characteristic form of "enterprise" to economic
organization as a whole and accounts for the particular
income of the entrepreneur."

It is here proposed that the techniques of empirical investigation
have developed to the extent that this neglected area of uncertainty
(suggested by Knight as giving the characteristic enterprise to
economic organization) can be investigated in regard to its effects
and its interactions with various policies of entrepreneurs. Simulation

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9 Frank H. Knight, Risk, Uncertainty and Profit, Houghton Mifflin
Company, New York, 1921, pp. 224 and 225.

10 Ibid., Frank H. Knight, pp. 231 and 232.
has made the empirical investigation of firm growth and analytical possibility and one of ultimate practical value.\textsuperscript{11}

**Conceptual Model:**

The model designed for this empirical analysis of firm growth is composed of five unique components. These five components are:

1. A set of values that characterize the ability of the firm to transform the various resources at its command into final products or output.
2. A decision model for the firm.
3. A means of incorporating the variability that is associated with the various production activities of the firm.
4. A method for testing the hypotheses concerning the factors affecting firm growth.
5. Hypotheses concerning various factors affecting firm growth.

Component number one consists basically of developing budgets that accurately reflect the cost of the various inputs and the technical ability of the farm firms to transform these inputs into final goods. This process is called Enterprise budgeting and is commonly used in allocation studies and/or in farm management analysis of the operation of farm firms. \textsuperscript{12}

The demands on the decision model, component number two, for flexibility and size, limited the alternatives. A linear programming model of the form shown below in vector notation was chosen.

\[
\text{Max } c^T x \quad \text{subject to } Ax \leq b \quad \text{and } x \geq 0
\]

where:
- \( c \) = net returns from various activities
- \( x \) = various activities included in the model
- \( A \) = Matrix of transformation coefficients
- \( b \) = resource restrictions


\textsuperscript{12}Lawrence A. Bradford and Glenn L. Johnson, Farm Management Analysis, John Wiley and Sons, Inc., New York, 1953, pp. 315-316.
This conventional linear programming model can be modified to represent a multi-period decision model by dating activities and supplying transfer activities and equations for the purpose of carrying firm operation forward from one year to another. Transfer activities are simply provided by designating slacks.

The connection between static and dynamic linear programming models (using dynamic in the sense defined above) is summarized very concisely and neatly in the following quotation.

"Economists are familiar with the way in which a dynamic model of analysis may be developed from a static one, and the usual procedure applies in linear programming. Static linear programming rests on the relationships by which quantities of homogeneous goods and services (inputs) are transformed into other homogeneous goods and services (outputs), as we have seen. If we consider a production program as continuing over a number of periods of time, specify the quantity of each input that becomes available at the beginning of each period as a function of activities in earlier periods, and seek to determine the level of each process in each period, the framework of a dynamic analysis results. A genuine dynamic quality is imported to the analysis when the limitations on the activities of any period are expressed in terms of the results of previous periods. In this way a feedback is introduced into the system, and the successive periods are linked together by a set of linear difference equations which determine the maximum rate of growth of the system, the level of operation of each process during each period, and any inherent tendency to cyclical behavior."\(^\text{13}\)

A review of the model sketched above is sufficient for the conclusion that it is reasonably similar to the dynamic model described by Dorfman. The production in year two is related to the production in year one and the production in year three is related both to the

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production in years two and one—in other words—there is a provision for "feedback" in the decision model outlined above. The feedback is a result of the fact that the model is solved simultaneously for all of the years.

The third component of the empirical analysis of the growth of the firm is constructed in a manner unique to this study. The treatment of yield variability outlined below cannot be objectively classified as either risk or uncertainty. Simulation is the technique and that provides a basis for incorporating yield variability into empirical analysis of firm growth. Simulation is defined for this analysis as a technique of setting up a stochastic model of a real situation, and then performing sampling experiments on the model. A major part of the "stochastic model of a real situation" is the multi-period linear programming model which is used to characterize the actions of the farm firm over time. All that remains for the completion of the stochastic model is the innumeration and characterization of the sources of variation. In this analysis crop yields are assumed to be the only sources of variation to the farm firm. The data available for estimating the variability of the yields of alternative crops are time series. Using time series data in simulation models presents a serious question:

"The design of a stochastic model always involves a choice between using frequency or probability distributions of raw data, and the best theoretical fit that can be attained by the use of these distributions. This question is really

fundamental, because the use of raw data in a stochastic model implies that all one is doing is simulating the past.\textsuperscript{15}

In this particular analysis the time series data is used to construct probability distributions for crop yields. Some of the obvious limitations of this procedure reduced by constructing probability distributions with provision for explicitness including various levels of serial correlation.\textsuperscript{16}

With the inclusion of the stochastic yield variables the multi-period programming model has been modified so that some of the elements in the transformation matrix (e.g., $A_{ij}$) are assumed to have distributions associated with them. Hence, they might be written $A_{ij} + u$, where $u$ has some distribution. Therefore, the problem as defined is stochastic in the true sense of the word and the solution of this model of firm growth involves the solution of a stochastic programming problem. An approximate solution to the stochastic set of simultaneous equations can be found by simulating the model as follows.

1. Generation of random or pseudo-random numbers
2. Making the appropriate transformations on the random numbers to associate them with corresponding values for crop yields from the yield probability distributions.
3. Substitution of yield "observations" generated by this pseudo sampling technique.
4. Solution of the multi-period linear programming model.

The fourth component of the scheme for quantitatively analyzing firm growth exists due to some special properties of components two and three. Although the hypotheses are discussed in the following section

\textsuperscript{15}Ibid., Harling, p. 314.

It should be noted here that they are implemented by varying appropriate portions of the decision model over discrete levels. Due to the fact that the distributions that are to be sampled from are known and the fact that the multi-period decision model is formulated in such a way that it is a conditional linear transformation on the variables generated from the distribution, valid statistical comparisons of the effect on firm growth of the various hypothesized structures of the decision model are possible. Statistical tests or comparisons are possible since the nature of the distributions associated with solution points can be deduced. Other tests involve simply evaluating the means and variances of the distributions that result from various structures of the model.

Component number five is, the hypotheses concerning factors which may affect firm growth. The discussion of this component is incorporated with the statement of the objectives of the study. Since this study is one of the first quantitative studies of farm firm growth, the objectives are necessarily concerned with broad relationships and their significance on farm firm growth. Information attained from a personal interview of a sample of the farm firm operators in the area and from related literature suggested that one or a combination of the following four factors might have an important influence on firm growth.

1. The initial asset position of the farm firm.
2. Capital or Credit use policies of the farm firm.
3. The nature of the variability of crop yields.
4. Consumption policies.

Starting position of the firm, is rationalized as a factor affecting firm growth as follows. Firms with a relatively large amount of assets are able to sell more credit and thus are more insured against the
results of their imperfect knowledge about the environment than are firms with a relatively small amount of assets. Capital and/or credit use policies of an individual firm may have a pronounced influence on the growth of the firm. Firms that are liberal users of capital and credit may make rapid growth during the periods in which the uncertain environment provides years favorable for crop production. However, they are confronted with the possibility of severe losses should a series of years occur that are unfavorable for crop production. The nature of and degree of the variability of crop yields is the result of the unstable environment in the High Plains and is therefore an important factor in an analysis of growth of firms. There has been some indication that the environment in the area is such that it gives a rise to series of good and bad crop yields. Attempts to test these series of good and bad years against an assumption of some specific cycle have met with limited success. At any rate it would benefit the analysis if series of good and bad years of crop yields could be generated which conform to various assumptions about the length of these series to determine the effect (if any) of this serial correlation upon the accumulation potential of particular firms. Consumption policies of individual firms have been characterized in the tradition Keynesian manner. Since, household consumption is siphoned off of net income or the capital of a firm during its yearly operation, it may have a pronounced effect on the capital position of a firm over a number of years. This may be especially true in the case of firms whose

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Incomes tend to be variable. Thus, the nature of alternative patterns of family or household consumption could affect the accumulation of assets or the growth of firms.

Both practical and theoretical objectives are pursued in this analysis. Since the subject manner is relatively new and the particular method of analysis used has its origin in this study, some practicality has been sacrificed to allow emphasis on the methods developed for quantitatively analyzing firm growth. The theoretical objectives are:

1. To construct an analytical framework that has the capacity for quantitative investigations of firm growth.
2. To derive a method for satisfactorily incorporating variable factors into economic analysis of growth.
3. To yield conclusions that suggest profitable areas for further more specialized research on growth in both agricultural and non-agricultural firms.

Practical objectives are naturally related to the particular area on which the analysis was made and are:

1. To provide the farmers and other business men in the area with general statements about the expected results of various capital, consumption, and management policies on firm growth.
2. To provide farmers in the area with information on the strategies that have proven experimentally successful in the simulated environment for survival and capital accumulation.

ANALYTICAL TECHNIQUE

The development of the analytical model for the problem outlined in the previous section is presented below. Particular emphasis is given the specific factors of the analysis that are
unique to this study. These factors include those parts of the model devoted to the process of modifying the multi-period model to account for yield variability. After the model that is used to simulate the firm has been set out, two alternative techniques are suggested for utilizing the data produced in testing the hypotheses of the study.

I. The Decision Model or Multi-Period Programming Model

Formulation of the 15 year linear programming model is a rather straightforward procedure. Essentially, the model consists of 15 one-year, linear programming models with the right-hand-side for the initial year being constructed from the hypotheses of the analysis, and right-hand-sides for subsequent years are developed through the use of "transfer equations." The "transfer equations" then, facilitate the recursive relations that exist within the model. The first three years of the multi-period linear programming model are presented in Table I. The matrix of coefficients for the complete 15 year model is triangular so that this shortened three year version will include all of the information critical to the construction of the entire model. The firm decision model characterized in the multi-period linear programming tableau presented in Table I is reasonably abstract. This rather severe simplification or abstraction of the actual firm decision situation is rationalized on two counts.

\[18\] The data used in constructing the multi-period tableau and the data which were the basis for the distributions used to generate yearly yield information are not discussed. A complete description of the analysis may be found in the following reference. Stanley R. Johnson, "A Multi-Period Stochastic Model for Simulating Firm Growth," Ph.D. dissertation in progress, to be submitted to the Graduate School at Texas A&M University.
First, the over-all model is an exploratory one and thus more emphasis
was placed on implementation of the technique than upon achieving
realism in the results. Essentially, the study was undertaken with
a primary objective of formulating and testing a technique that would
be of use in the analysis of the growth of agricultural firms under
less than certain situations. The secondary objective was to achieve
realistic results. Secondly, computer time involved in the solution
of these stochastic type linear programming models by simulation
technique is substantial. Therefore, the size of the model and con­
sequently the realism of the model were partially a function of the
availability of computer time.

Preliminary models were solved that contained other productive
activities including livestock (stocker feeder), rented land, and
alternative techniques for cotton and grain sorghum production.
The livestock alternative was consistently inferior to crop alterna­
tives. The skip-row method of producing cotton seemed superior to
the 40 inch row method included in the model. However, yield data
from this type of production practice were so limited that it was
impossible to estimate with reasonable confidence average yield and
yield variability. Due to the data limitation the 40 inch row
productive technique was used for cotton.

Within the firm decision model depicted in the tableau in Table
I there are two decision alternatives for the firm in each year.

1. To produce
2. Not to produce
Table I -- Shortened Version of Simulated Decision Model For The Firm

<table>
<thead>
<tr>
<th>HEADINGS</th>
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<tbody>
<tr>
<td>Y.1 Objective Function I</td>
</tr>
<tr>
<td>Y.2 Objective Function II</td>
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<tr>
<td>Y11 Land Own</td>
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<tr>
<td>Y12 Expense</td>
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<tr>
<td>Y13 Gross Returns Cotton</td>
</tr>
<tr>
<td>Y14 Gross Returns Grain Sorghum</td>
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<tr>
<td>Y15 Operating Capital</td>
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<tr>
<td>Y16 Machinery Capital</td>
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<tr>
<td>Y17 Credit Reserve</td>
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<td>Y18 Income Tax &amp; Consumption</td>
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<tr>
<td>Y19 Accumulated Worth</td>
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<td>Y23 Gross Returns Cotton</td>
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### Table 1 — Shortened Version of Simulated Decision Model for the Firm

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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE I -- SHORTENED VERSION OF SIMULATED DECISION MODEL FOR THE FIRM
The restriction of the decision set of the firm is basically a result of the fact that only one productive activity was included for each year. This means that no choice among alternative production techniques was allowed in the model. Two criterion or objective functions were used to characterize entrepreneur's behavior. They were (1) maximization of reinvestment income defined according to equation Yo,0 and activity Xo,0 in the tableau, and (2) maximization of accumulated firm asset value as defined in equation Y3,9 and activity X3,13 in the tableau. When subtracted from the initial asset position the latter objective function is interpreted as the growth of the firm over the 15 year period.

Enterprise budgets for cotton and grain sorghum were used in construction the income producing activity. Coefficients of the productive activity in the transformation matrix were constructed by weighting the appropriate items in the cotton and grain sorghum budgets by .35 and .65 respectively. The firm was assumed to purchase machinery in units, each of which is defined as a dollar's worth of homogeneous machinery of constant productivity. Similarity of productive methods for cotton and grain sorghum was the basis for this assumption. All charges for machinery except the cost of machinery capital are carried in the productive activity. Machinery selling was possible with the salvage price of average machinery set at two-thirds the credit reserve necessary to secure it. Land was assumed to be purchased on a 20 year contract. Constant yearly payments of $20.92 were required to retire the debt amortized over a period of 20 years. For each of the 20 yearly payments the average interest
cost was $8.42 and the average principal retired was $12.50. If more years would have been included in the model the actual interest costs and principal retired for each year would have been used instead of the average. Realism in this case was sacrificed in favor of an attempt to make the model representative for farm owners of all ages with initial assets similar to those assumed in the model, not those with just 15 years to retirement. Provision for income tax and consumption withdrawals from the credit reserve was also included in the multi-period model. Withdrawal for tax and consumption was assumed to be $.65 of every dollar of net income above the $3,000 constant value of the consumption function. The actual consumption function, for disposable income (net income less tax), can be derived as follows:

\[
\begin{align*}
W_c &= .40 (I) = C \\
W_t &= .25 (I) \\
\text{and} & \quad C = b (1-W_t) \\
.40 (I) &= b [1-.25 (I)] \\
\text{or} & \quad b = .40 = .533 \\
\end{align*}
\]

where \( \text{I} \) = net income -3000

\( W_c \) = withdrawal from net income for consumption

\( W_t \) = withdrawal from net income for tax

\( C \) = amount of variable income after taxes consumed

\( b \) = marginal propensity to consume income after taxes.

The consumption function in terms of disposable income is then:

\[
C = 3,000 + .533 (1-W_t)
\]
Gross income from the two crops, cotton and grain sorghum, and expenses incurred in the production of the two crops are carried forward from the year in which production takes place to the subsequent year through transfer equations and activities. It is in these transfer equations that the stochastic element of the model is made operational. In table I the betas and gammas on the coefficients of the transfer activities represent a correction factor that is generated from the yields distributions assumed for cotton and grain sorghum. The method of deriving these coefficients from the assumed distributions is the subject of the next section of the paper.

One final note should be made in regard to the format of the firm decision model as illustrated in Table I. This is a perfect knowledge model. Since the equations are solved simultaneously the decision making unit portrayed in the model is in effect in the position of allocating resources on the basis of variable yields but with perfect knowledge of the exact yield on any given year within the model. Estimated firm growth, therefore, may be somewhat high since within the model the decisions are made with perfect knowledge. An alternative model could be formed with decisions being made on less than perfect knowledge to estimate any difference type in conclusions that might occur. A method for formulating and solving the model suggested above will be presented later.

II. The Stochastic Element of the Multi-Period Programming Model

The parameters of the decision model that are postulated as probability distributions are cotton and grain sorghum yields. The
implicit assumption is that most of the variability associated with the operation of the farm firm in the High Plains dryland area results from the variability of yields. Possibly a simple example of the type of problem that results from the assumption of variable yields will serve to clarify the nature of model actually solved within the study. The problem is of the form:

\[
\text{Max } P_1X_1 + P_2X_2 + P_3X_3 + \cdots + P_nX_n
\]

Subject to

\[
\begin{align*}
A_{11}X_1 + A_{12}X_2 + \cdots + A_{1n}X_n &\leq C_1 \\
A_{21}X_1 + A_{22}X_2 + \cdots + A_{2n}X_n &\leq C_2 \\
&\vdots \\
A_{m1}X_1 + A_{m2}X_2 + \cdots + A_{mn}X_n &\leq C_m
\end{align*}
\]

and \(X_i \geq 0\) for \(i = 1, 2, \ldots, n\).

In essence the alteration that makes the model stochastic is the assumption that some of the \(A_{ij}\)'s are not constants but that they are density functions. Suppose in this simple model the coefficient \(A_{11}\) is assumed to have the distribution \(N(A_{11}, \sigma_{A_{11}})\). This could be written equivalently as \(A_{11} + \mu\) where \(\mu\) is distributed as \(N(0,1)\).

Thus, the stochastic linear programming model is similar to the ordinary linear programming model except that some of the \(A_{ij}\)'s have probability distributions. The solution of linear programming models that have stochastic elements in the transformation matrix is somewhat difficult, especially for large models. In fact, at present there exist no general techniques for finding optimum solutions.
to problems of this type.\textsuperscript{19} One method of approximating solutions to these stochastic problems is simulation.\textsuperscript{20} This is a method whereby the problem is solved a number of times, each time with the stochastic elements in the transformation matrix at a specific value generated from the assumed probability distribution by a random draw. This method will yield an approximation to the exact solution of the problem whose preciseness is a function of the number of times the problem is solved or repeated. Convergence of the approximate solution to the true solution depends upon the particular model involved.

As noted earlier, the yields are assumed to be the stochastic elements in this analysis. To solve the stochastic programming problem by simulation or the Monte Carlo Method, it is necessary to formulate a method for randomly drawing specific yields from the assumed distributions associated with them. This procedure is outlined in some detail below. The assumed distributions of crop yields used in the analysis were based on empirical series gathered at the Lubbock Agricultural Experiment Station. Soil, moisture, temperature and growing season at Lubbock are representative of the study area. The initial yield series was multiplied by a set of


constant prices, $1.50 per hundredweight for grain sorghum, $29.00 per hundredweight for cotton lint, and $45.00 per ton for cotton seed and corrected for the harvest and hauling costs that are based on the amount of the crop harvested or the yield of the crop. The yield series had been collected over a period of 31 years, 1927 through 1957.\textsuperscript{21} The mean and variance for the grain sorghum series were $22.04/acre and 163.92/acre respectively. The cotton mean was $51.34/acre and the variance was 710.90/acre. Since cotton and grain sorghum yields are both linked by a mutual cause, weather, the yields must be considered as a bivariate distribution and another parameter, the correlation coefficient, is necessary. The correlation coefficient was estimated from the two yield series as 48.

The procedure of generating varieties from particular probability distribution is based on one of the fundamental theorems of theoretical statistics. The theorem is: "any density for a continuous variate $x$ may be transformed to a uniform density $f(y) = 1$ for $0 < y < 1$ by letting $y = G(x)$, where $G(x)$ is the cumulative distribution of $x$".\textsuperscript{22}

The implications of this theorem for the generation of variates from specified distributions stems from the fact that the inverse of this theorem is true for most types of distributions. Unfortunately, the inverse cannot be stated as generally as the theorem and will

\textsuperscript{21}For more detailed description of the procedure used in constructing the yield series see S. R. Johnson and K. R. Tefertiller, Estimating the Influence of Diversification on Farm Income Variability, Texas Agricultural Experiment Station, M.P. 751, December 1964.

have to be done specially for distributions assumed in the model. The basic type of distribution that is assumed for generation of the observations for the multi-period model is a bivariate normal distribution. The procedure developed below for generating the variates from the specific distributions consists of two steps. In step one, the method of starting with two variates from a rectangular distribution and arriving at two deviates from a standard normal distribution is outlined. In step two, the two standard normal deviates generated in step one are transformed into deviates of the bivariate normal distribution of the mean variance suggested by the empirical data gathered in regard to this particular problem.

Step One:

It is advantageous to start the process of generation of variates from the rectangular distribution. The advantage stems from the (almost obvious) relationship between the rectangular distribution and random numbers. The characteristic of the rectangular distribution that suggests its relationship to random or pseudo random numbers is illustrated below. Given

\[ f(y) = 1, \text{ for } 0 < y < 1 \]

The probability of drawing an observation from the interval \((a,b)\) is exactly equal, regardless of the position of the interval on the \((0,1)\) portion of the \(y\)-axis. In essence all this means that the probability of selecting the interval in one position is equivalent to that of selecting the interval in any other position. Now it follows that the relationship between random numbers and the rectangular
distribution of unit length is that every random number is a variate of the unit rectangular distribution. The interval \((a, b)\) or probability of generating a particular number is then a function of the precision specified or synonymously the number of relevant places to the left of the decimal. Therefore, in finding the function necessary to transform a variate of a unit rectangular distribution into a variate of a standard normal distribution a method is automatically generated that will transform a random number into a variate of a standard normal distribution. Recall that at the outset the objective was to generate deviates of a standard normal distribution. An efficient method of achieving this objective is outlined below.

"Let \(U_1, U_2\) be independent random variables (random numbers) from the same rectangular density function (distribution) on the interval \((0,1)\). Consider the random variables:

\[
Y_1 = (-2 \log_e U_1)^{1/2} \cos 2\pi U_2 \\
Y_2 = (-2 \log_e U_1)^{1/2} \sin 2\pi U_2
\]

Then \((Y_1, Y_2)\) will be a pair of independent random variables from the same normal distribution with mean zero and unit variance."\(^{23}\)

This conclusion can be demonstrated in the following manner. From the above equations the following inverse relationships can be obtained.

\[
U_1 = e^{-\left(\frac{Y_1^2 + Y_2^2}{2}\right)}
\]

\[ U_2 = -\frac{1}{2\pi} \arctan \frac{Y_2}{Y_1} \]

It follows that the joint density of \( Y_1, Y_2 \) is:
\[ f(Y_1, Y_2) = \frac{1}{2\pi} e^{-\frac{(Y_1 + Y_2)^2}{2}} \cdot \left( \frac{1}{2\pi} e^{-\frac{Y_2^2}{2}} \right) = f(Y_1) \cdot f(Y_2) \]
or that \( Y_1 \) and \( Y_2 \) are two independent standard normal deviates. 24

**Step Two:** 25

Given the two standard normal deviates \( y \sim N(0, I_n) \) from above, find the variates that represent the distributions that were hypothesized for the crop yields. "Let \( y \) be distributed \( N(0, I_n) \) (\( I_n \) is the unit matrix of size \( n \)) and let \( X = Cy \). Then \( x \) is distributed \( N(0, \Sigma) \)." 26

Now let \( \Sigma \) be equal to \( \Sigma \) (the variance-covariance matrix derived from the empirical observations of crop yields).

\[
\begin{bmatrix}
  a_{11} & a_{12} & \ldots & a_{1n} \\
  a_{21} & a_{22} & \ldots & a_{2n} \\
  \vdots & \vdots & \ddots & \vdots \\
  a_{n1} & a_{n2} & \ldots & a_{nn}
\end{bmatrix}
\]


25 Matrix notation is used in this exposition. It lends to the simplicity and generality.

The matrix CC' is unique and readily determined if we choose C to be lower triangular.

Example: Suppose we want to generate \( \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \) with mean \( \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \) and variance-covariance matrix

\[
\begin{pmatrix}
\sigma_1^2 & \rho \sigma_1 \sigma_2 \\
\rho \sigma_2 \sigma_1 & \sigma_2^2
\end{pmatrix}
\]

Let \( C = \begin{pmatrix}
\sigma_1 & 0 \\
\rho \sigma_2 & \sigma_2 \sqrt{1-\rho^2}
\end{pmatrix} \)

Following the procedure outlined above

1. Generate \( \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} \sim N(0, I_n) \) (Two standard normal deviates)
2. Let \( x_1 = \sigma_1 y_1 + u_1 \)
3. Then \( \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \sim N \left( \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}, \begin{pmatrix}
\sigma_1^2 & \rho \sigma_1 \sigma_2 \\
\rho \sigma_2 \sigma_1 & \sigma_2^2
\end{pmatrix} \right) \)

By programming the suggested routine on a computer and utilizing some technique of generating the random numbers (pseudo-random numbers) within the machine, it is possible to start with the two empirically estimated distributions and generate literally an unlimited number of variates. Clearly, then the only remaining operation necessary
is fitting the observations generated from by the method outlined above for the multi-period decision model. This is done merely by expressing generated variates as a percentage of their respective means. After the generated variates are expressed as percentages of their respective mean they become the betas and gammas used to "correct" the gross income from operation of the farm firm as it is carried forward from one year to the next.

III. Exponential Smoothing Serial Correlation in Yields, and Optimal Decisions For Firm Growth

One of the objectives of the analysis was to attempt to determine the nature of the effect of serially correlated yields for the two crops on the optimal growth path of the farm firm. Much of the criticism that has been directed at farm management research -- especially in the Great Plains -- has as its basis the fact that most of the farm management research has failed to take this fact into account.27 Researchers, usually, select by some means or another an average and in doing so completely disregard any effect that serial correlation in yields of even prices might have on the conclusions or their analysis.

Examination of the yield series used in this analysis suggested the existence of serial correlation. Note in Figure 1. The non-random character of the shift through time from relatively good to relatively poor years is taken as evidence of serial correlation.

Due to this evidence of serial correlation at attempt was made to introduce it into the yield generation mechanism and to examine its effect on the movement of the firm through time. The technique utilized for introducing the auto-correlation is exponential smoothing.\(^{28}\)

Essentially, it is just a rather crude but quite operational method for introducing a systematic relationship between years. The technique of exponential smoothing has been used quite successfully in inventory and analysis and other problems of industrial engineering concerned with time series and forecasting.

Again it may be useful to set forth a simple example prior to superimposing the technique on the method used to generate the specific values of the transformation matrix coefficients used in solving the stochastic programming problem.

Let the definition of the smoothed function of an observation be:\(^{29}\)

\[
S_t(X) = \phi X_t + (1 - \phi) S_{t-1}(X)
\]

where: \(\phi = \) smoothing constant

\(X_t = \) the observation or variate in period \(t\)

\(t = 1, 2, \ldots, n\) and \(n = \) number of periods.

The expected value of this function: \(E[S(X)]\) is \(E(X)\) and thus smoothing scheme does not destroy the theoretical structure of the model. When this technique is altered slightly and superimposed


\(^{29}\)Ibid., (Brown), p. 100-102. The entire discussion parallels the noted passage in Brown quite closely.
FIGURE 1. YIELDS OF GRAIN SORGHUM AND COTTON GRAPHERD WITH TIME AS EVIDENCE OF HYPOTHESIS CONCERNING SERIES OF 'GOOD' AND 'BAD' YEARS.
upon the method of generating variates from the bivariate distribution assumed in the model, the following modification is achieved. Note that the smoothing technique has been employed so that the means of the distributions from which $X_{1t}$ and $X_{2t}$ are drawn reflect the previous draws $X_{t-1}, 1$ and $X_{t-1}, 2$.

As before:

$$X_1 = \sigma_1 Y_1 + U_1$$
$$X_2 = \rho_2 Y_1 + \sigma_2 \sqrt{1-\rho^2} Y_2 + U_2$$

and then

$$X_{1t} = \sigma_1 Y_1 + U_1 + (1-\alpha) X_{1t-1}$$
$$X_{2t} = \rho_2 Y_1 + \sigma_2 \sqrt{1-\rho^2} Y_2 + \alpha U_2 + (1-\alpha) X_{2t-1}$$

where the second subscript on the $X$'s refers to the time period for which this variate is generated.

The estimation of the value of the smoothing coefficient from the empirical data used as a background is not particularly difficult. The definitional equation can be solved for $\alpha$.

First rewrite the definitional equation

$$S_t (X) - S_{t-1} (X) = \alpha [X_t - S_t - 1 (X)]$$

and

$$\alpha = \frac{S_t (X) - S_{t-1} (X)}{X_t - S_{t-1} (X)}$$

Search through the data for a group of observations that are of approximately the same magnitude. Let this series be $X_{t-1}$ and its mean be $S_{t-1} (X)$. Form another series of the observations that are lagged one time period
from each observation in the initial series $X_t$. Let the mean of $X_t$ be $S_t(X)$ and utilize this information from these two series to approximate the value $\sigma_t$. Estimated values for $\sigma_t$ that were found in the yield series were consistently between .9 and .7. Thus, these values were chosen as those to be included in the simulation analysis of the firm.

IV. Summary and Suggested Interpretations of Results.

In simulating the behavior of the farm firm in the high plains of Texas through time the objective was to gain some insight into the particular factors (cited in the introduction) that influenced the ability of the firm to accumulate assets or gain in net worth (defined as growth). Due to the high variability of yields in the area it was concluded that an analysis of the growth process that left this factor out would have little practical value. The inclusion of a method to account for yield variability in the multi-period decision model for the firm caused it to be stochastic. Since a linear programming model was chosen to approximate the multi-period decision model hypothesized, there appeared the problem of solving a stochastic linear programming problem. Due to the rather low precision demands on the results and the fact that no simple logarithm was available for the solution of this problem a decision was made to approximate its solution by what is called the Monte Carlo Method. The results of this stochastic model or its solutions are in terms of probability distributions. One of the major results of the study is attained by a systematic comparison of the respective means and variances of these solutions. By evaluating these solutions insight can be gained about relative importance of the
factors that contribute to growth or the ability of the firm to increase in net worth. Once the model is formed the only limit to the precision and number of tests of this type performed is computer time.

Another type of test that may be used to summarize the results of the simulation of firm behavior is one which may help to gain insight into the type of functional relationship that exists between the factors hypothesized as affecting firm growth. In abstract terms growth \( X \) may be postulated as being a function of several factors, say \( a, b, \ldots, z \), so that it might be written

\[
X = f(a, b, \ldots, z).
\]

By solving the simulation model of the firm it is possible to approximate the surface that is represented by the function either in its totality or in part. For example it may be quite interesting and useful to know the relationship that exists between the constant of the Keynesian type consumption function, the marginal propensity to consume and the ability of the firm to accumulate assets over time with other factors held constant in the growth function. This surface might reveal some information of significant value for both farmers and policy makers. Other such partial functional relationships are possible. Some of these are approximated with a few points in the following section on the results.

The two types of tests suggested here have certainly not exhausted the possibilities that exist. They just seem to be the more obvious and are unique to this particular formulation of the problem. Other data generated in the solution of the simulation model may prove to be more useful. However, the point to be made here is that the type of results suggested above are a step beyond those that farm manage-
ment people seem to be offering policy makers and farmers today.

PRELIMINARY RESULTS

Data obtained from successive solutions of the simulated multi-period model are presented below for some of the firm situations examined. Accumulated wealth is used as the criterion for evaluation of the results. Other variables in the solution such as land purchases, net income to the firm per year, consumption and etc. have stochastic terms associated with them and, in fact, may merit interpretation as results of the study. However, the discussion here is limited to the ability of the firm to accumulate wealth over time which is, according to the definitions used in this analysis, the prime consideration in describing the growth of firms over time. The results are presented in two parts. First, the results of four firm situations selected for discussion are set out and summarized. Then, a comparison of these firm situations is made as a basis of indicating the relevance of this type of information for growth decisions of High Plains Dryland farmers. Although quite possible no statistical tests are performed on the results. The results are presented in crude form and mainly with the objective of indicating the types of information that the model is capable of producing.

Situation 1

The firm simulated in connection with this first situation is characterized in the following assumptions.
(1) Initial asset position: 320 acres of land owned and $50,000 of credit reserve.

(2) Consumption function: \( Y = a + bX, \ a = \$3,000 = \) subsistence level of consumption, \( b = .533 = \) marginal propensity to consume net income after taxes.

(3) Income tax rate: the average tax rate on net farm income was assumed to be 25 percent.

(4) Technical relationships within the firm: these are characterized in Table I.

(5) Investment policy: each dollar invested by the firm was assumed to be backed by one dollar of credit reserve -- no borrowing on the anticipated crop was permitted.

(6) Crop yields and variability: both cotton and grain sorghum yields were assumed to be distributed normally with the means, variances and correlation coefficient - indicated in the previous section. The smoothing coefficient was entered at the levels 1.0, .9, .7, -- .7 indicating the highest degree of serial correlation.

(7) Objective function or behavioral assumption for firm operator: maximization of accumulated wealth.

The 15 year model of the farm firm described by the above characteristics was solved 20 times using yield variates generated from the assumed distributors to find an approximation of the true solution. Only a limited number of replications were needed to approximate the solution with reasonable accuracy. The rather easy approximation of the solution was probably a function of the limitations on the decision set of
the firm operator. A summary of the yearly solutions to the multi-period stochastic model representing this situation is presented in Table 2. In this table, the yearly expected accumulation of wealth is presented along with its standard deviation for the firm under each of three levels given the exponential smoothing coefficient. Appearing in the last column of the table is yearly tally of the increase in wealth when the means of distributions of cotton and grain sorghum are inserted as the realized yields for each year. The solution of the firm model under these conditions will be treated as a control in the presentation of the results. A comparison of the yearly means for each level with the control serves as a measure of the reduction in the ability of the firm to grow caused by the introduction of yield variability. The reflection of yield instability on the accumulation process is particularly evident in the years 10 to 15. Variability of expected yearly accumulation represented by the three standard deviation columns in Table 2, is surprisingly similar for each of the levels of $\phi$. Apparently the effect of serial correlation on the multi-period growth model as depicted in this situation is almost negligible. Also, note that the ratio of the mean to the standard deviation decreases at the number of years increase. This is due to the fact that the model is recursive. The recursiveness of the model causes the effect of yield variability to be compounded as the number of years increases. Another rather subtle fact revealed in the data from the model is concerned with the constant value within the consumption function. It is interesting to speculate as to the reason for the increasing yearly additions to the wealth accumulated by
the firm. The magnitude of the constant term in the consumption function which represents a constant capital withdrawal seems to contribute substantially to this uneven increase in wealth accumulation. This conclusion is not particularly apparent in the results presented. However, it results from the fact that in the beginning years the constant withdrawal is almost of the same magnitude as net income after tax. Results of both stochastic and non-stochastic multi-period growth models seem to be quite sensitive to constant capital withdrawals. The prominence of this factor in the accumulation process becomes even more evident as the results of subsequent firm situations are examined. In Figure 2, the growth or accumulated wealth for both the simulated and control firm is plotted against the years within the model for comparison and to illustrate the effect of instable yields on the solution of the model. Fluctuations in first few years in this figure should be discounted since they are primarily due to a peculiarity in the formulation of the model—the fact that no machinery was included in the initial assets of the firm. Finally, the data summarized in Figure 2 can be used as an alternative basis for inferences regarding the importance of serial correlation in yields on the ability of the firm to accumulate wealth over time. The failure of the means associated with each of the yearly levels of accumulated wealth could be taken as strong evidence in support of a hypothesis that serial correlation in yields is a somewhat insignificant consideration for farm firms as they move over time. Again, strong conclusions must be tempered by the fact that the decision set of the firm was severely restricted.
Table 2, Summary of the Simulation Results for the Farm Firm Characterized by Situation I.

<table>
<thead>
<tr>
<th>Year</th>
<th>Accumulated Wealth = 1</th>
<th>Accumulated Wealth = 0.9</th>
<th>Accumulated Wealth = 0.7</th>
<th>Accumulated Wealth X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>1</td>
<td>$49,271</td>
<td>$2,438</td>
<td>$49,141</td>
<td>$3,235</td>
</tr>
<tr>
<td>2</td>
<td>50,002</td>
<td>4,679</td>
<td>50,988</td>
<td>5,015</td>
</tr>
<tr>
<td>3</td>
<td>49,450</td>
<td>4,109</td>
<td>50,829</td>
<td>6,750</td>
</tr>
<tr>
<td>4</td>
<td>51,592</td>
<td>3,625</td>
<td>51,311</td>
<td>8,370</td>
</tr>
<tr>
<td>5</td>
<td>53,745</td>
<td>7,704</td>
<td>52,604</td>
<td>10,715</td>
</tr>
<tr>
<td>6</td>
<td>56,601</td>
<td>8,734</td>
<td>53,761</td>
<td>11,795</td>
</tr>
<tr>
<td>7</td>
<td>56,557</td>
<td>9,066</td>
<td>56,893</td>
<td>13,335</td>
</tr>
<tr>
<td>8</td>
<td>57,989</td>
<td>11,175</td>
<td>58,509</td>
<td>16,875</td>
</tr>
<tr>
<td>9</td>
<td>59,275</td>
<td>10,560</td>
<td>61,219</td>
<td>18,405</td>
</tr>
<tr>
<td>10</td>
<td>61,035</td>
<td>13,279</td>
<td>64,207</td>
<td>23,155</td>
</tr>
<tr>
<td>11</td>
<td>64,914</td>
<td>16,232</td>
<td>64,912</td>
<td>26,140</td>
</tr>
<tr>
<td>12</td>
<td>67,875</td>
<td>18,789</td>
<td>69,443</td>
<td>29,380</td>
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<tr>
<td>13</td>
<td>72,146</td>
<td>22,728</td>
<td>71,598</td>
<td>29,685</td>
</tr>
<tr>
<td>14</td>
<td>78,421</td>
<td>30,768</td>
<td>82,640</td>
<td>42,805</td>
</tr>
<tr>
<td>15</td>
<td>83,988</td>
<td>31,668</td>
<td>87,262</td>
<td>48,045</td>
</tr>
</tbody>
</table>

1) This column contains results of the multi-period model with mean yields inserted for each year and is treated as a control in this description.
Figure 2. Accumulated credit reserve over 15-year period for three levels of serial correlation and a control.
Situation II.

In situation II, only one of the assumed characteristics for the model just discussed is altered. Results evident in the data generated in connection with situation I were in regard to the nature of the yearly accumulation of wealth. In this situation, the initial asset position is doubled and the effect of this change, on the ability of the firm to accumulate wealth over time is observed. (The initial asset position is now 640 acres of land and $160,000 credit reserve).

Data generated for the firm described by these characteristics is summarized in Table 3. Results are much the same as they were in situation I. Again, the existence of auto-correlation in the yields seems to have relatively little effect on the firm's ability of the firm to accumulate wealth over time. The increased initial position of the firm reduces the impact of the constant withdrawal for consumption and the accumulation process proceeds in somewhat the same fashion as before but more smoothly.

Situation III.

In both previous situations, a rather liberal investment policy was assumed for the farm firm. In the firm characterized in the assumptions set out below a more conservative investment policy is postulated. The firm was assumed to have the following characteristics:

(I) Initial asset position: 320 acres of land, $50,000 credit reserves.

(2) Consumption function \( Y = a + bX \), \( a + $3,000 = \) subsistence level consumption, \( b = .533 = \) marginal propensity to consume net income after taxes.
(3) Tax Rate: average tax rate of 25 percent on net income.

(4) Technical relationships within firm: characterized by the coefficients in Table 1.

(5) Investment Policy: each dollar borrowed for production purposes is backed by 2 dollars of credit reserve.

(6) Crop yields and variability: both cotton and grain sorghum were assumed to be normally distributed with the means, variances and correlation coefficient indicated above. The coefficient $\phi$ was set at 1.0, .9, and .7.

(7) Objective function: Firm operator was assumed to be maximizing accumulated wealth.

This firm follows an investment policy which would always insure enough credit reserve to sustain an operation of a given size for a two year period. This strategy was quite common among the dryland farmers interviewed in connection with this study in the High Plains. Information generated in connection with this firm is presented in Table 4. Ten replications of the model were used to compute the data for the analysis of this firm situation. The reduction in the ability of the firm to grow as a result of the more conservative investment policy is substantial. In fact, in the initial years the capital withdrawal (due to the constant value in the consumption function) caused the firm growth quite slowly. The fact that this is a perfect knowledge model detracts considerably from the ability to interpret the differences in results that appear to be due to alternative investment policies. As the knowledge of the realized yields in subsequent years decreases the merits of this investment policy in relation to the previous
Table 3, Summary of the Simulation Results for the Farm Firm Characterized by Situation II

<table>
<thead>
<tr>
<th>Year</th>
<th>Accumulated Wealth $a = 1$</th>
<th>Accumulated Wealth $a = .9$</th>
<th>Accumulated Wealth $a = .7$</th>
<th>Accumulated Wealth $X$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Standard Deviation</td>
<td>Mean Standard Deviation</td>
<td>Mean Standard Deviation</td>
<td>Mean Standard Deviation</td>
</tr>
<tr>
<td>1</td>
<td>$101,683$ $4,921$</td>
<td>$101,461$ $6,632$</td>
<td>$101,660$ $4,915$</td>
<td>$101,142$</td>
</tr>
<tr>
<td>2</td>
<td>$106,332$ $9,956$</td>
<td>$107,397$ $11,598$</td>
<td>$106,446$ $9,274$</td>
<td>$105,281$</td>
</tr>
<tr>
<td>3</td>
<td>$109,005$ $8,358$</td>
<td>$111,399$ $13,861$</td>
<td>$108,805$ $8,967$</td>
<td>$110,851$</td>
</tr>
<tr>
<td>4</td>
<td>$116,506$ $12,690$</td>
<td>$115,829$ $13,297$</td>
<td>$117,205$ $13,210$</td>
<td>$111,933$</td>
</tr>
<tr>
<td>5</td>
<td>$124,717$ $16,386$</td>
<td>$122,213$ $22,474$</td>
<td>$125,638$ $16,510$</td>
<td>$123,620$</td>
</tr>
<tr>
<td>6</td>
<td>$138,194$ $18,842$</td>
<td>$128,372$ $25,298$</td>
<td>$135,260$ $19,807$</td>
<td>$131,036$</td>
</tr>
<tr>
<td>7</td>
<td>$138,161$ $19,833$</td>
<td>$134,495$ $28,990$</td>
<td>$139,345$ $20,315$</td>
<td>$139,338$</td>
</tr>
<tr>
<td>8</td>
<td>$145,202$ $23,397$</td>
<td>$147,166$ $37,525$</td>
<td>$145,944$ $23,420$</td>
<td>$148,738$</td>
</tr>
<tr>
<td>9</td>
<td>$152,560$ $24,167$</td>
<td>$156,333$ $41,938$</td>
<td>$153,659$ $26,638$</td>
<td>$159,518$</td>
</tr>
<tr>
<td>10</td>
<td>$158,740$ $30,138$</td>
<td>$171,777$ $53,535$</td>
<td>$161,674$ $32,655$</td>
<td>$172,077$</td>
</tr>
<tr>
<td>11</td>
<td>$175,771$ $38,736$</td>
<td>$175,120$ $60,655$</td>
<td>$178,028$ $41,300$</td>
<td>$186,986$</td>
</tr>
<tr>
<td>12</td>
<td>$188,219$ $47,781$</td>
<td>$194,673$ $66,750$</td>
<td>$190,877$ $52,005$</td>
<td>$205,101$</td>
</tr>
<tr>
<td>13</td>
<td>$204,239$ $56,899$</td>
<td>$204,338$ $67,750$</td>
<td>$209,686$ $60,695$</td>
<td>$227,778$</td>
</tr>
<tr>
<td>14</td>
<td>$227,158$ $79,482$</td>
<td>$237,074$ $105,075$</td>
<td>$230,774$ $82,290$</td>
<td>$257,306$</td>
</tr>
<tr>
<td>15</td>
<td>$248,492$ $88,225$</td>
<td>$256,919$ $121,050$</td>
<td>$254,493$ $88,305$</td>
<td>$297,521$</td>
</tr>
</tbody>
</table>

1) This column contains results of the multi-period model with mean yields inserted for each year (non-stochastic) -- treated as a control.
Table 4, Summary of Simulation Results for the Farm Firm Characterized by Situation III

<table>
<thead>
<tr>
<th>Year</th>
<th>Accumulated Wealth = 1 Mean</th>
<th>Standard Deviation</th>
<th>Accumulated Wealth = .9 Mean</th>
<th>Standard Deviation</th>
<th>Accumulated Wealth = .7 Mean</th>
<th>Standard Deviation</th>
<th>Accumulated Wealth Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$48,467</td>
<td>$2,390</td>
<td>$48,747</td>
<td>$3,116</td>
<td>$49,467</td>
<td>$4,253</td>
<td>$48,483</td>
</tr>
<tr>
<td>2</td>
<td>48,063</td>
<td>3,085</td>
<td>50,888</td>
<td>5,860</td>
<td>48,587</td>
<td>3,622</td>
<td>49,162</td>
</tr>
<tr>
<td>3</td>
<td>48,131</td>
<td>3,605</td>
<td>50,919</td>
<td>6,215</td>
<td>48,187</td>
<td>3,869</td>
<td>49,943</td>
</tr>
<tr>
<td>4</td>
<td>49,364</td>
<td>4,930</td>
<td>51,525</td>
<td>7,214</td>
<td>49,613</td>
<td>5,263</td>
<td>50,841</td>
</tr>
<tr>
<td>5</td>
<td>51,614</td>
<td>5,675</td>
<td>51,836</td>
<td>7,695</td>
<td>52,048</td>
<td>5,745</td>
<td>51,877</td>
</tr>
<tr>
<td>6</td>
<td>51,035</td>
<td>5,210</td>
<td>52,594</td>
<td>8,060</td>
<td>52,499</td>
<td>5,867</td>
<td>53,075</td>
</tr>
<tr>
<td>7</td>
<td>52,768</td>
<td>5,480</td>
<td>52,241</td>
<td>8,565</td>
<td>53,420</td>
<td>5,965</td>
<td>54,465</td>
</tr>
<tr>
<td>8</td>
<td>53,957</td>
<td>7,550</td>
<td>55,567</td>
<td>13,170</td>
<td>54,534</td>
<td>7,144</td>
<td>56,086</td>
</tr>
<tr>
<td>9</td>
<td>55,461</td>
<td>8,675</td>
<td>56,827</td>
<td>13,850</td>
<td>56,072</td>
<td>8,636</td>
<td>57,989</td>
</tr>
<tr>
<td>10</td>
<td>56,435</td>
<td>11,130</td>
<td>59,245</td>
<td>15,420</td>
<td>56,804</td>
<td>11,616</td>
<td>60,242</td>
</tr>
<tr>
<td>11</td>
<td>56,995</td>
<td>10,670</td>
<td>60,451</td>
<td>20,045</td>
<td>58,439</td>
<td>11,190</td>
<td>62,935</td>
</tr>
<tr>
<td>12</td>
<td>58,549</td>
<td>12,155</td>
<td>61,703</td>
<td>20,795</td>
<td>58,247</td>
<td>12,670</td>
<td>66,187</td>
</tr>
<tr>
<td>13</td>
<td>58,351</td>
<td>11,755</td>
<td>61,041</td>
<td>21,875</td>
<td>58,966</td>
<td>12,999</td>
<td>70,213</td>
</tr>
<tr>
<td>14</td>
<td>58,558</td>
<td>15,265</td>
<td>69,483</td>
<td>33,750</td>
<td>59,546</td>
<td>16,527</td>
<td>75,261</td>
</tr>
<tr>
<td>15</td>
<td>62,439</td>
<td>18,085</td>
<td>72,388</td>
<td>37,385</td>
<td>64,357</td>
<td>20,402</td>
<td>81,693</td>
</tr>
</tbody>
</table>

1) This column contains results of the multi-period model with mean yields inserted for each year and is treated as a control.
one in situations I and II would be expected to increase. However, this situation does make quite evident the limitation placed on growth potential by such conservation investment policies.

In general, the results of this situation are much like those of the two previous models. There is a reduction in the growth of the firm due to the instability of yields. The magnitude of this difference can be estimated by comparing the approximated solutions of the stochastic models in Table 4 to the solution of the control. Serial correlation in the yield data seems as before to have little effect on the accumulation of wealth or its variance.

Situation IV

The initial asset position is increased to 640 acres of land and $100,000 credit reserve for this situation. All other characteristics are the same as those in Situation III. Data related to this situation are summarized in Table 5. Results are quite similar to those of the previous situation. The limiting effect of the more conservative investment policy is easily seen. This situation was included mainly so that it could be used as a comparison in the following section. Results of other situations could be easily obtained from the model. Those presented have just been some of the more basic situations.

Comparison:

Some of the information presented in connection with each of the firm situations is drawn together here as a means of indicating the method of constructing the response surfaces described at the
end of the section on the analytical technique. Data presented here may be of limited practical value since the four firm situations considered provide only a very limited number of points on each surface. For a given yield assumption ($\alpha = 1$ in this case) the relationship between investment policy, initial asset position and growth or accumulated wealth would seem to hold economic significance. Information from the firm situations applicable to this surface is:

<table>
<thead>
<tr>
<th>Point</th>
<th>Initial Asset Position</th>
<th>Investment Policy</th>
<th>Accumulated Wealth Over the 15 year Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>320 Acres, $50,000 credit reserve</td>
<td>1:1</td>
<td>$83,988</td>
</tr>
<tr>
<td>2</td>
<td>640 Acres, $100,000 credit reserve</td>
<td>1:1</td>
<td>248,855</td>
</tr>
<tr>
<td>3</td>
<td>320 Acres, $50,000 credit reserve</td>
<td>1:2</td>
<td>62,439</td>
</tr>
<tr>
<td>4</td>
<td>640 Acres, $100,000 credit reserve</td>
<td>1:2</td>
<td>190,188</td>
</tr>
</tbody>
</table>
Table 5, Summary of Simulation Results for the Farm Firm Characterized by Situation IV

<table>
<thead>
<tr>
<th>Year</th>
<th>Accumulated Wealth = 1 Mean</th>
<th>Standard Deviation</th>
<th>Accumulated Wealth = .9 Mean</th>
<th>Standard Deviation</th>
<th>Accumulated Wealth = .7 Mean</th>
<th>Standard Deviation</th>
<th>Accumulated Wealth = X Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$100,299</td>
<td>$4,845</td>
<td>$100,603</td>
<td>$6,357</td>
<td>$100,799</td>
<td>$4,845</td>
<td>$100,052</td>
</tr>
<tr>
<td>2</td>
<td>102,408</td>
<td>6,260</td>
<td>108,220</td>
<td>12,072</td>
<td>102,745</td>
<td>6,150</td>
<td>104,610</td>
</tr>
<tr>
<td>3</td>
<td>105,803</td>
<td>7,475</td>
<td>111,595</td>
<td>12,943</td>
<td>106,002</td>
<td>8,080</td>
<td>109,402</td>
</tr>
<tr>
<td>4</td>
<td>111,776</td>
<td>10,190</td>
<td>113,274</td>
<td>12,185</td>
<td>112,300</td>
<td>10,925</td>
<td>114,782</td>
</tr>
<tr>
<td>5</td>
<td>120,176</td>
<td>11,645</td>
<td>120,443</td>
<td>16,192</td>
<td>121,111</td>
<td>11,805</td>
<td>120,514</td>
</tr>
<tr>
<td>6</td>
<td>129,084</td>
<td>13,265</td>
<td>125,636</td>
<td>19,394</td>
<td>130,304</td>
<td>13,730</td>
<td>126,778</td>
</tr>
<tr>
<td>7</td>
<td>130,023</td>
<td>12,710</td>
<td>128,418</td>
<td>18,123</td>
<td>131,087</td>
<td>12,885</td>
<td>133,673</td>
</tr>
<tr>
<td>8</td>
<td>136,452</td>
<td>17,105</td>
<td>140,841</td>
<td>30,653</td>
<td>137,729</td>
<td>17,675</td>
<td>141,328</td>
</tr>
<tr>
<td>9</td>
<td>114,520</td>
<td>20,485</td>
<td>147,384</td>
<td>31,194</td>
<td>146,232</td>
<td>20,425</td>
<td>149,991</td>
</tr>
<tr>
<td>10</td>
<td>147,684</td>
<td>32,025</td>
<td>157,715</td>
<td>35,248</td>
<td>152,319</td>
<td>27,855</td>
<td>159,642</td>
</tr>
<tr>
<td>11</td>
<td>165,505</td>
<td>38,350</td>
<td>165,372</td>
<td>46,655</td>
<td>160,843</td>
<td>27,215</td>
<td>170,822</td>
</tr>
<tr>
<td>12</td>
<td>165,728</td>
<td>40,420</td>
<td>173,362</td>
<td>48,835</td>
<td>167,203</td>
<td>33,830</td>
<td>183,871</td>
</tr>
<tr>
<td>13</td>
<td>171,505</td>
<td>41,102</td>
<td>175,762</td>
<td>52,455</td>
<td>170,720</td>
<td>33,355</td>
<td>199,399</td>
</tr>
<tr>
<td>14</td>
<td>175,632</td>
<td>41,450</td>
<td>203,248</td>
<td>85,070</td>
<td>177,822</td>
<td>44,630</td>
<td>218,320</td>
</tr>
<tr>
<td>15</td>
<td>190,188</td>
<td>51,995</td>
<td>218,862</td>
<td>94,985</td>
<td>197,365</td>
<td>54,855</td>
<td>241,789</td>
</tr>
</tbody>
</table>

1) This column contains results of the multi-period model with mean yields inserted for each year and is treated as a control.
Each of the above combinations of credit reserve policy and initial asset position corresponds to the density function describing a point in the wealth accumulation plane. Other parts on this plane could be estimated by considering firm situations with different investment policies and initial asset positions.

Another comparison which serves to suggest the possible use of the information generated with respect to each of the above situations for firm growth is that between serial correlation in yields, investment policy, and accumulated wealth or growth. Information describing this relationship is:

<table>
<thead>
<tr>
<th>Point</th>
<th>Serial Correlation</th>
<th>Investment Policy</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(\alpha = 1)</td>
<td>1:1</td>
<td>83,988</td>
<td>31,668</td>
</tr>
<tr>
<td>2</td>
<td>(\alpha = .9)</td>
<td>1:1</td>
<td>87,262</td>
<td>48,045</td>
</tr>
<tr>
<td>3</td>
<td>(\alpha = .7)</td>
<td>1:1</td>
<td>86,242</td>
<td>43,280</td>
</tr>
<tr>
<td>4</td>
<td>(\alpha = 1)</td>
<td>1:2</td>
<td>62,439</td>
<td>18,085</td>
</tr>
<tr>
<td>5</td>
<td>(\alpha = .9)</td>
<td>1:2</td>
<td>72,388</td>
<td>37,385</td>
</tr>
<tr>
<td>6</td>
<td>(\alpha = .7)</td>
<td>1:2</td>
<td>64,357</td>
<td>20,402</td>
</tr>
</tbody>
</table>

This information comes from situations I and III which are the same except for credit policy. Although the accumulated capital associated with \(\alpha\) at .9 is somewhat higher in both instances with \(\alpha\) at 1.0 and .7 the means all fall within a rather small range. Again, more estimates of the density functions associated with points on this surface could be found by considering other firm situations.

Generally then, in making these comparisons a method has been indicated that will yield the functional relationship between the factors hypothesized as affecting firm growth. These functional relationships would seem to be useful information for agricultural people at both firm and policy levels.
TENTATIVE CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The conclusions that can be drawn from the results of the analysis are somewhat limited by the unrefined manner in which the results were presented. However, in spite of the lack of statistical tests some rather interesting inferences may be formed from the results in their present form. The failure of the presence of strong serial correlation in yearly yields to substantially effect either the amount of wealth accumulated or its variance over the 15 year span of the model was rather interesting and unanticipated. Constant capital withdrawals seem to be of considerable consequence in the accumulation process. The $3,000 "a" value in the consumption function was large enough to inhibit growth in both of the situations with the smaller initial asset position. Comparison of the solutions for the four situations selected for presentation was sufficient to show that this type of research technique holds possibilities for the estimation of some rather revealing relationships that exist as a result of the interaction of the hypothesized factors effecting farm firm growth. In the comparisons presented the relationships seemed to be intuitively appealing. More conservative investment policies seem to lead to reductions in both potential accumulation and its variation. Again, the importance of the analysis was that it made possible the estimation of the magnitudes of these relationships. With more points, which could be generated by considering more situations, the entire surface could be statistically approximated by some sort of least squares or curve fitting procedure. Probably the most significant conclusions in relation to the multi-period stochastic model lie in the possibility for its use in further research. The model as formulated and solved in
this study has some rather severe practical limitation which are mainly the result of the very unrealistic assumption of perfect knowledge. There is a distinct possibility that with slight alteration this multiperiod stochastic model can be made to represent situations of less than perfect knowledge. Basically this could be accomplished by shortening the time span over which the solutions for individual years within the entire model are calculated. For example, results gained by superimposing a five year moving average type solution scheme upon the entire number of years in this problem could yield results under conditions of less than perfect knowledge. Essentially, the procedure would be to add one year and drop one year off with each progressive sub-solution. Assumed yield expectations of the entrepreneur could be included in all but the first year in which yields would be supplied in the manner used here. Following a procedure of this general format solutions could be gained that would reflect less than perfect knowledge on the part of the firm operation. The fact that this suggested model seems to be rather close to the situation faced by agricultural firms would seem to add to the interest in this type of approach.
OBSERVATIONS AND REFLECTIONS WITH RESPECT TO THE SESSION

By

Ulf Renborg*

By way of introduction, I find that my remarks fall under three headings: (1) criteria for evaluation, (2) observations and reflections, and (3) summary proposals for further work. After merely listing the criteria, I will discuss each in connection with some observations and reflections, after which I will summarize.

Five criteria, I believe, are useful in our evaluation of this seminar on firm growth. The five criteria are:

(1) Work must be on important problems for agriculture and society as a whole.

(2) Work has to be focussed on (a) the growth process and (b) the development of useable (manageable and understandable) decision models for firms that have to grow.1

(3) The models to be developed have to be consistent with economic theory.

(4) The models have to be consistent with reality.

(5) Enough research resources have to be put into the project to solve it within a reasonable time.

*Professor, Department of Agricultural Economics, Agricultural College, Uppsala, Sweden.

1/This means that the objectives for the project, as earlier outlined by the group, have to be met. These objectives are:

(1) Study the ways in which farmers get started and the best strategies for starting.
(2) Investigate the preferable organizational pattern for profitable growth.
(3) Investigate the preferable operational strategies for profitable growth.
(4) Indicate the best combination of ways to get started and of organizing and operating a farm firm for profitable growth.
Importance of Problems

The group here seems convinced that an important problem is being attacked. Thus it has been stated from many sides: (a) that growth is necessary for the farmer to maintain reasonable, i.e. rising, income over time, (b) that our knowledge of the growth process is poor, (c) that the way in which plans are made for farmers today does not stress the growth element enough if at all.

Focus of Work

The U. S. studies that were presented here focus more on the growth process per se, how it operates and its characteristics. to quote from Martin's paper "this is a growth and not a decision model." In contrast, the Swedish group has focussed more on the possibilities to develop manageable decision models on various levels of "refinement."

Martin's and Johnson's studies try to answer two questions: What does the capital accumulation process under certainty and risk in fact look like? and What happens to growth when the initial level of equity capital, the propensity to consume, the yields, etc., all vary? Walker demonstrates how the growth process can be visualized with the help of simulation procedures and operational games, and how these procedures can be used both in teaching and research to indicate important features of growth.

Especially Martin's model can, to my judgment, be easily developed into a decision model. Thus it already has in it the indications on how land and capital have to increase to fulfill the growth goal.
I can see the following possible ways to develop it further:
(a) increasing the number of operating activities to cover
    the important alternative growth directions,
(b) including into the requirements matrix more goal constraints
    (consumption levels, survival standards, etc.),
(c) adjustment costs (nothing but the lack of capital now stops
    the expansion).

The Swedish work is--after some rough empirical studies on the
growth problems of individual firms--focussed on development of use­
able planning methods. It is obvious, however, that we have a long
way to go before the rough outline of possible planning methods is
boiled down to a manageable planning procedure. I see a difference
between U. S. and Swedish studies. You in the U. S. have picked some
technique that you were familiar with and then tried to simulate
(illustrate) a growth process or to develop a decision model. This
has rapidly brought you to the hard facts in calculation. It is,
however, somewhat dangerous as a research approach.

The Swedish group has started by exploring literature in search
for a general planning model and for various possible techniques
to be put into this general model to build a decision model for long
run planning of firms for growth. This means that we have used our
time to explore and have not yet reached the stage of calculating
and experimenting.

Models and Economic Theory

It seems to me that it is difficult to find the theory for
growth of the firm. However, a warning is that our lists of litera-
ture obviously are not yet complete and not yet boiled down to the essence of the "theory of growth": Only 4 out of 26 items in the U. S. list and 4 of the 100 in the Swedish are the same!

This warning—and I think also the various references—indicates that there are still very many valuable "theoretical ideas" or "pieces of theory" that have to be picked up and introduced in our models—no matter if they are models of the growth process or decision models for planning. Examples are:

1. Penrose's ideas on how to find incentives to growth.

2. Harrod-Domar's growth models and the extensions thereof to many sectors (i.e. operating activities) and many factors of production that Tinbergen and Bos have developed.

3. Baumol's growth models where he matches growth profit against expansion costs.

etc.

The concept of growth has to be explored further. We have had several proposals for defining growth as: an increase in total value of resources used; an increase in accumulated wealth; or an increase in total output.

It is obvious that we as yet do not know which is the best goal or objective function for our models. Will we have one function and

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optimize it? If so: What function is the best one to describe the goal or goals? Will we introduce a set of goal standards to be satisfied? If so: What standards and how shall they be determined?

Many problems are still connected with the establishment of the length of the planning period. "Planning in stages" according to Tinbergen-Bos may be of importance for our models. If this is not possible the models will be unmanageable. This, however, is sub-optimization and the effect of it has to be explored. Tinbergen-Bos are optimistic as to the possibilities of using the planning in stages. In this respect Martin's model is well designed but as we have already said maybe too much simplified.

**Models and Reality**

It is necessary to test the models--growth as well as decision models--for reality. Tinbergen-Bos requires that three questions be answered. Are the models complete in the sense that no really important aspects of the growth or planning problem is overlooked? Are they correct in the sense that they are in reasonable agreement with reality? Are the coefficients that go into the model known or can be obtained without too costly work?

Part of this may be achieved through an extensive simulation of the planning environment. Here I think that both Walker's and Johnson's models can give us important possibilities to test for reality. A testbed is needed for both growth and decision models. However, I also think it is necessary to make empirical studies on relevant growth problems (Johnson and the Swedish group have made
this). Other possibilities, especially for decision models: (a) planning of individual firms and following the results (ex post for farms with good accounts or ex ante for pilot or study farms) and (b) "the proof of the pudding is in the eating."

Are the models presented consistent with reality? My feeling is that much work for all of us remains on this point. The various U. S. models are, of course, consistent with the theory for the individual model. The interesting question here, however, is which of these or other possible models show the best consistency with reality. For example, if the planning environment of the agricultural firm is mainly characterized by risk, then Johnson's approach can be important. If it is characterized by uncertainty then the games presented by Walter—probabilities not shown to the players—may be the best starting point for developing decision models.

In this connection I think it is important to point out the necessity—at least for the decision models the Swedish group is trying to develop—the necessity to develop from empirical studies (simulations or other) the goal standards or goal constraints that have to go into the model, i.e. how to decide on consumption levels, on liquidity and flexibility standards, on capital-output rations, adjustment costs, etc.

Research Resources

Here only two questions will be put forward. Will we within reasonable time be able to present manageable growth models and decision models that can have an important impact on the better and better solution of adjustment problems micro and macro of agriculture
with research resources now devoted to this problem? What is the priority to be put on these studies compared with other possible research efforts?

I do not know the answers to these questions. Personally I think that the priority of these types of studies is high and thus I hope that enough resources can be made available for them. I also hope for closer national and international cooperation on this problem. Especially do we need international exchange of models and testbeds of the Johnson or Walter type.

**Summary**

In connection with criterion number two, the focus, I should say the Swedish studies have to be supplemented by experiments for studying the growth process. The U. S. studies have to be focussed also on the development of decision models for firms that have to grow.

In connection with criterion number three, we need more extensive exploration of existing "theoretical ideas" or "pieces of theory." We also need to define the concept of growth. We need to make a theoretical and empirical comparison of possible goal function or functions. We need to define the length of the planning period.

In connection with criterion number four, we need general work on making our models more realistic. We should ask ourselves which models of growth and for decision are most consistent with reality? This includes testing for reality. We must develop goal standards or goal criteria from empirical studies.
In connection with criterion number five, research resources, high priority on these kinds of studies is sufficient reason for asking for research funds. It is also reason for wider national and international cooperation. Why not an international seminar?
WHAT'S AHEAD IN GP-2

By

Warren R. Bailey

This has been a most successful seminar. The papers were excellent, exhibiting careful work; moreover, they complemented each other, thanks to the authors and the coordinating efforts of our program chairman.

Two of the papers develop different operational models for the accumulation of capital and reinvestment in the business firm. Both of them focus on the process of capital accumulation. Both are elementary types as they do not provide for decision making—no choice of production enterprises or processes except the one set that was built into each model. However, both models can be expanded to include enterprise choice and other modifications which we can expect in future versions. Another paper provided a complete outline for the planning process toward achieving growth of the farm business firm. A fourth paper concerned with management games reminded us of the realities within which management decisions are made.

These papers help to set the stage for further research in GP-2 with its new emphasis on firm growth. The new work promises to be both interesting and challenging, and, hopefully will provide a better understanding than we now have of the problems of organizing and managing farms in the Plains.

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1/Economic Research Service. The opinions expressed are not necessarily those of ERS.
As the seminar closes several questions remain unresolved, but I suspect we are not yet ready for definite solutions. One such question is a definition of "growth." Is it volume of output, or amount of resources controlled, or net worth, or some other? While the concept of growth may apply to all of these aspects, they certainly are not synonymous. For example, growth in size of business could be quite different than growth in manager's net worth. Which concept is appropriate in each instance will depend upon the research problem as viewed by the individual researcher. To me it seems inappropriate at this time to narrow the definition of growth. As we move ahead there will also be other definitions and concepts we should strive to sharpen and refine. In future meetings we can return to this question.

Martin asked whether the subject of our GP-2 research is firm growth per se, or risk and uncertainty. We left his question unanswered but I want to speak to it.

While the GP-2 research during the early years was focused on year-to-year variability, the basic subject originally was and still is the organization and operation of farms. The setting of the problem was and still is the Plains environment which is a setting of risk and uncertainty. In a more positive vein, the revised GP-2 regional project associates firm growth with capital accumulation, an important goal of farmers and an objective of organizing and operating a farm. Moreover, the project accepts the growing firm as more realistic than the static firm, for economic analysis. Finally, the project title reads in part, "... establishment, survival, and growth of dryland farms ..."
Emphasis

The old GP-2 recognized the goal of capital accumulation in the form of increasing equity in a farm unchanging in size—essentially a static approach. The new GP-2 adds the concept of firm business growth. This provides a more realistic setting for our research, a setting in which the business firm may grow in size and output over time. Both the process of capital accumulation itself and the problems of enterprise choice and of resource organization take on new dimensions under a dynamic concept of growth, as I will illustrate in a moment. On the other hand, there are abundant reasons for studying growth and the process of growth per se.

Over time, as a consequence of learning, managers grow in skill and capacity for management. For them the optimum size firm may increase. Successful managers acquire earned savings which can be reinvested in the firm itself or invested elsewhere. As equities accumulate, they will support a larger business. On the other hand, mortgage amortization schedules require farm entrepreneurs to save and to accumulate equity capital in land and machines purchased by means of loans. Consequently a moot question is whether today's efficient farms may require more equity in capital investment than a manager can accumulate out of current earnings. Finally, a setting of growth may be more appropriate than a static setting for analyzing the conventional farm management problems: resources organization, enterprise choice, adoption of technology, rate of inputs, financial management, and others.

In addition to emphasizing growth, our new contributing studies should tie into one or more of the four objectives of the regional
project: (1) getting started in farming, (2) strategies of organizing resources for capital accumulation, (3) operational strategies for survival, and (4) synthesizing or optimizing the strategies for getting started, organizing, and operating farms.

**Empirical Studies**

I hope our contributing research projects will continue to stress the use of empirical studies, as provided in the research procedures of all four objectives of the project outline. The usefulness of empirical studies to GP-2 research, or any other research for that matter, comes about in at least four ways.

For one, such studies provide the "real world" facts that working hypotheses must take into account if they are to survive. For example, experience shows that few farmers in the Plains have intensive livestock enterprises except on a minor scale. I refer here to hogs, lot-feeding of cattle, chickens, and turkeys. Instead, Plains farmers tend to specialize in grain production; they keep cattle mainly to graze the interspersed range land. Yet farm budget and linear programming analyses consistently indicate that intensive livestock enterprises not only would be profitable but essential to maximization of net return on typical grain farms. The divergence between the real world of grain farmers and the budget or programming results indicates either that:

(a) Grain farmers are maximizing something other than total annual net returns, or

(b) The budget analysis contains gross errors of data (coefficients, restraints, or restrictions)
Either the goals we attribute to farmers or our analyses are wrong. Instead of maximizing total net returns to fixed resources, the grain farmers may be maximizing the returns per dollar of outlay. This would be the better strategy (than maximizing total net returns to fixed resources) if the farmer has the opportunity to invest all of his capital in the highest-return enterprise, which might be the situation where farm businesses have the opportunity of growth.

Second, empirical studies are essential to the testing of hypotheses. For example, we might advance several hypotheses to explain why farmers specialize in grain farming. Empirical studies would provide the facts about grain farming for testing the hypotheses advanced.

Third, empirical studies may, and often do, generate ideas from which new hypotheses are born. Especially may this happen in the course of farmer interview surveys. An alert researcher often discovers critical but unexpected economic relationships in what farmers say or in their attitudes toward economic problems. Farm operators as active and self-interested observers often can suggest hypotheses (though perhaps crudely formulated) before they occur to the researcher.

Fourth, empirical studies are a necessary adjunct to the research built upon econometric models. The latter models are voracious users of facts such as input-output coefficients, various kinds of restraints, and the rest. A shortage of facts is one of the chief shortcomings of many econometric models. After completion of the analysis, the empirical studies provide a picture of the real world against which to evaluate the analytical results.
An outstanding example of empirical research of interest to the new GP-2 is the Montana study (Bulletin 579) in which the starting capital and the progress in capital accumulation was determined for a sample of farmers who had begun farming in different periods of time. The study encompassed both "getting established" and "growth."

**Research Approaches**

The contributing projects of GP-2 can accommodate a variety of research approaches, each to accomplish a different purpose. In other words, not all the analyses need be of the maximizing or optimizing type. Currently our profession has a great propensity for these types of analyses which many workers seemingly regard as the ultimate. Maximizing analyses often are very difficult and sometimes impossible in any meaningful sense because of lack of data or lack of sound conceptual framework. Also, optimizing and maximizing analyses often put a great strain on defining the objective function, the "what ought to be."

We should not overlook the more modest economic questions (and simple approaches) such as, for example:

1. Is growth of a farm business firm faster in crop farming or in intensive livestock feeding? Here is a very practical economic question; the answer would be useful to many farmers. The analysis is a simple budgeting comparison in which capital accumulation is computed for two kinds of farming and then compared.

2. Same question as (1) but analyzed for a specified sequence of crop yields such as 1951-65. Again the solution is provided by simple budgeting.
(3) What combination of management devices in crop farming permit the operator to control (use) the largest amount of land and capital goods, to produce the largest output, and make the most net income? The question here is how can the services of land and machines (which ordinarily are owned by the firm) be obtained with the least outlay of capital investment? If the services themselves could be purchased as needed—land rented for a year at a time; machines hired by the day—then all expenses would be direct expenses and no long-term investment would be needed. There must be many other equally practical questions ready for research.

Now, as to techniques. Not all of our future research on growth of the farm firm need be built around linear programming, currently a popular and widely used technique. Another technique called "simulation" is coming into use among economic researchers. Like budgeting and linear programming, simulation involves models. The computations usually are done on a rapid digital computer. Computer simulation makes feasible certain things that are possible though not as feasible in budgeting and programming. In simulation the effect of a change in operation can be projected over many time periods; and, with simulation we can deal with events where the expected outcome is not accurately described by an average value. Let me suggest some of the attributes our research techniques should have.
To study growth, our models and techniques must accommodate a series of (annual) events over time. Models and techniques should have the capacity to reinvest in the firm any surplus earnings above farm operating and family living expenses. They need to have a choice of enterprises and be able to choose those in which the reinvestment will take place. They need to accommodate stochastic elements such as a random selection of annual crop yields from a probability sample, as Johnson's model does. Our models need to be as realistic and flexible as possible.

Finally, we need empirical data on how fixed or flexible are farm expenses and household consumption functions. Do farmers borrow in bad years and pay back in good years? Are the proceeds of high income years reinvested in the farm business, or are they spent for new furniture, a new car, or a vacation?

**Where to Start**

Each of us should seek some real live economic problems in the agriculture of our respective states as a place to start the new GP-2 research. Let's not start with problems that are primarily academic or those of interest only to a researcher. Practical problems are desirable because the results have a ready market. Also they nearly always provide opportunities for using and developing economic theory—have their theoretical aspects—hence practical problems are intellectually satisfying.