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THE UNIVERSITY OF ALBERTA

Structure and Technology on Alberta Grain Farms

by

Larry E. Ruud

A THESIS

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Date 25 April 1988

ABSTRACT

The purpose of this research was to examine the relationship between farm structure and technology on east-central Alberta commercial grain farms. Three points in time were studied: 1971, 1981 and 1986. A sample of 27 commercial grain producers, each present throughout the 1971 - 1986 period, provided the evidential base for the analysis.

Three objectives were established for the research. First, the evolution of the structure of commercial grain farms during 1971 to 1986 was defined and measured. Secondly, the relationship between structure and technology was explored. The final objective was to determine the consistency of selected policies with the present technology-structure relationship.

The first step in the analysis of the interaction between structure and technology was to examine the relationships between output, factor inputs and technology. It was hypothesized that simultaneous relationships existed between output, factor inputs and technology in 1981 and 1986. A simultaneous equation approach, along with single equation ordinary least squares estimation, were used to test endogeneity for 1981 and 1986. The results did not support the working hypothesis of simultaneity, suggesting the analysis of structure and technology could be carried out using single equation functions.

Using single equation double log functions, the direction of causality in the structure and technology relationship was examined for 1971, 1981 and 1986. Three structure variables: capital/labour, land/labour and capital/land ratios per farm, and four technology variables: horsepower, type of fertilizer applicator used per farm, grain intensity and sales per acre on a per farm basis, were used in the analysis. The results suggest that in 1971 and 1981, structure was predominantly a function of technology, while in 1986 the relationship was bidirectional. Over the fifteen year period, the complexity of the interaction between structure and technology swelled, where the number of significant relationships and the influence of lagged values increased.

The implications of the results for agricultural policy, suggest past policies facilitating land extensification and capital intensification during periods of strong commodity prices may

have locked producers into a relatively inflexible structure, limiting subsequent technical advance.

ACKNOWLEDGEMENTS

My sincere thanks goes out to Dr. L. P. Apedaile for his guidance and support throughout the study. The research would not have been possible were it not for the funding provided by Farming for the Future.

I would like to thank Dr. F. Ahmadi-Esfahani and Dr. M. MacMillan who provided helpful comments and suggestions and reviewed the transcript. I would also like to thank Dr. D. Gill for his comments and for chairing the defense.

Comradery and office discussions added to the learning experience and somewhat eased graduate study tensions. For this, I thank Ward, Diane and Ann, as well as all my office mates over the two years. I would also like to thank the staff of the Department of Rural Economy for the assistance they have provided.

If a dedication were to have been made for this study, it would have been to my father whose work ethic, farming and policy experience instilled in me a desire to learn. A sincere appreciation is extended to both my parents, family and friends for providing support throughout my University education. Finally, I thank my wife, Mary Ann, whose love and patience enabled me to complete the study without excessive hardship.

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I. INTRODUCTION

A. Context of the Research

Farmers, legislators, and interest groups frequently have different objectives and therefore have different concepts of the optimum farm structure. As well, the optimum structure will quite likely change over time due to changes in resources, technology, prices, and the environment.

Two commonly held objectives for the development of the agricultural sector are growth and productivity. Growth, in a development context, usually refers to the expansion of output. Productivity gains arise from a reorganization in the factors of production and/or the introduction of new or quality improved methods.

Agricultural development is important from a social, political and economic standpoint. A prosperous agricultural industry is valued by society for aesthetic reasons. The maintenance of the family farm is a fundamental objective held by many interest groups. Sustenance of rural communities is desireable as they unify sparsely populated areas, while many regions of Canada depend on agriculture for economic vitality.

Agricultural development necessitates that the industry's structural attributes change in order to maintain growth and productivity advancement. Structural change in the grains industry has occurred since the early advances in subsistence technology facilitated the movement from hunter-gatherer to horticultural societies.[1] More recently, the 1970's and early 1980's have experienced substantial changes in capital for labour substitution, extensification-intensification, tenure, size, off-farm work, and operator age.

Packer, in his study of the 1971 - 1981 decade, found some dramatic changes in Alberta cereal agriculture systems.[2] The study, based on a farming systems approach, utilized the census of agriculture as the data source. In Alberta, the number of commercial grain

[1]Lenski, G. and Lenski, J., **Human Societies: An Introduction to Macrosociology**, 4th ed. McGraw-Hill Book Co. 1982. pp. 134-136.
[2]Packer, K., **Structural Changes in Alberta Cereal Agriculture Systems between 1971 and 1981**, Unpublished M.Sc. Thesis. Department of Rural Economy, University of Alberta. 1986.

producers declined by 12.4 per cent to 30,006, over the 1971 - 1981 decade.[3] The average improved area per farm rose from 685 acres in 1971 to 863 acres in 1981. Over the same period, the percentage of grain farms renting land increased from 54 to 59 per cent, while the percentage of commercial grain farms organized as individual proprietorships decreased to 83 per cent from 88 per cent.

The level of off-farm work went up by 26 per cent to 39 days per year in 1981, while labour use per farm, measured in person-years, declined from 1.12 to 1.10.[4] Machinery value per acre, in 1981 dollars, increased from $67 to $133 per acre over the decade. Sales per acre increased 56.7 per cent to $94, while gross margin per acre only rose by 31.1 per cent to $59 per acre.

Evidence has also shown that the distribution of sales, and gross margin among farm sizes represented by sales groups has been changing over the years in favour of larger farm sizes. Small farms are steadily becoming noneconomic, while medium farm sizes have tended to hold onto a constant share of sales and gross margin. No longer can an undiversified agriculture policy be sought as a means to resolving current problems in the industry. As well, regional differences demand a targeted approach to policy formulation.

Agricultural development is a dynamic process, where structural changes in terms of the fixed factor proportions and distributional shifts seem to occur to adapt to an ever-changing economic and natural environment. However, the causes of structural change have not been studied well in the literature. One of the hypothesized causes, technical change, has been quantitatively researched in terms of measuring the magnitude of a technical change factor. Up until the late 1960's, technical change was treated as being exogenous to the economic system.[5] However, "(as) the significance of factor substitutability and biases came to be realized,"[6] technical change was realized to be endogenous to the system. Several

[3] A commercial grain farmer was defined as a producer who owned/rented at least 320 acres, with 100 acres or more in crop.

[4] Labour use, in person-years, was measured as (300 - Days off farm work)/300 + (Weeks of paid labour/52).

[5] Binswanger, H.P. and Ruttan, V.W., **Induced Innovation**, John Hopkins University Press, 1978.

[6] Lee, Jung-Hwan, "A Review of the Theory of Technological Change in Agriculture:

methods for measuring technical change have been used in the literature, the most common of which has been the production function in its various forms. A common constituent in all the research thus far has been to assign an *a priori* cause-effect relationship between technical change and factor inputs to the production process. The lack of empirical work on the interaction between technology and structural variables was the basis for initiation of this research. Insight into this technology-structure relationship should enable a fuller understanding of the impact of related agricultural policies on the structure of the farming sector.

B. Problem Definition

Agricultural policy may be producing structural changes different from the purpose and priorities held by agricultural leaders and written into the policies themselves. Technology, tax policies, marketing systems, pricing and credit may be benefiting larger farm operations.

Technical progress is a continuous process which has a definite impact on the structure of the Alberta grain industry. Firms who do not take advantage of the cost economies, or production increases associated with new technology find, with time, increasing difficulty uptaking new technology. Apedaile and Packer in their study of the 1971 - 1981 decade, found capital to be continually substituted for labour over the range of commercial grain farm sizes, suggesting that earlier barriers to larger farms had been overcome.[7]

The relationship between structure and technology may be different during periods of economic growth than under recessionary periods. Policies aimed at inducing producers to borrow up to their equity limits may be locking them into an inflexible structure, from which they have no choice but to search for low investment technologies complementary to their present structure. As well, as the agriculture sector becomes more interrelated with the general economy, the complexity of the structure and technology relationship seems to be increasing, such that decision making becomes riskier. Producers with more accessible information, credit,

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[6](cont'd) Biases and Substitutability," *Journal of Rural Development.* 4 (June 1981):55-66

[7]Packer, **op. cit.**

and markets appear better able to handle risk related decisions.

As noted earlier, the interaction of technology and structure has not been studied well in the literature. A number of authors have hypothesized on the relationship, but little empirical work has been carried out. Heady, in his writings on technology and structure, suggests that advances in yield per acre were possible with fertilizer and improved seed varieties, which were thought to be substitutes for land and labour.[8] Babb states that technology is an important factor affecting farm structure, especially in the number and size of farms, and in the specialization. He further claims that technology is of little importance in owner control and in the socio-economic dimension.[9] Lu asserts that technology makes structural change possible, whereby the benefits of technical change are a function of the elasticities of supply and demand.[10] Research thus far constitutes a number of assertions and hypotheses with few empirical tests.

C. Purpose

The purpose of this research was to determine to what extent grain production technology is altering the structure and economic prospects for family grain farms in Alberta. The interaction of technology and structure is complex, such that no facile assumption on the type of relationship can be made *a priori* to the research. One area, census division 10 (CD 10) of Alberta, was chosen to provide the evidential base required for examination of the structure and technology relationship.

D. Objectives

Three objectives were established to meet the above purpose. The first objective was to define and measure the evolution of the structure of family grain farms during the period 1971 - 1986. Three points in time were studied: 1971, 1981, and 1986.

[8] Heady, E.O., **Agricultural Policy Under Economic Development**, Chapter 7.
[9] Babb, E., "Some Causes of Structural Change in U.S. Agriculture," *Structure Issues of American Agriculture*. USDA. Washington, 1979.
[10] Lu, Yao-Chi, "Technological Change and Structure," *Structure Issues of American Agriculture*. USDA. Washington, 1979. pp. 121-126.

The second objective was to explore relationships between structure and technology in east-central Alberta grain farms. Measures for both mechanical and biological technology were used in the study.

The final objective was to determine the consistency of selected policies with the present technology-structure relationship.

E. Hypotheses

Two hypotheses were established for the research. First, it was hypothesized that the relationship between sales per farm, factor inputs, and technology was simultaneous.

Secondly, it was hypothesized that during and following times of increasing agricultural commodity prices, technical change induces structural change of cereal agriculture in Alberta. The opposite relationship was hypothesized to exist following a period of declining relative commodity prices. Both hypotheses are developed in the next chapter.

F. Organization

The thesis is organized into five chapters. The first chapter sets out the subject of the research. The second chapter discusses the theoretical basis for the hypotheses, with agricultural development as the overlying pretext. Chapter three traces the methodology used in the study. The results of the analysis are given in chapter four. Based on these results, some interpretations are drawn in chapter five, along with limitations of the research and suggestions for further research.

II. THEORETICAL BASIS FOR HYPOTHESES

A. Agricultural Development

Agricultural development can be defined as a process by which an economy can increase or maintain an acceptable rate of growth of output and productivity in agriculture. The literature on agricultural development has evolved from a simplistic 'resource exploitation' model to incorporating technical and institutional change into the development framework. Resource constraints imposed on a sector can be overcome by technical change, allowing the substitution of elastic factors of production for inelastic factors. Hayami and Ruttan's induced innovation model employs technical change as an endogenous element in the economic system.

Agricultural development necessitates that producers be willing to accept technical and social change. This suggests the industry's structural attributes change in order to maintain growth and productivity advancement.

B. Structural Change

Concept of Structure

The concept of structure is relatively all-embracing, referring to the characteristics of the firm which affect its behavior and performance in the industry. Following the framework set out by Ehrensaft and Bollman, the following dimensions of structure can be established:[11]

1. the number and size distribution of farms for agricultrual production as a whole and for specific commodities and region;
2. specialization in commodity production both at the level of individual farms and between geographic regions;

[11]Ehrensaft, P. and Bollman, R.D., **Structure and Concentration in Agriculture: A Micro-analysis of the Census of Agriculture**, Paper prepared for presentation to the Annual Meeting of the Canadian Sociology and Anthropology Assn., June 2, 1983. pp.3-4.

3. the internal organization of farms as business enterprises, which includes patterns in the use of land, labour, and technology; financing; legal organization of the enterprise; land tenure; and the locus of entrepreneurial decisions;
4. entry and exit patterns and farm firm growth (and contraction) patterns for different commoditites and regions; and
5. the socio-economic characteristics of farm operators and their families.

The above dimensions of structure cover economic, social, and spatial considerations delimiting the heterogeneity of agriculture. The term structure, in the context of this research, refers to the fixed factor proportions per farm.

The Alberta grains sector has undergone substantial structural changes in the last fifteen years. The number of farms has declined, while farm size, sales concentration, and machinery value per year of labour have all risen.

As farming becomes more industrialized and closely integrated with the general economy, the forces which guide the evolution of farm structure become more important, as they are increasingly controlled by human institutions. The focus of this research is on technology and its relationship with structure. A specific causal link does not appear to exist, but rather a complex system of feedback and circular adjustments.

C. Technical Change

The purpose of this section is to develop the evolution of thought on technical change. Also discussed, are the characteristics of technical change which are important in terms of measuring the bias, if one exists, of technical change.

Evolution of Thought

Early researchers realized that growth in labour productivity was not determined solely by growth in captial inputs, but also by another factor.[12] Solow(1957)[13] termed this

[12]Abramowitz, Moses. "Resource and Output Trends in the U.S. since 1870," *American Economic Review*, 46:5-23 (1956).
[13]Solow, R.M. "Technical Change and the Aggregate Production Functions," *Review of Economics and Statisitics*, 39:213-320 (1957).

factor technical change while Domar(1961)[14] termed it technological change; the difference being one of definition. Technological change signifies the act of producing new knowledge whereas technical change concerns the incorporation of this new knowledge in the production processes of firms.

Technical change has also been defined in terms of its factor saving bias. Technical change is said to be neutral if the marginal rate of substitution(MRS) of one factor input for another is not affected. More commonly, technical change is nonneutral being, for example, either labor saving (capital using) or capital saving (labor using). Technical change is labor saving if the marginal product of capital increases faster than the marginal product of labor increases. Once technical changes can be measured successfully, the testing of theories explaining their causes or effects can proceed.[15]

According to the induced innovation hypotheses, the rate of technical change is influenced by changes in relative factor prices and the growth of product demand. There is a substitution of relatively abundant factors for relatively scarce factors. Hayami and Ruttan suggest the usefulness of decomposing changes in factor proportions into the effect of factor substitution along a fixed-technology isoquant in response to changes in relative factor prices and the effect of biased technical change.[16] Hayami and Ruttan note the changing sources of growth:

"This century is experiencing a transition from an era when most of the increases in world agricultural production occurred as a result of the expansion in area cultivated to a period when most of the growth in crop and animal production must come from increases in the frequency and intensity of cultivation- from changes in land use which make it possible to crop a given area of land more frequently and more intensively and hence to increase the output per unit area per unit of time."[17]

[14]Domar, E. "On the Measurement of Technological Change," *Economic Journal,* 71:709-729 (1961).
[15]Yotopoulos, P.A. and J.B. Nugent, **Economics of Development**, 1976.
[16]Hayami, Y. and V.W. Ruttan, **Agricultural Development. An International Perspective**, The John Hopkins University Press. p. 188. 1985.
[17]Hayami, Y. and V.W. Ruttan, **Agricultural Development. An International Perspective**, The John Hopkins University Press. pp. 44-45. 1985.

The trend that agricultural development takes is dependent upon the availability and relative prices of resources. In countries, such as Japan, where the supply of farm land is inelastic, there has been a historical trend towards biological, land saving technology. This has led to the development of seed varieties which are more responsive to high levels of fertilization. On the other extreme, countries like Canada and the U.S. traditionally have had an elastic supply of farm land but a scarcity of labour. This has led to the development of mechanical, labour saving technology facilitating the movement towards extensification of the farming enterprise.[18] However, as the price of land rises relative to that of fertilizer, there has been a shift to cropping intensification. Figure II.1 depicts cases for both neutral and non-neutral technical change.

D. Capital Accumulation and Technological Progress

Economic development has long been thought the key to greater social wealth. Historically, capital accumulation was considered to be the impetus to economic development.[19] However, capital accumulation cannot by itself be relied upon to achieve economic development, nor is it inevitable that resources will be freed for the formation of capital or that any resources not used for consumption will be used for capital formation.

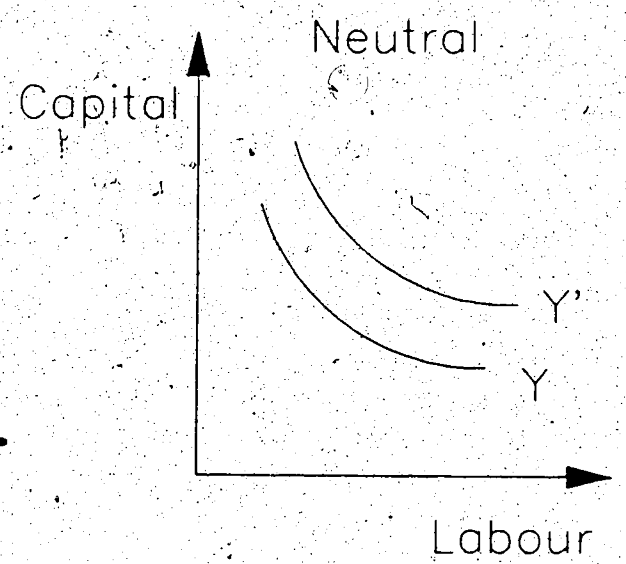
Solow suggests that growth of productivity and output is partially dependent upon capital formation. However, technical progress, growth of product demand and institutional change are all necessary growth conditions.[20] The theories underlying capital accumulation and technological progress are outlined in the following two sections.

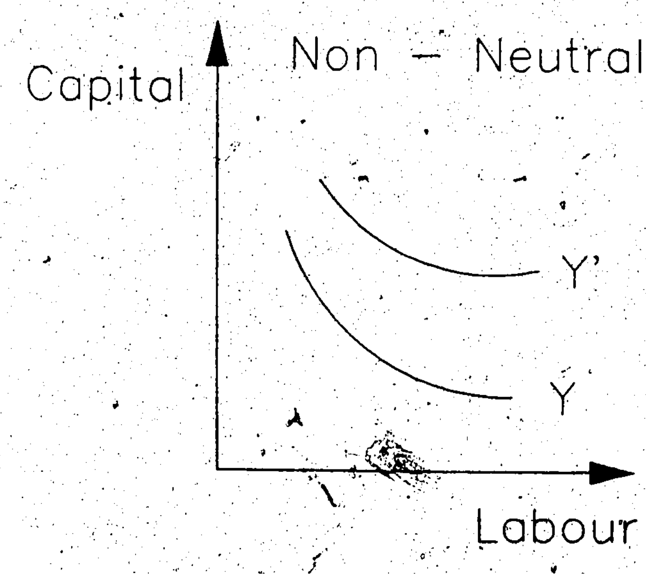
Capital Accumulation

Saving-centered theorists believe the accumulation of money wealth to be the driving force behind technological advancement. [21] Adam Smith, founder of the

[18]Ibid.
[19]Capital, for general purposes, includes plant and equipment, social overhead, and human captial.
[20]Solow, R.M., "Technical Progress, Capital Formation, and Economic Growth," *American Economic Review*, 52:76-86. May, 1962.
[21]Dugger, W.M., "The Nature of Capital Accumulation and Technological Progress in

Figure II.1: Neutral and Non-Neutral Technical Change in Agriculture





saving-centered theory, believed there existed a natural "profit motive" amongst individuals to better ones condition.[22] The basic principle is that capital accumulates through savings, retention of profits and investing.

On the other side, demand-side theorists assert abstinence is more likely to impede capital accumulation. Eichner found that a corporate levy has been used recently by industry to finance new investment. "The size of the corporate levy and the total amount it generates depends upon a number of factors....Most important among these factors for our own purposes are the long-term growth goal and the actual capacity utilization rate of the corporation receiving the levy."[23]

A more recent attempt to explain economic growth relies on the theory of human capital. "The chief source of economic growth in the country has been human capital and its increase: the greater education, higher skills, potential productivity, and inventiveness of workers whose effort, combined with capital, yields current output. Technological change itself represents a return on human capital since people, including scientists as well as developers, discover new knowledge and devise new products or processes."[24]

The processes of agricultural development and capital accumulation are closely interconnected. "A high rate of capital formation usually accompanies a rapid growth in productivity and income; but the causal relationship between the two is complex and does not permit of any facile assumption that more capital formation will of itself bring about a corresponding acceleration in the growth of production."[25]

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[21](cont'd) the Modern Economy", *Journal of Economic Issues*, 18(3) (1984).
[22]Ranson, B., "The Unrecognized Revolution in the Theory of Capital Formation", *Journal of Economic Issues*, 17(2) (1983).
[23]Dugger, op. cit.
[24]Bell, C.S., "Human Capital Formation and the Decision Makers," *Journal of Economic Issues*, 18(2) (1984).
[25]Cairncross, A.K., "The Role of Capital in Economic Progress", in *Capital Accumulation and Economic Development*, ed. by S.S. Tangri and H.P. Gray (D.C. Heath and Co., 1967).

Technological Progress

"..., efforts to impute the recorded expansion in industrial production to the additional labour and capital contributing to it invariably leave a large unexplained residue. It is necessary, therefore, to take account of other influences, such as technical progress..., which may operate through investment, or independently of it, so as to raise the level of production."[26]

Mansfield defines technology as "society's pool of knowledge regarding the industrial and agricultural arts."[27] According to Thirwall, technical or technological progress may be described in three different senses. First, technical progress can refer to the effects of changes in technology on the growth process. Second, technical progress is used "to describe the character of technical improvements, and is often prefaced for this purpose by the adjectives 'labour-saving', 'capital-saving' or 'neutral'."[28] Lastly, technical progress can refer to the changes in technology itself; be it mechanical, bio-chemical, or information technology.

Supply-side economists believe the individual entrepreneur reigns supreme in the technological process, just as the individual saver does in capital accumulation. Contrarily, demand-siders assert "(T)he joint invention-innovation process as Veblen and Ayres explained, is a social process based on the accumulation, dissemination, and implementation of a joint stock of knowledge and skill."[29]

Technical progress may not necessarily "involve high net investment: indeed it may permit of a reduction in the stock of capital or an expansion in output without any comparable investment."[30] In agriculture, the adoption of optimal seed and fertilizer placement methods is an example of technological progress which does not require a large investment. The adoption of a double-swath swather is an example of mechanical

[26]Cairncross, op. cit.
[27]Mansfield, E., **Microeconomics: Theory and Application**, 4th ed., W.W. Norton and Company, 1982.
[28]Thirwall, A.P. **Growth and Development**, 2nd ed. 1977.
[29]Dugger, op. cit.
[30]Dugger, op. cit.

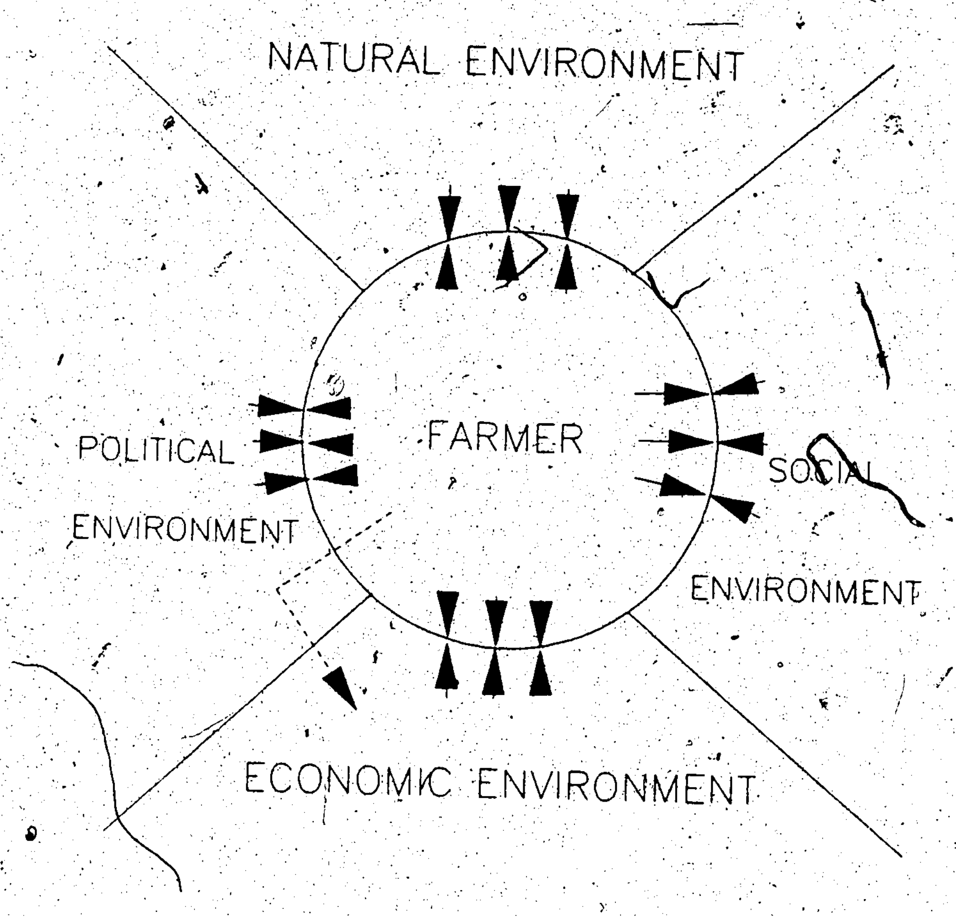
technology which may permit a reduction in the total capital stock.

E. Link Between Structure and Technology

The link between structure and technology is explored within a systems theoretical framework. The agricultural industry is an open system, constantly in exchange with its environment; the economic, political, social, and agro-climatic spheres. The commercial grain producer strives to both open and close certain segments of the environment. Figure II.2 portrays the relationship of the farmer with his environment. On the natural environment front, pests, adverse weather, topographical restrictions, soil erosion and depletion tend to diminish production as well as the net margin of the commercial grain producer. The producer attempts to minimize the influence of these factors through technology decisions; be they new seed varieties, fertilizers, pesticides, machinery, etc. Within the economic and political environments, government, industry, financial institutions and international markets all endeavor to open the boundary between them and the producer. Over time this boundary erodes as producers become more dependent upon international markets, government, and the recurrent industrial inputs market. The producer strives to maintain this boundary, while pressuring for a more open international market to dispose of surplus production.

During his efforts to maintain the boundary with the natural environment, the producer may not realize the boundaries with the economic and political spheres become more permeable. For example, a technology decision in the form of a new fertilizer to ward off soil depletion, and increase production implies an investment decision. The new input and the capital for its purchase most commonly come from the industrial sector and financial institutions. Over time the producer may realize an increase in production of his land base beyond: 1. what the market can support, 2. what he needs to maintain a desired standard of living, and/or 3. the capabilities of the current factors of production (technically beyond the optimal marginal productivities). Consequently a structural adjustment in one or more of the factors of production may be required to maintain equilibrium.

Figure II.2: Relationship Between the Farmer and his Environment.



Neoclassical theory suggests this scenario ends with the structural adjustment. However, no quantitative research has been done to support this theory. There does not appear to be a simple, direct link between technology and structure, but rather a complex system of feedback channels and indirect links, which are additional to or lie behind the factor price effects and product demand issues raised by the induced innovation hypothesis. Figure II.3 outlines the hypothesized technology-structure relationship developed for this research. As can be seen, the above scenario may not be a simple cause-effect chain of events. The dashed lines in the figure represent the permeable link to the environment.

Figures II.4 through II.8 show the specific flowcharts used to model the relationship. Figure II.4 depicts the structure - technology relationship in 1971. The number of relationships does not appear to make decision making complicated. The one way causation of the fertilizer application index to output takes into account the relatively simple fertilizer - application technology available in 1971.

Figures II.5 and II.6 illustrate the structure - technology connection for 1981, with the effect of lagged variables shown in the second figure. Compared to 1971, the model is more complex, where the number of relationships has risen. As well, each lagged variable tends to have an effect on at least two variables in 1981, suggesting a growing complexity in decision making where the producer is partially bound by past decisions.

In 1986, figures II.7 and II.8 show the number of relationships increased to the point where it becomes difficult to separate any two variables from the rest of the system. As well, the lagged effect from 1981 increased to the point where most variables in 1981 influence at least four variables in 1986. The implications of these figures suggest that as the agriculture sector integrates into the general economy, decision making becomes increasingly bound by former decisions.

Quantitative analysis of the technology-structure relationship at one point in time enables understanding the complexities of the association. Comparison of different points in time facilitates the understanding of this relationship as it moves over time. The complexity of the technology - structure relationship increases over time as the producer becomes more integrated with the general economy: the figures illustrate the increase in complexity.

F. Research Hypotheses

Hypothesis One

Underlying the structure of a farm are the factor inputs, which when taken in fixed factor proportions, comprise structure. Over time, producers tend to expand their land base and intensify the use of of factor inputs, particularly land, labour, capital, and intermediate inputs. A decision to extensify and/or intensify the farm operation, through the adoption of new technology and/or a capital purchase, may simultaneously change the level of output, the use of factor inputs, and the technologies employed on the farm. Understanding the interaction between output, the factor inputs and technology was viewed as fundamental to the analysis of farm structure and technology. The general working hypothesis was that the interaction among output, the factor inputs and technology was simultaneous.

Hypothesis Two

The causal relationship between structure and technology may be quite different during and following an economic boom, than following a recessionary period. In expansionary periods producers tend to enjoy increasing commodity prices and appreciating land values. During such an expansionary period as the 1971 - 1981 decade, agricultural lending policies were centered around inflationary expectations for the prices of the factor inputs. Favourable economic conditions usually allow the producer more easily to obtain financing for the adoption of larger, technologically advanced machinery and equipment. Such a change in technology may induce a change in the capital/labour, capital/land, and land/labour ratios.

During periods of declining commodity prices, and land devaluation, producers may not be able to obtain financing for technological adoption. Structure may be limiting to technological adoption, such that technology may be sought which is complementary to their present structure. Such an example would be the adoption of new fertilizer application techniques, seed varieties and chemicals. Lending policies throughout the 1981 to 1986 recessionary period remained based on the expected value of the input, rather than on profitability and repayment capabilities of the farm. Consequently, it was hypothesized that during and following periods of increasing commodity prices, technical change induces structural change of cereal agriculture in Alberta. The opposite relationship was hypothesized to exist following declining relative commodity prices. In the time frame studied, 1971 to 1981 was a period of increasing commodity prices, while 1981 to 1986 experienced a decline in commodity prices.

Figure II.3: Evolution of the Technology and Structure Relationship within a Commericial Grain Producer's Farming System over time t.

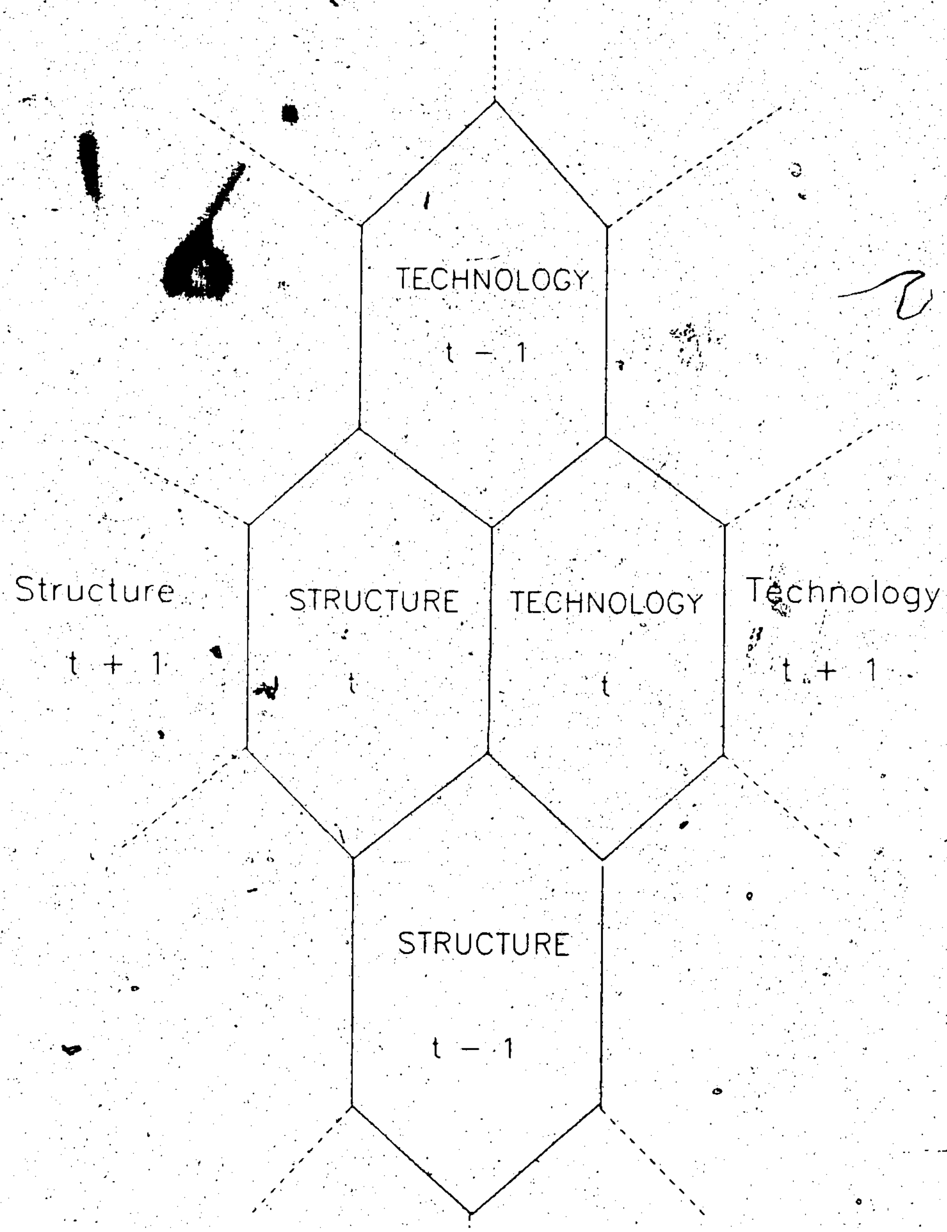


Figure II.4:
Structure - Technology Relationships for Commercial Grain Producers in 1971.

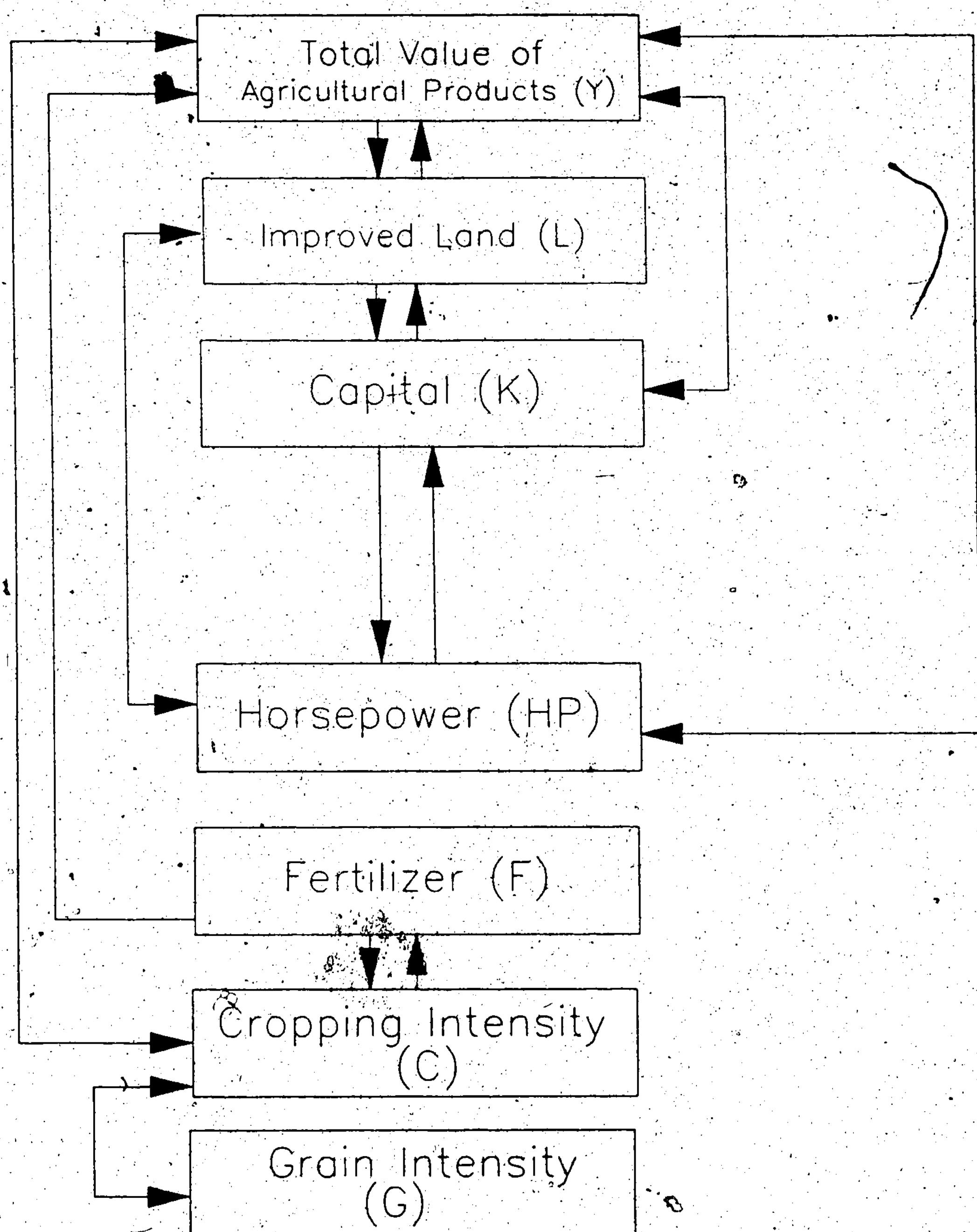


Figure II.5:
Structure - Technology Relationship for Commercial Grain Producers in 1981.

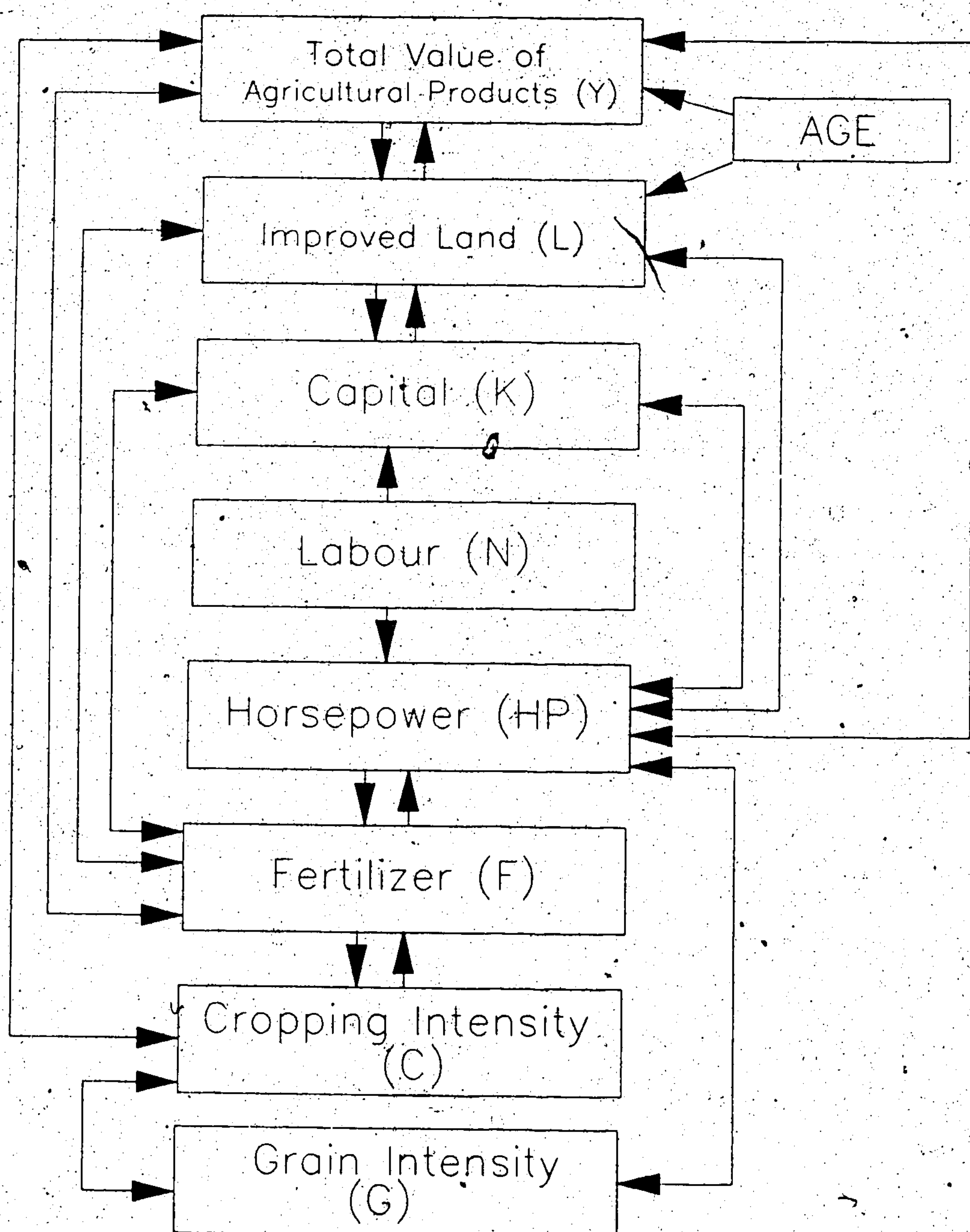


Figure II.6:
Lagged Structure and Technology Effects on a Commercial Grain Producer's Structure and Technology in 1981.

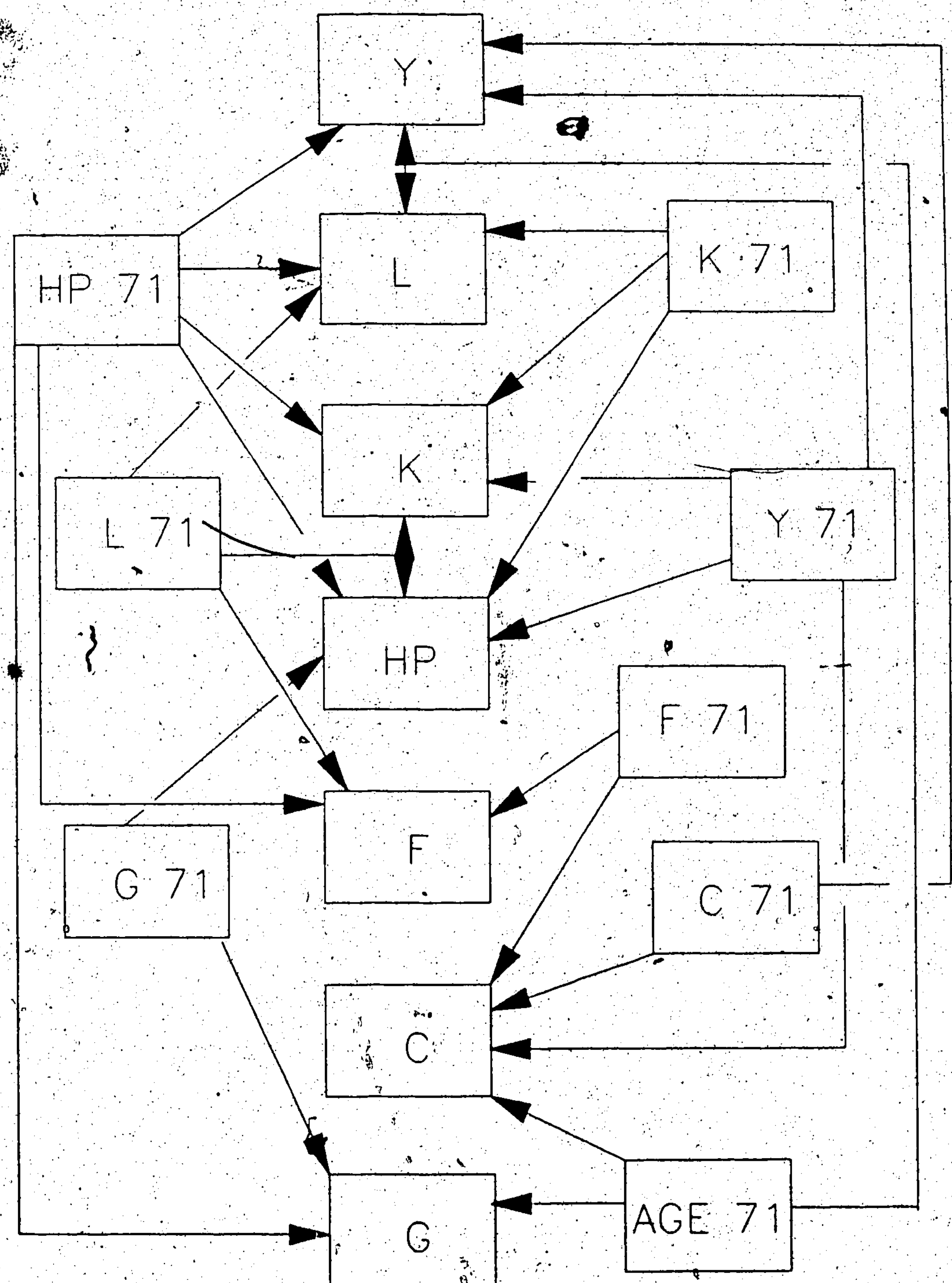


Figure II.7:
Structure - Technology Relationship for Commercial Grain Producers in 1986.

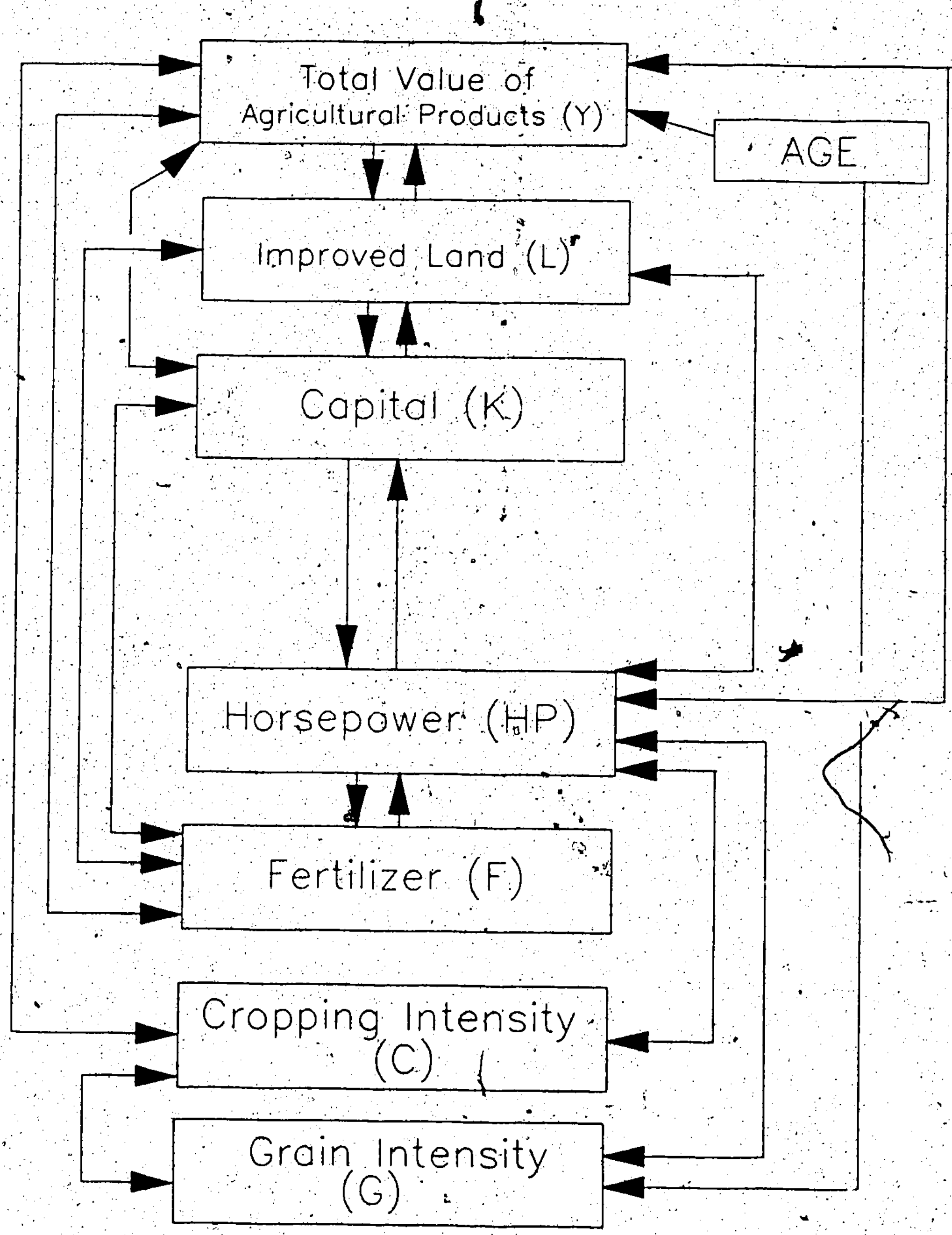
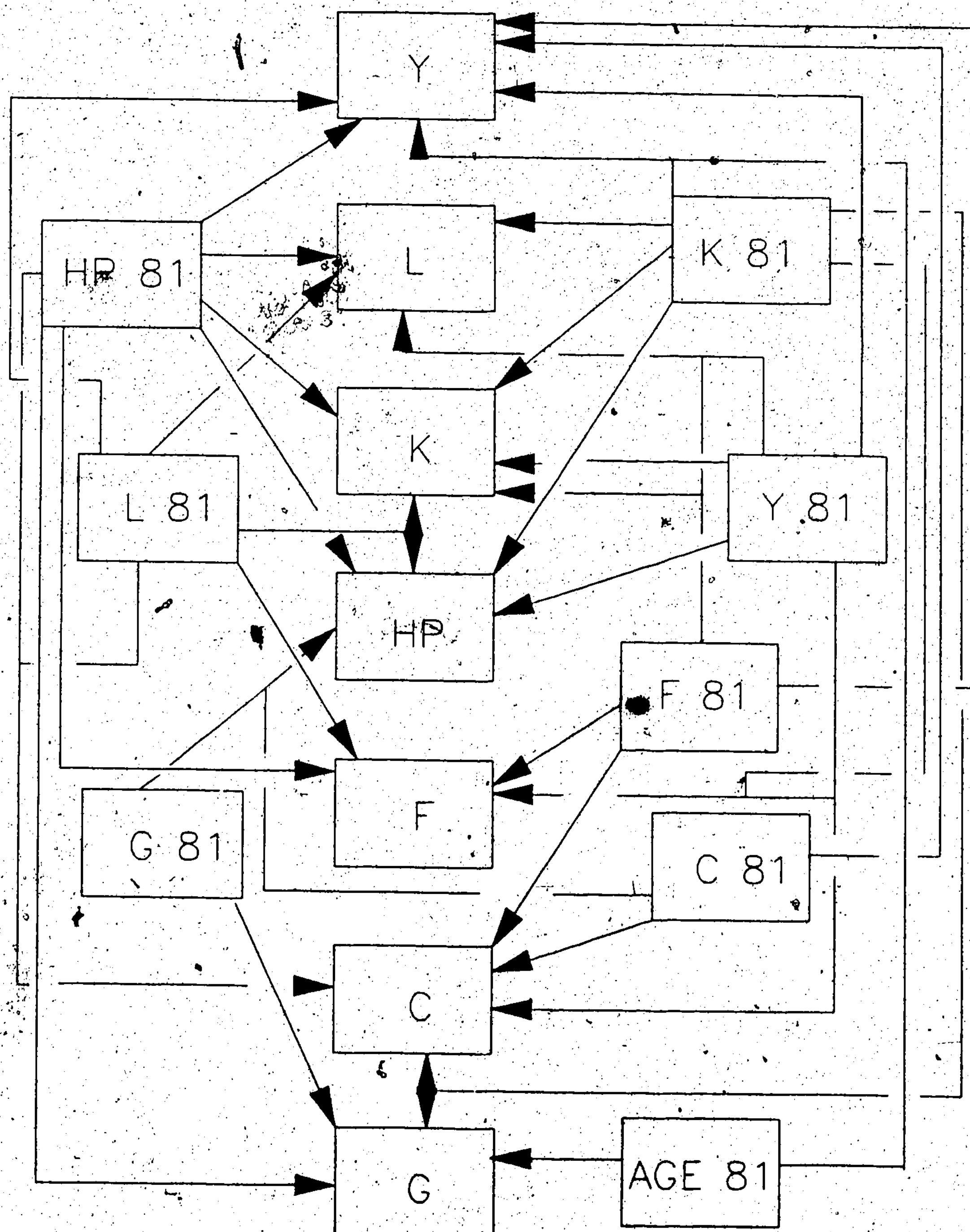


Figure II.8:
Lagged Structure and Technology Effects on a Commercial Grain Producer's Structure and Technology in 1986.



III. METHODOLOGY

A. Introduction

Chapter III traces the methodology used to examine the structure-technology relationship. The interaction of technology and structure is a complex issue which necessitates some abstractions to be made from the general economic system. This research was primarily concerned with the supply side of the Alberta grain industry. As such, purely competitive theory, of the traditional neoclassical framework, was viewed as best describing the Alberta grains sector, as well as the basic economic unit of study; the commercial grain producer.

Initially, a number of variables describing both structural attributes and technology employed per farm were developed, from which correlation matrices were studied to examine the interplay between variables. Simultaneity was hypothesized to exist amongst a number of variables. Simultaneous equation models along with single equation functions were used to test the first hypothesis described in chapter I. The analysis rejected the hypothesis of simultaneity. The results are given in Appendix C.

Based on the above analysis, a single equation approach was used to examine the relationship between structure and technology. Three structure variables; capital/labour, land/labour, and capital/land ratios were developed, while four technology variables; mechanical, biological, intensification (grain and cropping), and sales per acre were analyzed. The results of the analysis are presented in chapter IV.

The final part of the chapter outlines the data sources and collection procedure. Primary data from 27 east-central Alberta grain producers provided the evidential base for the research. Cross sectional data from three points in time; 1971, 1981, and 1986, was used in the analysis.

B. Variables Used for Testing the Hypotheses

The fundamental components to structure are the factors of production used in the farm. Prior to examining the relationship between structure and technology, the link between the factors of production, technologies employed, and sales per farm had to be understood. The first hypothesis of the research was that a simultaneous relationship existed amongst sales per farm, the factors of production, and technology in 1981 and 1986. The year 1971 was excluded from the analysis due to a lack of data prior to 1971. The following variables were established to test the first hypothesis of simultaneity:

1. Improved area per farm = cropped acreage + summerfallow + improved land for pasture + other improved land.
2. Cropping intensity = (total improved area - summerfallow area) / total improved area.
3. Grain intensity = (grains and oilseeds area) / total improved area.
4. Capital (Machinery) Value per farm = market value of tractors, combines, and swathers per farm, which were viewed as representative of the capital value per farm. Capital was deflated using the Machinery Price Index, where 1981=100.
5. Labour use per farm = person years of labour = [(300 - Days of off farm work)/300] + [Weeks of paid labour / 52].
6. Total Value of Agricultural Products per farm = grains and oilseeds + other farm income + carryover + onfarm use. Output was deflated using the Farm Input Price Index, with 1981=100.
7. Operator age.

Off-farm work, rented area per farm, organization, and interest paid were also originally thought to play a significant role in the input-output relationship. However, there was little off-farm work and insignificant variation in the type of farm organization within the sample. Rented area and interest paid per farm were excluded because fewer than half the producers rented land, and responses to the interest paid question were erratic.

The technology variables presumed to reflect innovativeness were:

1. Mechanical technology = drawbar horsepower of the largest tractor.

2. Biological technology = type of applicator used for applying supplemental Nitrogen. The applicators considered were deep banders, cold flow system, anhydrous ammonia, broadcast, and a consideration for no supplemental nitrogen applied. An index value was assigned to each applicator according to its introduction date, where the most recently adopted fertilizer application technology was considered the most advanced technology. An index of 100 was allotted to deep banding as the most recently introduced technology. An index of 95 was given to cold flow applicators, which were adopted around 1980, while an index of 90 was assigned to anhydrous applicators adopted during the mid 1970's. Broadcasting was considered a lower level of technology, such that a value of 70 was given to those producers using broadcasting. An index of 50 was given to those producers not applying supplemental nitrogen. An equal interval index, using 4,3,2,1 or 0 for the five levels of fertilizer technology respectively, failed to produce significant results in all models.

The above variables were developed for each of 1986, 1981, and 1971, with the exception of the labour variable, which was not available for 1971. Table III.1 gives the mean values and standard deviations for each of the variables used in the analysis. A skewness coefficient was calculated for each variable on the basis of the mean, mode, and standard deviation.[31] From this, it was determined that each variable was normally distributed.

The following structure and technology variables were established to test hypothesis two;

Structure variables:

1. Capital - labour ratio (K/N);
2. Land - labour ratio (L/N);
3. Capital - land ratio (K/L).

Technology variables:

1. Mechanical = horsepower (HP);
2. Fertilizer applicator index (FERT);

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[31] Kendall, M.G. and Stuart, A., **The Advanced Theory of Statistics**, vol. 1. Hafner Publishing Co., New York. 1958.

3. Grain intensity (G);[32]

4. Sales per acre (Y/L).

Grain intensity reflects the rotational choices of the producer. Following Ruthenberg's thinking, farms with high grain intensities are considered to be more developed and receptive to new technologies in the grains sector. Sales per acre captures changes in yield-enhancing bio-chemical technologies, while it was realized that market factors, including real price changes and variable weather patterns over the census division also influence sales per acre.

C. Relationship between Output, Input, and Technology Variables

According to Ruthenberg, the structure of any farm at any point in time is the result of interactions between the internal relations of a farm and the preceding state of the environment.[33] As well, to quote Boulding, "The more complex the system we are considering, the more difficult it is to apply any simple concepts of cause and effect."[34]

The first step in the estimation of the structure-technology relationship, was to examine correlation matrices for all the variables in each year, as well as between years to account for any lagged effect. The sole purpose of this procedure was to establish a framework for further modelling. Table III.2 gives the correlation matrix for each year, while Table III.3 presents the correlation matrices between years.

The results show there to be no simple direct relationship between the variables which can be supported on *a priori* grounds. As well, over the fifteen year period, the number of significant coefficients increased, suggesting an expanded complexity of the input, output, and technology relationship. To model such a relationship, a simultaneous equation model was used for further analysis.

[32]Cropping intensity was also tried. However, the results and significance levels did not change.
[33]Ruthenberg, H. **Farming Systems in the Tropics.** Oxford University Press. 1976.
[34]Boulding, K. *The Economy as an Ecosystem,* **Systems Economics,** edited by K.A. Fox and D.G. Miles. Iowa State University Press, 1987. p.9.

Table III.1: Means and Standard Deviations of Structural Attribute and Technology Variables for a Sample of 27 Commercial Grain Producers in CD 10 of Alberta in 1986, 1981, and 1971.

	1986		1981		1971	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Sales (real)	78,239	45,230	86,366	66,717	105,130	67,728
Area (acres)	885	423	903	413	753	305
Labour (person yrs)	1.08	0.23	1.01	0.38		
Capital (real)	70,013	45,431	67,481	41,844	30,651	19,299
Fertilizer index	86	17	79	17	64	13
Horsepower	136	45	116	40	70	25
Age	58	9	53	9	43	9
Crop intensity	0.87	0.11	0.88	0.10	0.81	0.12
Grain intensity	0.69	0.18	0.71	0.17	0.58	0.20

Note: All variables are on a per farm basis.
Sales and capital values were deflated using Farm Input Price Index and Machinery Price Index respectively, with 1981=100.

Table III.2: Correlation Matrices for Factors of Production and Technology for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta, 1986, 1981, and 1971.

1986

SALES (Y)	1.00								
LAND (L)	0.54*	1.00							
LABOUR (N)	0.20	0.21	1.00						
CAPITAL (K)	0.67*	0.59*	0.65*	1.00					
FERT	0.40	0.56*	0.08	0.43	1.00				
HP	0.40	0.57*	0.31	0.68	0.47	1.00			
AGE	-0.38	-0.14	-0.01	-0.22	-0.10	-0.24	1.00		
CROP INT (C)	0.37	0.25	-0.01	0.30	0.23	0.36	-0.11	1.00	
GRAIN INT (G)	0.19	0.07	-0.11	0.26	0.15	0.53*	-0.37	0.46	1.00
	Y	L	N	K	FERT	HP	AGE	C	G

1981

SALES (Y)	1.00								
LAND (L)	0.55*	1.00							
LABOUR (N)	0.19	0.42	1.00						
CAPITAL (K)	0.28	0.64*	0.37	1.00					
FERT	0.36	0.53*	-0.03	0.44	1.00				
HP	0.36	0.55*	0.35	0.77*	0.41	1.00			
AGE	-0.38	-0.36	0.13	-0.14	-0.28	-0.26	1.00		
CROP INT (C)	0.32	0.27	-0.13	0.22	0.43	0.19	-0.32	1.00	
GRAIN INT (G)	0.18	0.18	0.04	0.27	0.22	0.60*	-0.46	0.52*	1.00
	Y	L	N	K	FERT	HP	AGE	C	G

1971

SALES (Y)	1.00							
LAND (L)	0.28	1.00						
CAPITAL (K)	0.23	0.52*	1.00					
FERT	0.21	0.16	-0.21	1.00				
HP	0.20	0.45	0.76*	-0.08	1.00			
AGE	-0.18	0.03	0.15	-0.15	-0.07	1.00		
CROP INT (C)	0.44	-0.07	-0.08	0.22	0.01	-0.02	1.00	
GRAIN INT (G)	0.26	0.19	0.10	0.21	0.41	-0.26	0.39	1.00
	Y	L	K	FERT	HP	AGE	C	G

Note: all variables are on a per farm basis. * indicates coefficients are significant at 1% level of significance.

Table III.3: Inter-Year Correlation Matrices for Factors of Production and Technology for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta, 1986, 1981, and 1971.

1986

	Y	L	N	K	FERT	HP	AGE	C	G
SALES (Y)	0.86*	0.64*	0.16	0.41	0.54*	0.38	-0.38	0.42	0.21
LAND (L)	0.33	0.83*	0.41	0.66*	0.28	0.45	-0.14	0.05	-0.01
LABOUR (N)	0.31	0.24	0.64*	0.19	0.06	0.19	-0.01	0.17	0.06
CAPITAL (K)	0.67*	0.63*	0.56*	0.67*	0.35	0.64*	-0.22	0.24	0.25
FERT	0.34	0.60*	0.15	0.45	0.45	0.43	-0.10	0.02	-0.03
HP	0.39	0.53*	0.24	0.69*	0.14	0.74*	-0.24	0.32	0.48
AGE	-0.38	-0.36	0.13	-0.14	-0.28	-0.26	1.00	-0.32	-0.46
CROP INT (C)	0.38	0.37	-0.16	0.42	0.46	0.34	-0.11	0.50*	0.18
GRAIN INT (G)	0.23	0.24	-0.08	0.39	0.28	0.69*	-0.37	0.24	0.81*

1981

1981

	Y	L	K	FERT	HP	AGE	C	G
SALES (Y)	0.60*	0.20	0.26	-0.18	0.30	-0.38	0.39	0.19
LAND (L)	0.27	0.66*	0.34	-0.13	0.38	-0.36	0.29	0.38
CAPITAL (K)	0.33	0.61*	0.67*	0.19	0.69*	-0.14	0.28	0.45
FERT	0.22	0.47	0.20	0.50*	0.30	-0.28	0.22	0.22
HP	0.30	0.48	0.61*	0.06	0.66*	-0.26	0.05	0.50*
CROP INT (C)	0.35	-0.04	0.01	0.40	0.01	-0.31	0.48	0.40
GRAIN INT (G)	0.15	-0.03	0.20	0.13	0.31	-0.46	-0.02	0.61*

1971

Note: all variables are on a per farm basis. * indicates coefficients are significant at 1% level of significance.

D. Simultaneous Equation Models

A simultaneous equation model jointly estimates the behavior of all variables. The purpose of a system of equations is to explain, to predict, and to control a set of interrelated variables. Consider the following three-equation system adapted from Pindyck and Rubinfeld:[35]

$$Y_1 = \alpha_0 + \alpha_2 Y_2 + \alpha_3 Y_3 + \alpha_4 Z_1 + \alpha_5 Z_2 + \mu_1$$

$$Y_2 = \beta_0 + \beta_1 Y_1 + \beta_3 Y_3 + \beta_4 Z_1 + \beta_5 Z_2 + \mu_2$$

$$Y_3 = \gamma_0 + \gamma_1 Y_1 + \gamma_2 Y_2 + \gamma_4 Z_1 + \gamma_5 Z_2 + \mu_3$$

As shown, Y_1, Y_2, and Y_3 are endogenous, while Z_1, and Z_2 are predetermined variables. It is assumed that each error term is normally distributed with a mean of 0, and constant variance. A further assumption of no contemporaneous correlation between equations can be added in the case of exactly identified models, or when absence of correlation is theoretically plausible. The above model is most commonly estimated using either Two Stage Least Squares or Three Stage Least Squares, depending upon identification and the exent of contemporaneous correlation between equations.[36]

The specification of a system of equations directly effects the distribution properties of various estimators, as well as the method of estimation.[37] Important in the specification is the classification of variables into endogenous and exogenous variables. The exogenous and lagged variables are known as the set of predetermined variables.

As mentioned earlier, the question of predeterminedness is usually settled before or at the time of specification of the function. However, to establish a proper relationship between structure and technology variables, the question of endogeneity should be considered. The Wu-Hausman endogeneity test was employed to facilitate the specification of the structure -

[35]Pindyck, R.S. and Rubinfeld, D.L. **Econometric Models and Economic Forecasts,** McGraw-Hill Book Co. 1976. pp. 266-268.

[36]For a review of estimation methods involving simultaneous equation models, see Johnston, J. **Econometric Methods,** 3rd ed. McGraw-Hill Book Co. 1984. pp. 439-492.

[37]Wu, De-Min, "Tests of Causality, Predeterminedness and Exogeneity," *International Economic Review,* Vol. 24, No. 3, October, 1983. pp. 547-558.

technology relationship.[38]

Modelling Simultaneity in the Input-Output and Technology Relationship

The focus of the first hypothesis was on the input-output, output-technology, capital-technology, and ~~land~~-technology relationships. Two models, one for each of 1981 and 1986, were estimated using cross sectional data for current and lagged variables. Four submodels, each involving either a two or three equation simultaneous system, were estimated based on the following associations: (1) input-output submodel, (2) output-technology, (3) capital-technology, and (4) land-technology submodels. The submodels were estimated for each of the two time periods.

Actual levels of the input, output, and technology variables were used in the analysis. The general form of the simultaneous model may written as:

$$y = Y_1\beta + X_1\gamma + \mu$$

where y is the focus variable, Y_1 a matrix of current endogenous variables, and X_1 a matrix of predetermined variables. Under ordinary least squares (OLS) all coefficients would be biased and inconsistent due to the correlation of Y_1 with μ, the error term. To solve the estimation problem of simultaneity, the systems estimation technique of Two Stage Least Squares (2SLS) was used in the analysis.[39] All equations were also estimated using OLS from which Wu-Hausman endogeneity tests were performed on current structure and technology variables.[40]

The Wu-Hausman test measures the difference between the OLS and 2SLS estimators, standardized by a variance estimator. Consider the following equation:

$$Y = bHP + \gamma X + \mu$$

[38]For a good explanation of the Wu-Hausman test see: Thurman, W.N., "The Poultry Market: Demand Stability and Industry Structure," *American Journal of Agricultural Economics*, Vol. 69, No.1, February, 1987. pp. 30-37.
[39]Three Stage Least Squares was also tried, but it was found there was not significant contemporaneous correlation between equations.
[40]The Wu-Hausman test was originally applied in supply-demand analysis under a competitive framework. The use of the endogeneity test in this study was considered a new application of the Wu-Hausman test.

Ho: simultaneous Ha: causal

where Y and HP are output and mechanical technology respectively. X is a matrix of predetermined variables, and μ is the error term. Underlying the alternative hypothesis of causality are two distinct relationships: unidirectional and bidirectional. A bidirectional relationship between two variables suggests there is a feedback effect, whereby a change in the first variable yields a change in the second variable, which in turn has a feedback effect on the first variable.

If b is the estimator from an OLS regression, and b^* the estimator from 2SLS, the test statistic can be shown as:

$$T = (b - b^*)[V(q)]^{-1}(b - b^*)$$

$$\text{where } V(q) = Var(b^*)[(\sigma^2_{\mu.OLS})/(\sigma^2_{\mu.2SLS})] Var(b)$$

$$Ho: Cov(HP,\mu) = 0$$

T is asymptotically chi square. A large value for T rejects the null hypothesis of predetermined mechanical technology.[41]

Each submodel served as a basis for specification of the next submodel, where the degree of endogeneity and collinearity were uncovered which facilitated the development of the next submodel. Results of the analysis are given in Appendix C. The analysis rejected the research hypothesis of simultaneity among all relationships. Therefore, the structure-technology relationship was examined using single equation functions.

E. Modelling the Structure-Technology Relationship

As outlined earlier in the chapter, three structure and four technology variables were used in the analysis. The second hypothesis pertained to two time periods: (1) 1971 to 1981, and (2) 1981 to 1986. The 1971 to 1981 era was characterized by increasing commodity prices and appreciating land values, while the 1981 to 1986 period encountered a downward slide in both crop prices and land values.

[41] Thurman, W.N., "Endogeneity Testing in a Supply and Demand Framework," *The Review of Economics and Statistics*, 1986. pp. 638-646

The lack of previously reported research on the relationship between structure and technology was outlined in chapter 2. Neoclassical theory implies a one way causation of technology inducing structure, usually in the form of a time trend or as a change in the residual over time. Other research has used changes in relative factor prices as a proxy for technical change, while in this research technology proxies are in the form of presumptions about the innovativeness of the producer, captured in the level of use of technology at any one point in time. Three models were developed to determine the relationship between structure and technology on Alberta commercial grain farms. Each model involves independently estimated single equation submodels. The first model described the effect of the four technology variables on each of the structure variables. The equations can be shown as:[42]

$$\log K/N = \log A + \beta_1 \log HP + \beta_2 \log FERT + \beta_3 \log G + \beta_4 \log(Y/L)$$

$$\log L/N = \log A + \beta_1 \log HP + \beta_2 \log FERT + \beta_3 \log G + \beta_4 \log(Y/L)$$

$$\log K/L = \log A + \beta_1 \log HP + \beta_2 \log FERT + \beta_3 \log G + \beta_4 \log(Y/L)$$

Each of the above equations was estimated for 1971, 1981, and 1986. HP and FERT were presumed to be both capital and land using, with the capital using effect outweighing the land effect. An increase in HP induces an investment in a larger tractor and field equipment, while enabling the producer to cover more acres in one day. A change in fertilizer applicator to, say, an anhydrous applicator from broadcasting would require the use of a larger tractor. As well, yield advantages and potentially increased profits associated with newer, technologically advanced applicators were presumed to induce producers to increase their land base. As grain intensity increases, producers tend to reduce their livestock operation. While the movement towards grain production would allow the producer to dispose of some livestock related equipment, the added investment in grain production machinery was presumed to be greater. An increase in sales per acre, resulting from increased yields from the use of better seed varieties, fertilizers and chemicals, would allow the producer to form and finance capital for new machinery and land extensification.

[42]Semi-log and linear forms were also tried in the analysis, however the double log form proved to give better results overall.

The second model outlined the reverse effect of structure on technology. The capital/labour and land/labour variables were used as predetermined variables. The equations are described as follows:

$$\log Y/L = \log A + \beta_1 \log(L/N) + \beta_2 \log(K/N)$$

$$\log FERT = \log A + \beta_1 \log(L/N) + \beta_2 \log(K/N)$$

$$\log G = \log A + \beta_1 \log(L/N) + \beta_2 \log(K/N)$$

The structure variables, L/N and K/N, were presumed to positively influence the technology variables. Producers with a higher L/N and/or K/N ratio tend to be more technologically innovative, in an attempt to maximize profits while minimizing risk.

The third model examined the relationship between 1981 and 1986 values for the structure and technology variables. Only the best functions from the above two models were used in the analysis. The equations can be described as:

$$\log K/N = \log A + \beta_1 \log HP_{81} + \beta_2 \log FERT_{81} + \beta_3 \log G_{81} + \beta_4 \log(Y/L)_{81}$$

$$\log L/N = \log A + \beta_1 \log HP_{81} + \beta_2 \log FERT_{81} + \beta_3 \log G_{81} + \beta_4 \log(Y/L)_{81}$$

$$\log Y/L = \log A + \beta_1 \log(L/N)_{81} + \beta_2 \log(K/N)_{81}$$

$$\log G = \log A + \beta_1 \log(L/N)_{81} + \beta_2 \log(K/N)_{81}$$

where the left hand side variables are at their 1986 levels and all right hand side variables are at 1981 levels. All variables were presumed to have a postive sign, with the explanations identical to those given above. The results for the above three models are given in the following chapter.

The first order test criteria used in the analysis were the F-test and t-test. Significance in the context of this research refers to statisitical significance. Cross sectional analysis usually gives lower r-squared values due to the exclusion of lagged variables. Consequently, lower r^2 values were tolerated. A 1% level of confidence was used in the F-test, to determine whether the regression explained a significant amount of the variation in the dependent variable. Cross sectional analysis tends to give weaker t-values, such that in the analysis, levels of confidence were taken up to 10%.

F. Data Sources

Characteristics of the Study Area

This research concerns dry land farming in Alberta. Census division 10 (east-central Alberta) was chosen as the data base. CD 10 is comprised of the counties of Lamont, Camrose, Beaver, Minburn, Two Hills, and Vermilion River. Figure III.1 illustrates the area of study.

The area contains no significant irrigation, with varying degrees of livestock intensities. The soil is dark brown to black chernozemic, with a moisture classification of subhumid. There exists a pocket of black solonetzic soil in the lower central area of the census division. The soil temperature class is cold to moderately cold cryoboreal, having a moderate growing season with an insignificant soil thermal period over 15 degrees Celsius.

The Population

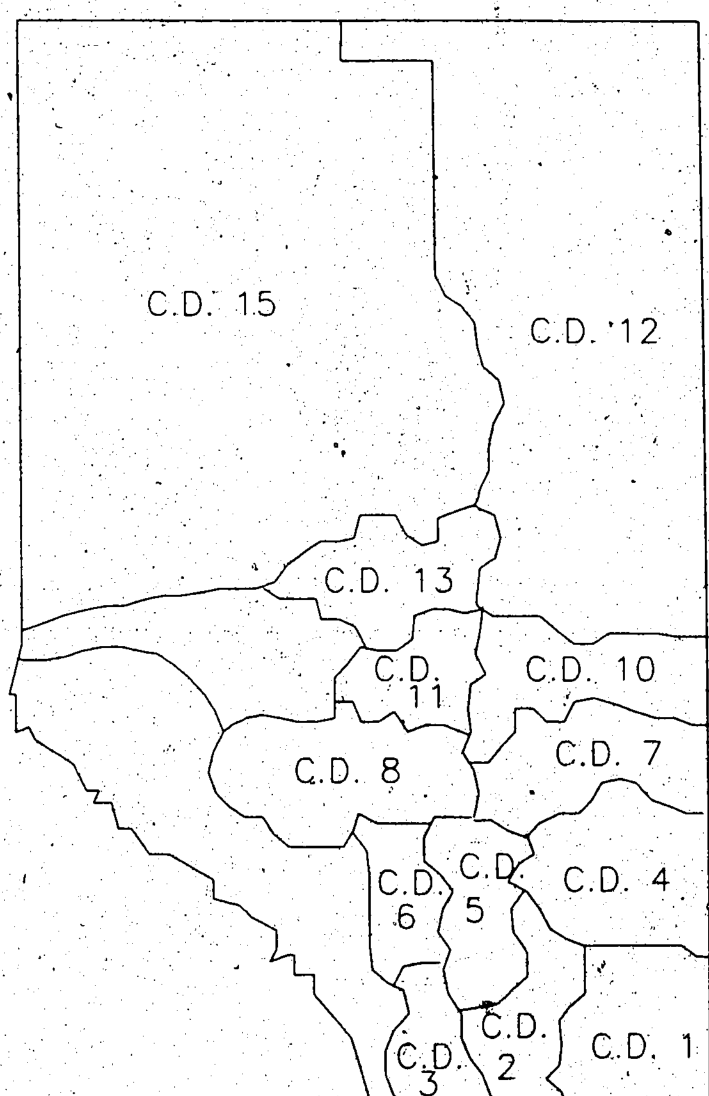
Only producers deriving the majority of their income from commercial grain production are of interest to this research. A commercial grain producer was defined as a farmer who owned/rented at least 320 acres, with 100 acres or more in crop. The producer had to satisfy this restriction in all three years, 1971, 1981 and 1986. This classification ruled out hobby farms, market gardens, small part-time farms, ranches and feedlots which did not meet the criteria.

Census data shows the number of commercial grain producers declined over the 1971-1981 decade by 17 per cent, from 5353 to 4442, while the average farm size rose by 30 per cent to 715 acres. Provincially the average farm size for 1981 was 863 acres, representing an increase of 26 per cent from 1971.

Sampling Method

Data collection is perhaps the most important stage in research, as it strengthens model building and gives credence to interpretations. There are various means of collecting data depending upon the research topic and resources available. The first, and most common source is published, secondary data. The next two sources, observation and

Figure III.1: Census Division 10 boundaries in 1986.



experimentation, are prevalent in the physical sciences. The final source and the one employed in this research, was interview and survey methods, typical of the social sciences.

On-farm interviews and mail out questionnaires provided the evidential base for the measurement of technology and structure of cereal agriculture. The sampling method was two stage: 1) township sampling, and 2) commercial farm enumeration.

In stage I, townships with less than or equal to 12 sections of CLI 1, 2, and 3 soils were excluded, eliminating areas with a predominance of livestock. As well, townships with greater than 5 sections of land in non-agricultural use were excluded. Non-agricultural use was defined as the sections being designated as: a) crown land, b) town or village, c)provincial or federal parks, d) private or government owned grazing reserves, or e) subdivisions. Townships with water bodies encasing greater than two-thirds of the land were also excluded. Thirty townships were randomly chosen from the remaining 154 townships in CD 10.

In the second stage, every farmyard was visited in each of the 30 townships to determine the degree of commercialization of each farm. Only those producers conforming to the guidelines established for a minimum commercial farm size were sent a follow-up mail-out questionnaire.

Stages of Data Collection

The data collection procedure was divided into two stages. The first stage employed on-farm interviews, while the second stage used mail out questionnaires with a phone follow up.

Thirty townships were visited in CD 10, within which there were approximately 500 farmyards. A copy of the first stage questionnaire is contained in Appendix A. The main purpose of stage I was to determine if the producer met the criteria established for a commercial grain producer. The remainder of the questions determined land use, biographic and socio-economic characteristics, to allow comparison of the producer to the Census of Agriculture averages for 1981.

The second stage of data collection dealt only with the commercial grain producer. The purpose of this stage was to obtain detailed structure and technology information for the years 1986, 1981, and 1971. As well, the survey was designed to acquire data concerning farming history, future perceptions, and motivations for changing technology.

The questionnaire, along with a covering letter, was mailed to 322 commercial grain producers. A phone follow up procedure was used to encourage the producer to fill out and return the questionnaire. 45 questionnaires were returned from the original number sent out to producers.

Response bias was checked through the comparison of land use answers with the answers for land use obtained in the on-farm interview. Only one respondent differed significantly in his land use answers. Two questionnaires were discarded due to erratic responses. Two questionnaires were missing their respective sales figures, for which a sales figure was estimated using regional yields, prices for wheat, barley, and canola, as well as the respondents' cropping data. Tests for normality were performed for two key variables; improved land, and total revenue, and all outliers were eliminated from the data set.

The questionnaire covered the years 1971, 1981, and 1986; spanning a period of 15 years, for which there was entry and exit in the farm sector. To determine the structure-technology relationship over time, only responses from producers present in all years studied were used in the analysis. The final sample of 27 farms covered fifteen townships spread over four counties in CD 10.

The sample of commercial grain producers was compared to the 1981 Census of Agriculture figures for commercial grain producers in CD 10. At a 98% confidence interval, there was no significant difference between the sample and population in terms of total improved land and person years of labour, permitting the conclusion that the sample was an unbiased representation of the population.

Questionnaire Design

The initial, on-farm survey served as the basis for applying selection criteria for commercialization. The survey also developed a positive, working relationship between the respondent and the researcher. This survey was structured in three parts: The first part established degree of commercialization, while part two contained land use questions to determine intensification-extensification movements over time. The land use questions also served as a check for response bias in the mail questionnaire. The final part of the survey contained biographic and socio-economic questions enabling comparison of the sample group to the census population.

The follow up, mail questionnaire incorporated a variety of questions pertaining to structure and technology, and was designed to minimize response time. Nine parts were established in the questionnaire: Part I, as in the first survey, determined the degree of commercialization. The second part of the survey covered the various types of organization, while the next part covered land use. Part IV asked for the main varieties of wheat, barley, and canola in an attempt to create an index of innovativeness for biological technology. Following this same reasoning, part V covered fertilizer use with respect to fertilized acres, applicator type, and pounds per acre of supplemental Nitrogen applied on wheat and barley. Part VI asked for an inventory of the vehicles, machinery and equipment used in the farm business. The next part determined the amount of labor employed in the farm business. Part VIII estimated the total value of agricultural products achieved from the farm business. The final part of the questionnaire covered the producers' farming history and future perceptions.

G. Summary

The relationship between structure and technology is best studied using low aggregated data, due to the hetergeneous nature of the agriculture sector. As a result, a primary data collection procedure was used to collect data from a group of commercial grain producers in CD 10, who were present throughout the 1971 - 1986 period. It was established that the sample group, based on their 1981 responses, was representative of the population in CD 10.

A simultaneous equation approach was used the determine the relationship between sales per farm, factor inputs, and technology in 1981 and 1986. Each equation was also estimated under OLS estimation, from which endogeneity testing were performed. A summary of results are given in chapter 4, while all details of the results are presented in Appendix C.

Based on the results from the endogeneity tests, a single equation approach was used to examine the relationship between structure and technology in each of 1971, 1981, and 1986. Three models were established: (1) structure as a function of technology, (2)technology as a function of structure, and (3) effect of 1981 structure on 1986 technology and the effect of 1981 technology on 1986 structure. Results are given in the following chapter.

IV. RESULTS

A. Introduction

A summary of the results for the first hypothesis of simultaneity among sales per farm, factor inputs, and technology is presented in this chapter. Chapter IV also provides the results of the analysis of the structure and technology relationship. A double log functional form was used for all equations. Table IV.1 illustrates the mean values and standard deviations for the structure and technology variables in each of the three years. Significance refers to the statistical definition, whereby in this research all F-values are reported at a 1% level of confidence and t-values are reported up to the 10% level of confidence.

B. Hypothesis One: Simultaneity of Output, Factor Inputs and Technology

The method for testing hypothesis one was two phase, the first of which involved modelling the relationships in simultaneous equation systems, upon which Two Stage Least Squares (2SLS) was performed. The second phase involved the estimation of each equation through the use of Ordinary Least Squares (OLS), from which results could be compared and tests of endogeneity could be conducted. Different specifications, wherever possible, and functional forms were used to check for sensitivity of the Wu-Hausman endogeneity tests. The collinear relationships among structure, and between the structure and technology variables, while expected, posed analytic problems.

Four submodels were used in the estimation. In submodel 1, the link between output, land, and capital was estimated, while in submodel 2, the tie between land, biological technology and mechanical technology was established. Submodel 3 involved the estimation of the bond between capital and the two technology measures. Submodel 4, the focus model, disclosed the relationship amongst output and the technology measures, taking into account the previous findings of the other submodels. Based on the correlation matrices of the variables between years, lagged values were included to aid in the indentification of the model. Most models were exactly identified. Specific findings for the 1981 and 1986 are reported in

Appendix C. At a 10% level of confidence, the results of the endogeneity tests did not reject the statistical null hypothesis of predeterminedness.

The working hypothesis, established for the research, of simultaneity between the output per farm, inputs and technology employed per farm in 1981 and 1986 was rejected under the decision criterion of the Wu-Hausman endogeneity test. Based on the above results, a single equation approach was used to examine the relationship between structure and technology in 1971, 1981 and 1986.

C. Structure Determined by Technology: Test of Hypothesis Two

Capital/Labour ratio and Technology Relationship

The double-log function can shown as:

$$\log \frac{K}{N} = \log A + \beta_1 \log HP + \beta_2 \log FERT + \beta_3 \log G + \beta_4 \log \frac{Y}{L}$$

Results are given in table IV.2. The regression is significant in 1986 and 1971, but not significant in 1981. Mechanical technology is significant in 1971 and 1986, while FERT is only significant in 1981. G is not significant in any of the years and sales per acre is only significant in 1986. All variables as expected, with the exception of FERT in 1971, had a positive influence on the K/N ratio in all years.

Land/Labour ratio and Technology Relationship

The double log function can shown as:

$$\log \frac{L}{N} = \log A + \beta_1 \log \text{[illegible]} + \beta_2 \log FERT + \beta_3 \log G + \beta_4 \log \frac{Y}{L}$$

Results are given in table IV.3. The expected signs were to be positive. The regressions are significant in 1986 and 1971, but not in 1981. HP and Y/L are significant in 1971, but not in 1981 and 1986. G is not significant in any of the years. FERT is significant in 1981 and 1986. HP was positive in 1986 and 1971, but negative in 1981. FERT had a positive effect in all years, while sales per acre had a negative impact in all years. The coefficient for G was negative in 1971 and 1981, and positive in 1986.

Table IV.1: Mean Values and Standard Deviations for the Structure and Technology Variables for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta, 1986, 1981, and 1971.

	1986		1981		1971	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Structure Variables						
Capital/Labour	62,380	34,673	83,141	90,567	30,651	19,299
Land/Labour	827	398	1273	2035	753	305
Capital/Land	80	41	76	45	41	24
Technology Variables						
Horsepower	136	45	116	40	70	25
Fertilizer Appl	86	17	79	17	64	13
Grain intensity	0.69	0.18	0.71	0.17	0.58	0.20
Sales/Acre	92	40	96	48	147	76

Note: All variables are on a per farm basis. Sales and capital values were deflated using Farm Input Price Index and Machinery Price Index respectively, with 1981=100.

Table IV.2: Structure Represented by the Capital/Labour Ratio Regressed on Various Proxies for Technology for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta in 1971, 1981 and 1986.

	1971	1981	1986
R^2	0.59	0.41	0.72
F	7.80***	3.77	14.42***
α	5.29	-0.018	-1.16
	(1.71)	(-0.0054)	(-0.57)
elasticities for:			
HP	1.42	0.56	1.56
	(4.88)***	(1.19)	(4.09)***
FERT	-0.31	1.91	0.61
	(-0.54)	(2.73)**	(1.39)
G	0.48	0.007	0.03
	(1.13)	(0.01)	(0.08)
Y/L	0.073	0.014	0.39
	(0.33)	(0.05)	(2.01)*

Table IV.3: Structure Represented by the Land/Labour Ratio Regressed on Various Proxies for Technology for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta in 1971, 1981 and 1986.

	1971	1981	1986
R^2	0.47	0.27	0.55
F	4.81***	2.06	6.67***
α	3.26	1.84	0.66
	(1.99)*	(0.66)	(0.37)
elasticities for:			
HP	0.55	-0.31	0.40
	(3.57)***	(-0.79)	(1.22)
FERT	0.45	1.60	1.19
	(1.48)	(2.77)**	(3.14)***
G	-0.16	-0.048	0.13
	(-0.69)	(-0.09)	(0.38)
Y/L	-0.20	-0.13	-0.[illegible]
	(-1.72)*	(-0.57)	([illegible])

Note: n=27. t-values are in parentheses. All variables are on a per farm basis. In 1971, N is assumed to equal 1. Packer (1986) found N=0.96 for CD 10, in 1971.
*** indicates significance at 1% level of confidence.
** indicates significance at 5% level of confidence.
* indicates significance at 10% level of confidence.

Capital/Land ratio and Technology Relationship

The double log function can shown as:

$$\log \frac{K}{L} = \log A + \beta_1 \log HP + \beta_2 \log FERT + \beta_3 \log G + \beta_4 \log \frac{Y}{L}$$

Results are given in table IV.4. As with the two prior models, the regressions are significant in 1986 and 1971, but not in 1981. HP is significant in all three years, while FERT and G are not significant in any of the years. Y/L is only significant in 1986. The coefficients for HP and Y/L are positive in all years as expected. G had a positive influence in 1971 and 1981, and a negative influence in 1986. FERT had a negative impact in 1971 and 1986, and a positive effect in 1981. The negative signs were not as expected.

D. Technology Determined by Structure: Test of Hypothesis Two.

Sales/Acre and Structure Relationship

The double log function can shown as:

$$\log \frac{Y}{L} = \log A + \beta_1 \log(L/N) + \beta_2 \log(K/N)$$

Results are given in table IV.5. The regression is only significant in 1986. The intercept term is significant in all three years. L/N ratio is significant in 1971 and 1986, but not in 1981. K/N ratio is only significant in 1986. The coefficient for L/N is negative in all years, which was not expected. The coefficient for K/N as expected is positive in all years.

Fertilizer Applicator Index and Structure Relationship

The double log function can shown as:

$$\log FERT = \log A + \beta_1 \log(L/N) + \beta_2 \log(K/N)$$

Results are given in table IV.6. All signs were as expected, with the exception of the negative sign for K/N in 1971. The regression is significant in 1981 and 1986. The intercept term is significant in all three years. L/N ratio is only significant in 1986, while K/N ratio is only significant in 1981. L/N ratio had a positive impact on FERT in all

Table IV.4: Structure Represented by the Capital/Land Ratio Regressed on Various Proxies for Technology for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta in 1971, 1981 and 1986.

	1971	1981	1986
R^2	0.49	0.42	0.57
F_r	5.23***	3.99	7.25***
α	2.03	-1.86	-1.82
	(0.68)	(-0.80)	(-0.87)
elasticities for:			
HP	0.87	0.87	1.16
	(3.10)***	(2.68)**	(2.99)***
FERT	-0.77	0.30	-0.58
	(-1.37)	(0.63)	(-1.29)
G	0.64	0.055	-0.099
	(1.56)	(0.12)	(-0.24)
Y/L	0.27	0.15	0.66
	(1.29)	(0.76)	(3.38)***

Note: n=27. t-values are in parentheses. All variables are on a per farm basis.
*** indicates significance at 1% level of confidence.
** indicates significance at 5% level of confidence.
* indicates significance at 10% level of confidence.

years. K/N ratio had a negative influence on FERT in 1971 and a positive influence in 1981 and 1986.

Grain Intensity - Structure Relationship

The double log function can shown as:

$\log G = \log A + \beta_1 \log(L/N) + \beta_2 \log(K/N)$

Results are given in table IV.7. The regressions are not significant in any of the years. L/N ratio exerted a negative, but insignificant influence on G in all years. K/N ratio had a positive and significant impact on G in all years.

E. Lagged Effect of 1981 Variables on 1986: Test of Hypothesis Two.

Effect of 1981 Structure on Technology in 1986.

The double log functions can be described as:

$\log Y/L = \log A + \beta_1 \log(L/N)_{81} + \beta_2 \log(K/N)_{81}$

$\log G = \log A + \beta_1 \log(L/N)_{81} + \beta_2 \log(K/N)_{81}$

Results are given in table IV.8. Neither regression is significant. L/N ratio in 1981 had a negative, but insignificant influence on Y/L and G in 1986. K/N ratio in 1981 had positive, but insignificant effect on Y/L in 1986 and a postive and significant impact on G in 1986.

Effect of 1981 Technology Variables on Structure in 1986.

The double log functions are shown as follows:

$\log K/N = \log A + \beta_1 \log HP_{81} + \beta_2 \log FERT_{81} + \beta_3 \log G_{81} + \beta_4 \log(Y/L)_{81}$

$\log L/N = \log A + \beta_1 \log HP_{81} + \beta_2 \log FERT_{81} + \beta_3 \log G_{81} + \beta_4 \log(Y/L)_{81}$

Results are presented in table IV.9. The K/N function is significant, while the L/N function is not significant. HP in 1981 had a positive and significant impact on K/N and L/N in 1986. FERT in 1981 had a positive, but insignificant influence on the structure variables, while G had a negative and insignificant influence on the structure variables. Y/L in 1981 had a positive and significant impact on K/N in 1986, and a negative and

Table IV.5: Technology Represented by Sales per Acre Regressed on Structure for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta in 1971, 1981 and 1986.

	1971	1981	1986
R^2	0.18	0.05*	0.32
F	2.69	0.64	5.73***
α	7.37	4.38	3.39
	(4.29)***	(3.27)***	(2.93)***
elasticities for:			
L/N	-0.68	-0.25	-0.49
	(-2.30)**	(-1.10)	(-2.71)**
K/N	0.19	0.16	0.40
	(1.39)	(0.95)	(3.23)***

Table IV.6: Technology Represented by Fertilizer Applicator Regressed on Structure for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta in 1971, 1981 and 1986.

	1971	1981	1986
R^2	0.11	0.36	0.47
F	1.45	6.68***	10.65***
α	3.68	2.63	2.13
	(5.56)***	(5.61)***	(4.05)***
elasticities for:			
L/N	0.18	0.034	0.24
	(1.58)	(0.42)	(2.89)***
K/N	-0.071	0.13	0.068
	(-1.34)	(2.23)**	(1.21)

Note: $n=27$. t-values are in parentheses. All variables are on a per farm basis. In 1971, N equals 1.
*** indicates significance at 1% level of confidence.
** indicates significance at 5% level of confidence.
* indicates significance at 10% level of confidence.

Table IV.7: Technology Represented by Grain Intensity Regressed on Structure for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta in 1971, 1981 and 1986.

	1971	1981	1986
R^2	0.19	0.13	0.22
F	2.79	1.83	3.30
α	-0.83	-0.92	-2.15
	(-0.91)	(-1.51)	(-2.91)***
elasticities for:			
L/N	-0.22	-0.16	-0.005
	(-1.38)	(-1.52)	(-0.04)
K/N	0.17	0.15	0.16
	(2.35)**	(1.90)*	(2.10)**

Note: n=27. t-values are in parentheses. All variables are on a per farm basis. In 1971, N equals 1.
*** indicates significance at 1% level of confidence.
** indicates significance at 5% level of confidence.
* indicates significance at 10% level of confidence.

insignificant effect on L/N in 1986.

Table IV.8: Influence of 1981 levels of Structure on Various Proxies for Technology in 1986 for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta.

Dependent Variable	$(Y/L)_{86}$	G_{86}
R^2	0.04	0.26
F	0.48	4.27
α	3.51	-1.67
	(3.15)***	(-2.89)***
elasticities for:		
$(L/N)_{81}$	-0.076	-0.15
	(-0.40)	(-1.54)
$(K/N)_{81}$	0.13	0.21
	(0.91)	(2.84)***

Table IV.9: Influence of 1981 levels of Technology Proxies on Structure in 1986, for a Sample of 27 Commercial Grain Farms in CD 10 of Alberta.

Dependent Variable	$(K/N)_{86}$	$(L/N)_{86}$
R^2	0.66	0.28
F	10.89***	2.14
α	0.76	2.37
	(0.36)	(1.13)
elasticities for:		
HP_{81}	1.24	0.58
	(4.15)***	(1.96)*
$FERT_{81}$	0.60	0.47
	(1.36)	(1.06)
G_{81}	-0.014	-0.29
	(-0.03)	(-0.68)
$(Y/L)_{81}$	0.37	-0.14
	(2.07)**	(-0.79)

Note: n=27. t-values are in parentheses. All variables are on a per farm basis.
*** indicates significance at 1% level of confidence.
** indicates significance at 5% level of confidence.
* indicates significance at 10% level of confidence.

V. INTERPRETATIONS

Chapter V provides an interpretation of the results and presents some limitations of the research. Two hypotheses were developed for the research. First, it was hypothesized the relationship between sales per farm, the factors of production (capital and land), and technology (horsepower and fertilizer applicator index) was simultaneous in 1981 and 1986. The second hypothesis concerned the relationship between structure and technology in 1971, 1981, and 1986. It was hypothesized technical change induced structural change during the 1971 - 1981 period of increasing commodity prices and appreciating land values, while during the 1981 - 1986 period of declining commodity prices, structural change induced technical change.

Over the 1971 - 1981 decade, there was a general increase in the values of all structure and technology variables, with the exception of real sales per acre. The changing structure and change in technology proxies over the decade may have been the result of increasing commodity prices and ascending land values. From 1981 to 1986, real capital stock per acre, horsepower, and the fertilizer applicator index continued to rise, while all other variables declined. Producers facing declining commodity prices and land values, and a high debt load reduced their acreage while adopting mechanical and fertilizer related biological technology in an attempt to increase productivity.

Two findings, specific to the hypotheses are discussed below: 1. predeterminedness of all variables, 2. direction of causality in the structure and technology relationship for 1971, 1981, and 1986: a. structure as a function of technology, and b. technology as a function of structure.

Over the fifteen year period studied, it was found there was not significant endogeneity amongst the inputs comprising the structural attributes and the technology variables (Appendix C). The exogenous relationship between output, capital and land is the basis of production theory. The lack of simultaneity amongst all the variables suggests a decision on one of the variables does not simultaneously determine the level of use of another variable, be it a technology or structure related variable. Increasing collinearity amongst the variables over the period studied was discovered however. As well, a number of new relationships appeared over time, particularly between current and lagged variables. These two findings imply a movement over time towards simultaneous decision making, or increasing complexity, involving output, inputs and the technologies employed. The logical consequence of this evolution is a more stringent structure moulded by previous technology and structure related decisions, and constrained by the ability of the producer to form and finance capital for structural and/or technical changes.

Once having established the likelihood of one way causality, the direction of causality between structure and technology was tested for 1971, 1981, and 1986. The first step in the analysis was to examine structure as a function of technology. Refer to Tables IV.2, IV.3 and IV.4.

Technology had a significant influence on all three structure variables in 1971 and 1986. No relation could be established for 1981, possibly due to the high standard deviations of the capital/labour and land/labour ratios for that year. Sampling error may have contributed to the results for 1981. However, one would have expected the variance in 1971 to be larger still, which given the design of the mail questionnaire, asked the producer to answer the questions one at a time, for each of 1986, 1981, and 1971. Another possible reason for the 1981 results was that producers were in a transitional period following the boom of the 1970's. During this transition, producers may have been making more major fixed factor decisions than usual, possibly increasing the variability in the values of the structure variables over the sample.

In the capital/labour function (Table IV.2), in all three years, the significant technology coefficients had a positive sign, suggesting a bias towards capital using (labour saving) technologies. The positive relationship of horsepower with the capital/labour ratio is natural, as the two are indirectly related. The positive, and significant influence of fertilizer in 1981 may be due to the movement in the farming sector towards cultivator-type fertilizer applicators, which occurred around the 1981 era. The adjustment of the farm's machinery and equipment to larger and predominantly yield enhancing fertilizer applicators was complete by

1986, possibly explaining the insignificant effect of the fertilizer variable in 1986. Sales per acre did not influence the capital/labour ratio until 1986.

Technology in 1981 had a positive, significant influence on the capital/labour ratio in 1986 (Table IV.9). Consequently, variations in the capital/labour ratio became less flexible whereby producers were increasingly bound by past decisions. Technologies embodied in capital tend to be lumpy, such that credit limitations and large depreciation losses in the first few years after purchase act as constraints to a short capital turnover rate.

The results describing the impact of technology on the land/labour ratio suggest technology may have only been a factor in 1971 and 1986 (Table IV.3). There seems to have been a shift over the fifteen year period in the sources of growth in the land/labour ratio from mechanical technology (HP) to fertilizer related biological technology. Table IV.3 illustrates the shift of influence from the horsepower variable to the fertilizer variable. The second interesting result to come from the land/labour - technology function is the negative sign of the sales per acre coefficient in all three years. A possible explanation of the negative sign is the labour using effect of increased sales per acre may have outweighed the land extensification effect. However, given that real sales per acre declined over the fifteen year period, the sign associated with sales/acre may be due more to market factors rather than technology factors inherent in the sales per acre variable.

Technology in 1981 had an insignificant effect on the land/labour ratio in 1986 (Table IV.9). Land related technologies are more in the form of the intermediate inputs of fertilizer, seed, and chemicals, which are more easily varied from year to year. The positive, significant influence of horsepower in 1981 on the land/labour ratio in 1986 may have been the result of two related effects: 1. The positive sign implies the larger the horsepower in 1981, the larger the land/labour ratio in 1986, suggesting producers may have been underutilizing their power source, enabling them to increase their land base without a consequent increase in horsepower requirement. 2. The producers decision to increase his land base in 1986 was constrained by a prior decision on the level of horsepower, possibly due to credit and cash flow limitations.

The influence of technology on the capital/land ratio was, as with the previous functions, significant in 1971 and 1986, but not in 1981 (Table IV.4). Horsepower had a positive, significant impact on the capital/land ratio in all three years. The predominantly positive influence of horsepoweer on capital/land and land/labour suggests mechanical technology is both capital and land using, with the capital using effect possibly outweighing the land using effect. This latter result may be due to the technology being embodied in capital and/or the producer being unable to finance both the adoption of mechanical technology and the expansion of land.

The negative sign of the fertilizer variable in 1971 in the capital/land function suggests fertilizer related technologies were land using and/or capital saving. The negative sign, in 1971, of the fertilizer variable in the capital/labour function and positive sign in the land/labour function supports the above interpretation. Given the positive sign of fertilizer in 1986 on the capital/labour and land/labour ratios, the negative sign of fertilizer in 1986 on capital/land may be due to the land using effect outweighing the capital using effect. Fertilizer related biological technologies are linked more to enhancing land productivity than capital productivity.

The second step in the analysis was to examine technology as a function of structure. Refer to Tables IV.5, IV.6 and IV.7. In 1971 and 1981, the structure variables did not significantly explain the variation in the technology variables, with the exception of the 1981 regression of fertilizer on capital/labour and land/labour (Table IV.6). The grain intensity variable was regressed on capital/labour and land/labour, which gave an insignificant functional relationship (Table IV.7). The structure influence on fertilizer was significant in 1981 and 1986, suggesting over the fifteen year period, as the agriculture sector developed, fertilizer related technologies became interrelated with the structure variables. The ordinary least squares estimation of sales per acre on structure (Table IV.5) was only significant in 1986, with land/labour exerting a negative, significant effect and capital/labour a positive, significant effect. The negative influence of the land/labour ratio on sales per acre was possibly due to the producer expanding his land base beyond his managerial capabilities. The positive impact of changes in the capital/labour ratio on sales per acre may have been due to: 1. increased productivity of the capital stock as the producer expanded or updated his machinery and equipment, and 2. those producers having a higher capital/labour ratio using better seed varieties, chemicals and fertilizer.

Implication of Findings on Hypothesis Two.

Generally, in 1971 and 1981, the structure variables did not significantly explain the variation in the technology variables. In 1971, the technology variables explained a significant amount of the variation in all three structure variables. In 1981, the F values were generally larger in the structure as a function of technology equations. The results for the 1971 to 1981 decade suggest technology had a greater influence on structure than the reverse effect, supporting the first part of hypothesis two.

In 1986, the results suggest a bidirectional relationship between structure and technology, which does not support the second part of hypothesis two. The results for 1986 may have been the product of the economic downturn in the agriculture sector since 1982, motivating producers to more carefully assess decisions and related influential factors such as structure, technology, prices, cash flow and credit.

A. Limitations

Prior to data collection procedure, it was anticipated a large stratified sample would be obtained using the farming systems classification, developed by Packer, based on grain and cropping intensity.[43] However, stratification of the sampling frame, developed from the first stage sample, was not possible, given an unsuccessful field season of farm visits in 1986. Some of the field problems encountered were: 1. timing of the interviews to not conflict with the producers schedule, and 2. staffing problems, wherein one of the main interviewers hired, lacked motivation and had personality conflicts with some of the producers.

The data collection procedure relied upon the recall of the producer for 1981 and 1971, contributing to error. The need for primary data was fundamental to the research. The

[43]Packer, op. cit.

lack of records on the part of the producer contributed to the field problems of collecting the data.

Defining the technology proxies was difficult, as very little research has been done in this area. A number of proxies were originally developed, based both on the knowledge of the researchers about the behavior of producers, and on previous work by Hayami and Ruttan. Originally five proxies were developed: 1. seed varieties, 2. pounds of supplemental nitrogen applied per acre, 3. type of fertilizer applicator used on the farm, 4. horsepower and 5. sprayer width. High variability and erratic responses eliminated the seed variety proxy. Answer omission and erratic responses excluded the second proxy. There was not significant difference in the sprayer width over time and between producers, thus eliminating this proxy.

Multicollinearity problems tended to lead to simplification in the analysis, particularly in testing the first hypothesis. In specifying the simultaneous equations, some variables were excluded from some of the equations due to collinearity with other right hand side variables. Throughout most of the analysis, multicollinearity problems lead to the use of two equation simultaneous systems rather than larger systems with more equations and variables.

The use of a double log function can not represent complementary relationships amongst the predetermined variables. As well, the elasticity of substitution is fixed at 1. Further research is needed in specifying the functional form describing the structure and technology relationship.

B. Synoptic Overview

The 1971 - 1981 decade was characterized by increasing commodity prices and ascending land values. The results showed there to be a predominantly one way causation, with structure being a function of technology in 1971 and 1981.

During the 1971 to 1981 period, producers were induced by technological innovations to change their input mix, expand their land base and consequently adjust the structure of their farms. Agricultural policy was directed towards increasing the standard of living of farmers, tax incentives and low interest long term loans, all facilitating land extensification and capital intensification. The economic boom imparted optimism towards land appreciation, leading to financial lending policies being based more on speculative capital gains, favourable credit terms, and tax advantages, than on profitability and repayment capabilities of the farm.

The relationship between structure and technology in 1986, as shown by the results, was bidirectional. Consequently, a change in structure would have induced a change in technology, which in turn induced a structural change, and so on. The same effect would have been true for an initial change in technology, making it difficult to determine the major driving force in the system. As well, it would have been difficult to determine the point of equilibrium.

As the economy moved into a downturn in the early 1980's, credit and taxation policies did not adapt to the change. Producers locked into long term loans faced declining revenues and equity levels, such that they were unable to form capital for further structural adjustments. Technologies complementary to the relatively inflexible structure were sought to increase the productivity of the factors of production, particularly land, labour and capital. Structure seems to have been limiting to technical advance.

Lending practices by such government institutions as AADC and FCC, aimed at preserving the family farm and attracting new producers, may have locked producers into an inflexible structure. Lending decisions based on profitability and repayment capabilities of the farm operation tend not to distort decision making. Taxation policies such as the investment tax credit, tax rebates, and capital cost allowances are means of stimulating growth during economic downturns. However, during periods of increasing commodity prices, such policies tend to obscure the correct rationale for decision making by the producer.

Evidence of the change in structure and technology relationship over time can be seen by viewing the technologies available on the market in the 1980's compared to the 1970's. In the 1970's, mechanical technology was centered around larger machinery and equipment allowing the producer to cover more acres in a day than he thought possible. In the 1980's, technology has been predominantly directed at increasing the productivity of the current structure through: 1. combining operations such as cultivation and fertilizer application, and

2. permiting a reduction in capital stock, such as double-swath swathers.

Further research is needed to better specify the form of the structure and technology relationship, such as nonlinear forms better able to represent complementary and substitution relationships, as well as the interaction among predetermined variables. As well, further research using macroeconomic variables, such as interest rates, wage rates, and relative factor and commodity prices would add to the understanding of the connection between structure and technology. An extension of this research involving industrial organization theory examining the relationship between concentration, farm numbers, entry and exit and technology would also add to the understanding of structure and technology in grains agriculture.

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APPENDIX A

PART I

The purpose of this research is to follow the movement of the industry from 1971-1986.

1. In 1971, did you own and/or rent at least 320 acres? Yes ____ No ____
2. Of this, were 100 acres or more in crop? Yes ____ No ____

   Skip to Part II if the response to questions 1 and 2 was 'yes'.
3. In 1981, did you own and/or rent at least 320 acres? Yes ____ No ____
4. Of this, were 100 acres or more in crop? Yes ____ No ____

PART II - Land Use

Now I would like to ask you a few questions about your cropping rotation and intensity for the years 1971, 1981, and 1986.

1. How many acres of cereal grains did you seed to be harvested as grain? (This includes wheat, barley, oats, rye and corn).

   1986 ________ 1981 ________ 1971 ________
2. How many acres of oilseeds did you seed?

   1986 ________ 1981 ________ 1971 ________
3. How many acres of greenfeed, hay or silage will be/were harvested?

   1986 ________ 1981 ________ 1971 ________
4. How many acres of summerfallow do/did you have?

   1986 ________ 1981 ________ 1971 ________
5. How many acres of improved land for pasture do/did you have? (This includes pasture or grazing land, improved by seeding, draining, irrigating, fertilizing or brush or weed control. This does not include area to be cut for hay, silage or seed).

   1986 ________ 1981 ________ 1971 ________
6. How many acres of other improved land such as farmyard, new unseeded breaking, etc. do/did you have?

   1986 ________ 1981 ________ 1971 ________

PART III - Biographic and Socio-economic Questions

The last few questions I would like to ask you will be used as a comparison to the 1981 Census of Agriculture.

1. In what year were you born? ________

2. Did you employ hired agricultural labour in 1980? (Include only persons 15 years of age and over. Do not include housework or custom work and other non-agricultural work).

   Yes ____ No ____(If no, skip to question 4).

3. How many weeks of paid hired labour did you have in 1980? (Note: 1 month is equivalent to 4 weeks - 1 year is equivalent to 52 weeks).

   Total Weeks ________

4. How many days did you work off the farm in 1980? (Do not include exchange work. Note Interviewer: Convert part days to full days on the basis of an 8 hour day).

   None ________ Days ________

5. In June, 1981 how many cattle and calves were on this farm? ________

6. What is your estimate of the value of all machinery and equipment on this farm in 1981? (Please include all machines and equipment located on this farm regardless of ownership. Do not include old machines which were no longer used).

   $ ________

Comments: ____

APPENDIX B

CONFIDENTIAL CODE ____

THE EFFECTS OF CHANGING TECHNOLOGY ON THE STRUCTURE
OF ALBERTA GRAIN FARMS BETWEEN 1971 and 1986.

NOTE: Name and address not required. Each questionnaire is coded to ensure confidentiality. All information is CONFIDENTIAL and in no way will the information be connected to you. That's a promise!

The purpose of this research is to determine changes which have occurred in the industry between 1971, 1981, and 1986. Naturally you may find it difficult to remember way back to 1971. We hope the questions are straight forward enough to make it easy for you to remember.

Please return by July 20, 1987 to:

Department of Rural Economy
Faculty of Agriculture and Forestry
University of Alberta
Edmonton, Alberta T6G 2E9

PART I

1. In 1971, did you own and/or rent at least 320 acres? Yes ____ No ____

2. Of this, were 100 acres or more in crop? Yes ____ No ____

   Skip to Part II if the response to questions 1 and 2 was 'yes'.

3. In 1981, did you own and/or rent at least 320 acres? Yes ____ No ____

4. Of this, were 100 acres or more in crop? Yes ____ No ____

PART II - Type of Organization

1. Which of the following best describes this holding for the years 1986, 1981, and 1971? Please mark an 'x' on the appropriate line.

	1986	1981	1971
Individual or family holding	____	____	____
Partnership			
b. with a written agreement	____	____	____
c. with no written agreement	____	____	____
Corporation (A Legally Constituted Company)			
d. with the majority of the shares owned by you and your family	____	____	____
e. with the majority of the shares owned by other person(s) or business	____	____	____
Other Type of Organization (please specify)____________	____	____	____

PART III - Land Use

Now I would like to ask you a few questions about your cropping rotation and intensity for the years 1971, 1981, and 1986.

1. How many acres of land did you own and rent in 1986, 1981, and 1971?

   1986 __________ 1981 __________ 1971 __________

2. How many acres of cereal grains did you seed to be harvested as grain? (This includes wheat, barley, oats, and rye).

   1986 __________ 1981 __________ 1971 __________

3. How many acres of oilseeds (canola, mustard, etc.) did you seed?

   1986 __________ 1981 __________ 1971 __________

4. How many acres of greenfeed, hay or silage were harvested?

   1986 __________ 1981 __________ 1971 __________

5. How many acres of summerfallow did you have?

   1986 __________ 1981 __________ 1971 __________

6. How many acres of improved land for pasture did you have? (This includes pasture or grazing land, improved by seeding, draining, irrigating, fertilizing or brush or weed control. This does not include area cut for hay, silage or seed).

   1986 __________ 1981 __________ 1971 __________

7. How many acres of other improved land such as farmyard, new unseeded breaking, etc. did you have?

   1986 __________ 1981 __________ 1971 __________

8. For the years 1986, 1981 and 1971, how many acres of your total improved land was rented?

   1986 __________ 1981 __________ 1971 __________

PART IV - Seed Use

1. Please list the main varieties of wheat, barley and canola sown on your farm.

	1986	1981	1971
WHEAT variety, OR place a check mark for			
unspecified variety			
do not remember			
BARLEY variety, OR			
unspecified variety			
do not remember			
CANOLA variety, OR			
unspecified variety			
do not remember			

PART V - Fertilizer Use

Fertilizer and chemicals are two of the major costs during spring seeding which deplete a farmer's operating capital. The next two questions will help reflect the changes that have occurred in fertilizer use between the years 1981 and 1986. Please be as accurate as possible.

1. For the years 1986 and 1981, how many acres of your crop were fertilized? (Exclude area under hay, and pasture)

   1986 __________ 1981 __________

2. Of this, on how many acres was the fertilizer applied with the seed?

   1986 __________ 1981 __________

3. How many acres received supplemental nitrogen?

   1986 __________ 1981 __________

4. Please circle the type of application used for supplemental nitrogen.

1986	1981	1971
a) No supplemental N applied	a) No supplemental N applied	a) No supplemental N applied
b) Deep Band	b) Deep Band	b) Deep Band
c) Anhydrous Applicator	c) Anhydrous Applicator	c) Anhydrous Applicator
d) Cold flow system	d) Cold flow system	d) Cold flow system
e) Broadcast	e) Broadcast	e) Broadcast
f) Other(please specify) __________	f) Other(please specify) __________	f) Other(please specify) __________

5. For your **WHEAT** on summerfallow, how many pounds per acre of supplemental nitrogen(actual N) did you apply?

	1986	1981
Granular	__________	__________
Anhydrous	__________	__________

6. For your **BARLEY** on stubble, how many pounds per acre of supplemental nitrogen(actual N) did you apply?

	1986	1981
Granular	__________	__________
Anhydrous	__________	__________

PART VI - Farm Vehicles, Machinery and Equipment

Please report only vehicles, machinery and equipment used in the farm business.

1. Please list the make, model and year for tractors used in 1986, 1981 and 1971. As well, please list the year of purchase for those tractors used in 1986 and 1981.

1986				1981			
Make	Model	Year	Year of Purchase	Make	Model	Year	Year of Purchase

1971		
Make	Model	Year

2. Please list the farm vehicles used in your farm business.

1986			1981			1971		
Make	Model	Year	Make	Model	Year	Make	Model	Year

3. Please list the combine(s) and swather(s) used in your farm business.

1986			1981			1971		
Make	Model	Year	Make	Model	Year	Make	Model	Year

4. Please list the tillage and planting equipment used in your farm business. Try your best on the earlier dates.

1986			1981			1971		
Make/Model	Width	Year	Make/Model	Width	Year	Make/Model	Width	Year

5. Please list the make, width(feet) and year for the sprayer(s) used in your farm business.

1986			1981			1971		
Make	Width	Year	Make	Width	Year	Make	Width	Year

APPENDIX D

The data used in the study can be accessed on the disk contained in the pocket of the back cover of the thesis. Files WD86, WD81 and WD71 contain the working data for 1986, 1981 and 1971 respectively, while II86 is the command file which provides a listing of the variables. Files DATALL86, DATALL81 and DATALL71 contain the raw data, while COM86, COM81 and COM71 give the format of the data and description of variables. The working data is also given in the following three tables for 1971, 1981 and 1986 respectively. The variable order is: total value of agricultural products (Y), total improved area (L), person years of labour (N) for 1986 and 1981 only, capital stock (K), fertilizer applicator index (FERT), horsepower (HP), age (AGE), cropping intensity (C), grain intensity (G) and rented area (RENT). All variables are on a per farm basis.

282214	1040	39251	90	073	40	1.000	0.961	020
182395	0660	34748	50	076	57	0.924	0.681	000
132486	0740	19098	90	046	41	1.000	0.540	000
061403	0675	23076	50	092	22	0.851	0.740	000
061403	0705	61273	50	110	37	0.886	0.780	000
058983	0320	29177	50	030	47	0.718	0.000	000
132138	0530	15119	70	055	29	1.000	0.849	000
188581	0700	28381	90	085	46	1.000	0.571	100
027828	0480	03183	70	023	42	0.687	0.270	000
070780	0773	49071	70	079	43	0.857	0.776	000
[illegible]	0906	25994	50	052	49	0.779	0.772	000
[illegible]	0430	13262	70	028	31	0.622	0.577	000
062310	0410	06631	50	052	46	0.878	0.707	060
232909	0910	48806	50	084	36	0.934	0.417	000
057168	0307	03978	50	039	54	0.771	0.433	000
065638	1000	04774	70	043	44	0.850	0.400	250
067150	0475	16710	70	050	53	0.842	0.421	000
[illegible]	0614	53050	50	099	52	0.776	0.600	065
[illegible]	0853	07957	70	062	43	0.742	0.662	690
060496	1605	41114	70	084	46	0.750	0.616	000
065638	0650	36074	70	090	36	0.784	0.538	000
065638	0480	19893	70	091	39	0.687	0.625	000
198729	0895	54376	50	085	40	0.664	0.446	000
225045	0955	22811	70	084	29	0.738	0.680	500
063520	1270	68965	70	110	48	0.503	0.496	480
060496	0690	41114	70	090	55	0.855	0.695	000
124016	1240	59681	50	078	52	0.854	0.443	000

101737	1040	1.23	148000	090	202	50	1.000	0.961	020
156693	0735	1.00	039000	050	125	67	0.931	0.714	000
054956	0790	0.07	034000	090	046	51	1.000	0.569	000
194277	1530	0.93	073000	095	145	32	1.000	0.915	000
072783	1208	1.00	146000	050	159	47	0.834	0.745	000
041103	0455	1.19	014000	050	084	57	0.725	0.659	000
228625	1630	1.00	071000	100	157	39	1.000	0.981	000
124276	1200	1.00	093000	090	085	56	1.000	0.604	300
020438	0507	0.41	008000	070	073	52	0.753	0.339	000
028045	1450	1.05	127000	090	155	53	1.000	0.910	000
079482	0916	1.00	038000	070	108	59	0.825	0.818	140
047008	0450	1.00	015000	070	074	41	1.000	0.955	000
022709	0365	1.00	006000	050	035	56	0.835	0.616	000
252980	1094	1.07	088000	090	131	46	0.817	0.533	000
018848	0307	1.00	020000	050	065	64	0.781	0.540	000
059043	1250	1.00	035000	090	085	64	0.840	0.480	400
063699	0535	1.00	062000	090	094	63	1.000	0.607	000
056773	0523	1.00	071000	090	145	62	0.791	0.728	000
052231	0804	1.00	052000	070	109	53	0.782	0.720	690
045418	1705	2.00	139000	090	163	56	0.765	0.592	000
045418	0420	0.50	088000	090	154	46	1.000	1.000	000
053139	0450	0.63	061000	070	100	49	0.666	0.666	000
133530	1015	1.96	062000	070	123	50	0.901	0.719	000
102191	1065	1.00	077000	090	135	39	0.868	0.845	600
090836	1110	1.00	077000	090	159	58	0.828	0.819	480
045418	0630	1.00	056000	090	115	65	0.841	0.761	000
140229	1190	1.30	122000	090	095	62	0.848	0.462	000

122795	1040	1.23	127133	090	202	55	1.000	0.961	020
088742	0820	1.00	083617	090	186	72	0.878	0.682	000
079643	0840	1.07	038395	090	154	56	1.000	0.595	000
102063	0680	1.00	060580	090	160	37	1.000	0.955	000
077673	1810	1.00	093856	100	261	52	0.889	0.773	000
023639	0480	1.15	017064	050	084	62	0.687	0.625	000
188485	1155	1.00	129692	100	171	44	1.000	0.974	155
137406	1350	1.00	075938	090	110	61	1.000	0.518	600
018105	0337	0.82	009385	100	073	57	0.703	0.370	148
045121	1050	1.07	064846	100	155	58	0.924	0.800	000
084427	1011	1.00	076791	090	146	64	0.837	0.830	140
080675	0450	1.15	044368	070	109	46	0.522	0.477	000
017636	0412	1.00	006399	050	073	61	0.781	0.587	030
182270	1142	1.30	139931	090	131	51	0.869	0.537	000
017917	0183	1.00	019624	050	074	69	0.879	0.475	000
084427	1550	1.00	023890	090	085	59	0.903	0.451	400
062195	0500	1.00	042662	090	094	68	1.000	0.580	000
046904	0534	1.00	042662	095	155	67	0.801	0.739	000
041651	0922	1.05	041808	090	109	58	0.783	0.726	690
075046	1750	1.15	125426	100	163	61	0.771	0.577	000
040337	0450	1.00	075085	050	145	51	1.000	0.977	000
038367	0570	0.63	034129	100	100	54	0.877	0.877	000
069981	0950	2.00	163822	100	180	55	0.894	0.631	000
121951	1065	1.00	084470	090	143	44	0.868	0.845	30[illegible]
075046	1110	1.30	110921	100	160	63	0.873	0.864	480
075046	0611	1.00	021331	090	115	70	0.826	0.785	000
114915	1110	1.30	136518	090	140	67	0.838	0.495	000