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THE UNIVERSITY OF ALBERTA

Productivity Growth and Production Technology in the Prairie Grain Sector

by

Ali Abdulati Rahuma

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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T. S. Veeman

Supervisor

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External Examiner

Date April 26, 1989

Dedication

To my parents.

Abstract

The study of agricultural productivity in Western Canada was disaggregated to the prairie grain sector. The analysis, based on five major grains and oilseeds, was further disaggregated to the provincial level and to the major prairie soil zones (brown, dark brown, black, and gray). Two main features of the empirical work included (1) the generation of zonal price data for wheat and barley based on grade distributions and (2) the deriviation of input use figures for the grain sector which used census information to divide input use in agriculture between crops and livestock.

Tornqvist-Theil index procedures were utilized to derive output, input, and total factor productivity indexes. The rate of productivity advance for the prairie grain sector was estimated at 1.2 percent per year over the period from 1962 to 1983, with Manitoba having the highest provincial rate of productivity growth, followed by Alberta and Saskatchewan. The productivity growth rates for soil zones show the gray zone exibiting the highest rate, followed by the black, brown, and dark brown zones. There is evidence that productivity performance in the black and gray soil zones was stronger since 1973, whereas productivity in the brown and dark brown soil zones appears to have slowed in the years since 1973.

Production relations were estimated for the Alberta grain sector using the translog cost function approach. Based on likelihood ratio tests, the non-homothetic translog cost function could not be rejected statistically while homothetic, Hicks - neutral, and Cobb-Douglas specifications were rejected. The estimated coefficients of the non-homothetic cost function were used to derive key production parameters such as elasticities of substitution, own-price and cross-price elasticities of demand for various inputs, and the direction of technical change in the Alberta grain sector. For example, substitute relations were found between the land-fertilizer, labor-machinery and machinery-fertilizer input pairs whereas the land-labor, land-machinery and labor fertilizer input pairs were found to be complements. Finally, the general direction of technical change is strongly labor saving and machinery and fertilizer using.

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1. Introduction

The growth potential and productivity performance of the prairie grain sector continues to be of vital importance to prairie farmers and policy-makers. Improvements in productivity in the prairie grain sector are essential to overcoming cost-price squeeze pressures and to retaining competitiveness in world markets.

In this study, total factor productivity, defined as the ratio of output to all inputs combined, is measured, and the production relations are also estimated and analyzed for a specific, but very critical subsector in prairie agriculture -- the prairie grain sector. In addition, the measurement of productivity is disaggregated to the provincial level and to the major soil zones of the prairie grain growing region. The approach to productivity measurement which is taken uses flexible-weight, Divisia-related index number procedures which, in turn, are closely tied to improved "flexible form" production specifications. The production relationships, on the other hand, are estimated by utilizing the translog cost function which is dual to the translog production function.

1.1 Nature and Scope of the Problem

Productivity growth continues to be seen as an important issue with respect to the relative profitability and competitiveness of Canada's resource industries, including agriculture. In both rich and poor nations, productivity growth tends to be regarded as a mainspring of agricultural growth. The prairie grain sector is a major component of Canadian agriculture. The analysis and assessment of productivity trends in the prairie grain sector, then, are important areas of study. There have also been concerns expressed that productivity performance in Canadian agriculture in general and in the prairie grain sector in particular may be lagging.

A better understanding of productivity growth and the production structure which underlies this growth is extremely important to grain producers, consumers, and regional and national policy planners. For grain producers, increases in productivity may increase their incomes and help them to overcome the adverse effect of cost-price squeeze pressures through more technically efficient use of factor inputs. Productivity growth for consumers means lower prices for food. And for regional and national planners, knowledge about productivity growth in grains will help in decision-making concerning resource allocation on farms and in the public sector.

The prairie grain sector made important contributions to the growth of the Canadian economy historically and continues to be a reasonably important sector. The direct contribution of prairie agriculture to Canadian GNP is approximately 3 percent and to aggregate gross provincial product on the prairies is about 8 percent (Economic Council of Canada 1988). Grain and other crops have recently comprised 65 percent of total farm cash receipts in the prairie region. Indirectly, the prairie grain sector also stimulates economic activity in sectors forwardly and backwardly linked to the grain sector (Veeman and Veeman, 1984). The major current contribution of the prairie grain sector to the Canadian economy, however, occurs with respect to Canada's balance of international trade. Between 1974 and 1981, grains and oilseeds contributed 8.3 percent, on average, of total Canadian exports and comprised over 70 percent of Canadian agricultural exports. In 1987, wheat export sales alone exceeded $3 billion and grains and oilseeds made a net contribution to Canada's merchandise trade balance of 44 percent (Economic Council of Canada 1988).

Most previous studies of agricultural productivity in Canadian agriculture (Furniss, 1970; Shute, 1975; Islam, 1982; Brinkman and Prentice, 1983; Veeman and Fantino, 1985; Manning, 1986; Capalbo and Denny, 1986; and Lapierre and others, 1987) have concentrated on the measurement of aggregate output, aggregate input use, and productivity for the primary agricultural sector as a whole. It is also important, however, to measure and analyze agricultural productivity at a more disaggregated level. In this study, the prairie grain sector has been chosen for more detailed and disaggregated analysis. Such sectoral productivity studies have been undertaken in Australian agriculture in, for example, the sheep industry (Lawrence and McKay, 1980), and in Alberta agriculture in the beef industry (Anderson, 1985).

In addition to measuring and assessing productivity trends in the grain sector in the prairie region as a whole, it is also useful to disaggregate productivity analysis in the grain sector to the respective provincial levels as well as to the four major soil zones of the prairie region. An interesting analytical and policy question is whether productivity growth in the grain sector in Alberta in higher or lower than that experienced in Saskatchewan or Manitoba. A further issue is whether productivity performance has been similar or different in the 1960s, 1970s, and early 1980s among the brown, dark brown, black, and gray soil zones of the prairies. The approach to productivity analysis and measurement which is proposed rests on flexible weight index number procedures which are now regarded to be conceptually superior to previously used aggregation procedures.

Increased productivity in the grain sector is a direct result of several (often interrelated) factors including specialization in grain farming, change in land use, improvements in technology, introduction of new and improved capital items, and greater managerial skills. These sources of increasing productivity are in turn the product of basic inputs, principally, research and education. Knowing how these input factors (land, labor, capital, chemicals, and materials) are combined and interact in the production process will improve our knowledge of changing input use and acricultural productivity. Studying the production technology, and the inflence of factor prices on input use in the Alberta grain sector, for example, will shed light on changing input use and technological changes in this sector. Such studies will provide information on the substitutability and complementarity relationships between each pair of inputs, generate own and cross price elasticity of demand for different input factors, and provide indications of the direction of technical change.

1.2 Area of the Study

The prairie grain sector is defined in this study to include the five major cereal and oil seeds (wheat, barley, oats, flaxseed, and canola) grown in the prairie region of Alberta, Saskatchewan, and Manitoba. The prairies are the major sources of grain and oilseeds in Canada; they provide a supply from these commodities to meet the requirement for local consumption and for export to foreign markets. In the crop year 1981-82 the three prairie provinces (Alberta, Saskatchewan, and Manitoba) provided 96 percent of Canadian wheat production, 65 percent of total coarse grain production, 92 percent of total barley output, and 97 percent of the oats produced in Canada (Veeman and Veeman, 1984). The production of these five major grains takes place in four major soil zones in the prairie region (the brown, dark brown, black, and gray zones). These soil zones are delineated on the basis of soil organic matter content, general moisture availability, and other distinguishing soil/agronomic characteristics. The following simplifying assumptions were made: grain production in Manitoba was considered to be entirely in the black soil zone; the relatively narrow gray soil zone across northern Saskatchewan was subsumed into the black soil zone; and in Alberta where census divisions more clearly overlapped two soil zones, portions of these census divisions were allocated to respective soil zones.

1.3 Objectives of the Study

The primary objectives of this study are to measure and analyze productivity growth in the prairie grain sector and its major soil zones for the period of 1961-84, and to estimate the production relations for the Alberta grain sector for the period of 1957-84. Specifically, the following objectives are sought:

1. To estimate the growth rates of output, input, and total factor productivity of the prairie grain sector.
2. To estimate and analyze the productivity growth rate of the prairie grain sector as disaggregated to:
   a. Provincial level (Alberta, Saskatchewan, and Manitoba).
   b. Zonal level (brown, dark brown, black, and gray).
   c. Provincial zonal level such as: the brown, dark brown, black, and gray soil zones in Alberta; the brown, dark brown, and black zones in Saskatchewan; and the black soil zone in Manitoba.
3. To estimate changes in the terms of trade (prices received by farmers/prices paid by

farmers), and the returns/cost ratio (an indicator of profitability for grain farmers), for the prairie grain sector and disaggregated to provincial and soil zone levels.

4. To focus attention on the conceptual and empirical problems of estimating input use for the grain sector. These problems arise because of the lack of information on input use for each agricultural subsector (grain or livestock).
5. To derive reasonable estimates of zonal prices of grain output, especially for wheat and barley. This is mainly because of the differences in the grade distributions of wheat and barley across soil zones. As a consequence it is not appropriate to apply the average prairie wheat and barley prices to each soil zone.
6. To derive estimates of zonal prices of the land input, this problem arising due to the existence of wide differences among soil zones in terms of land quality, fertility, and moisture availability.
7. To derive zonal output and input figures, and to construct aggregate output and input quantity indexes, as well as corresponding output and input price indexes, for each soil zone.
8. To estimate a "flexible form" translog cost function in order to study:
    a. the influence of factor prices on the substitutability and complementarity relationships among input factors in the Alberta grain sector.
    b. to estimate and analyze own and cross price elasticities of demand for different input factors; and
    c. to examine the direction of technical change in the Alberta grain sector. In other words, to see whether technical change, for example, is labor saving and capital using or fertilizer using and land saving.

1.4 Analytical Procedures

Productivity can be expressed either in terms of total factor productivity (TFP), which is defined as the ratio of output to all input combined, or in terms of partial productivity such as output per acre of land or per unit of labor. Although partial productivity measures are widely cited, they have serious limitations and can be misleading in some uses. Therefore, the main concern of this study is total factor productivity rather than partial productivity.

Among the several index numbers available, the Laspeyres index and the Divisia-related index are the two major procedures which have been used to measure the growth of total factor productivity in Canadian agriculture. The Laspeyres approach uses a linear aggregation of quantities of various inputs with fixed base period prices as weights: this, in turn, has been shown to imply that elasticities of substitution between factor inputs are infinity, i.e., the factors of production are perfect substitutes in the production process. On the other hand, the Divisia-related index approach is flexible enough to incorporate prices from adjacent years, and it can be used when substitution between input factors takes place in the production process. The flexibility of the procedure stems from the fact that the Divisia-related index is closely linked analytically to the homogeneous translog production or cost function (Diewert, 1976). These kinds of functions do not impose *a priori* restrictions on the elasticities of substitution between inputs and they can be used when complementarity takes place among factors of production. Therefore, this study will utilize the Divisia-related index approach to aggregate inputs and outputs to measure the productivity growth in the grain sector in the province of Alberta and the prairie region by soil zone.

The grain and oilseed production process involves inputs such as land, labor, fertilizer, machinery, and materials which are used to produce grains (wheat, oats, and barley) and oilseeds (flaxseed and canola). To study the relationship among these factors of production, one needs to specify the appropriate functional forms underlying production. There are a wide variety of functional forms which have been utilized to study production relations in the agriculture sector as well as in other sectors of the economy. Among these functional forms are highly restrictive forms which impose *a priori* restriction on elasticities of substitution and which can not be used when complementarity takes places in the production process -- such as the Cobb-Douglas and constant elasticity of substitution

(CES) functions. Other forms are classified as flexible forms which impose fewer restrictions *a priori*, and which can handle complementarity between inputs. These flexible forms include the generalized Leontief function, the generalized Cobb-Douglas function (Diewert 1971, 1973), and the transcendental (translog) production function (Christensen, Jorgenson and Lau, 1971). The differences between these two groups of production functions will be discussed in detail in Chapter 6.

The development of duality theory since the early 1970s allows us to estimate production relations more precisely by using the cost function approach. This precision can be attributed to: (a) there is often less multicolliniarity among factor prices, and (b) data on input and output prices are sometimes more readily available and possibly more accurate than data on output and input quantities. Hence, in this study, a specific flexible functional form -- namely, the translog cost function -- will be utilized to investigate the substitutability and complementarity relationships among input factors, to estimate own and cross price elasticities of demand for different input factors, and to determine the nature of technical change in the Alberta grain sector.

1.4.1 Input Allocation

The basic input categories in the grain sector to be studied include land, labor, machinery, chemical, and materials. Most of these input classes are used in both grain and livestock production; therefore, a major conceptual and empirical problem involved is the separation of input use figures which are attributable solely to grain operation when many prairie farms, in fact, are mixed crop and livestock enterprises. The difficulty arises because input use figures are not collected or published explicity for either the crops or livestock sector in Canada. Moreover, Statistics Canada does not provide systematic time series data on representative farm types such as exist in Australian BAE surveys. Given these constraints, the procedure adopted in this study was to allocate input use between major productive uses and among soil zones, on the basis of census data.

In this study, input use is regarded to comprise two distinctive components. First, there are those inputs which are readily and directly attributable to grain production, such as land (cropped land), fertilizer, pesticides, energy and seeds. Second, there are those input categories which are extremely difficult to attribute either to grain or livestock production, especially on mixed farms. Such inputs include machinery which is used jointly in grain and livestock production, labor, and buildings. The estimation of input use attributable to grain in the latter categories necessarily involves some arbitrary assumptions and value judgments.

To overcome this task one option is to use respective total cash receipts from grain and livestock as a basis for allocating total input use between crops and livestock (Weaver 1982). The other alternative which was actually used in this study is to use the proportional share of crop farms to total farms in the prairie region as a basis to allocate labor, machinery, and depreciation on buildings between crops and livestock. Input use, except land and owner operator and family labor, was allocated among soil zones according to the soil zone shares of total expenditure on major input classes in respective censuses. The land input, on the other hand, was allocated among soil zones according to the location of census divisions (or crop districts) in respective soil zones. Owner operator and family labor were allocated among soil zones according to the soil zone share of the number of farms to total farms in the province. Finally, the zonal prices of the land input were derived by utilizing the zonal quantities of cropped land and the zonal values of cropped land and buildings.

1.5 Outline of the Study

This study is divided into seven chapters. Different analytical procedures which have been used to aggregate outputs and inputs, as well as their corresponding prices, are presented in Chapter 2. The resultant total factor productivity measures, including a discussion of their relative advantages and disadvantages, are discussed. As well, some selected studies on productivity measurement in Canadian agriculture will be reviewed in this chapter. In Chapter 3 the estimating procedures which have been applied to derive grain output for each soil zone in the provinces of Alberta and Saskatchewan are outlined, as well as the procedures used to derive zonal output prices for wheat and barley. The various procedures which have been used to allocate input use between crops and livestocks, and among soil zones, as well as those procedures which have been utilized to generate zonal land input prices and selected input quantity indexes and cost shares, will be the main content of Chapter 4. Estimation of total factor productivity for the prairie grain sector, the grain sector in the respective prairie provinces, and the major soil zones in the prairies and the various provinces will be presented in Chapter 5. In Chapter 6, the theoretical background on functional forms which have been used to study production structure in agriculture, together with some selected studies on the production technology in Canadian agriculture, are discussed. Production relations in the Alberta grain sector are estimated using a translog cost function approach which yields estimates in turn, of the elasticities of substitution, own and cross price elasticities of input demand, and the nature of technical change. In Chapter 7, a summary, the major conclusions, and the limitations of this study are presented.

2. Measurement of Agricultural Productivity: Conceptual and Empirical Background

2.1 Introduction

The main concern of this chapter is to demonstrate the theoretical background and analytical procedures which will be utilized in this study to measure productivity growth in the prairie grain sector. Historically, the Laspeyres index number procedure has been utilized to aggregate input(s) and output(s) to measure productivity growth in different sectors of the economy. Despite the popularity of this procedure, it has been criticized on the grounds that it involves base period prices as fixed weights in aggregation and that it corresponds to a linear production function which, in turn, implies that input factors are perfect substitutes in production. As a consequence, the Laspeyres procedure should not be applied when substantial input price changes and substitutability among input factors takes place in the production process over time. The conclusions of most studies which have been concerned with the estimation of production relations in agricultural and other sectors suggest that both substitutability and complementarity among input factors exist, and that the Divisia-related index procedure which is related to the translog cost function is more appropriate to aggregate inputs and outputs in productivity studies.

In this chapter the nature and merits of total factor productivity measures as opposed to partial productivity measures will be demonstrated. Secondly, the major index number procedures which have been used to aggregate outputs and inputs will be outlined. The two major indexes which have been utilized to measure productivity growth in North American agriculture will be discussed in further detail. Finally, previous empirical studies of agriculture productivity will be summarized in the last part of this chapter.

2.2 Productivity Measures

Productivity is often expressed in terms of output per unit of a single input; such a measure is called partial factor productivity (PFP). Output per unit of a single input such as land or labor is a particular measure of productivity in the sense it does not account for the effect of other factor inputs. Labor productivity, for example, does not exactly measure the attributes of labor as a productive resource because higher output per man can be achieved by increasing the use of machinery, fertilizer, and other capital equipment. Therefore, such partial productivity measures reflect the joint effect of the contribution of input factors other than labor in the production process. As a consequence of this situation, the concept of total factor productivity has emerged as a superior measure of productivity (Christensen 1975). Total factor productivity (TFP) can be defined as the ratio of output to all inputs combined. Therefore, by definition, the total factor productivity measure will reflect the effect of all factor inputs in the production process. Such overall measures of productivity are beneficial to farm managers and to policy decision makers in providing valuable information about productivity growth in the agricultural sector, and provide a useful yardstick with which to compare productivity in agriculture with productivity in other sectors of the economy.

The above discussion indicated that productivity can be expressed either in terms of total factor productivity which relates output to all inputs combined, or in terms of partial productivity measures such as output per acre of land or per unit of labor. Although partial productivity measures are widely cited in the literature, they have serious limitations and can be misleading in some uses. Therefore, the main concern of this study is total factor productivity in the grain sector in the prairie region rather than partial productivity.

2.3 Total Factor Productivity and Efficiency

Based on the Farrell (1957) method of decomposing and measuring efficiency, Yotopoulos and Nugent (1976) have distinguished three types of efficiency: overall economic efficiency and its two sub-components, price or allocative efficiency and technical efficiency. Price or allocative efficiency occurs when equality between the ratio of marginal product and the corresponding input price ratio is obtained. Technical efficiency, on the other hand, is the ratio of physical output and physical inputs; improvements in technical efficiency are represented by an outward shift of the production function. Alternatively,a shift of the production function can be represented by an inward shift of the corresponding isoquant. The shift of the production function can be attributed to pure technical effects, that is, the prices of input factors have no influence on this shift. As Yotopoulos and Nugent (1976, p. 72) state: "Price efficiency and technical efficiency are necessary, and also, when occurring jointly, they are sufficient conditions for economic efficiency".

Total factor productivity (TFP) is interpreted in the literature to be identical to the technical efficiency with which resources are combined to produce output and services. (Yotopoulos and Nugent, 1976; and Kendrick, 1961). Consequently, in this study total facctor productivity will be considered to be conceptually equivalent to technical efficiency.

2.4 Different Forms of Index Numbers

There are four major indexes which have been used to aggregate various outputs (or inputs) into an overall physical measure of aggregate output (or input). Similarly, index number methods are needed to derive aggregate output price or input price indexes. These index number procedures, as well as their respective advantages and disadvantages, will be outlined in the following section.

2.4.1 The Laspeyres Index

The Laspeyres quantity index can be written as:

$$Q_t = \Sigma P_{io} X_{it} / \Sigma P_{io} X_{io} \qquad 2\text{-}1$$

And the Laspeyres price index can be expressed in the following form:

$$q_t = \Sigma P_{it} X_{io} / \Sigma P_{io} X_{io} \qquad 2\text{-}2$$

Q_t is the aggregate output (input) quantity index in period t, and P's and X's are prices and quantities of various outputs (inputs). The subscript zero is the base period and the subscript t is the comparison period, and the q_t is the output (inputs) price index.

Equation (2-1) shows that the Laspeyres index is linear in nature and uses fixed base year prices as weights in the aggregation process. Therefore, the year to year price effect on aggregate quantity of inputs and outputs is not captured by this procedure. In other words, such an indexing procedure will tell us only the change in magnitude of total quantity of output or input resulting from pure quantity change. The widespread use of the Laspeyres quantity (price) index can be attributed to its ease of construction and use. In the next section we shall discuss this procedure in fuller detail.

2.4.2 The Paasche Index

The Paasche quantity and price indexes can be represented by equations 2-3 and 2-4 respectively:

$$Q_t = \Sigma P_{it} X_{it} / \Sigma P_{it} X_{io} \qquad 2\text{-}3$$

$$q_t = \Sigma P_{it} X_{it} / \Sigma P_{io} X_{it} \qquad 2\text{-}4$$

where the interpretation of Q_t, q_t, P's and X's is the same as in equations 2-1 and 2-2. The Paasche quantity index is similar to the Laspeyres quantity index in the sense that both are linear in nature which implies that (for input quantity indexes) the elasticity of substitution between input pairs is infinity. The only difference between the Laspeyres index and the Paasche index is that the former uses base year price as a weight and the latter uses end year price as a weight. As a consequence of this difference, the Paasche price (quantity) index is greater than the Laspeyres price (quantity) index if prices and quantities tend to move in the same direction between years 0 and t; the Laspeyres index is the greater if prices and quantities tend to go in opposite direction (Allen 1975).

2.4.3 Fisher Ideal Index

The Fisher quantity index can be written (Allen 1975) as:

$$QI_{0t} = \sqrt{\{ Y_{0t} (P_0) Y_{0t} (P_t)\}} \qquad 2\text{-}5$$

Where QI_{0t} is the Fisher Ideal Index

$$Y_{0t}(P_0) = \Sigma P_0X_1/\Sigma P_0X_0 \qquad \text{Laspeyres quantity index}$$

$$Y_{0t}(P_1) = \Sigma P_1X_1/ \Sigma P_1X_0 \qquad \text{Paasche quantity index}$$

The Fisher index is a geometric mean between the Laspeyres index and Paasche index. In other words, this index utilizes the average weight of both the base period and the comparison period. Therefore, the problems of under estimation and over estimation which are inherent in the Laspeyres and Paasche indexes (Ruttan 1954) could be minimized by applying the Fisher index.[1] Moreover, the Fisher index is exact for a flexible quadratic aggregator function and for this reason it is regarded as a superlative index (Diewert 1976). Since the Divisia-related index, which will be discussed in the following sub-section, is not defined at zero quantity, the Fisher Index is more appropriate to use when the quantity of some input is zero in the data set (Diewert 1976). Finally, the Fisher index was recently used by Salem (1987) to study productivity and technical change in the Canadian food and beverage industries.

2.4.4 Divisia-Related Index

The continuous version of the Divisia-Index can be expressed (Christensen 1975) as:

$$Q_{(t)}/Q_{(0)} = \exp \{\int[\Sigma\, W_{it}(\dot{X}_{it}/X_{it})]\} \qquad 2\text{-}6$$

where: $W_{it} = P_{it}X_{it}/\Sigma\, P_{it}X_{it}$

W_{it} may be regarded as the share of the i-th factor in total cost or share of the i-th output in total value product. P's and X's are the prices and quantities of inputs or outputs.

The Divisia-related index is preferred to other indexes because it utilizes the prices of both the base period and the comparison period. Further it recognizes both substitute and complement relationships between factor inputs in the production process. For these reasons this approach is being increasingly used to study the growth of total productivity in agriculture (Christensen, 1975; Ball, 1985), including Canadian agriculture (Islam, 1982; Veeman and Fantino, 1985; and Manning, 1984, 1985). More detailed discussion of this approach will follow in the next section.

[1]For more detailed information about the Fisher Ideal index and other indexes, see R.G.D. Allen (1975), *Index Numbers in Theory and Practice.*

2.4.5 Geometric Index

The Cobb-Douglas production function can be expressed as:

$$Q_t = A_t K_t^{\alpha} L_t^{\beta} \qquad 2\text{-}7$$

where the parameters of this function can be defined as: Q_t is the real output at a time t, A_t is the index of technology (Total Factor Productivity), K_t is an index of capital services, L_t is an index of labor services, α is the partial elasticity of output with respect to capital (or capital's factor share), and β is the partial elasticity of output with respect to labor (or labor's factor share). Since K and L are in index form, weighted respectively by α and β, then this form of the production function exactly represents a geometric index of inputs (Domar 1961). This kind of index restrict the elasticity of substitution to unity. This in turn implies that this approach is unduly restrictive with respect to the nature of substitute relations and, in fact, rules outs the possibility of complementary relations between input pairs in the production process. The second limitation is that α and β represent a given state of technology; therefore, they are apt to change whenever technology changes, unless technical change happens to be neutral.

2.5 Index Numbers and Production Functions

The recent development of the duality concept, and the application of the flexible functional forms since the early 1970s, set the theoretical guideline for the choice among these index numbers. Diewert (1976) has termed the Tornqvist index which is an approximation to the Divisia index, and the Fisher ideal index as being superlative. A quantity index (Q) is defined to be a superlative index if it is exact for a neoclassical aggregate production function which is capable of providing a second order differential approximation to a twice continuously differentiable linearly homogeneous aggregate production function. A price index (P) is defined to be superlative if it is exact for a unit cost function (translog cost function) which can provide a second order differential approximation to an arbitrary twice differentiable unit cost function. According to this definition and by applying the duality concept, Diewert (1976) shows that if (P) is a superlative price index and (Q) is the corresponding quantity index, this implies that (Q) is also a superlative index and vice versa.

Specific relationships between functional forms and index numbers have been demonstrated in recent decades by many economists and researchers. [2] The Geometric index has been found to be related to the Cobb-Douglas. On the other hand, the Laspeyres and Paasche indexes are connected with the linear production function, whereas the Fisher index is related to the quadratic cost function. The Divisia-related index has been found to be exact for the translog cost and profit functions (Diewert 1976, 1977). Therefore, the choice or the preferability among these indexes is related in many ways to the preference among these functional forms. Allen (1981) pointed out that the Leontief and Cobb-Douglas functions can be regarded as first order approximations to production or cost functions, while quadratic and translog functions can be regarded as second order approximations. According to this argument Allen concluded that one would expect that the quadratic and translog functions would fit the data more closely. Therefore, there are grounds for preferring the use of the Divisia-related index and the Fisher index in aggregating inputs and outputs and their correponding prices in productivity measurement.

2.6 Measuring Procedures for Productivity Growth in Canadian Agriculture

The Laspeyres index and the Tornqvist index (which is an approximation to the Divisia index) are the two major indexes which have been used to measure total factor productivity in Canadian agriculture. In this section, these two indexes will be discussed in more detail, and their respective advantages and disadvantages will be outlined. The section concludes with a brief discussion of procedure for the calculation of growth rates.

Laspeyres index approaches have been the most common method used in the aggregation of inputs, outputs, and their corresponding prices in Canadian agriculture (for example, Furniss, 1970; Shute, 1975; Brinkman and Prentice, 1983; and, recently, the updated study of Brinkman and Prentice by Lapierre and others 1987). Such index number procedures, wherein base period prices are used as weights in aggregation, have been shown

[2]For more details about this subject see Allen (1982), Berndt (1978) and Diewert (1976).

to imply that the underlying aggregate production function is linear in nature and that inputs in the production process are perfect substitutes. Equation (1) shows the general form of this index, which can be rewritten as:

$$Q_t = \frac{\Sigma\ (X_{it}/X_{io})\ P_{io}X_{io}}{\Sigma\ P_{io}X_{io}} \qquad 2\text{-}8$$

or

$$Q_t = \Sigma\ W_{io}(X_{it}/X_{io}) \qquad 2\text{-}9$$

where: $\Sigma\ W_{io} = P_{io}X_{io}/\Sigma\ P_{io}X_{io}$

The wide use of the Laspeyres index can be attributed to the ease in computing, understanding, and constructing it. Since prices are fixed at the base period, what one needs to construct the Laspeyres index is the quantity of outputs or inputs in each year for all the years in the period under study. However, there are certain problems associated with this procedure. First, the Laspeyres index number procedure implies a linear production or cost function (Diewert, 1975) which is not appropriate in the study of production structure and productivity when substitutability between factor inputs (such as fertilizer and chemicals for land or machinery for labor) takes place in the production process. Second, since the prices are fixed at the base period, the Laspeyres procedure does not tell us how farmers in general respond to input price changes. According to this procedure which implies that input factors are perfect substitutes, one can infer that when the price of one input increases, its use in the production process will be terminated (Christensen, 1975). Third, the increase in prices due to quality change of inputs and outputs is not captured by this fixed base period price procedure, and this may lead to biased estimates of total factor productivity levels and as a consequence total factor productivity growth.

Because of the above limitations of the Laspeyres index number procedure, the application of the Divisia-related index number approach has emerged in recent years as a more appropriate method to aggregate output and inputs in Canadian agriculture. The Divisia-related index procedure has been used to study the growth of total factor productivity in both Canadian and Western Canadian agriculture (Islam, 1982; Manning, 1984, 1985; Veeman and Fantino, 1985). The Divisia-based approach can be derived from Equation (4) in the previous section. Equation (4) can be rewritten in terms of a discrete approximation to the Divisia index which converges to the (arithmetic average) weighted log-change index or simply the Tornqvist index or Tornqvist-Theil-translog index as:

$$\text{Log } (X_i/X_0) = \Sigma\ \bar{W}_i \text{ Log } (X_{i1}/X_{i0}) \qquad 2\text{-}10$$

$$\text{where: } \bar{W}_i = 1/2(W_1 + W_0)$$

The parameters Wi's are average input cost shares (or output value shares) for adjacent years and Xi's are input quantities (or output quantities), as previously defined. Historically, this index was first discussed by Fisher (1922), has been advocated by Tornqvist (1936) and Theil (1965), and has been used extensively by Christensen and Jorgenson (1973) and others (Caves, Christensen, Diewert 1982). To estimate equation (10) one needs to know the quantities and prices of inputs (or outputs) for each year during the period of study. Hence, the Tornqvist index procedure is flexible enough to incorporate the yearly change in prices of inputs (or outputs) and as a consequence the change in the cost share equation for the period under study. The flexibility of the Tornqvist index stems from its strong relation with the flexible forms of production and cost functions. Diewert (1976) demonstrated that the Tornqvist index is exact for the homogeneous translog production or cost function. This implies that there is no *a priori* restriction on the magnitude of the elasticity of substitution between input pairs. The link between the Tornqvist index and the translog production function has been also summarized by Christensen (1975), as follows:

> "The translog production function does not require inputs to be perfect substitutes. If the relative price of an input increases, the producers decreases its use (substituting other inputs) until all marginal productivities are proportional to the new prices. Hence, the prices from both periods enter the Tornqvist index to represent the marginal productivities in both periods".

The basic difference between the Tornqvist index procedure and the Laspeyres index procedure is that the former procedure requires more price information and utilizes prices for each year for the whole period under study. Further, this flexible weight procedure recognizes any degree of substitutability between factor inputs in the production process. On the other hand, the Laspeyres procedure is a fixed weight approach. If input prices are changing rapidly and considerable input substitution is occurring, the Laspeyres weighted procedure is inadequate and estimated input cost shares will be fixed.

The superiority of the Tornqvist index can be attributed also to its ability to capture input price changes due to the quality change of inputs such as improved skill of labor, quality of machinery or quality of seeds. Star (1974) related quality change of inputs to error of aggregation which occurs due to the changes in the input mix over time — that is, aggregating inputs and outputs with constant prices will ignore the change in price due to quality change. Star's empirical results for the U.S. manufacturing sector demonstrates that the use of the Laspeyres index to aggregate capital and labor components can lead to substantial errors. Jorgenson and Griliches (1967) argue that aggregation error of input and output data will introduce serious biases in the measurement of total factor productivity. To eliminate these biases they suggested the use of the Tornqvist index procedure to aggregate inputs and outputs. Finally, this index has been described as the most widely utilized superlative index in recent empirical research (Caves, Christensen, and Diewert 1982).

From the previous discussion one can conclude that there are strong conceptual reasons for choosing the Tornqvist index procedure relative to other indexes. Therefore, in this study outputs and inputs will be aggregated by using the Tornqvist procedure.

2.7 Estimating the Growth Rates

The growth rate of total factor productivity (TFP) in the prairie grain sector is estimated by fitting a regression line to take into account the interaction between TFP and t, rather than merely using the residual difference between the rate of growth of aggregate grain output and the rate of growth of all inputs used in grain production. The following procedure will be utilized to calculate the appropriate annual compound rate (r) of growth[3] of any variable such as output, input and TFP:

$$P_t = P_0 \, (1+r)^t \qquad \text{2-11}$$

[3]For more information on trend analysis, see Veeman (1975).

where P_t is the productivity level in year t.

P_0 is the productivity level at t_0

r is the trend rate of productivity growth to be calculated.

t is the number of observations or number of years.

By using a logarithmic transformation, equations (2·11) can be written in linear form as:

$$\ln P_t = \ln P_0 + [\ln (1+r)]^t \qquad 2\text{-}12$$

Equation (2-12) can be written in simplified econometric form as:

$$\ln P_t = \alpha+\beta t+U_t \qquad 2\text{-}13$$

where: $1+r$ = antilog β

r = antilog β-1

U_t: is the error term

From equations 2-12 and 2-13 the following points can be made. First, the value of (r) depends on the value of the slope β. Second, (r) will represent the average compound rate of growth of productivity over the period of study. Third, the estimation procedure utilizes all the time series data and not merely the two end points.

2.8 Relevant Literature

A brief review of the previous productivity studies in Canadian agriculture as well as some selected agricultural productivity studies which have been conducted in other countries will be outlined in this section. The main emphasis will be on the methodologies which have been applied and on the main empirical findings of these studies.

2.8.1 Productivity Studies in Canadian Agriculture

One of the early studies of total factor productivity in Canadian agriculture was conducted by Furniss (1970). In this study, the Laspeyres index procedure was used to derive the output and input quantity indexes. The empirical results of this study showed that total factor productivity (TFP) in Canadian agriculture increased by 1.9 percent per year over the period 1950-1969 and by 2.03 percent per year between 1960-1969. Shute

(1975), in updating the work by Furniss, also used Laspeyres procedures to study national and regional productivity in Canadian agriculture. This study indicated that the growth rate of Canadian agricultural productivity was 0.86 perccent per year for the period 1961-1974, but only 0.07 percent annually over the period 1962-1974. For the prairie region, the annual increase in total productivity was 1.17 percent for the period 1961-1974, and an annual decrease of -0.35 percent over the period 1962-1974. This decrease in the estimated growth rate of total factor productivity in Canada and the prairie region in the second period (1962-1974), is related to the exclusion of 1961, a bad drought year, which has a significant effect on the total output indexes.

Islam (1982) in his Ph.D dissertation used both Divisia and Lasreyres indexes to measure partial and total factor productivity in Canadian and Western Canadian agriculture. By using the Divisia index procedure and man hour data,[4] he reported an annual growth rate of 1.01 percent in Canadian agricultural productivity over the period 1961-1978, and an annual growth rate of 0.034 percent when the drought year 1961 was excluded. For Western Canadian agriculture this study shows an annual productivity growth rate of 2.48 percent for the period 1961-1978, and an annual growth rate of 1.7 percent when the drought year 1961 was excluded. The author concluded that the exclusion of the drought year, 1961, significantly affected the estimate of the productivity growth rate. Using the Laspeyres index procedure, Islam calculated an annual growth rate of TFP of 1.09 percent for the period 1961-1978 and 0.66 percent between 1962-1978 for Canadian agriculture. He also found an annual rate of 2.031 percent for Western Canadian agriculture over the period 1961-1978 and 1.8 percent when the drought year 1961 is excluded.

Anderson (1983) used the Laspeyres index procedure to aggregate inputs and outputs to estimate the productivity growth rate in Alberta agriculture. This study shows that total factor productivity in Alberta agriculture has an annual growth rate of 2.04 percent over the period 1930-1980.

[4]Islam argues that using man hours data will provide a more reliable indicator of productivity growth, as opposed to using person employed figures as a measure of labor service flows. For more detailed discussion see Islam (1982).

Brinkman and Prentice (1983) studied multifactor (or total factor) productivity in Canadian agriculture. In this study, chain-linked Laspeyres indexes have been utilized to aggregate inputs and outputs. The authors indicated that the excessive distortion due to constant base — year price weightings over long periods of time will be avoided by utilizing such kind of procedures. Their procedure (splicing index number series) can be summarized as follows: first, 1961 base-year price weights are used for the 1961-1970 period; second, 1971 base-year price weights are used for the 1971-1980 period; and third, the percentage difference in the two series in the overlap year (1971) is used as an adjustment to link these two series together. This study shows an annual trend increase of 1.79 percent for Canadian agriculture during the 1961 to 1972 period and an approximate average annual trend increase of 1.06 percent during the 1968 to 1980 period. For Eastern Canada an annual trend increase of 2.16 percent in the first period and 1.18 percent in the second period have been reported in this study. For Western Canadian agriculture this study shows an annual increase of 1.76 percent in first period compared to 1.65 percent in the second period. The empirical results of this study tell us that the productivity growth rate is declining in the second period (1968-1980), compared to the first period (1961-1972). This decline might be partially attributed the fact that the drought year 1961 is included in the first period of the sample.

Veeman and Fantino (1985) used the Tornqvist procedure to examine productivity growth in Western Canadian agriculture for the period 1962 to 1980. Their study shows that total factor productivity in Western Canadian agriculture, uncorrected for weather influences, was 1.00 percent annually over the period of study. Veeman and Fantino in this study also investigated the effect of weather variables, technology, and inflation on the productivity growth rate in Western Canada. They concluded that the growth rate of TFP, corrected for weather influences, was 1.03 percent per year over the entire period. Manning (1986) also used the Tornqvist index procedure to derive aggregate indexes of inputs and outputs to estimate the growth rate of Alberta agricultural productivity. This study shows that the growth rate of TFP in Alberta agriculture has increased at annual compound rate of 1.1 percent over the period 1946-1984, and the ratio of output prices to input prices has declined at an annual compound rate of 1.0 percent over the period of study.

Capalbo and Denny (1986) tested a long-run productivity model for Canadian and U.S. agriculture sector for the period of 1962-78. The discrete approximation to the Divisia index is also used to aggregate outputs and inputs and their corresponding prices. The conclusion of their study shows that total factor productivity and labor productivity grew more quickly in Canada than in the U.S. during the period of 1962-78. Their study also provides estimates of TFP and labor productivity for two subperiods (1962-70) and (1970-78). In both countries the annual growth rates of TFP are higher in the second subperiod (1970-78) while growth rates of labor productivity are lower in the second subperiod as compared to first subperiod (1962-78).

Lapierre *et. al.* (1987) used the Laspeyres index to update Brinkman's study of multifactor productivity in Canadian agriculture for the period of 1961-84. The empirical results of their study indicated a slowdown in productivity growth rates in the 1970's in Canada and the regions (Eastern and Western regions). Their study also shows a gradual levelling of productivity growth rates up to the middle 1980's in Canada. However, on the regional level their empirical work shows that productivity growth rates in the 1980's rose sharply in Eastern Canada to levels of the 1960's, while in Western Canada productivity growth rates fell very sharply below levels of the 1970's.

2.8.2 Selected Agricultural Productivity Studies Outside Canada

Lawrence and McKay (1980) utilized the Tornqvist index procedure to study the productivity growth of the sheep industry in Australian agriculture. Their work might be considered as the first disaggregated study, on a subsectoral level, of agricultural productivity. This study indicated that TFP in the Australian sheep industry increased annually by 2.9 percent over the period 1952-1977. Their empirical results also show an annual decrease of 4.1 percent in the growth rate of prices received to prices paid by the sheep industry over the period of study.

Ball (1985), in his study of TFP in American agriculture, utilized the Tornqvist-Theil index to aggregate inputs and outputs. Indexes of total factor productivity in this study are derived from a flexible multioutput — multifactor representation of the structure of production constrained to constant returns to scale. Ball argued that this procedure will give the best estimate of indexes and growth of total factor productivity.[5] Moreover, Ball utilized Gollop and Jorgenson procedures to measure wage rates as well as hours worked by characteristics of individual workers. Likewise, the perpetual inventory method (Jorgenson) is used in Ball's study to estimate the level of capital stock.

The empirical results of Ball's study indicated that the growth rate of total factor productivity in American agriculture has an annual increase of 1.75 percent compared with 1.7 percent per year estimated by U.S. Department of Agriculture. According to these results one can argue that both the transformation function procedure and the Tornqvist procedure lead to almost identical results. The similarity of these two results stems from the fact that both of these procedures are exact for the translog cost function (Diewert 1976; Caves, Christensen, and Diewart 1982).

In the most recent study, Capalbo (1988) measured the components of aggregate productivity growth in U.S. agriculture. She decomposed the growth in total factor productivity into effects due to nonconstant returns to scale and technical change. The scale effects and technical change in her study are measured by utilizing a translog cost function model, and the TFP indexes are derived by applying the Tornqvist-Theil index procedures. The conclusion of her study shows that TFP for U.S. agriculture grew by an annual rate of 1.56 percent, the rate of technical change is 1.74, and the return to scale measure is 0.788 percent per year for the period of 1950-82. The return to scale measure in her study implies that U.S. agriculture is characterized by decreasing returns to scale for the period of 1950-82. She also indicated in her conclusion that the growth rate of TFP in U.S. agriculture for the period of 1950-82 misrepresented the rate of technical change primarily due to the nonconstant scale effects.

[5]For more detailed discussion on this subject, see Gollop and Jorgenson (1980) and subsequent comment by Berndt.

3. The Derivation of Output Quantities and Prices in the Prairie Grain Sector

3.1 Introduction

Grain output is defined in this study to include the five major grains (wheat, barley, oats, flaxseed and canola) grown in the brown, dark brown, black and gray soil zones in the prairie provinces. The prairie region is the major source of these cereals and oilseeds in Canada. In the crop year 1981-82, for example, the three prairie provinces (Alberta, Saskatchewan and Manitoba) provided 96 percent of Canadian wheat production, 65 percent of total coarse grain production, 92 percent of total barley output, and 79 percent of the oats produced in Canada.

The production shares of the three prairie provinces in total production of the each of the five grains are remarkably different - - see Table 3-1. During the period 1981-84, for instance, Saskatchewan provided 60 percent of wheat produced in the prairie region, leaving 25 percent to Alberta and 15 percent to Manitoba. In terms of oats and barley production, Alberta is the leading province providing over half of prairie barley output and some 44 percent of prairie oat production. In the early 1980s, Alberta and Saskatchewan had virtually the same share of canola (rapeseed) production. Finally, as Table 3-1 shows, Manitoba has the highest share of production of flaxseed among the prairie provinces.

3.2 Soil Zone Classification

Since the primary objective of this study is to estimate the growth of total factor productivity of the grain sector in the prairie region by soil zone, the grain output data of the prairie region have to be organized and spatially sub-divided to facilitate the achievement of this objective. However, separating output by soil zones in the prairie region is not an easy task, especially in Alberta where the soil zones boundaries do not coincide with census district boundaries. The matching of grain production data, provided sub-provincially on a census district (or agricultural reporting area) basis, with specific soil zones inevitably involved arbitrary assumptions.

Table 3-1. Provincial Shares of Production of the Five Major Grains, Prairie Provinces, 1981 to 1984

	1981	1982	1983	1984	Average
			All Wheat		
Alberta	0.265	0.232	0.268	0.252	0.254
Saskatchewan	0.594	0.625	0.598	0.553	0.593
Manitoba	0.141	0.143	0.134	0.195	0.153
			Oats		
Alberta	0.440	0.423	0.450	0.445	0.439
Saskatchewan	0.394	0.399	0.378	0.330	0.376
Manitoba	0.166	0.178	0.172	0.225	0.185
			Barley		
Alberta	0.548	0.539	0.575	0.517	0.545
Saskatchewan	0.258	0.270	0.247	0.265	0.260
Manitoba	0.194	0.191	0.178	0.218	0.195
			Flaxseed		
Alberta	0.119	0.111	0.063	0.049	0.086
Saskatchewan	0.326	0.307	0.264	0.329	0.306
Manitoba	0.555	0.582	0.673	0.622	0.608
			Canola (Rapeseed)		
Alberta	0.417	0.433	0.421	0.410	0.420
Saskatchewan	0.416	0.356	0.424	0.417	0.404
Manitoba	0.167	0.211	0.155	0.173	0.176

Source:

This table is derived from the Agricultural Statistics Yearbooks for the provinces of Alberta, Saskatchewan, and Manitoba, various years.

The following assumptions have been utilized regarding the distribution of area within the three prairie provinces among the various soil zones (see Figure 3-1):

1. Manitoba: Grain production in this province is assumed to occur entirely within the black soil zone.
2. Saskatchewan: From the front page of *Agricultural Statistics 1985* (Saskatchewan Agriculture) which is reproduced as Figure 3-2, one can distinguish three different soil zones:
   a. the brown soil zone.
   b. the dark brown soil zone
   c. the black soil zone.

   Therefore, it has been assumed in this study that Saskatchewan has these three distinctive soil zones and that small areas of gray soil which exist along Saskatchewan's northern agricultural frontier have been included in the black soil zone.
3. Alberta: There are four major soil zones in Alberta, namely:
   a. the brown soil zone,
   b. the dark brown soil zone,
   c. the black soil zone,
   d. the gray soil zone.

These four major soil zones have been distinguished by superimposing an Alberta census division and crop reporting area (ARA) map (Figure 3-3) on an Alberta soil zone map. For more precision we have taken into account the small subdivisions (counties). The census divisions in Saskatchewan and Alberta are simply classified into a particular soil zone, except for census divisions 2, 3, 7, 13 and 14 in Alberta. The boundaries of these latter census divisions extend into more than one soil zone. Macartney (1984) suggested that if 50 percent or more of the land area in a particular subdivision fell into one of the soil zones, the entire subdivision be classified into that zone. The procedure which is applied in this study is more specific than Macartney's procedure in the sense that portions of a given subdivision are allocated to a particular

Figure 3-1. Major Soil Zones, Prairie Provinces

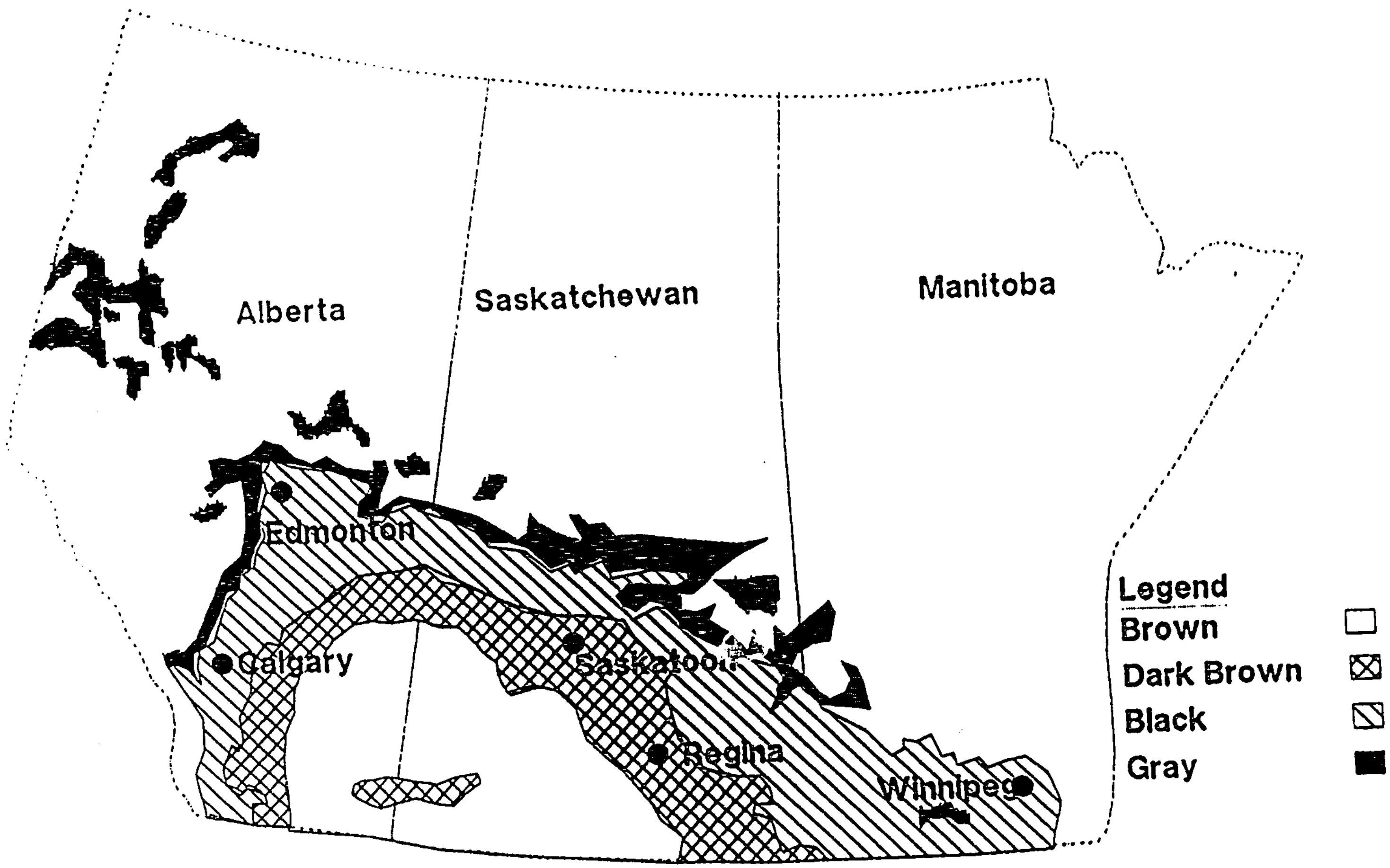


Figure 3-2. Major Soil Zones and Crop Districts, Saskatchewan

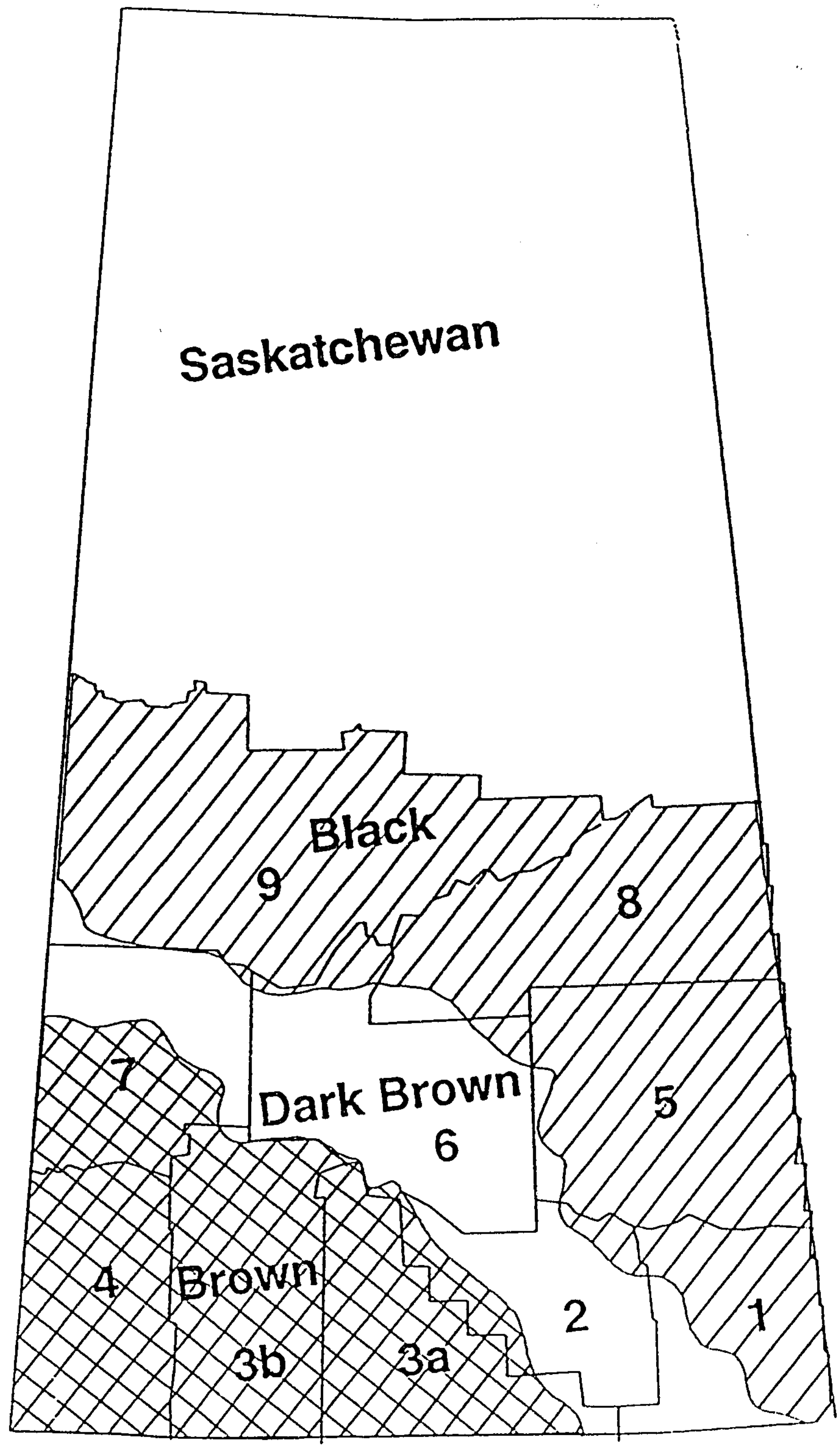
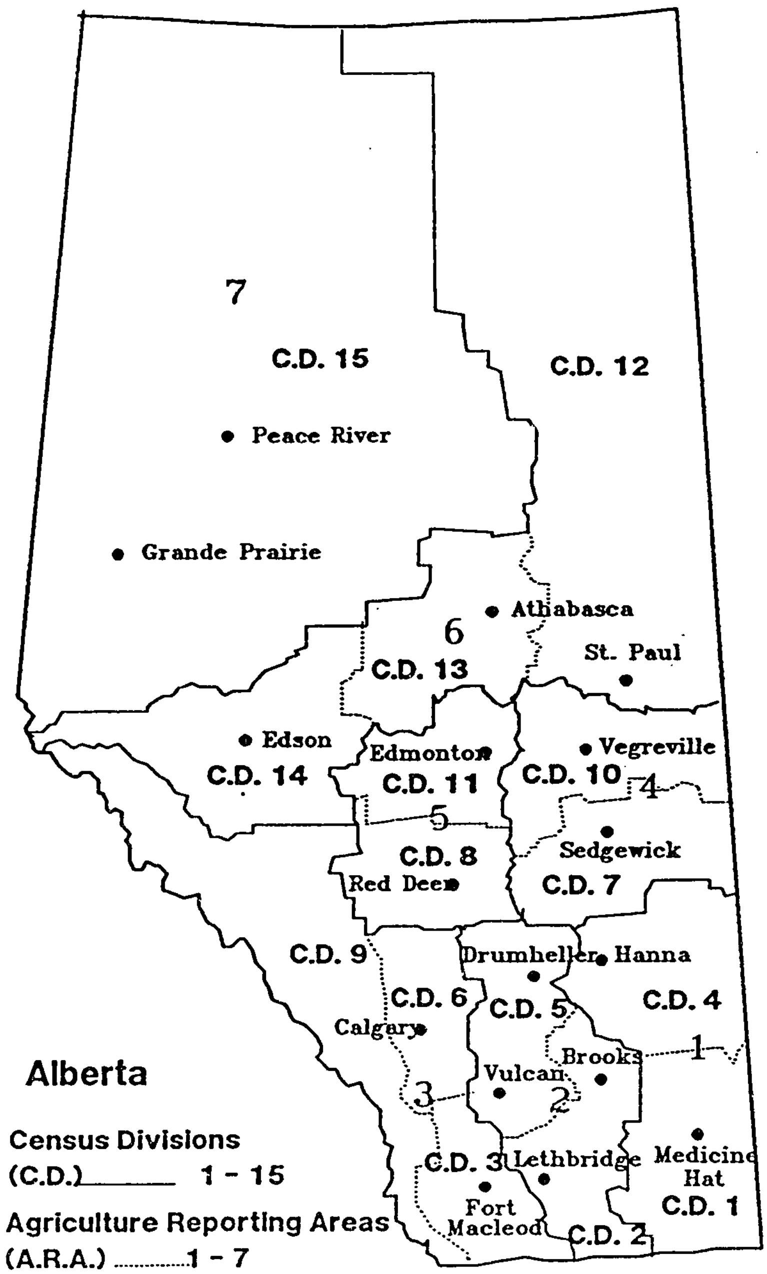


Figure 3-3. Census Division, Alberta



soil zone. This procedure can be summarized in three steps. First, by superimposing an Alberta subdivision map (counties and census division map) on an Alberta soil zone map (Figure 3-1), we can allocate, by using inspection, each county or parts of a given county to respective soil zones. Second, the average of 1971 and 1976 census data on crops on census farms by subdivision, has been utilized to determine the percentage of the crop area of each county which is located in any particular soil zone. Thirdly, since each census division (CD) is composed of a number of counties, we can estimate the relative percent of the crop area for each CD in question which is classified into a particular soil zone. In Table 3-2, the results of this procedure are summarized.

Table 3-2. Classification of Census Divisions No. 2, 3, 7, 13 and 14 into Particular Soil

Zones in Alberta

Census Division	Soil Zones			
(CD) Number	Brown	Dark Brown	Black	Gray
2	54%	46%	—	—
3	—	27%	73%	—
7	—	68%	32%	—
13	—	—	27%	73%
14	—	—	27%	73%

This table shows that 54 percent of the area in CD-2 is located in the brown soil zone, leaving 46% to the dark brown soil zone, which is almost the same as the brown soil share. Therefore, if we classified CD-2 as being entirely within the brown soil zone because over half of its area is located within the brown soil zone, we would be likely to over estimate grain production in the brown soil zone and under estimate it in the

Table 3-3. Classification of the Prairie Provinces by Census Divisions into Different Soil Zones.

Province	Brown CD's[1]	Dark Brown CD's	Black CD's	Gray CD's
Alberta	1	46% of 2	73% of 3	12
	54% of 2	27% of 3	6 & 9	73% of 13 & 14
	4	5	32% of 7	15
		68% of 7	8, 10, 11	
			27% of 13 & 14	
Saskatchewan	3, 4	1a, 2, 6	1b, 5, 8, 9	--
	7a	7b		
Manitoba	--	--	All black	--

[1]CD's refers to the census division in the Province of Alberta and to crop district in the Province of Saskatchewan.

dark brown soil zone. The same argument can be made for the other census divisions. Therefore, we can conclude that our classification procedure is relatively more detailed and specific because it takes into account each portion of each subdivision and classifies it into a particular soil zones.

The overall prairie region has been classified in this study into four distinctive soil zones: brown, dark brown, black, and gray. As previously indicated, Manitoba is coded as being in the black soil zone, ignoring the small pockets of gray soil in the northwest corner of this province. Saskatchewan is classified into the brown, dark brown, and black zones and Alberta is classified into the brown, dark brown, black, and gray soil zones. In Table 3-3 the classification of the prairie provinces by census division into different soil zones is shown. From this table one can infer that the black soil zone has the lion's share in the total prairie grain area, followed by the dark brown, brown, and gray soil zones.

3.3 The Derivation of Output Quantity Data

Having done the proceeding classification of census divisions by respective soil zones in the prairie provinces, the collection of output data for the five major grains in the prairie region by soil zone became a less difficult task. The respective outputs of these cereals and oil seeds by soil zone were collected from unpublished statistics sources and from agricultural statistics year books provided by Alberta Agriculture, Saskatchewan Agriculture and Manitoba Agriculture for the period 1961-1984 as follows:

1. Brown Soil Zone:

   The grain output which is attributed to the brown soil zone includes the yearly production of wheat, oats, barley, flaxseed and canola grown in census division (CD) 1, CD 2 (54 percent), and CD 4 in Alberta as well as crop district numbers 3 and 4 and CD 7A in Saskatchewan.

2. Dark Brown Soil Zone:

   The grain output of this soil zone is defined to include the annual production of the five cereals and oil seeds in question which are grown in the following census divisions in Alberta: 46 percent of CD 2, 27 percent of CD 3, all of CD 5 and 68 percent of CD 7. The dark brown zone also includes crop district 1A, 2, 6 and 7B in the province of Saskatchewan.

3. Black Soil Zone:

The output of the black soil zone includes the annual output of wheat, oats, barley, flaxseed and canola (rapeseed) grown in the province of Manitoba; 73 percent of CD 3, all of CD 6 & 9, 32 percent of CD 7, all of CDs 8, 10, and 11 and 27 percent of CD 13 & 14 in Alberta; and crop districts 1B, 5, 8, and 9 in the province of Saskatchewan.

4. Gray Soil Zone:

The total annual output of grain produced in the gray soil zone includes the output of CD 12, 73 percent of the output of CDs 13 and 14, and the output of CD 15 in Alberta.

In Table 3-4, the average share of each soil zone in the total output of each of wheat, oats, barley, flaxseed, and canola is depicted for the recent four year period, 1981-1984. The entire time series data for prairie grain output is produced in Appendix 1.

As Table 3-4 shows, the black soil zone has the highest share of prairie grain production, followed by the dark brown soil zone. On the average of those four years, the black soil zone produced 45 percent of all wheat produced in the prairie provinces, 59 percent of total prairie oats output, 68 percent of total barley production, 80 percent of total flaxseed, and 70 percent of total canola (rapeseed) produced in the prairie region. The high share of grain production in the black soil zone is very consistent with the high share of the area of the black soil zone in the prairies. The brown soil zone is ranked third in terms of average share of production, keeping in mind the fact that most of the production of these grains and oil seeds in the brown soil zone are considered to be of higher quality compared to production associated with the black soil zone. Grain quality issues will be discussed later in this chapter.

Table 3-4. Soil Zone Shares of Total Production of the Five Major Grains, Prairie Provinces, 1981-84

Soil Zone	1981	1982	1983	1984	Average
			All Wheat		
Brown	0.250	0.261	0.261	0.212	0.246
Dark Brown	0.300	0.303	0.299	0.244	0.286
Black	0.435	0.421	0.421	0.522	0.450
Gray	0.015	0.015	0.019	0.022	0.018
			Oats		
Brown	0.158	0.185	0.179	0.109	0.158
Dark Brown	0.144	0.148	0.129	0.100	0.129
Black	0.585	0.568	0.574	0.651	0.595
Gray	0.113	0.099	0.118	0.140	0.118
			Barley		
Brown	0.039	0.040	0.043	0.022	0.036
Dark Brown	0.163	0.165	0.154	0.105	0.147
Black	0.678	0.672	0.660	0.720	0.683
Gray	0.120	0.123	0.143	0.153	0.134
			Flaxseed		
Brown	0.039	0.055	0.027	0.032	0.038
Dark Brown	0.178	0.193	0.130	0.115	0.154
Black	0.770	0.742	0.834	0.846	0.798
Gray	0.013	0.010	0.009	0.007	0.010
			Canola (Rapeseed)		
Brown	0.006	0.008	0.007	0.006	0.007
Dark Brown	0.167	0.178	0.173	0.154	0.168
Black	0.702	0.703	0.693	0.717	0.704
Gray	0.125	0.111	0.127	0.123	0.121

* Total adds to 1.00 across soil zones for each crop.

3.4 The Derivation of Output Price Data

To construct aggregate output indexes which are an essential component in estimating grain productivity by soil zone, one must have both output and price data. The problem of output by soil zone has been resolved in the preceding discussion. Therefore, this part is concerned with deriving prices, including prices for each soil zone, for the major grains. The question of differential prices for key grains, particularly wheat and barley, across soil zones arises because the quality of output produced in each soil zone differs. For example, the quality of wheat and barley produced in the brown soil zone is generally the highest, whereas the black soil zone produces lower quality grain. In other words, higher quality wheat (which, in turn, commands higher prices per tonne) such as 1 CWRS or 2 CWRS is produced mainly in the brown and dark brown soil zones in the prairies. In contrast lower quality wheat (which is associated with lower prices) such as 3 CWRS and feed is produced mainly in the black and gray soil zones. Since there are differences in grade distribution for each soil zone as well as differences in price associated with each grade of grain, it is not appropriate to apply the same price to the wheat or barley output of different soil zones. Failure to make such an adjustment will lead to the overestimation of productivity growth of the black and gray soil zones and to the underestimation of productivity growth of the brown and dark brown soil zones.

Zonal price adjustments were undertaken for both wheat and barley, the two major prairie grain crops. Such adjustment were not undertaken for oats, flaxseed, and canola -- because these crops are more minor and because differences in grade distribution across soil zones are not that important.

The following general estimating procedure has been applied to derive the prices of wheat and barley for each soil zone:

1. The average grade distribution for wheat (barley) by census division (CD) was obtained.
2. The average share of production for each census division in terms of total production of wheat (barley) in each soil zone was estimated.
3. The average distribution of wheat (barley) grades by census division was weighted by

the average share of each census division in zonal production to obtain an average distribution of grades for each soil zone.

4. The annual prices of different grades of wheat (barley) which are given by the Canada Wheat Board were utilized to estimate zonal prices.
5. The zonal price has been calculated by multiplying the weighted average of grades of wheat (barley) grown in a particular zone by the corresponding prices by grade. For example, if a particular soil zone produced 60 percent grade 1 CWRS (at $3.00 per bushel) and 40 percent 2 CWRS (at $2.50 per bushel), the wheat price for that zone would be equal to (0.60 X $3.00) + (0.40 X $2.50) or $2.80 per bushel.
6. A provincial price for wheat (barley) which is consistent with zonal prices can be calculated as follows:
   a. The share of each soil zone in total production of wheat (barley) in the province is calculated.
   b. These zonal shares are multiplied by their corresponding zonal prices which are calculated in step 5. Then, by adding all these fractions of price, the provincial price for a particular grain can be derived.

More detailed discussion of these steps is the main concern of the latter half of this chapter. Before moving to this task, it is useful to briefly outline some key features of the Canadian grain grading system which bear on grain quality and grain grades.

3.4.1 The Canadian Grain Grading System

The Canadian Grain grading system[6] is the segregation of a particular grain into quality classes. Canada Western Red Spring Wheat (CWRS), for example, is classified into three classes of grades: 1 CWRS, 2 CWRS, and 3 CWRS. These classifications are usually done: (a) to facilitate price determination for each grade in the market; (b) to facilitate handling, transportaion, and storage of the same grades; and (c) to increase market efficiency.

[6]This section is heavily based on Wilson (1979)

3.4.2 Definition of Grain Grading System

The grading of different grains in Canada has been defined in Schedule I of the Canada Grain Act or under the grain regulations approved under the authority of that act. Under this act four classes of grades are defined for Canadian grain and grain screenings:

I. Class 1 Grades (Statutory): This class of grades is as defined in Schedule I of the Canadian Grain Act. It includes the commonly used grades. Consequently the majority of Canadian grain is classified into this class of grades.

II. Class 2 Grades (Special Grades): This class of grades includes grades of new grain varieties (such as experimental new varieties of grains) and other grains which are not classified in class I grades due to unfavorable growing conditions.

III. Class 3 Grades (Off-Grades): These grades include the grains which are rejected from Class I grades due to poor conditions or admixture.

IV. Class 4 Grades (Screenings): This class of grades includes the lowest quality of grains such as screenings removed during cleaning.

3.4.3 Grading Factors

The segregation of a particular grain into grade classes depends on certain quantitative as well as qualitative factors. For illustration, Canada Western Spring Wheat is segregated into three grades: 1 CWRS, 2 CWRS, and 3 CWRS. These three grades are differentiated by different factors usually called grading factors such as: (1) test weight, (2) variety, (3) purity, (4) vitreousness, (5) soundness, (6) maximum limit of foreign material, (7) dockage, (8) moisture content, and (9) protein content. Some of these factors (such as test weight, moisture content, protein content, and dockage) can be tested objectively or quantitatively. Other factors (such as vitreousness and soundness) do not lend themselves to precise verbal definitions and must be determined qualitatively by visual inspection; therefore, their evaluation depends on the judgment and experience of the grain inspector (Wilson 1979). The degree of soundness is one of the most important grading factors. Sound kernels are well developed, mature and physically undamaged. The soundness of grain is impaired by many types of damage such as immaturity, weathering during harvest, frost, disease, and handling or heating in storage. Test weight which is defined as an indicator of plumpness of grain is not a limiting grading factor under normal growing conditions. The percentage of moisture content in the grain and the protein content are also not considered as limiting grading factors. The percentage of moisture or protein will qualify the grade but will not alter the grade -- for instance, 1 CWRS, 13.5 protein and 14.5 moisture content (Wilson 1979).

3.4.4 Grain Grades Distribution

The preceding discussion indicates that the grain grading factors are influenced by weather conditions including precipitation and frost and to a certain degree by soil fertility. Therefore, the distribution of these grades among the soil zones and among the CDs within the soil zones are expected to vary accordingly. The level of precipitation increases as one moves from the brown to dark brown to black and gray soil zones. As well, the degree of the moisture efficiency usually follows the same direction. Higher moisture levels are usually accompanied by higher levels of soil organic matter as one moves from the brown to the dark brown, and then to the black and gray soil zones (Rennie and Ellis, 1979).

The distribution of grain grades usually follows the opposite direction. The percentage share of higher quality grades of wheat such as 1 CWRS and 2 CWRS as well as the share of higher quality barley, tends to decrease as one moves from brown to dark brown to black and gray soil zones. This can be intuitively deduced from Tables 3-5, 3-6, 3,7 and 3-8 which show the average grade distribution of Canada Western Spring Wheat (CWRS) in Alberta and Saskatchewan, the barley grade distribution in Alberta, and the canola grade distribution in Alberta, respectively. It can be seen from Table 3-5 that the distribution of 1 CWRS, as well as that of durum, winter and soft wheat, are concentrated mainly in CDs 1, 2, 3 and 4 which are located in the brown and dark brown soil zones. Grade 2 CWRS wheat is almost evenly distributed among the soil zones while the distributions of 3 CWRS and feed wheat are concentrated in the black and gray soil zones. In Table 3-6 the average grade distribution of red spring wheat in Saskatchewan is presented. Saskatchewan produces higher quality wheat than Alberta, but the general

Table 3-5. Wheat Grade Distribution in Alberta, Seven-Year Average, 1978 to 1985.

CD	1 CWRS	2 CWRS	3 CWRS	Feed	Durum	Winter & Soft
			Percentage			
1	67.21	8.17	3.23	1.33	19.94	—
2	47.97	12.73	4.47	1.50	16.82	16.51
3	41.72	18.86	14.30	5.81	7.34	11.87
4	42.97	19.27	13.38	6.37	18.28	—
5.	45.46	15.94	18.58	8.28	11.74	—
6 & 9	33.33	25.81	27.21	13.20	—	—
7	19.85	28.34	36.84	14.70	—	—
8	2.38	20.64	41.40	35.68	—	—
10	7.78	23.58	45.91	22.73	—	—
11	3.08	16.49	42.08	38.35	—	—
12	1.78	13.82	38.86	45.54	—	—
13 & 14	1.28	11.34	42.75	44.18	—	—
15	6.29	10.55	53.13	30.03	—	—

Notes:

• Feed grades 1 and 2 CU are added to 3 CU (feed) because their prices are not readily available, and their shares are relatively small.

• The grade distibutions of winter wheat and soft white wheat were added together for the following reasons:

(a) their shares involve relatively small percentages and are concentrated in CDs 2 and 3.

(b) the lack of price data on soft white wheat.

Source: This table is derived by utilizing statistical data provided by Alberta Wheat Pool, Series C, *Crop Report, Estimates of Quality by District*, Form 811-AIF.

Table 3-6. Distribution of Grades for Spring Wheat in Saskatchewan, Seven-Year Average, 1978-1984.

Crop District	1 CWRS	2 CWRS	3 CWRS	Feed
		Percentage		
1A	40.98	34.03	19.87	5.12
1B	29.50	23.25	27.25	11.00
2	27.25	27.06	11.75	3.94
3	72.85	13.05	13.66	0.62
4	85.45	9.88	2.92	1.75
5	25.50	28.68	30.25	15.57
6	59.49	24.19	11.38	4.94
7A	70.75	17.63	7.00	4.62
7B	54.28	22.75	17.10	5.87
8	23.32	23.44	33.43	19.81
9	22.00	32.31	33.44	12.25

Notes:

* This table does not show the distribution of durum, soft, and winter wheat because these data were not readily available.

Source: This table is derived by utilizing the statistical data provided by Alberta Wheat Pool, Series C, *Crop Report, Estimate of Quality by District*, Form 811-AIF.

Table 3-7. Barley Grade Distribution in Alberta, Seven-Year Average, 1978-1984.

Census Division	1 & 2 CW 6 Row	1 & 2 CW 2 Row	1 Feed	2 & 3 Feed
		Percentage		
1	5.18	16.15	75.96	2.71
2	2.30	27.24	67.45	3.01
3	1.78	10.99	63.83	23.40
4	2.73	1.00	88.43	6.83
5	3.30	23.63	66.13	6.94
6 & 9	3.45	8.84	75.25	12.46
7	3.44	4.18	73.36	19.02
8	4.49	3.21	75.28	17.02
10	1.19	0.63	65.30	32.88
11	2.18	0.76	70.15	26.91
12	0.13	0.23	65.28	34.36
13 & 14	0.74	1.41	70.83	27.02
15	1.75	2.03	74.69	21.53

Notes:

2 & 3 feed barley are added together due to the relatively small percentage of 3 feed barley and the lack of price data on 3 feed barley.

Source: This table is derived by using data provided by Alberta Wheat Pool, Series C. *Crop Report, Estimate of Quality by District*, Form 811-AIF.

Table 3-8. Canola (Rapeseed) Grade Distribution by Agricultural Reporting Area (ARA), Alberta, Seven-Year Average, 1978-1984.

ARA	1 CA	2 CA
	Percentage	
1	85.18	14.82
2	82.80	17.20
3	79.78	20.22
4A	87.53	12.47
4B	83.63	16.37
5	81.41	18.59
6	81.80	18.20
7	81.11	18.89

Source: This table is derived by utilizing the statistical information provided by Alberta Wheat Pool, Series C, *Crop Report, Estimate of Quality by District*, Form 811-AIF.

pattern of the distribution of grain grades across soil zones is somewhat similar to that in Alberta.

The seven-year average of the barley grade distribution in Alberta in shown in Table 3-7. From this table one can infer that the highest quality is also concentrated in the brown and dark brown zones. The distribution of 1 Feed barley is almost the same in different soil zones. On the other hand the distributions of 2 and 3 Feed barley are concentrated in the black and gray zones. Since the data on barley grade distribution in Sakatchewan was not readily available, it was assumed that this distribution followed the same distribution as in Alberta. Finally, in Table 3-8 the canola (rapeseed) grade distribution in Alberta is presented. The percentage share of top grade canola is consistently high over time (averaging between 80 and 85 percent) and is remarkably similar across census districts and soil zones in Alberta. This led us to assume in this study that the grade distribution of canola was evenly distributed among soil zones in both Alberta and Saskatchewan. Since oats and flaxseed are much less important grain crops, prices for these two grains were assumed to be the same across soil zones.

3.4.5 Deriving Zonal Grade Distributions

The derivation of grain grade distributions for wheat and barley at the soil zone level requires that respective grain grade distributions by census division or crop district be weighted by the average shares of production of CDs in each soil zone for the same period of time, 1978 to 1984. This procedure involved: (a) calculating the total production of each soil zone and CD in the soil zone for each grain; (b) dividing the production of each CD by the total production of the soil zone, the results being the respective shares of the CDs in the total production in the soil zone; and (c) multiplying the production shares of the CDs by their corresponding grade distribution figures. The end result was the generation of weighted average grade distribution for each soil zone. For illustrative purposes, the weighted average grade distribution by soil zone of all wheat in Alberta is presented in Table 3-9.

Table 3-9. Average Wheat Grade Distribution of All Wheat in Alberta for Different Soil Zones.

Wheat Grade	Brown	Dark Brown	Black	Gray
		Percentage		
1 CWRS	0.538	0.343	0.185	0.060
2 CWRS	0.136	0.213	0.225	0.119
3 CWRS	0.066	0.245	0.362	0.498
1 Feed	0.027	0.099	0.190	0.323
Durum	0.185	0.061	0.015	—
Soft & Winter	0.048	0.038	0.023	—

From this table one can notice the difference in quality of wheat among the Alberta soil zones. The percentage share of 1 CWRS, durum, and soft & winter wheat decreases as we move from the brown to black and gray zones. However, the concentration of production of 3 CWRS and feed wheat increases in the opposite direction. It can be seen from this table, for example, that 54 percent of wheat produced in the brown soil zone is 1 CWRS compared with only about 6 percent in the gray soil zone. It can be also seen from this table that over half of wheat produced in the black soil zone grades either 3 CWRS or feed and over 80 percent of wheat produced in the gray soil zone falls into these two grades. This wide discrepancy in the distribution of wheat grades among soil zones will be reflected in differences in wheat prices among these zones.

3.5 Derivation of Zonal Output Prices

Zonal prices for wheat and barley in Alberta and Saskatchewan have been derived by multiplying the Canadian Wheat Board prices for principal grades of wheat and barley received by producers basis in store Thunder Bay or Vancouver, by the weighted average grade distribution in each soil zone. The derivation of these prices can be demonstrated in the following discussion.

3.5.1 Wheat Prices

The zonal wheat prices are calculated for the period 1978 to 1984 for Alberta and Saskatchewan by utilizing Wheat Board prices for 1 CWRS, 2 CWRS, 3 CWRS, and feed wheat. The prices of durum, winter and soft white wheat, on the other hand, were obtained from *Grain Trade of Canada*, Catalogue No. 22-201, annual. These respective prices for various grades and types of wheat were multiplied by their corresponding percentage shares in the weighted average grade distribution for each soil zone in order to derive zonal prices of wheat. In Table 3-10 and Table 3-11, such zonal prices for wheat are presented for Alberta and Saskatchewan, respectively, for the crop years between 1978-79 and 1984-85. The construction of Tables 3-10 and 3-11 is also based on the following minor assumptions: (1) Off-board wheat is selling at same price as Board wheat. (2) The prices of winter wheat are also applied to soft white wheat. (3) 3C utility (feed) prices are used as a proxy for feed wheat prices.

As Table 3-10 portrays, there are price differences among the soil zones for wheat in Alberta. For example, using the seven year average figures, there are $11 and $18 per tonne differences in wheat prices between the brown and black soil zones and between the brown and the gray soil zones respectively. As well, some differences in wheat prices between the dark brown and the black zones and between the dark brown and gray zones can be observed from Table 3-10. These differences in wheat prices in Alberta are consistent with differences in the pattern of the distribution of wheat grades and types across soil zones. For Saskatchewan, as shown in Table 3-11, the differences in wheat prices between soil zones are slightly narrower, although there is still nearly an $8 per tonne difference between wheat from the brown soil zone and wheat from the black soil zone.

Table 3-10. Zonal Prices of Wheat, Derived Provincial Wheat Prices, and Actual CANSIM Wheat Prices, Alberta, 1978-1979 to 1984-85.

Crop Year	Brown	Dark Brown	Black	Gray	Derived Alberta	CANSIM Alberta
			Dollars per Tonne			
1978/79	151.33	149.51	146.02	140.84	148.29	135.00
1979/80	190.61	182.43	174.43	164.23	180.44	179.00
1980/81	218.86	212.17	205.83	197.66	209.19	197.00
1981/82	193.85	189.37	183.89	175.93	187.42	185.00
1982/83	183.95	181.22	178.53	170.69	179.95	167.00
1983/84	188.48	183.14	177.55	170.13	180.76	173.00
1984/85	182.11	176.52	171.19	164.16	173.76	163.00
Average	187.03	182.05	176.78	169.09	179.97	171.29

Provincial wheat prices which are consistent with the foregoing zonal prices are also derived for Alberta and Saskatchewan by using the following formula:

$$\text{Provincial Wheat Price} = \sum_i S_i P_i \qquad 3\text{-}1$$

where S_i = share of soil zone i in total provincial wheat production.

P_i = price of wheat in soil zone i.

The derived provincial prices of wheat for Alberta and Saskatchewan are also shown in Tables 3-10 and 3-11, respectively. These derived or constructed provincial prices are slightly different from the provincial CANSIM prices of wheat which are also shown in Tables 3-10 and 3-11 for comparison purposes. The main reasons why the derived and CANSIM prices differ slightly are: (a) transportation and handling costs are included in the

Table 3-11. Zonal Prices of Wheat, Derived Provincial Wheat Prices, and Actual CANSIM Wheat Prices, Saskatchewan, 1978-79 to 1984-85.

Crop Year	Brown	Dark Brown	Black	Derived Saskatchewan	CANSIM Saskatchewan
			Dollars Per Tonne		
1978/79	151.32	152.47	147.91	150.59	142.00
1979/80	191.87	188.72	178.12	187.32	179.00
1980/81	221.23	217.88	209.16	215.86	209.00
1981/82	193.31	193.40	186.64	191.12	188.00
1982/83	184.23	185.64	179.60	183.16	172.00
1983/84	190.43	188.65	180.77	186.56	179.00
1984/85	183.80	181.93	174.37	179.25	176.00
Average	188.03	186.95	179.51	184.84	178.00

derived wheat prices, while these cost charges have been removed from CANSIM prices; (b) part of the differences in the two prices might be attributed to our assumption that off-board prices are the same as board prices; (c) in any given year, the actual grade distribution for that particular year may deviate from the long term average which was used in generating the derived price series; and (d) possible differences between the CWB and CANSIM price series for wheat.

The prairie zonal prices for wheat were also estimated in this study by utilizing the following procedure: (a) total wheat production was aggregated each year for the period 1978-79 to 1984-85 for each prairie soil zone; (b) the shares of each provincial soil zone in total wheat production of the corresponding prairie soil zone were calculated; and (c) the prairie zonal wheat price was simply calculated by multiplying the provincial zonal share by the provincial zonal price of wheat and summing over all relevant provinces. To illustrate this procedure, we will demonstrate how the prices of wheat for the brown soil zone in the prairie region were derived: The prairie brown soil zone prices for wheat = (the share of the Alberta brown soil zone in total prairie brown zone in Alberta) X (the wheat price in the brown soil zone in Alberta) + (the share of the Saskatchewan brown soil zone in total prairie brown zone production) X (the price of wheat in the brown zone in Saskatchewan). Zonal prices at the prairie aggregate level for the period 1978-79 to 1984-85 are presented in Table 3-12. The differences in these prices can be attributed to differences in the distribution of wheat grades among the soil zones.

Table 3-12. Prairie Wheat Prices, by Soil Zone, and the Associated Derived Aggregate Price, 1978-79 to 1984-85.

Crop Year	Brown	Dark Brown	Black	Gray	Derived Prairie
			Dollars Per Tonne		
1978/79	151.32	151.69	142.37	140.84	147.56
1979/80	191.60	186.86	174.38	164.23	183.36
1980/81	220.66	215.86	206.73	197.66	212.50
1981/82	193.46	192.06	182.03	175.93	187.72
1982/83	184.17	184.42	174.41	170.68	179.81
1983/84	189.94	187.08	177.97	170.14	183.32
1984/85	183.38	180.20	172.97	164.16	176.46
Average	187.79	185.84	175.84	169.09	181.53

3.5.2 Barley Prices

Parallel procedures which were used to derive the preceding wheat prices were utilized to derive barley prices for different soil zones. Further assumptions were needed to derive barley prices, such as: (a) it was implicit that off-board barley was selling at the same price as board; (b) the #1 feed price was the reported feed price, not the designated or malting price; (c) the prices of #2+3 feed were assumed to be the same; and (d) for top grades, designated prices were used. In Table 3-13 barley prices by soil zone, the associated derived provincial prices for barley and actual CANSIM prices for barley in Alberta are presented. In this table a relatively wide divergence between the derived prices of barley and the CANSIM prices is evident. This is likely due to three possible reasons. First, the cost of transportation and handling of barley has not been removed from the derived prices. Second, our implicit assumption that all barley produced in Alberta was sold through the Canadian Wheat Board is too simplistic; in reality a considerable quantity of barley is sold off-board at lower prices. As a consequence, due to the lack of information on off-board quantities, our methodology does not capture this impact. Third, in any year the actual grade distribution may not equal the longer term average, thereby producing discrepancy in prices. For instance, the wide descrepancy in 1984/85 between the derived and CANSIM barley price is partially due to the distribution of barley grades in 1984/85 being worse than the average on which the $152.39 figure is based.

3.5.3 Relative Price Conversion Factors

The construction of relative price conversion factors was needed to derive zonal grain prices for the entire time period from 1961 to 1984.[7] A relative price conversion factor can be defined as the ratio between the (average) zonal prices and the derived provincial price. Since data on grain grade distribution by CDs was not readily available prior to 1978, especially for Saskatchewan, we have made use of more recent and accessible data (seven years average) to derive zonal, provincial, and the prairie prices for the period 1978 to 1984. In this process the relative price conversion factor was calculated by taking the

[7]Provincial and zonal grain prices in Alberta were derived for the period of 1957-84.

Table 3-13. Zonal Prices, Derived Prices, and CANSIM Prices of Barley, Alberta, Seven-Year Average, 1978-79 to 1984-85.

Crop Year	Brown	Dark Brown	Black	Gray	Derived Alberta	CANSIM Alberta
			Dollars Per Tonne			
1978/79	98.11	96.69	92.45	91.26	93.36	79.00
1979/80	122.39	120.20	111.40	109.00	112.96	106.00
1980/81	161.54	159.19	150.09	147.63	151.78	139.00
1981/82	144.57	142.45	134.24	132.02	135.67	115.00
1982/83	124.41	121.92	112.74	110.35	114.26	90.00
1983/84	147.33	145.89	140.24	138.84	141.29	116.00
1984/85	159.63	157.97	151.86	150.36	152.39	121.00
Average	136.85	134.91	127.58	125.64	128.81	109.43

Table 3-14. Relative Price Conversion Factors for Wheat and Barley by Soil Zone.

	Brown	Dark Brown	Black	Gray
Alberta				
Wheat	1.039	1.012	0.982	0.939
Barley	1.062	1.047	0.990	0.975
Saskatchewan				
Wheat	1.017	1.011	0.971	—
Barley	1.054	1.039	0.983	—
Prairie				
Wheat	1.035	1.022	0.969	0.939
Barley	1.067	1.063	0.989	0.975

seven year average of a given zonal price and dividing it by the seven year average of the corresponding derived provincial price. The relative price conversion factors for wheat and barley are presented in Table 3-14.

The practical implications of the information in Table 3-14 are that the price of wheat produced in the brown and dark brown zones in Alberta, as an example, are above the provincial price of wheat in Alberta by 3.9 and 1.2 percent, respectively. On the other hand the prices of wheat produced in the black and gray soil zones in Alberta are below the average provincial price by 1.8 and 6.1 percent, respectively. In addition barley prices for the brown and dark brown soil zones in Alberta exceed the provincial barley price in Alberta whereas barley prices in the black and gray soil zones are below the overall provincial price level by about 1 and 3 percent, respectively. The zonal prices of wheat and barley in Saskatchewan and the prairie region follow a similar pattern.

These relative price conversion factors have been utilized to derive the zonal prices of wheat and barley for Alberta, Saskatchewan, and the prairies for the period, 1961 to

1984, under the assumption that the average grain grade distribution of wheat and barley during 1978-79 to 1984-85 can be applied during the entire period. This is simply done by multiplying the zonal relative conversion factors by the CANSIM prices of wheat and barley. These relative conversion factors have been applied to the published CANSIM provincial prices for wheat and barley because the CANSIM prices are more accurate on a yearly basis (than our "derived" prices) and can be viewed as farm-gate prices. In Appendix 2 of this thesis, the prices of wheat and barley are presented -- by soil zone, by province, and for the prairie region as a whole. Price data for canola, flaxseed, and oats are also presented in Appendix 2.

3.6 Output Quantity and Output Price Indexes

In the previous sections of this chapter the grain output quantities by province, soil zone, and for the prairie region, as well as their corresponding prices, have been derived for the period of 1957-84 for Alberta and Manitoba and for 1961-84 for Saskatchewan and the prairies. This time series data on grain outputs and prices were utilized, along with the Tornqvist index procedures which have been described in Chapter 2, to construct aggregate grain output quantity indexes and grain output prices indexes for each province, for each soil zone, and for the prairie region as an aggregate. In the following section, we shall discuss briefly the output quantity indexes, the output price indexes and their derived growth rates for the prairie grain sector and its major soil zones. More detailed discussion of these subjects will follow in Chapter 5.

The output quantity indexes of the grain sector in the prairie region and its major soil zones were constructed by using the output quantities and prices of the five major grains (wheat, barley, oats, canola, and flax) grown in the brown, dark brown, black, and gray soil zones in the prairie region. The data on grain outputs for each province and its soil zones, and for the prairie aggregate were obtained from provincial statistics yearbooks for the entire period of study. The data on output prices by province and for the prairie aggregate were provided by computerized data banks of Statistics Canada (CANSIM). However, zonal output prices (mainly for wheat and barley) were derived by utilizing the procedures just outlined in Section 3.5. These zonal prices for wheat and barley were constructed for each soil zone in Alberta, Saskatchewan and the prairie region.

The aggregate output quantity indexes for the prairie brown, dark brown, black, and gray soil zones, along with their growth rates, are presented in Table 3-16. Output price indexes for the prairies and its major soil zones are presented in Table 3-17. It can be seen from Table 3-16 that output quantity indexes for the prairies and its major soil zones are characterized by wide fluctuations around the trend. The severe effects of drought years, such as 1961 and 1984, for example, on prairie grain production are clearly evident. The output quantity indexes reached their maximum level in 1982, and their lowest level in 1961; such discrepancies in production among years could be attributed mainly to weather variables. On the other hand, the decrease in grain production in 1970 can be attributed to the effect of the Lower Inventories for Tomorrow (LIFT) program.

It can be seen from Table 3-15 that grain output in the prairie region grew by 3.6 percent per year over the 1961-84 period (or, alternatively, 2.9 percent annually over the 1962-84 period). This result indicates that the inclusion or exclusion of the drought year, 1961, has a direct effect on the estimated growth rate of grain output. On the zonal level, grain output increased somewhat less rapidly in the brown zone (2.0 percent per year) and the dark brown zone (2.3 percent per year) during 1962-84. On the other hand, grain output rose by 3.2 percent per annum in the black soil zone and by a remarkable 6.2 percent per year in the (Alberta) gray soil zone. The higher growth rates of the output quantity index in the gray soil zone is attributed to the adoption of higher yielding seed varieties, more timely cultural practices and the use of fertilizer and pesticides (Deloitte, 1980). Finally, on the provincial level, the growth rates of the output quantity indexes are higher in Manitoba, followed by Alberta and Saskatchewan, for the period 1961-84.

Table 3-15. Divisia Indexes of Grain Output for the Prairies and its Major Soil Zones, 1961-84 (1971=1.000)

Year	Prairies	Brown	Dark Brown	Black	Gray
1961.	0.360	0.265	0.305	0.376	0.740
1962.	0.683	0.682	0.581	0.726	0.695
1963.	0.845	1.009	0.851	0.807	0.520
1964.	0.689	0.684	0.617	0.712	0.728
1965.	0.805	0.953	0.699	0.827	0.576
1966.	0.999	1.217	1.027	0.914	0.845
1967.	0.734	0.692	0.669	0.778	0.679
1968.	0.847	0.861	0.783	0.851	0.997
1969.	0.928	1.122	0.925	0.871	0.795
1970.	0.729	0.916	0.648	0.703	0.803
1971.	1.000	1.000	1.000	1.000	1.000
1972.	0.900	0.940	0.834	0.913	0.986
1973.	0.906	0.906	0.890	0.910	1.000
1974.	0.765	0.850	0.715	0.762	0.779
1975.	0.949	1.099	0.858	0.929	1.126
1976.	1.108	1.351	1.037	1.052	1.173
1977.	1.146	1.117	1.030	1.204	1.200
1978.	1.248	1.253	1.059	1.303	1.615
1979.	1.075	1.126	0.950	1.060	1.659
1980.	1.123	1.102	0.960	1.133	1.928
1981.	1.354	1.256	1.175	1.431	1.787
1982.	1.483	1.456	1.325	1.532	1.763
1983.	1.385	1.379	1.213	1.391	2.107
1984.	1.222	0.848	0.826	1.478	2.097
Annual Growth Rates in (%)					
1961-84	3.6	3.1	3.1	3.8	6.0
1962-84	2.9	2.0	2.3	3.2	6.1
1962-72	2.2	2.2	2.7	1.8	5.1
1973-84	4.5	1.8	2.7	5.5	9.0

Table 3-16. Divisia Indexes of Grain Output Prices for the Prairies and its Major Soil Zones, 1961-84 (1971=1.000)

Year	Prairies	Brown	Dark Brown	Black	Gray
1961.	1.360	1.344	1.363	1.362	1.430
1962.	1.287	1.293	1.288	1.329	1.329
1963.	1.269	1.234	1.333	1.309	1.333
1964.	1.269	1.234	1.258	1.283	1.339
1965.	1.321	1.297	1.316	1.331	1.388
1966.	1.374	1.355	1.372	1.381	1.421
1967.	1.245	1.242	1.252	1.244	1.242
1968.	1.037	1.024	1.039	1.040	1.103
1969.	0.969	0.969	0.982	0.998	0.975
1970.	1.058	1.055	1.056	1.059	1.046
1971.	1.000	1.000	1.000	1.000	1.000
1972.	1.552	1.483	1.531	1.582	1.630
1973.	3.351	3.382	3.405	3.325	3.281
1974.	3.190	3.188	3.223	3.179	3.177
1975.	2.812	2.776	2.824	2.815	2.935
1976.	2.372	2.229	2.337	2.428	2.535
1977.	2.216	2.143	2.213	2.238	2.341
1978.	2.651	2.802	2.733	2.592	2.508
1979.	3.219	3.582	3.369	3.087	2.917
1980.	3.782	4.183	3.936	3.644	3.357
1981.	3.416	3.766	3.554	3.295	3.010
1982.	3.002	3.397	3.167	2.859	2.569
1983.	3.409	3.606	3.493	3.351	3.119
1984.	3.313	3.518	3.391	3.254	3.046
Annual Growth Rates in (%)					
1961-84	5.8	6.3	6.1	5.7	4.7
1962-84	6.2	6.8	6.4	6.0	5.1
1962-72	-1.4	-1.5	-1.5	-1.3	-1.6
1973-84	1.6	1.9	1.9	1.2	0.1

The output price index of the prairie grain sector rose from 1.360 in 1961 to 3.313 in 1984, 144 per cent in percentage terms. The increases in the international demand for grains, especially wheat and feed, in the 1970's had a major impact on grain prices. On the zonal level, the differences in grain price indexes among soil zones can be easily seen from Table 3-17. In percentage terms, grain prices in the brown soil zone rose by 162 percent from 1961 to 1984, and in the dark brown by 149 percent for the same period of time. Grain prices rose by 139 percent and 113 percent for the black and gray soil zones, respectively, for the period of 1961 to 1984. This, in turn, can be attributed to the differences in the quality of grains produced in each soil zone. The best quality of wheat and barley, for example, is produced in the brown and dark brown soil zones, while lower quality grain is generally produced in the black and gray soil zones.

3.7 Summary

The main concern of this chapter was to derive zonal, provincial and prairie grain outputs for the five major grains and oilseeds (wheat, barley, oats, canola, and flax) grown in the brown, dark brown, black, and gray soil zones in the prairie region. Zonal wheat and barley prices were also derived in this chapter. The main points of this chapter are summarized as follows:

1. Zonal Output: The overall prairie region has been classified in this study into four distinctive soil zones: brown, dark brown, black, and gray. On the provincial level Manitoba is coded as black soil zone, Saskatchewan is classified into the brown, dark brown, and black zones, and Alberta is classified into the brown, dark brown, black and gray soil zones. The grain output levels for these distinctive soil zones in each province were derived by aggregating grain production data for those Census Divisions (CD) or crop districts (or parts thereof) located in each particular soil zone. The provincial grain outputs were derived by aggregating the zonal outputs in each province, and the prairie grain output was obtained by aggregating the provincial grain outputs.
2. Zonal Output Prices: The question of differential prices for key grains, particularly wheat and barley, across soil zones arises because the quality of output produced in

each soil zone differs. Higher quality wheat (which, in turn, commands higher prices per tonne) such as 1 CWRS or 2 CWRS is produced mainly in the brown and dark brown soil zones in the prairies. In contrast lower quality wheat (which is associated with lower prices) such as 3 CWRS and feed is produced mainly in the black and gray soil zones. It is important, therefore, to derive zonal prices of output to reflect the differences in grain quality produced in each soil zone. Zonal output price adjustments were undertaken for both wheat and barley, the two major prairie grain crops. Such adjustment were not undertaken for oats, flax, and canola, because these crops are minor and because differences in grade distribution across soil zones are not that important. Zonal prices of wheat and barley for Alberta, Saskatchewan, and the prairie aggregate have been derived by multiplying the CANSIM prices in each province by relative price conversion factors for wheat and barley in each soil zone. The relative price conversion factors, on the other hand, were obtained by utilizing the Canadian Wheat Board prices by grade for wheat and barley, the average grade distributions for wheat and barley (7 year average), and the average production share of wheat and barley (7 year average) in each soil zone to total production.

3. Output Quantity and Price Indexes: The Tornqvist index number procedure which is an approximation to the Divisia index approach has been utilized to construct output quantity and price indexes for each soil zone, for each province, and for the prairie aggregate. Grain output in the prairie region grew by 3.6 percent per year over the 1961-84 period (2.9 percent annually over the 1962-84 period). These results indicate that inclusion or exclusion of the drought year, 1961, have a direct effect on the estimated growth rate of grain output. On the zonal level, grain output increased somewhat less rapidly in the brown zone (2.0 percent per year) and the dark brown zone (2.3 percent per year) during 1962-84. On the other hand grain output rose by 3.2 percent per annum in the black soil zone and by a remarkable 6.2 percent per year in the (Alberta) gray soil zone. Finally, at the provincial level, the growth rate of the output quantity index is higher in Manitoba, followed by Alberta and Saskatchewan, for the period of 1961 to 1984.

4. The Derivation of Input Quantities and Prices in the Prairie Grain Sector

4.1 Introduction

The primary objectives of this study are to derive output, input, and their corresponding price indexes for the grain sector, to use these indexes to measure the annual growth rate of total factor productivity, and to estimate the production technology of the grain sector using the translog cost function. In this chapter, the derivation of input quantities and prices for the prairie grain sector which are needed to accomplish the foregoing objectives is outlined.

The basic input categories in the grain sector to be studied include land, labor, machinery, and purchased inputs. Most of these input classes are used in both grain and livestock production. Therefore, a major conceptual and empirical problem involved the separation of input use figures which are attributable solely to grain operations when many prairie farms, in fact, are mixed enterprises (crop and livestock). This difficulty arises because of the lack of information on input use for each agricultural subsector. This, in turn, is associated with the fact that Statistics Canada does not provide systematic time series data on representative farm types.

In this study, input use is regarded to comprise two distinctive components. First, there are those inputs which are readily and directly attributable to grain production, such as fertilizer, energy, and seeds. Second, there are those input categories which are extremely difficult to attribute either to grain or livestock production, especially on mixed farms. Such inputs include machinery which is used jointly in grain and livestock production, labor and buildings. The estimation of input use in this latter category will involve some arbitrary assumptions and value judgments. Therefore, our task in this study is to try to derive reasonable estimates of input use which are attributable to grain production in the prairie region. In this chapter we shall discuss in detail data classification and the procedures which have been developed to estimate input use which is attributable to the grain sector and to derive input use figures for respective soil zones.

4.2 Input Data Classification

The major inputs in grain production which have been ch^‿en for inclusion in this study include: cropped land (land which is in use for the five major grain crops), labor (owner operator, family and hired labor), machinery (depreciation and opportunity cost), chemicals (fertilizer and pesticides), and materials (seeds and irrigation equipment, fuel & oil and electricity). A brief discussion of these five input classes will be the main content of the remainder of this section.

Land

Unlike the previous studies of agricultural productivity in Canadian agriculture which have used the flow of services emanating from the total stock of agricultural land, the land input in this study is limited to the actual cropped land which is in current use by the five major grain crops (wheat, oats, barley, flaxseed, and canola). This measure of the land input, then, excludes summer fallow and the areas under minor crops. The annual flow of services of this stock of land was imputed to be five percent of the nominal capital value of this stock of land. The stock of land in this study is obtained from provincial statistics hand books for the period of the study. The price of land and buildings was taken from *unpublished Statistics Canada* time series information for the period, 1957-1984. Finally, the data on depreciation on building have been obtained from *Farm Net Income Catalogue* (21-202).

Labor

The labor inputs in this study consist of the three distinctive groups of labor which provide productive services in agriculture, namely, hired labor, owner operator labor, and family labor. There is some controversy in the literature concerning the use of man hours data or persons employed data in productivity studies. Brown (1978) argued that man hours data provides a better estimate for the labor index. Islam (1980) utilized both persons employed and man-hours data, and his reasoning indicated that man-hours data should give more precision in constructing labor indexes. Therefore, the data on actual hours worked in agriculture have been used in this study rather than labor employment data. since man-hour data are not available prior to 1966, the man-hour series was extrapolated back to 1961.

A second issue of concern with respect to labor data is the question of the imputation of a wage rate to owner operator and family labor. Some recent studies have assigned a wage rate to the owner operator which is the same as that paid to hired labor in agriculture, and have imputed a wage to family labor which is 70 percent of the hired wage rate. The latter imputation is typically justified on the ground that marginal productivity of family labor is lower than that of owner operator and paid labor (Islam and Veeman, 1980; Veeman and Fantino, 1985; Anderson, 1984). Ball (1985) argued that the opportunity cost of the owner operator's time is the same as that of industrial labor; accordingly, he assigned the industrial wage rate to the owner operator in agriculture. Brinkman and others (1984) applied the hired labor wage to the owner operator and 90 percent of this rate to family labor. In this study we assigned the hired labor wage to the owner operator and family labor. No discount to the wage for family labor was assigned because the role of family labor is very important in the production process. Further, there is a lack of empirical evidence concerning the productivity of family labor in agriculture which makes their role in farm business and their imputed wage very difficult to determine.

Data on hours worked in agriculture for the period 1966 to 1984 for each province were provided to the author by *Statistics Canada from unpublished farm labor survey data*. For the period 1966 to 1957, the data were obtained by extrapolating the farm labor survey data back to 1957. Hired labor data is provided by the *Farm Net Income Hand Book*. Average wage per hour without board for agriculture labor has been used for these three categories of labor (owner operator, family labor, and paid labor) to derive the labor cost in agriculture for each province. The average wage rates per hour were obtained from *Statistics Canada, Catalogue* 21-002 for 1957 through 1984.

Machinery

Machinery input in this study is composed of machinery depreciation and machinery opportunity cost. Costs on machinery repairs were excluded to prevent overlapping between depreciation cost and actual repair expenses. The machinery flow of services was estimated by applying a long term, real interest rate of 5 percent to the stock of capital. *Farm Net*

Income Hand Book provides data on machinery depreciation and the total value of capital for the period 1957-1984.

Chemicals

The data on fertilizer and pesticides quantities and their corresponding prices are not readily available for the period of 1957 to 1984. Therefore, in this study, we utilized total expenditures on these two inputs (which is provided by *Farm Net Income Hand Book*) and their price indexes (which are provided by *Farm Input Prices*, Catalogue 62-004) to construct an implicit quantity index for fertilizer and pesticides.

Materials

Fuel & oil, electricity irrigation expenses and seeds are the major components of materials used in this study. Expenditure data on these elements have been taken from *Farm Net Income Hand Book*, and their prices indexes have obtained from *Farm Input Price*, Catalogue 62-004. Again, an implicit quantity index for materials was derived from this expenditure data and price indexes.

4.3 Derivation of Inputs for Grain Enterprises

The above classes of inputs in a broad sense are related to all agricultural production sectors (crops and livestock). Therefore, our task is to derive those input categories which are solely related to grain production. Inputs such as fertilizer, pesticides, seeds, fuel and oil are considered in this study to be related entirely to crop production. Other input classes have to be manipulated in such a way that satisfactory estimates of inputs that are related to grain production are provided.

To overcome this task, one option is to use respective total cash receipts from grain and livestock as a basis for allocating total input use between crops and livestock. Weaver *et al* (1982) argued that for those input categories which are not specific to either crops or livestock (such as labor or depreciation for buildings), a pro-rated share can be attributed to crop production based on the proportion of total cash receipts accounted for by crops sale. The main disadvantage of this procedure is the likely bias of the output price effect, especially for the period after 1972 where the prices of grain output show a tremendous increase. Therefore, the derived inputs for crops may be under estimated or over estimated according to the direction of this bias.

The alternative procedure which was actually used in this study is to use the proportional share of crop farms[1] to total farms. This pro-rated share of crop farms in the total number of farms can be constructed under the assumption that farmers are "rational" decision makers who allocate their time and resources to these agricultural activities (crops or livestock) which will maximize their profits. If the crop sector is more profitable, for example, farmers will switch their resources to crops and the number of crop farms as a consequence will increase.

Using an allocation procedure based on relative farm types, the share of machinery, for example, is estimated to equal the share of crop farms in the total number of farms times total machinery input in that year. *The Census of Agriculture* provides data on the total number of farms and the classification of these farms by type (crops and livestock) for the census years 1961, 1966, 1971, 1976 and 1981. The annual share of crop farms to total farms for each of the prairie provinces is presented in Table 4-1. The data between census years are interpolated and the data from 1961 back to 1957 and from 1981 forward to 1984 are extrapolated to derive time series data for the entire period of study. It can be seen from this table that, on the average, about 60 percent of total farms in Manitoba, 80 percent in Saskatchewan and 50 percent in Alberta are crop farms. The effect of the LIFT program on the crop subsector can be easily recognized during 1970, a year in which the share of crop farms shows a remarkable decrease.

The coefficients (crop or grain farm shares) in Table 4-1 can be applied to the total input use value for each input in each province, under the assumption that farms will allocate their time and capital to either crops or livestock according to the share of these two subsectors in the total number of farms. The application of this procedure yields estimates of input use devoted to crops (grain) production each year for the period of the study. Finally, this procedure was applied to allocate labor, machinery, and depreciation

[1]Crop farms are assumed to be synonymous with grain farms. This is largely true, given the high share of the five major grains in prairie crop production.

Table 4-1. Ratio of Crop Farms to Total Farms, Prairie Provinces, 1957 to 1984.

	Manitoba	Saskatchewan	Alberta
1957	0.613	0.824	0.412
1958	0.619	0.830	0.419
1959	0.625	0.836	0.426
1960	0.631	0.842	0.433
1961	0.637	0.848	0.440
1962	0.644	0.854	0.448
1963	0.650	0.859	0.455
1964	0.657	0.865	0.462
1965	0.663	0.871	0.469
1966	0.625	0.836	0.445
1967	0.587	0.802	0.421
1968	0.548	0.767	0.396
1969	0.510	0.733	0.372
1970	0.472	0.698	0.348
1971	0.509	0.726	0.378
1972	0.546	0.753	0.408
1973	0.582	0.781	0.438
1974	0.619	0.808	0.468
1975	0.656	0.836	0.498
1976	0.649	0.834	0.507
1977	0.642	0.832	0.516
1978	0.635	0.829	0.525
1979	0.628	0.827	0.534
1980	0.621	0.825	0.543
1981	0.614	0.823	0.552
1982	0.607	0.821	0.561
1983	0.600	0.819	0.570
1984	0.593	0.817	0.579

Source: Derived from Statistics Canada, *Census of Agriculture* (Manitoba, Saskatchewan, Alberta), 1961, 1966, 1971, 1976, and 1981.

on buildings between crops and livestocks.

4.4 Zonal Grain Input Use

Zonal inputs simply refer to those inputs which are related to crop (grain) production in each soil zone. In this study we are concerned with four distinctive soil zones in the prairie region namely the brown soil zone, the dark brown soil zone, the black soil zone, and the gray soil zone. There are remarkable differences among these four classes of soil zones in moisture availability, the amount of organic matter, and as a consequence the level of fertility. Productivity growth in grain production is suspected to be somewhat different among these soil zones. In addressing this issue empirically, estimates of resource input use by respective soil zone is needed.

Total input use in Alberta and Saskatchewan was allocated among soil zones according to the share of each soil zone in total input use in the province as reflected in census data. The census of agriculture provides data on input use by census division for each province. The input use by census division was aggregated into zonal data according to the location of these CDs in a particular soil zone. Then, the soil zonal shares of input use were constructed by using the average of two census years, 1971 and 1981. It was assumed that the average of these shares was fixed over time. This assumption is not unreasonable given that the soil zonal shares of input use in Alberta and Saskatchewan for 1971 did not show any major difference from these shares in 1981. The soil zonal shares of input use in Alberta and Saskatchewan, respectively, are shown in Tables 4-2 and 4-3.

As shown in Table 4-2, the black soil zone in Alberta has the highest share of any soil zone in provincial input use for all major input categories: machinery use, fertilizer, pesticides, cash wages, fuel & oil, seeds, and electricity. The gray soil zone has the second highest share in terms of machinery use, fuel & oil, electricity and seeds, and the third highest share in terms of fertilizer and pesticides. The dark brown soil zone shares of machinery input, cash wages, fertilizer, and pesticides are ranked as the second highest, second only to those in the black soil zone. Finally, Table 4-2 shows that the brown soil zone shares of input use are the lowest compared with other soil zone shares. A similar

Table 4-2. Soil Zone Shares of Total Expenditure on Major Input Classes, Alberta, Average of the 1971 and 1981 Censuses.

Input Class	Brown	Dark Brown	Black	Gray
Machinery value	0.1306	0.1963	0.4579	0.2152
Machinery repair	0.1378	0.1820	0.4519	0.2283
Cash wages	0.1850	0.2154	0.4902	0.1094
Fertilizer	0.0876	0.2053	0.5239	0.1832
Chemicals	0.1304	0.2543	0.4661	0.1492
Seeds	0.1302	0.1826	0.4605	0.2267
Fuel & oil	0.1294	0.1876	0.4482	0.2348
Electricity	0.1210	0.1766	0.4761	0.2263

Source: Derived from Statistics Canada, *Census of Agriculture* (Manitoba, Saskatchewan, Alberta), 1971 and 1981.

Table 4-3. Soil Zone Shares of Total Expenditure on Major Input Classes, Saskatchewan, Average of the 1971 and 1981 Censuses.

Input Class	Brown	Dark Brown	Black
Machinery value	0.2600	0.2900	0.4500
Machinery repair	0.2622	0.3006	0.4372
Cash wages	0.2550	0.3070	0.4380
Fertilizer	0.1225	0.2284	0.6491
Chemicals	0.2209	0.2511	0.5280
Seeds	0.1421	0.2968	0.5611
Fuel & oil	0.2492	0.2970	0.4538
Electricity	0.2385	0.3104	0.4511

Source: Derived from Statistics Canada, *Census of Agriculture* (Manitoba, Saskatchewan, Alberta), 1971 and 1981.

pattern of the distribution of input use shares across the three major soil zones in Saskatchewan is portrayed in Table 4-3. The black soil zone has the dominant input use shares, followed in turn by the dark brown soil zone and the brown soil zone. Owner operator and family labor input on the other hand are allocated among soil zones according to the soil zone share of number of farms to total number of farm in the province. Hired labor input is allocated according to the zonal share of expenditure on wage labor to total expenditure on wage labor in the province.

4.5 Derivation of Zonal Quantity and Prices of Land

The soil zone quantities of the land input were constructed by applying an analogous procedure to that which was applied to grain output allocation across soil zones. The provincial agricultural statistics yearbooks provide data on both cropped land area and output per Census Division for different years. Therefore, the data on land input for grain production (the cropped land area under the five major crops) by CDs was aggregated into zonal aggregates according to the location of the CDs in a particular soil zone (see Appendix 3). The zonal shares of land input were also constructed by dividing the grain cropped area in the respective soil zone by the total provincial cropped area under grain production.

Deriving zonal prices for the land input was another major issue which had to be resolved in this study. The problem arises due to the major differences among the soil zones in terms of moisture content, organic matter, and fertility. As a consequence of these factors, there exists differences in land prices across soil zones. In other words, it is not appropriate to apply the price of land which is provided in the statistics for land in Alberta, for example, to each of the four major soil zones in Alberta. To overcome this problem, we have developed the following procedure in this study to derive reasonable estimates for land prices for each soil zone. Utilizing data on the value of land and buildings by census division which is provided by the *Census of Agriculture* for the years 1961, 1971, and 1981, (the data between census years are interpolated and the data from 1961 back to 1957 and from 1981 forward to 1984 are extrapolated to derive time series data for the entire period of study), the relative shares of each soil zone in the total value of land and building were derived. The (absolute) value of land and buildings in any province is implicitly the product of the total quantity of land and the price of land in that province. The zonal values of land and buildings were derived by multiplying the zonal share coefficients (see Tabe 4-4) by the total value of land and buildings in the province. Therefore, by dividing the value of land and buildings in each soil zone by the zonal quantity of land (in our case using cropped area as the quantity proxy), we can derive an implicit price per unit of land in that particular soil zone. In Tables 4-4 and 4-5, the soil zone relative shares of value of land and buildings in Alberta and Saskatchewan are depicted.

It can be seen from Table 4-4 that the share of the brown soil zone in the provincial value of land and buildings shows a steadily declining trend over time, while the share of the dark brown soil zone increases until 1971, and declines during the sub-period of 1971-84. However, the share of the black soil zone in provincial value of land and buildings shows a remarkable increase over time, and the share of gray soil zone increased up to 1971, and then started to decline thereafter. The share of the brown soil zone in Saskatchewan on the other hand as depicted in Table 4-5 shows a similar trend as compared with the share of the brown soil zone in Alberta. In contrast to the share of the dark brown soil zone in Alberta, the share of the dark brown soil zone in Saskatchewan increases considerably over time. Finally, it can be seen from Table 4-5 that unlike the black soil zone in Alberta the black soil zone share in provincial value of land and buildings in Saskatchewan shows a declining trend over time.

The derived land prices (per cropped acre, exclusive of summer fallow) are characterized by considerable differences among soil zones (see Appendix 3). In Alberta, for example, the black soil zone has the highest implicit price of land followed by brown, dark brown, and gray soil zone. In Saskatchewan, the black soil zone has the highest land price up to 1979; thereafter, the dark brown zone is ranked first, followed by the brown and black soil zone, until 1984. On the aggregate level on the other hand, the black soil zone in the prairies on the average has the highest price followed by the brown, dark

Table 4-4. Soil Zone Shares of the Provincial Value of Land and Buildings, Alberta, 1957 to 1984.[3]

Year	Brown	Dark Brown	Black	Gray
1957	0.1580	0.1773	0.4864	0.1269
1958	0.1560	0.1797	0.4871	0.1295
1959	0.1540	0.1821	0.4878	0.1321
1960	0.1519	0.1845	0.4885	0.1347
1961	0.1499	0.1869	0.4892	0.1373
1962	0.1479	0.1893	0.4899	0.1399
1963	0.1458	0.1917	0.4906	0.1425
1964	0.1438	0.1941	0.4913	0.1451
1965	0.1417	0.1965	0.4920	0.1477
1966	0.1397	0.1989	0.4927	0.1503
1967	0.1377	0.2013	0.4934	0.1529
1968	0.1357	0.2037	0.4941	0.1555
1969	0.1336	0.2061	0.4948	0.1581
1970	0.1316	0.2085	0.4955	0.1607
1971	0.1296	0.2109	0.4962	0.1633
1972	0.1278	0.2092	0.5012	0.1620
1973	0.1259	0.2075	0.5061	0.1606
1974	0.1240	0.2057	0.5111	0.1593
1975	0.1221	0.2040	0.5160	0.1579
1976	0.1203	0.2023	0.5210	0.1566
1977	0.1184	0.2006	0.5260	0.1552
1978	0.1165	0.1987	0.5309	0.1539
1979	0.1146	0.1971	0.5359	0.1525
1980	0.1127	0.1954	0.5408	0.1512
1981	0.1107	0.1937	0.5458	0.1498
1982	0.1088	0.1920	0.5508	0.1485
1983	0.1064	0.1903	0.5557	0.1471
1984	0.1050	0.1885	0.5607	0.1458

[3]Data between census years are interpolated; data between 1982 and 1984 are extrapolated.

Source: Derived from Statistics Canada *Census of Agriculture* (Manitoba, Saskatchewan, Alberta), 1961, 1966, 1971, 1976 and 1981.

Table 4-5. Soil Zone Shares of the Provincial Value of Land and Buildings, Saskatchewan, 1957 to 1984[a].

Year	Brown	Dark Brown	Black
1961	0.2970	0.2625	0.4396
1962	0.2963	0.2634	0.4394
1963	0.2956	0.2642	0.4393
1964	0.2949	0.2651	0.4391
1965	0.2942	0.2660	0.4389
1966	0.2935	0.2669	0.4388
1967	0.2928	0.2677	0.4386
1968	0.2921	0.2686	0.4384
1969	0.2914	0.2695	0.4382
1970	0.2907	0.2703	0.4381
1971	0.2900	0.2712	0.4379
1972	0.2898	0.2777	0.4317
1973	0.2895	0.2842	0.4256
1974	0.2893	0.2907	0.4194
1975	0.2891	0.2972	0.4132
1976	0.2889	0.3037	0.4071
1977	0.2886	0.3101	0.4009
1978	0.2884	0.3166	0.3947
1979	0.2882	0.3231	0.3886
1980	0.2879	0.3296	0.3824
1981	0.2877	0.3361	0.3762
1982	0.2875	0.3426	0.3701
1983	0.2872	0.3491	0.3639
1984	0.2870	0.3556	0.3577

[a]Data between census years are interpolated; and data between 1982 and 1984 are extrapolated.

Source: Derived from Statistics Canada *Census of Agriculture* (Manitoba, Saskatchewan, Alberta), 1961, 1966, 1971, 1976, and 1980.

brown, and the gray soil zone.

4.6 Grain Input Quantity Indexes, Input Price Indexes, and Input Cost Shares

The Tornqvist index number procedure which has been outlined in Chapter 2 of this thesis, together with the time series of input data which were defined earlier in this chapter, were utilized to construct input quantity indexes and input price indexes. The resultant indexes for land, labour, machinery, chemicals, and materials are reported in Tables 4-6 and 4-7, respectively, for the prairie grain sector for the period of 1961-84. The cost shares of these major input groups in total cost of the input mix were also derived for the prairie grain sector. The input indexes and the cost shares of land, labor, machinery, chemicals, and materials are depicted graphically in Figures 4-1 and 4-2, respectively, for the prairie grain sector for the entire period of study. Moreover, the input quantity indexes, input price indexes, and the cost shares for different input groups were constructed for provincial and zonal levels in the prairie region, and are presented in Appendices 4 and 5. The remainder of this section is devoted to a discussion of the changes in the input quantity indexes, input price indexes, and the cost shares of land, labour, machinery, chemicals, and materials for the prairie grain sector for the period of study.

Land

In this study, land is assumed to be comprised only of the cropped land component in the prairie region. The influence of summer fallow on grain production is not directly considered. Unit costs per acre of summer follow, such as costs of labor, machinery and petroleum, are not readily available or separable from general cost information. As shown in Table 4-6, Column 1, the cropped land quantity index in the prairie region rose from 0.826 in 1961 to 1.281 in 1984. In percentage terms, the quantity of cropped land devoted to grain production increased in total by 55 percent from 1961 to 1984 in the prairie region. This considerable increase in cropped land use might be attributed to the increase in the demand for and as a consequence the prices of grains and oil seeds in the 1970s and the declining role of summer fallow. As shown in Table 4-6, Column 1, the cropped land quantity index in the prairie region grew by an annual compound rate of 1.5 percent for the period of 1961-84. However, when the time series data of this study is divided into two sub-periods, one from 1961-72 and second from 1973-84, the cropped land quantity index grew by an annual compound rate of 0.5 and 2.6 percent in the first and second sub-periods, respectively.

Likewise, the price of land in the prairie region remarkably increased from 1973 to 1981. As shown in Table 4-7, Column 1, the price index of cropped land in the prairie region increased from 0.552 in 1961 to 6.581 in 1982, subsequently falling to 6.011 in 1984. This sharp increase in the price of land might be attributed to the purchase of land as a hedge against inflation and to the actual and perceived prosperity of the grain sector from approximately 1973 until the early 1980s. The price of land varies among provinces and soil zones in the prairie region. The price of agricultural land per hectare is the highest in Alberta, followed by Saskatchewan and Manitoba (*Statistics Canada, unpublished data*). The results of our procedure to derive zonal prices of land show that the black soil zone generally has the highest price per hectare, followed by the dark brown, brown and gray soil zones in the prairie region during 1961 to 1984. As shown in Table 4-7, Column 1, the price index of land input grew by an annual compound rate of 12.7 percent from 1961 to 1984. Moreover, the growth rate of land price grew more rapidly in the sub-period of 1973-84, where this rate reached 16.3 per year, as compared to 7.2 percent annually in the sub-period from 1961 to 1972.

As a consequence of the increases in both the quantity and the price of agriculture land, the cost share of land in total cost of the input mix naturally increased during the period of study. It can be seen from Table 4-8, Column 1, that the share of land in total input cost rose from 7 percent in 1961 to nearly 20 percent in 1981 and 1982, dropping somewhat to 16 percent in 1984. The share of cropped land in total cost grew by an annual compound rate of 3.5 percent for the period of 1961-84. Similarly to the growth rate of the land price index, the growth rate of the cost share of land grew more rapidly in the sub-period from 1973-84 than in the sub-period from 1961-72.

Labor

The labor input in this study, as defined earlier in this chapter, includes three distinctive components: owner operator, family labor, and hired labor. The hours worked data which has been obtained from *Statistics Canada (Farm Labor Survey, unpublished)* shows a considerable decline in labor input (hours worked) since 1966. Such a decline in labor input over the years could be attributed, among other things, to the relative decline in the number of smaller farms and to the remarkable increases in labor wages which make it possible for farmers to substitite the cheaper input (machinery) for the more expensive input (labor). As shown in Table 4-6, Column 2, the labor quantity index in the prairie grain sector decreased from 1.1422 in 1961 to 0.8218 in 1984. Our data support the long-standing Schultz (1957) contention that a primary cause of capital-for-labor substitution in North American agriculture has been that the price of labor has increased relative to the price of machinery.

As shown in Table 4-7, Column 2, the labor wage index increased from 0.6875 in 1961 to 3.5625 in 1984, an increase of approximately 400 percent. This increase in the labor wage is the result of improvements in labor skill, education and the competitiveness of other sectors in the economy (industrial and service sectors) on the demand for labor. As shown in Table 4-7, the labor wage index grew by an annual compound rate of 8.8 percent for the entire period of study, whereas the machinery price index increased less rapidly at 6.3 percent per year.

The labor input in the prairie grain sector declined by an annual rate of 1.3 percent for the entire period of study. Moreover, labor input declined relatively more rapidly in the 1973-84 sub-period, at 2.5 percent per year, as compared to 1.5 percent annually during 1961-72. This, in turn, also suggests that prairie farmers relied heavily on mechanical technology of a labor-saving bias in the sub-period since 1973.

As expected, the cost share of labor in the total cost of prairie grain production has sharply decreased, from 55 percent of total cost in 1961 to approximately 28 percent in 1984. This decline in the cost share is counter balanced by increases in the cost shares of other inputs such as fertilizer, land, and -- to a lesser extent -- machinery.

Machinery

The development of mechanical technology makes it easier for farmers to expand the size of their farms and to increase their agricultural output. The use of farm machinery and equipment has increased considerably in recent decades in prairie agriculture. It can be seen from Table 4-6, Column 3, that the machinery quantity index in the prairie grain sector rose from 1.01 in 1961 to 2.38 in 1984. The growth rate associated with this increase in the machinery quantity index was 4.8 percent per year over 1961-84. The growth rate of machinery use is higher since 1973 (although the LIFT program in 1970 biases the growth rate downward in the 1961-72 sub-period).

The machinery price index, on the other hand, increased somewhat less rapidly than did the price of land and labor during the period of study. For example, the machinery price index grew by an annual compound rate of 6.3 percent for the period of 1961-84. Further, when the estimated growth rates in the two sub-periods were compared, the machinery price index -- following the same pattern as the land price index and the labor index -- was characterized by higher growth rates in the second sub-period than in the first sub-period, 9.6 percent per year in the sub-period since 1973 versus only 3.0 percent per year over the sub-period from 1961-72.

The machinery cost share was roughly stable in the 1960s in the 17 to 19 percent range, declined slightly in the early 1970s to 16 to 18 percent, and then rose to levels slightly over 20 percent in the later 1970s and early 1980s.

Chemicals

Chemical inputs in the study are composed of two major components: fertilizers and pesticides. The use of the these two chemical components increased dramatically in prairie grain production over 1961-84. The consumption of nitrogen in Western Canada, for example, increased from 14.5 thousand tonnes in 1958 to 591.5 thousand tonnes in 1979 (Rennie, Beaton, and Hedlin, 1980). This increase in fertilizer use in Western Canada is partially due to the considerable decrease in soil organic matter (Rennie 1979). As shown in Table 4-6, Column 4, the results of this study show that the chemical quantity index increased from approximately 0.4 in 1961 to 4.9 in 1984. The growth rate associated with this index was 10.7 percent per year over 1961-84. Looking at the two sub-periods, the chemical quantity index growth rate increased from 9.2 percent in the first sub-period (1961-72) to 10.8 percent per year in the second sub-period (1973-84).

As shown in Table 4-7, Column 4, the price index for chemical inputs increased from 0.97 in 1961 to 3.6 in 1984. It can be seen also from this table that the chemical price index grew at an annual compound rate of 7 percent over the entire period of study, 0.6 percent per year over the sub-period 1961-72 and 10.6 percent over the sub-period since 1973. This considerable increase in chemical prices since 1973 could be attributed to the increases in energy prices during this period and to the increase in the demand for fertilizer by farmers in the prairie region. As a consequence of the increase in both the quantity of chemical inputs used in grain production and the prices of chemicals, the cost share of chemical inputs in total cost of the input mix considerably increased from 3 percent in 1961 to 19 percent in 1984.

Materials

The major components of material inputs in this study are: fuel & oil, electricity, seeds, and irrigation equipment. As shown in Table 4-6, Column 5, the material input index in prairie grain production increased from 0.732 in 1961 to 1.266 in 1984. The consumption of these components grew by an annual rate of 2.6 percent over 1961-84. Moreover, the growth rate of material input use slowed down in the period from 1973 to 1984. The materials index grew at an annual rate of 3.5 percent over the first sub-period (1961-72), and decreased to 2.3 percent in the second sub-period since 1973. This reduction in the growth rate over the sub-period of 1973-84 is probably caused by the slower rate of growth in energy consumption since 1973. The materials price index increased by an annual rate of 6.9 percent over 1961-84. Finally, the materials cost share was relatively stable in the 1960s at approximately 16 to 17 percent and then followed a U-shaped pattern from the early 1970s to 1984.

Table 4-6. Input Quantity Indexes, The Prairie Grain Sector, 1961 to 1984 (1971=1.000)

Year	Land	Labor	Machinery	Fertilizer	Material
1961	0.8260	1.1422	1.0090	0.3996	0.7322
1962	0.9081	1.1268	1.0078	0.4438	0.7277
1963	0.9371	1.1116	1.0510	0.5385	0.7492
1964	0.9638	1.0963	1.1254	0.6808	0.7807
1965	1.0015	1.0815	1.2273	0.7721	0.8175
1966	1.0573	1.0668	1.2580	1.1123	0.8539
1967	1.0594	1.0664	1.2103	1.3575	0.8889
1968	1.0549	0.9449	1.2094	1.5302	0.9112
1969	0.9878	1.0745	1.1238	0.9927	0.9411
1970	0.7873	0.9516	0.9164	0.7761	0.9688
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9392	0.9789	1.0860	1.1048	1.0474
1973	1.0104	0.9314	1.2063	1.5476	1.0763
1974	0.9864	0.9843	1.4685	1.8249	1.0599
1975	1.0437	1.1219	1.8078	2.0772	0.9759
1976	1.0761	1.0412	2.1157	2.0437	1.0270
1977	1.0720	0.9563	2.2234	2.2667	1.0944
1978	1.1285	0.9468	2.3176	3.0816	1.1892
1979	1.1502	0.9510	2.4023	3.7184	1.3080
1980	1.1729	0.8454	2.4696	3.2031	1.2464
1981	1.2618	0.8556	2.4999	3.6560	1.2411
1982	1.2804	0.8175	2.4769	3.8839	1.2301
1983	1.2722	0.7927	2.4255	4.5215	1.2779
1984	1.2819	0.8218	2.3765	4.8571	1.2664
Annual Growth Rates in (%)					
1961-84	1.5	-1.3	4.8	10.7	2.6
1961-72	0.5	-1.5	-0.1	9.2	3.5
1973-84	2.6	-2.4	5.5	10.8	2.3

Table 4-7. Input Price Indexes, The Prairie Grain Sector, 1961 to 1984 (1971=1.000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.5521	0.6875	0.7481	0.9726	0.8914
1962	0.5535	0.6875	0.7722	0.9681	0.9020
1963	0.6033	0.6875	0.7940	0.9842	0.9028
1964	0.6740	0.6875	0.8191	1.0282	0.9080
1965	0.7840	0.7500	0.8405	1.0304	0.8979
1966	0.8651	0.8125	0.8694	0.9959	0.9000
1967	0.9783	0.8750	0.8930	1.0351	0.9161
1968	1.0457	0.8750	0.9299	1.0586	0.9613
1969	1.0268	0.9375	0.9576	1.0301	0.9845
1970	1.0222	1.9375	0.9789	0.9664	0.9801
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.1064	1.1250	1.0254	1.0926	1.0148
1973	1.3368	1.2500	1.0592	1.1019	1.0842
1974	1.7234	1.5000	1.1800	1.4279	1.2695
1975	2.1266	2.8750	1.3710	1.9522	1.5224
1976	2.5058	2.1250	1.4683	2.2073	1.7120
1977	2.9149	2.4375	1.5771	2.2369	1.8351
1978	3.4207	2.5625	1.7309	2.2521	1.9275
1979	4.4001	2.7500	1.9431	2.4439	2.0142
1980	5.6284	3.8750	2.1875	3.1190	2.3697
1981	6.4020	3.1250	2.4291	3.5303	3.0800
1982	6.5807	3.3125	2.6078	3.5950	3.4832
1983	6.4173	3.4375	2.7243	3.5049	3.6238
1984	6.0107	3.5625	2.7949	3.5975	3.7786
Annual Growth Rates in (%)					
1961-84	12.7	8.8	6.3	07.0	06.9
1961-72	07.2	4.7	3.0	00.6	12.5
1973-84	16.3	8.3	9.6	10.6	12.1

Table 4-8. Input Cost Shares, The Prairie Grain Sector, 1961 to 1984.

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.0746	0.5515	0.1736	0.0310	0.1693
1962	0.0815	0.5392	0.1766	0.0340	0.1688
1963	0.0892	0.5172	0.1838	0.0407	0.1691
1964	0.0980	0.4878	0.1933	0.0515	0.1695
1965	0.1083	0.4801	0.1975	0.0535	0.1605
1966	0.1156	0.4699	0.1924	0.0682	0.1539
1967	0.1215	0.4693	0.1776	0.0803	0.1513
1968	0.1315	0.4230	0.1858	0.0942	0.1655
1969	0.1153	0.4915	0.1695	0.0567	0.1669
1970	0.1033	0.4964	0.1604	0.0469	0.1931
1971	0.1141	0.4896	0.1598	0.0556	0.1808
1972	0.1081	0.4916	0.1639	0.0612	0.1752
1973	0.1245	0.4606	0.1677	0.0766	0.1705
1974	0.1220	0.4546	0.1793	0.0911	0.1530
1975	0.1161	0.4719	0.1856	0.1033	0.1231
1976	0.1248	0.4394	0.2050	0.1018	0.1290
1977	0.1315	0.4207	0.2099	0.1040	0.1339
1978	0.1433	0.3863	0.2101	0.1255	0.1348
1979	0.1607	0.3563	0.2098	0.1406	0.1325
1980	0.1927	0.3043	0.2243	0.1421	0.1366
1981	0.1995	0.2832	0.2123	0.1554	0.1496
1982	0.1972	0.2718	0.2129	0.1592	0.1589
1983	0.1848	0.2645	0.2098	0.1748	0.1661
1984	0.1687	0.2750	0.2037	0.1865	0.1661
Annual Growth Rates in (%)					
1961-84	3.5	-2.8	0.9	7.2	-0.7
1961-72	3.4	-1.0	-1.1	5.5	0.8
1973-84	5.2	-6.0	1.7	7.9	1.1

Figure 4-1. Input Quantity Indexes, Major Input Groups, The Prairie Grain Sector, 1961 to 1984 (1971=1.000)

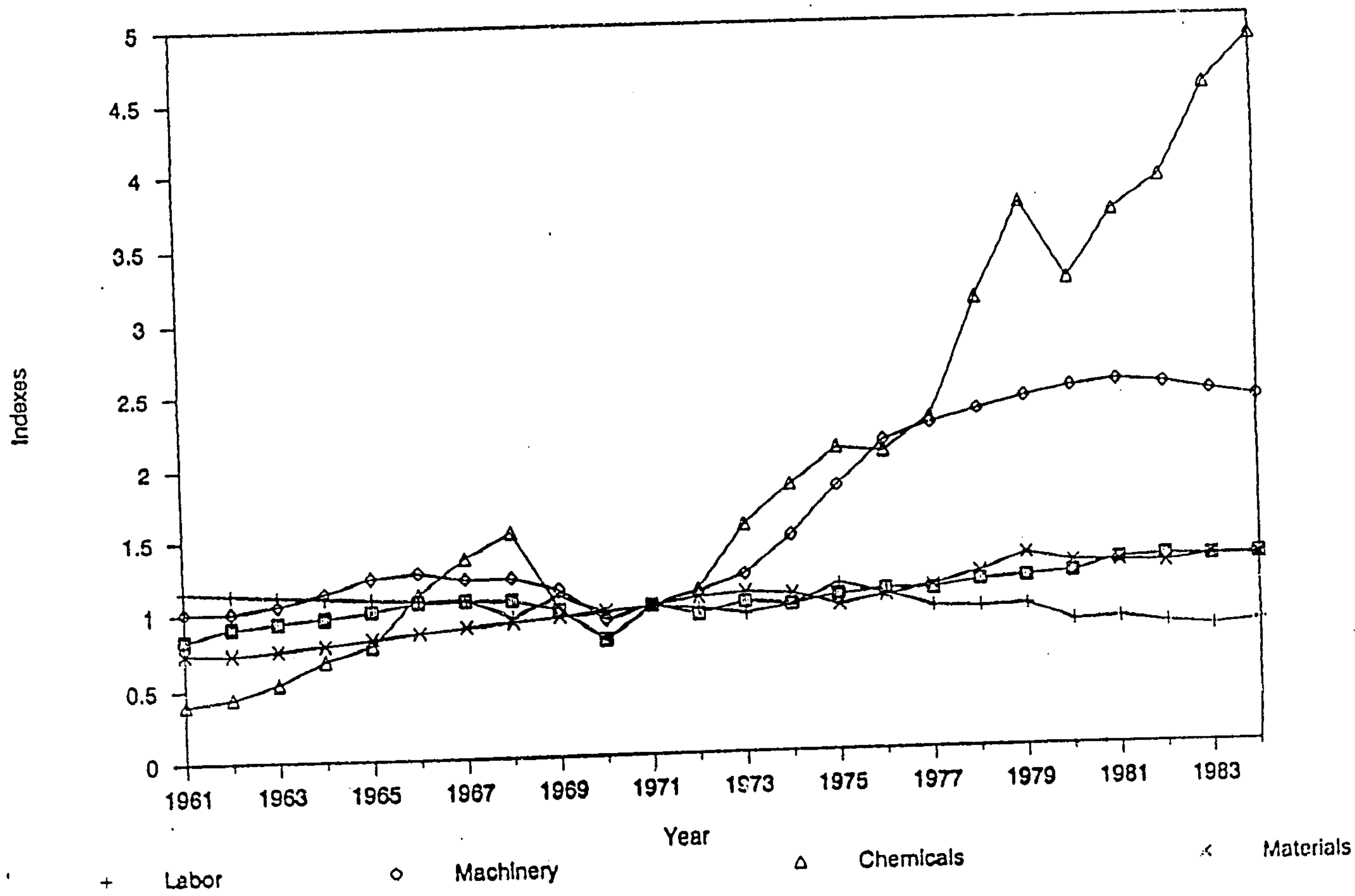


Figure 4-2. Input Price Indexes of Major Input Groups, The Prairie Grain Sector, 1961 to 1984 (1971=1.000)

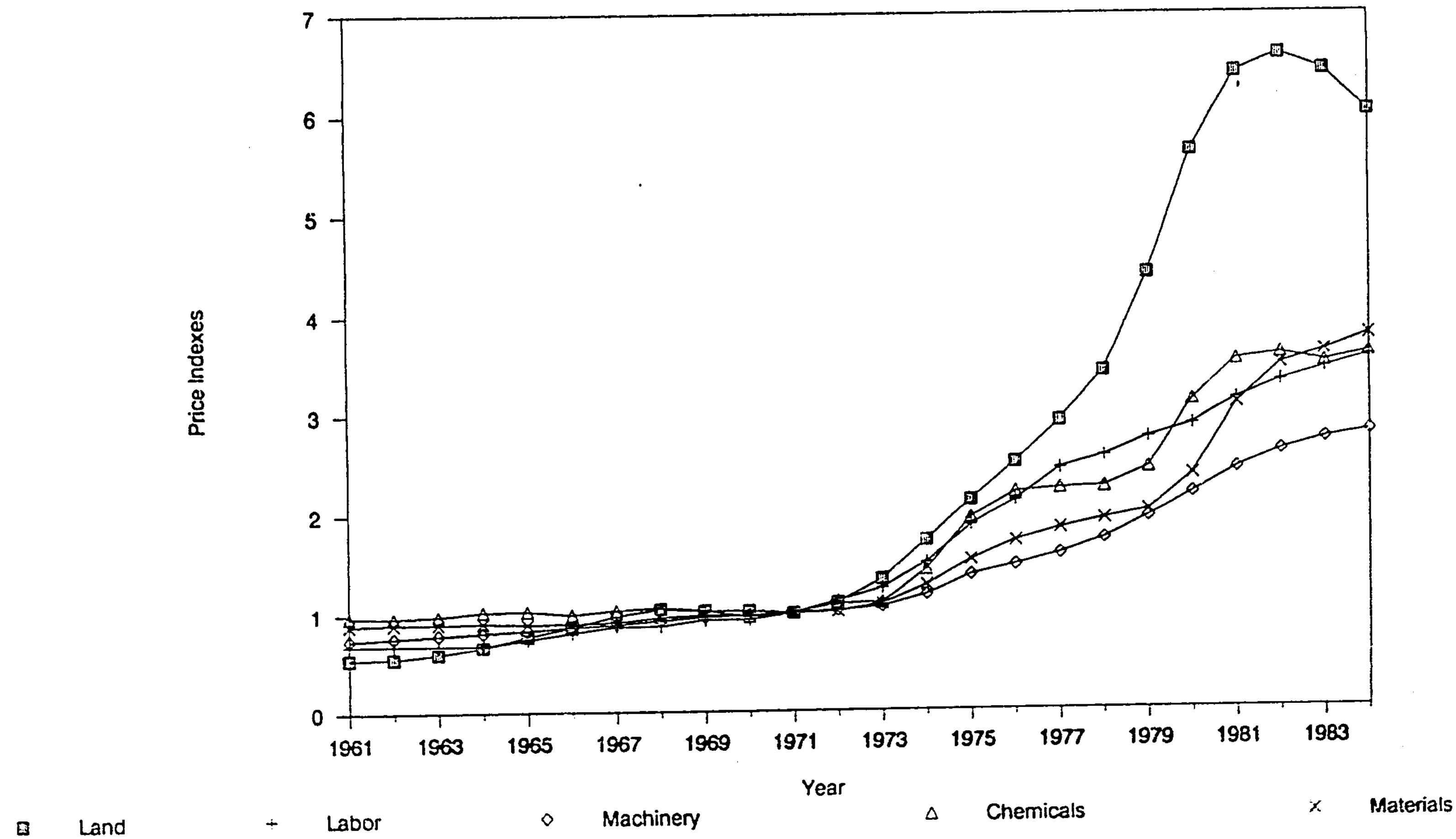
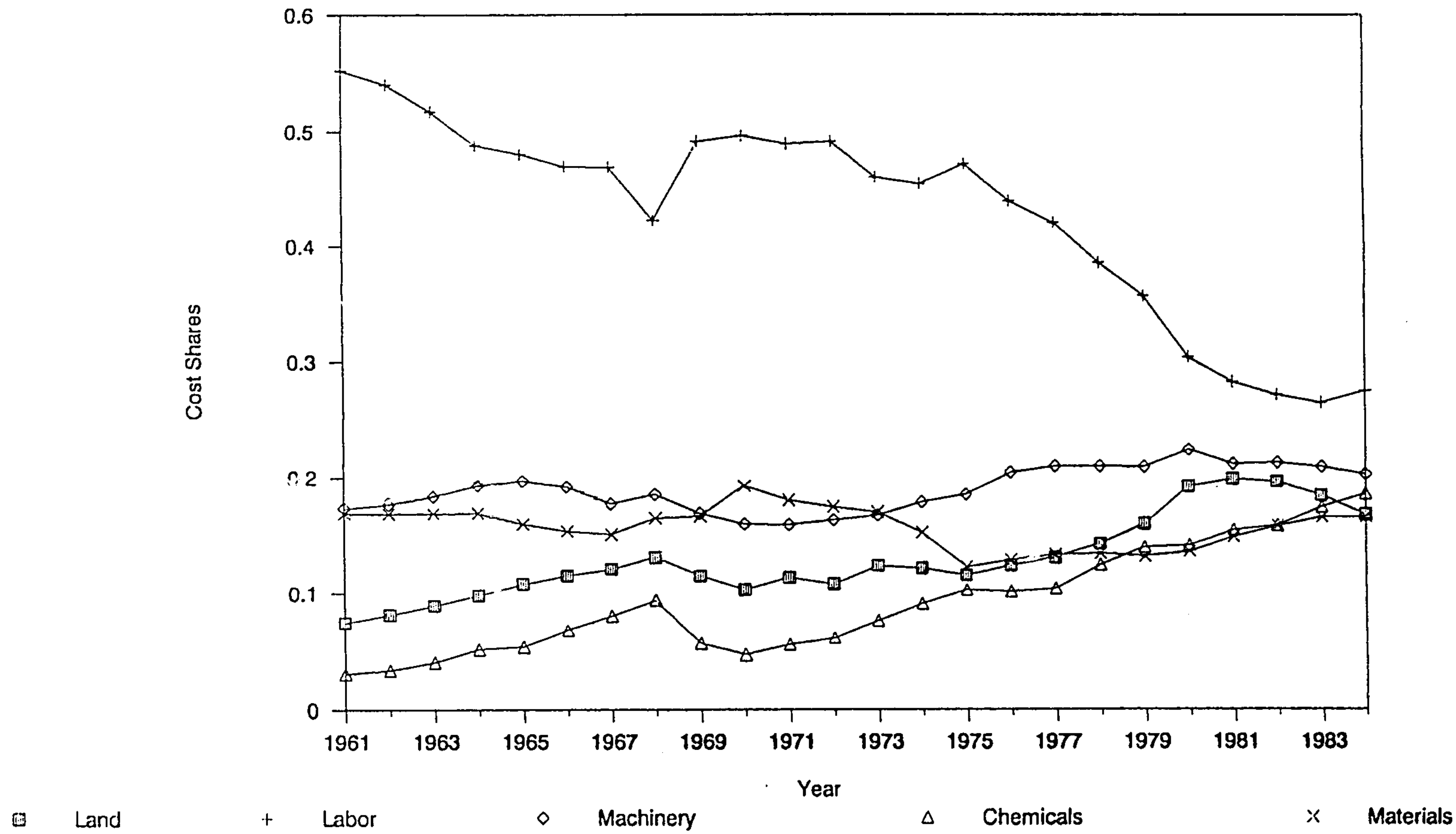


Figure 4-3. Cost Shares of Major Input Groups in Total Cost, The Prairie Grain Sector, 1961 to 1984



4.7 Summary

The major issues which have been discussed in the previous sections of this chapter can be summarized as follows:

1. Zonal input use except for land owner operator and family labor were derived according to the soil zone shares of total expenditure on major input classes. These shares have been utilized along with the provincial expenditure on major input classes to derive zonal input factors.
2. The owner operator and family labor inputs (man-hours), as well as the machinery input and depreciation on buildings were allocated between crops and livestock according to the proportional share of crop farms to total number of farms in the province.
3. Zonal quantities of land input (cropped land) were derived by applying an analogous procedure to that which was applied to grain output allocation across soil zones.
4. Zonal depreciation costs on buildings were obtained by utilizing the soil zone shares of the provincial value of land and buildings along with the provincial total value of depreciation on land and buildings.
5. The zonal prices of land input (cropped land area under the five major crops) were derived implicitly by utilizing the zonal quantity of land and zonal value of land and buildings.
6. Owner operator and family labor were allocated among soil zones according to the share of each zone in total number of farms in the province, while hired labor was allocated according to the share of each soil zone in total expenditure on wage labor in the province.
7. The Tornqvist index number procedure which has been outlined in Chapter 2, together with the time series on input data which are defined earlier in this Chapter, were utilized to construct input quantity indexes and input price indexes for land, labor, machinery, chemicals, and materials in the prairie sector for the period of 1961-84. The cost shares of these major input groups in total cost of input mix were also derived in this Chapter.

8. The cropped land use show a remarkable increase during the period of 1961-84. The cropped land quantity index increased from 0.826 in 1961 to 1.281 in 1984, and the growth rates associated with cropped land quantity index grew by an annual compound rate of 1.5 percent over 1961-84. Likewise the price of land in the prairie region remarkably increased especially from 1973 to 1981. The land price index rose from 0.552 in 1961 to 6.581 in 1984. As a consequence of the increases in both the quantity and the price of agriculture land, the cost share of land in total cost of input mix naturally increased during the period of study. The share of land in total input cost rose from 7 percent in 1961 to nearly 20 percent in 1981 and 1982, dropping somewhat to 16 percent in 1984.
9. The labor input in the prairie grain sector declined by an annual rate of 1.3 percent for the entire period of study. Further, labor input declined relatively more rapidly in 1973-84 sub-period, at 2.5 percent per year, as compared to 1.5 percent annually during 1961-72. This, in turn, suggests that prairie farmers relied heavily on mechanical technology of labor-saving basis in the sub-period since 1973. This decline in the labor input could be attributed to the remarkable increase in the labor wages, which make it possible for farmers to substitute the cheaper input (machinery) for the more expensive input (labor). The labor wage index in the prairie grain sector increased from 0.69 in 1961 to 3.6 in 1984, an increase of approximately 400 percent. The cost share of labor input in total cost also declined from 55 percent of total cost in 1961 to approximatly 28 percent in 1984.
10. The machinery quantity index in the prairie grain sector rose from 1.01 in 1961 to 2.38 in 1984. The growth rate associated with this increase in the machinery quantity index was 4.8 percent per year 1961-84. The machinery price index, on the other hand, increased somewhat less rapidly than did the price of land and labor during the period of study. For example, the machinery price index grew by an annual compound rate of 6.3 percent for the period of 1961-84. The machinery cost share was roughly stable in the 1960s in the 17 to 19 percent range, declined slightly in the early 1970s to 16 percent, and then rose to levels slightly over 20 percent in the later 1970s and early

1980s.

11. The chemical quantity index in the prairie grain sector rose from approximately 0.4 in 1961 to 4.9 in 1984. The growth rate associated with this remarkable increase in chemical input was 10.7 percent per year over 1961-84. The chemical price index, on the other hand, grew at an annual compound rate of 7 percent over the period of study, 0.6 percent per year over the sub-period 1961-72 and 10.6 percent per year over the sub-period since 1973. As a consequence of the increase in both the quantity of chemical inputs and the prices of chemicals, the cost share of chemical inputs in total cost of the input mix considerably increased from 3 percent in 1961 to 19 percent in 1984.
12. The use of materials input in the prairie grain sector grew by an annual rate of 2.6 percent over 1961-84. Further, the growth rate of material inputs use slowed down in the period from 1973 to 1984. The materials price index increased by an annual rate of 6.9 percent over 1961-84. Finally the materials cost share was relatively stable in the 1960s at approximately 16 to 17 percent and then followed a U-shaped pattern from the early 1970s to 1984.

5. Measurement of Total Factor Productivity in the Prairie Grain Sector

5.1 Introduction

In this chapter, estimates of yearly levels, as well as compound annual rates of growth, of output, input use, and total factor productivity for the prairie grain sector and its major soil zones are presented. Initially, estimates are derived for the grain sectors in the three prairie provinces (Alberta, Manitoba and Saskatchewan) and their respective soil zones. Estimates of terms of trade and returns-to-cost for the grain sector are also provided.

The Divisia-related index procedure which has been described in Chapter 2 was used to derive aggregate output and input quantity and price indexes. These indexes were constructed for the grain sectors in Alberta (including its respective soil zones) and Manitoba for the period of 1957-84, and for the grain sectors in Saskatchewan and the overall prairie region (including their distinct soil zones) for the period of 1961-84.[9] The year of 1971 has been taken as the base year for the construction of these indexes. The output and input data which have been utilized to obtain these indexes are described in Chapters 3 and 4 of this thesis. Total factor productivity (TFP) is calculated, as was discussed in Chapter 2, as the ratio of the output quantity index to the aggregate input quantity index for the region under consideration.

5.2 Estimates for Alberta and its Soil Zones

In this section the derived grain output, inputs and total factor productivity (TFP) indexes, and their estimated growth rates for different periods of time, for Alberta and its major soil zones will be presented, and briefly discussed.

[9]The main reason for selecting the period of 1961-84 for Saskatchewan is lack of ready availability of output data by crop district prior to 1961.

5.2.1 Grain Output Indexes

The quantity and price data for wheat, oats, barley, flaxseed, and canola were utilized to derive aggregate output quantity indexes and aggregate price indexes. The output quantity indexes so derived are presented in Column 1 of Table 5-1 for the overall Alberta grain sector and in Column 1 of Tables 5-2, 5-3, 5-4 and 5-5 for the brown, dark brown, black, and gray soil zones in Alberta respectively. The corresponding aggregate output price indexes are shown in Column 4 of these respective tables. The output quantity indexes for Alberta are characterized by wide ranging fluctuations which are mainly due to weather and climate factors. It can be seen from Table 5-1 that the output quantity index for the overall grain sector in Alberta increased from 0.576 in 1957 to 1.489 in 1984, reaching the highest point of 1.742 in 1982 and the lowest point of 0.555 in 1961, a severe drought year. In 1961, aggregate grain output was particularly low in the brown soil zone.

Annual compound growth rates of aggregate grain output in Alberta and its major soil zones in various time periods are presented at the bottom of Column 1 in Tables 5-1 through 5-5. The annual growth rate of the output quantity index for the five major crops in Alberta ranged from 4 percent over the 1957-84 and 1961-84 periods to 3.8 percent over 1962-84, keeping in mind that both 1957 and 1961 were drought years. Further, when the period of study is divided into two sub-periods, one from 1957-72 and the other from 1973-84, the first sub-period shows a growth rate of 4.3 percent per year while the growth rate of output was 5.8 percent in the second sub-period. The higher output growth rate since 1973 might be attributed to such factors as the continued use of mechanical technology, the intensified use of biochemical technology, and positive output supply response. The higher levels of output growth associated with the second subperiod (1973-84) holds not only for Alberta but also for all of its major soil zones, with the possible exception of the brown soil zone. Compared to a rate of 5.6 percent over 1962 to 1972, the annual rate growth of grain output in the brown soil zone was only 3.5 percent over 1973 to 1984, but was 6.1 percent over 1973 to 1983, excluding the serious drought year 1984.

As shown in Table 5-3 the output quantity index for the dark brown soil zone increased from 0.612 in 1957 to 1.246 in 1984, and it reached the lowest point in the drought year 1961. The annual growth rates of the output quantity index for this zone ranged from 3.6 percent for the period of 1961-84 and 3.2 percent for the period of 1962-84. Unlike the brown soil zone, the output growth rates rose from 4.0 percent in the subperiod, 1957-72 to 4.8 percent in the subperiod from 1973 to 1984. However, the general performance of the output growth rate in the brown soil zone over the entire period was generally higher than that in the dark brown zone, except for the subperiod since 1973 where the dark brown zone out-performed the brown soil zone.

The third soil zone in Alberta is the black which is the largest zone and which produces the highest proportion of grain and oilseeds. It can be seen from Column 1 of Table 5-4 that the output quantity index rose from 0.529 in 1957, an adverse weather year, to 1.469 in 1984. The growth rates associated with the output index in the black soil range from 3.7 for the entire period to 3.5 and 3.3 percent in the periods of 1961-84 and 1962-84, respectively. The output growth rate rose from 4.3 percent in the subperiod from 1957 to 1972, to 5.2 percent in the subperiod from 1973 to 1984.

A most interesting finding of this study is that among all soil zones in Alberta the gray soil zone has the highest output growth rates. This result is indirectly supported by Kelly and Moreau (1982) who found that the average yield of wheat per acre in the Peace River region was 0.9 bushels per acre above the provincial average for the period of 1976-80. As shown in Table 5-5, Column 1, the index of grain output in the gray soil zone rose from 0.514 in 1957 to 2.1 in 1984, and was at its lowest level in 1957. It is interesting to note that grain production in the gray soil zone, unlike the rest of the province, was not adversely affected by drought in 1961. As indicated, the growth rates of output in the gray zone are higher than those reported for Alberta and the other soil zones. The growth rates of output in the gray soil zone range from 5.4 percent for the entire period to 5.7 percent and 6.1 percent for 1961-84 and 1962-84, respectively. Moreover, the growth rate rose from 4.0 percent in the subperiod, 1957-72, to a striking 9.0 percent in the subperiod since 1973.

5.2.2 Grain Input Indexes

The major input groups which have been considered in this study consist of land (actual cropped land), labour (own operator, family labor, and hired labor), machinery (depreciation and opportunity costs), chemicals (fertilizer and pesticides), and materials (fuel and oil, electricity, irrigation equipment and seeds). Data modification for the purpose of this study as well as the major sources of the input data and their corresponding prices have been fully described in Chapter 4. The Tornqvist-Theil index was used to construct input quantity and input price indexes. The resultant input quantity and input price indexes are reported in Column 2 of Tables 5-1, 5-2, 5-3, 5-4 and 5-5 for Alberta and its respective soil zones.

The input quantity index in Alberta rose from 0.89 in 1957 to 1.52 in 1984. However, when the data set is divided into two subperiods as before, the magnitude of the shift of the input quantity index during the first as compared to the second subperiod is considerably different. It can be seen from Table 5-1, column 2 that the input quantity index in Alberta increased from 0.89 in 1957 to 1.04 in 1972 while in the second sub-period it rose from 1.1 to 1.52. The growth rate of the grain input quantity index in Alberta also increased from 1.1 percent in the first to 2.5 percent in the second sub-period. This significant increase in the input quantity index and the higher level of input growth is associated with various features of structural and technical change in Alberta agriculture. For example, improved technology was brought into use during the sub-period of 1973-84 especially biochemical technology (fertilizer and chemical inputs).

Culver *et. al.* (1984) showed that the use of nitrogen fertilizer increased by 350 percent between 1970 and 1980 in Western Canada. The share of farm operators applying fertilizer increased from 22.5 percent of farmers in 1970 to 50.9 percent in 1980 in Saskatchewan while in Alberta and Manitoba the percentage shares increased by 17.4 and 22.3 percentage points respectively, from 1970 to 1980. The Culver study also shows that the crop land being fertilized increased from 13.4 percent in 1970 to 46.2 percent in 1980 in Saskatchewan and that the corresponding percentage more than doubled in Alberta and Manitoba from 1970 to 1980.

The previous discussion suggested grain production in Alberta as well as its major soil zones has been characterized by relatively higher growth rates of inputs and outputs in the later sub-period from 1973-84 as compared to earlier sub-periods. However, the size of the input indexes and their growth rates differ across soil zones. The input quantity index of the brown soil zone, for instance, rose from 0.929 in 1957 to 1.577 in 1984, and the growth rate associated with this index ranged from 2.2 percent per year for the entire period to 2.7 percent for the period of 1962-84. Further, the growth rate of the grain input quantity index connected with the two sub-periods increased from 0.73 percent per year over 1957-72 to 2.8 percent in the second sub-period since 1973.

Meanwhile, the growth rates of the input quantity index in the dark brown soil zone are higher in comparison to those for the brown soil zone. It can be seen from Table 5-3, Column 2 that the input quantity index for the dark brown soil zone increased from 0.874 in 1957 to 1.623 in 1984. In other words, grain input use increased by 85.7 percent during the entire period in the dark brown zone compared to a 69.7 percent increase for the same period in the brown soil zone. The annual growth rates of the input quantity index in the dark brown zone ranged from 2.6 percent for the period of 1957-84 to 2.9 percent for the period of 1961-84. Moreover, the input growth rate rose from 1.3 percent in the sub-period from 1957-72 to 3.2 percent in the sub-period since 1973.

As shown in Table 5-4, Column 2, the input quantity index of the black soil zone, the largest soil zone in Alberta, increased from 0.883 in 1957 to 1.529 in 1984. That is, this index increased by 73.2 percent between 1957 and 1984. The growth rates of grain input quantity in this zone ranged from 2.3 percent per year for the entire period to 2.5 percent beween 1961 and 1984, and rose from 1.2 percent in the first sub-period (1957-72) to 2.6 percent in the second sub-period (1973-84).

Finally, the input quantity index of the gray soil zone incrased from 0.895 in 1957 to 1.49 in 1984, a slightly smaller increase in input use in comparison to that in other soil zones. The growth rates of input quantity in the gray zone vary from 2.0 percent per year for the entire period to 2.2 percent for the period of 1961-84, and rose from 1.0 percent per year over 1957-72 to 2.0 percent over 1973-84.

From the above discussion one can summarize that the growth rates of input quantity indexes differ among soil zones with the dark brown zone having the highest growth rate and the gray soil zone having the lowest input growth rate. In general, the input growth rates are lower in the first sub-period (1957-72) than in the sub-period since 1973.

5.2.3 Grain Productivity Indexes

Total factor productivity (TFP) is defined, as has been indicated, as the ratio of output to all inputs combined. Therefore, TFP indexes are obtained by dividing output quantity indexes by corresponding input quantity indexes. The resultant TFP indexes are reported in Column 3 of Tables 5-1 through 5-5 for Alberta and its major soil zones. The growth rates associated with these productivity indexes differ considerably across soil zones, and are very sensitive to the chosen period of time.

The growth rate of productivity in the Alberta grain sector ranges from 1.7 percent per annum for the entire period from 1957 to 1984, 1.5 percent for the entire period of 1961-84[10], only 1.2 percent over 1962-84 when the drought year of 1961 is excluded, and 1.3 percent over 1962-83 when the drought year of 1984 is also excluded. The productivity growth rates associated with earlier and latter sub-periods are almost identical; the estimated annual growth rates are 3.1 percent over 1957-72 and 3.2 percent over 1973-84. Accordingly, one can conclude that the growth rates of TFP in the Alberta grain sector as a whole did not decline in the late 1970's and early 1980's, as has sometimes been suggested. In fact, the results of this study indicate that the subperiod of 1973-84 is characterized by relatively high rates of growth of output, input, and TFP in Alberta grain production.

The growth rates of TFP in the grain sector in the brown soil zone were 1.7 percent per year over 1957-84 and 1.8 percent for the period of 1961-84. However, excluding 1961, the productivity growth rate sharply decreased to 0.7 percent per year over 1962-84 and 1.0 percent over 1962-83. This latter result indicates how sensitive estimated productivity

[10]The growth rates of output, input, and TFP are estimated for the period of 1961-84 for Alberta and its soil zones in order to compare these growth rates with those for Saskatchewan and the prairies for which our data set begins in 1961.

growth rates are to the inclusion and exclusion of a drought year such as 1961. Dividing the period from 1957 to 1984 into two sub-periods, the productivity growth rate decreases from 4.7 percent from 1957-72 to 1.0 percent in the second sub-period, 1973-84. The slowdown in the growth rate of TFP in the sub-period of 1973-84 can be attributed to the large increase in the input growth rate and the considerable decrease in the output growth rate during this period, the latter partly associated with the fact that 1984 was also a drought year in this zone. Over 1973-83, the annual productivity growth rate in the brown soil zone was 2.9 percent.

The dark brown soil zone has a generally weaker productivity performance than the brown soil zone, except over 1973-84. In the dark brown soil zone, output growth rates were generally lower and input growth rates somewhat higher compared to the brown soil zone. As shown in Table 5-3, Column 3, the growth rate of TFP in the dark brown soil zone was 0.9 percent for the entire period, 0.8 percent for the period of 1961-84, but only 0.2 percent when 1961 is excluded. Like the brown soil zone, the growth rate of TFP in the dark brown zone also declined from 2.7 percent in the sub-period, 1957-72, to 1.6 percent in the later subperiod, 1973-84. Looking at the 1973-83 period, the annual productivity growth rate in the dark brown zone is somewhat higher at 3.0 percent.

During the study period, the growth rates of productivity in the black soil zone were generally higher than those in the dark brown zone and lower than those in brown soil zone. It can be seen from Table 5-4, Column 3, that the growth rate of TFP in the black zone was 1.4 percent for the entire period, 0.9 percent for the period of 1961-84, and (when the year of 1961 was excluded) 0.7 percent per year over 1962-84. Further, the productivity growth rate decreased slightly from 3.1 percent per year from 1957 to 1972 to 2.6 percent in the subperiod from 1973-84.

Consequently, in comparing productivity performance across the three zones over the period from 1957 to 1984, the brown soil zone is ranked first, followed by the black and dark brown. This result may partially reflect the relative role of irrigation in the brown zone as well as the fact that our methodology is not fully incorporating the role of summer fallow. A comparison of productivity performance in the latter half of the period, 1973-84, shows the black soil zone ranked first, followed by the dark brown and brown soil zones. This ranking is not changed if productivity growth over 1973-83 is compared (eliminating 1984, a drought year which severely affected on the brown and dark brown zones), though the differentials in productivity growth among the brown, dark brown, and black are narrow.

Estimated productivity in the gray soil zone in Alberta is even higher than that in the other three soil zones in Alberta. It can be seen from Table 5-5, Column 3, that the growth rate of TFP in the gray soil zone increased remarkably at 3.3 percent per annum over 1957 to 1984 and at 3.7 percent over the period of 1962-84. It can be seen also from this table that exclusion of the year of 1961 has no effects on the productivity growth rate of the grain sector in the gray soil zone. Moreover, the growth rates of TFP associated with earlier and later subperiods indicate that productivity growth increased from 3.3 percent per year over 1957-72 to 6.8 percent in the sub-period since 1973.

In assessing performance in the gray soil zone, however, it must be remembered that grain production and productivity in this zone may have been at lower initial base levels at the start of the sample period. For example, the increasing returns associated with initial fertilzer and pesticide use might already have occurred in other zones prior to 1957 or 1961, whereas these gains may have occurred slightly later in the gray zone due to later adoption of technical inputs. Another possibility is that the gains may have in the gray zone reflect the success of research and management practices in overcoming trace mineral deficiencies on gray wooded soils. In part, however, the productivity performance in grain in the gray soil zone may reflect that the gray zone is a relatively moisture abundant zone, particularly compared to the brown and dark brown zones.

Grain output, input, and TFP indexes are depicted graphically in Figures 5-1, 5-2, 5-3, 5-4 and 5-5 for Alberta and its four major soil zones. The influence of weather and climate on output and productivity indexes is clearly evident in these diagrams. For example, the years 1961, 1967, and 1984 are clearly severe drought years, particularly in the brown and dark brown soil zones. It can be seen from these graphs that TFP and output quantity indexes tend to follow a similar pattern -- that is, both fluctuate in the same direction.

Moreover, when our time series is divided into two sub-periods, one from 1957-72 and the second, from 1973-84, these graphs help to explain and demonstrate the differences in the growth rates of output, input and TFP in these two sub-periods. The first sub-period is characterized by relatively slow growth of inputs for most of the soil zones. On the other hand, the growth rates of output and TFP are higher than that for input in this sub-period. The second sub-period is generally characterized by higher growth rates of both grain input and grain output in Alberta and its major soil zones.

In general, if one compares the 1957-72 period with the 1973-84 period, one sees that the productivity growth in the Alberta grain sector has increased slightly, with a considerable increase in the gray soil zone rate and some decrease in the rates of the other three zones. If only 1973-83 is considered (eliminating 1984), the productivity growth rate decreases only in the brown soil zone.

In conclusion, productivity performance in the Alberta grain sector has been relatively strong. TFP in this sector has increased by a compound rate of 1.7 percent per annum between 1957 and 1984. When the study of TFP is disaggregated by soil zone, the annual growth rate of TFP by zones show considerable discrepancy. TFP has grown at an annual compound rate of 1.7, 0.9, 1.4, and 3.3 percent for the brown, dark brown, black and gray soil zones, respectively, during the period of study. A particularly striking and unexpected conclusion is the relatively high productivity growth which appears to have occurred in grain production in the gray soil zone.

These results show the importance of the disaggregation of productivity studies into sectoral, provincial, and zonal levels. These results also clearly show the sensitivity of estimated growth rates of TFP to the particular time period chosen. The growth rates of both output and TFP are severely effected by inclusion or exclusion of drought years such as 1961 or 1984.

5.2.4 Terms of Trade and Return to Cost

The terms of trade is defined as the ratio of the index of the prices received by farmers to the index of the prices paid by farmers; alternatively, it is simply the aggregate output price index divided by the aggregate input price index. The returns to cost ratio, on the other hand, is defined as the ratio of the index of output value to the index of input value. The returns to cost ratio, a crude indicator of profitability in the sector, can be used to assess the welfare position of farmers and to analyze the degree to which productivity improvement in the grain sector might be offsetting adverse movment in its terms of trade (Lawrence and McKay 1980, and Islam 1982).

The output and input price indexes for the five major crops were constructed by using the Divisia-related (Tornqvist-Theil) index number procedure. Terms of trade and returns to cost ratios were derived. The estimated output price, input price, terms of trade, and returns to cost ratio indexes for Alberta and its soil zones are reported in Columns 4, 5, 6, and 7, respectively, of Tables 5-1, 5-2, 5-3, 5-4, and 5-5.

The growth rates of aggregate grain output price ranged from 4.7 to 5.6 percent per year while the growth rates of aggregate grain input price ranged from 7.2 to 7.6 percent for Alberta and its major soil zones during the entire period of study. However, the output price index increased dramatically in 1973 for Alberta and its soil zones, a factor which greatly complicates the analysis of terms of trade and returns to cost trends in the period of study. The dramatic rise in grain prices at the beginning of the so-called energy / food crises meant that the terms of trade and returns to cost in Alberta farming also sharply peaked at this point in time. In general, these tables indicate that input price indexes grew faster than output price indexes and, as a consequence, the terms of trade declined during the period of study for Alberta grain farmers. As shown in Tables 5-1 through 5-5, the terms of trade in Alberta and its major soil zones declined by a compound annual rate ranging from 2.1 to 2.4 percent over 1957 to 1984. This deterioration is accentuated by the considerable increases in input prices which occurred after 1973. The deterioration in the terms of trade is popularly known in the literature as the "cost-price squeeze". It has been argued that the income or welfare position of farmers can not be determined by terms of

Table 5-1. Indexes of Grain Output, Inputs, Prices, and Productivity, Alberta Grain Sector, 1957 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957	0.5756	0.8901	0.6467	1.0418	0.6678	1.5600	1.0089
1958	0.6151	0.8928	0.6890	1.0952	0.6740	1.6249	1.1196
1959	0.6824	0.9058	0.7534	1.1019	0.6926	1.5910	1.1986
1960	0.6500	0.9107	0.7137	1.2210	0.7007	1.7425	1.2437
1961	0.5553	0.9102	0.6101	1.4268	0.7161	1.9925	1.2156
1962	0.6856	0.9144	0.7498	1.3286	0.7364	1.8042	1.3528
1963	0.8382	0.9360	0.8955	1.3451	0.7623	1.7645	1.5801
1964	0.7943	0.9654	0.8228	1.3043	0.7793	1.6737	1.3771
1965	0.8733	0.9932	0.8793	1.3699	0.8071	1.6973	1.4924
1966	1.0735	1.0233	1.0491	1.4132	0.8445	1.6734	1.7556
1967	0.8556	1.0751	0.7958	1.2646	0.8963	1.4109	1.1228
1968	1.0100	1.0286	0.9819	1.0955	0.9411	1.1641	1.1430
1969	0.9927	1.0122	0.9807	0.9618	0.9649	0.9968	0.9775
1970	0.9080	0.9639	0.9420	1.0446	0.9745	1.0719	1.0098
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0492	1.0398	1.0090	1.6303	1.0725	1.5201	1.5338
1973	1.0128	1.1002	0.9206	3.3779	1.1722	2.8817	2.6529
1974	0.8811	1.1835	0.7445	3.1873	1.4067	2.2658	1.6869
1975	1.1180	1.3167	0.8491	2.9565	1.7586	1.6812	1.4275
1976	1.2096	1.4006	0.8636	2.4718	1.9716	1.2537	1.0827
1977	1.1796	1.2707	0.9283	2.2928	2.1773	1.0530	0.9775
1978	1.4067	1.3348	1.0539	2.6043	2.3062	1.1293	1.1901
1979	1.3912	1.4247	0.9765	3.2168	2.6304	1.2229	1.1942
1980	1.6262	1.4177	1.1471	3.7264	3.0994	1.2023	1.3792
1981	1.7418	1.5077	1.1553	3.3539	3.4866	0.9619	1.1113
1982	1.7369	1.4662	1.1846	2.8927	3.6827	0.7855	0.9305
1983	1.7144	1.4982	1.1443	3.3702	3.7074	0.9090	1.0402
1984	1.4885	1.5178	0.9807	3.2734	3.7370	0.8759	0.8590

Annual Growth Rates in %

Period	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957-84	4.0	2.2	1.7	5.0	4.7	-2.2	-0.5
1961-84	4.0	2.5	1.5	5.6	8.6	-2.7	-1.3
1962-84	3.8	2.5	1.2	6.0	8.9	-2.6	-1.5
1962-83	3.9	2.6	1.3	6.2	8.9	-2.5	-1.2
1957-72	4.3	1.1	3.1	0.1	3.3	-3.0	-0.03
1962-72	3.2	0.9	2.3	-1.6	3.8	-5.2	-3.1
1973-83	7.0	2.7	4.2	1.0	12.3	-10.0	-6.3
1973-84	5.8	2.5	3.2	1.1	11.3	-9.2	-6.3

Table 5-2. Indexes of Grain Output, Inputs, Prices, and Productivity, Alberta Brown Soil Zone, 1957 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957	0.7521	0.9293	0.8093	1.0222	0.6766	1.5108	1.2227
1958	0.7908	0.9472	0.8349	1.0784	0.6835	1.5778	1.3173
1959	0.7621	0.9667	0.7884	1.0644	0.6977	1.5256	1.2028
1960	0.4878	0.9493	0.5139	1.2270	0.7107	1.7265	0.8872
1961	0.2632	0.9485	0.2775	1.4162	0.7251	1.9531	0.5420
1962	0.4543	0.9380	0.4843	1.3216	0.7414	1.7826	0.8633
1963	0.7807	0.9588	0.8142	1.3717	0.7664	1.7898	1.4573
1964	0.7802	0.9887	0.7891	1.2719	0.7862	1.6178	1.2766
1965	1.0843	1.0178	1.0653	1.3443	0.8126	1.6543	1.7623
1966	1.3851	1.0445	1.3261	1.4027	0.8495	1.6512	2.1897
1967	0.9249	1.0848	0.8526	1.2860	0.8987	1.4310	1.2200
1968	1.2860	1.0413	1.2350	1.0787	0.9440	1.1427	1.4112
1969	1.2671	1.0266	1.2343	0.9412	0.9612	0.9792	1.2086
1970	1.0422	0.9740	1.0700	1.0376	0.9716	1.0679	1.1427
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9868	1.0471	0.9424	1.5585	1.0690	1.4579	1.3739
1973	1.0012	1.1196	0.8942	3.4309	1.1655	2.9437	2.6323
1974	0.9773	1.2094	0.8081	3.1755	1.3829	2.2963	1.8556
1975	1.3152	1.3253	0.9924	2.9125	1.7159	1.6974	1.6845
1976	1.5044	1.4264	1.0547	2.3346	1.9056	1.2251	1.2921
1977	1.0269	1.3387	0.7671	2.2245	2.0892	1.0648	0.8168
1978	1.4162	1.3891	1.0195	2.8294	2.2556	1.2544	1.2788
1979	1.3160	1.4852	0.8861	3.7485	2.5624	1.4629	1.2963
1980	1.4684	1.4774	0.9939	4.2629	3.0138	1.4145	1.4058
1981	1.8472	1.5781	1.1705	3.9252	3.3668	1.1659	1.3646
1982	1.7096	1.5254	1.1208	3.4662	3.5774	0.9689	1.0860
1983	1.8385	1.5708	1.1704	3.7054	3.5684	1.0384	1.2153
1984	1.1167	1.5773	0.7080	3.5369	3.6055	0.9810	0.6945

Annual Growth Rates in %

1957-84	4.0	2.2	1.7	5.6	7.2	-1.5	0.2
1961-84	4.5	2.6	1.8	6.3	8.3	-1.9	-0.06
1962-84	3.4	2.7	0.7	6.8	8.6	-1.7	-1.1
1962-83	3.9	2.7	1.2	7.0	8.7	-1.5	-0.4
1957-72	5.4	0.7	4.7	0.1	3.2	-3.0	1.5
1962-72	5.6	0.6	4.9	-1.8	3.7	-5.3	-0.06
1973-83	6.1	3.1	2.9	3.1	12.1	-8.0	-5.3
1973-84	3.8	2.8	1.0	2.8	11.1	-7.5	-6.6

Table 5-3. Indexes of Grain Output, Inputs, Prices, and Productivity, Alberta Dark Brown Soil Zone, 1957 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957	0.6123	0.8738	0.7007	1.0379	0.6632	1.5650	1.0966
1958	0.6963	0.8760	0.7949	1.0922	0.6712	1.6272	1.2935
1959	0.7433	0.8917	0.8336	1.0930	0.6887	1.5870	1.3230
1960	0.6743	0.9036	0.7462	1.2269	0.6961	1.7625	1.3152
1961	0.4646	0.8988	0.5169	1.4179	0.7141	1.9856	1.0263
1962	0.6052	0.9081	0.6664	1.3298	0.7327	1.8149	1.2095
1963	0.9418	0.9301	1.0126	1.3707	0.7608	1.8017	1.8244
1964	0.8731	0.9655	0.9043	1.2883	0.7786	1.6546	1.4963
1965	0.9876	1.0017	0.9859	1.3479	0.8029	1.6788	1.6551
1966	1.2130	1.0343	1.1728	1.4019	0.8428	1.6634	1.9508
1967	0.8686	1.0873	0.7989	1.2759	0.8954	1.4249	1.1384
1968	1.0743	1.0502	1.0229	1.0869	0.9424	1.1533	1.1797
1969	1.0331	1.0192	1.0136	0.9605	0.9643	0.9961	1.0096
1970	0.8683	0.9575	0.9068	1.0403	0.9769	1.0649	0.9657
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0564	1.0482	1.0078	1.5937	1.0749	1.4826	1.4942
1973	1.0331	1.1229	0.9200	3.3862	1.1753	2.8811	2.6506
1974	0.9421	1.2191	0.7728	3.2086	1.4089	2.2774	1.7600
1975	1.1359	1.3481	0.8426	2.9062	1.7615	1.6498	1.3902
1976	1.1916	1.4390	0.8281	2.4277	1.9672	1.2341	1.0219
1977	1.0698	1.3430	0.7966	2.2940	2.1647	1.0597	0.8442
1978	1.3875	1.4354	0.9666	2.6899	2.2953	1.1719	1.1328
1979	1.3926	1.5453	0.9012	3.3438	2.6167	1.2779	1.1516
1980	1.6183	1.5169	1.0668	3.7990	3.1231	1.2164	1.2977
1981	1.7750	1.6194	1.0961	3.4734	3.5147	0.9882	1.0832
1982	1.7593	1.5903	1.1063	3.0573	3.6840	0.8299	0.9181
1983	1.6452	1.6416	1.0022	3.4588	3.6675	0.9431	0.9452
1984	1.2455	1.6230	0.7674	3.3084	3.7613	0.8796	0.6750

Annual Growth Rates in %

1957-84	3.6	2.6	0.9	5.2	7.4	-2.1	-1.2
1961-84	3.7	2.9	0.8	5.8	8.6	-2.6	-1.8
1962-84	3.2	3.0	0.2	6.2	8.9	-2.5	-2.3
1962-83	3.5	3.0	0.5	6.4	8.9	-2.3	-1.9
1957-72	4.0	1.3	2.7	0.1	3.4	-3.2	-0.5
1962-72	2.7	0.9	1.8	-1.7	3.9	-5.4	-3.7
1973-83	6.6	3.5	3.0	1.6	12.3	-9.5	-6.8
1973-84	4.8	3.2	1.6	1.5	11.3	-8.8	-7.4

Table 5-4. Indexes of Grain Output, Inputs, Prices, and Productivity, Alberta Black Soil Zone, 1957 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957	0.5286	0.8830	0.5986	1.0471	0.6657	1.5729	0.9416
1958	0.6108	0.8837	0.6912	1.1007	0.6716	1.6389	1.1328
1959	0.6156	0.8925	0.6897	1.1118	0.6929	1.6046	1.1067
1960	0.6816	0.9024	0.7553	1.2214	0.6986	1.7484	1.3205
1961	0.6006	0.9035	0.6647	1.4315	0.7123	2.0097	1.3358
1962	0.7842	0.9106	0.8612	1.3291	0.7326	1.8142	1.5624
1963	0.9186	0.9326	0.9850	1.3283	0.7593	1.7494	1.7231
1964	0.7657	0.9627	0.7954	1.3164	0.7766	1.6951	1.3483
1965	0.8683	0.9931	0.8743	1.3895	0.8025	1.7315	1.5138
1966	0.9936	1.0224	0.9718	1.4227	0.8423	1.6891	1.6414
1967	0.8985	1.0772	0.8341	1.2579	0.8956	1.4045	1.1715
1968	0.8918	1.0278	0.8677	1.1038	0.9402	1.1740	1.0187
1969	0.9751	1.0149	0.9608	0.9643	0.9612	1.0032	0.9639
1970	0.9415	0.9644	0.9763	1.0485	0.9703	1.0806	1.0550
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0854	1.0420	1.0417	1.6733	1.0752	1.5563	1.6212
1973	1.0333	1.1022	0.9375	3.3974	1.1848	2.8675	2.6883
1974	0.8587	1.1844	0.7250	3.1841	1.4332	2.2217	1.6107
1975	1.0448	1.3211	0.7909	3.0175	1.7911	1.6847	1.3324
1976	1.1467	1.4011	0.8184	2.5242	2.0177	1.2510	1.0238
1977	1.2670	1.2726	0.9956	2.3022	2.2323	1.0313	1.0268
1978	1.3103	1.3282	0.9865	2.5525	2.3958	1.0654	1.0510
1979	1.2833	1.4130	0.9082	3.1599	2.7642	1.1432	1.0382
1980	1.5253	1.4160	1.0772	3.7451	3.2338	1.1581	1.2475
1981	1.6283	1.5141	1.0754	3.3124	3.6177	0.9156	0.9846
1982	1.6818	1.4749	1.1403	2.8034	3.8067	0.7364	0.8398
1983	1.5162	1.5088	1.0049	3.3774	3.8355	0.8806	0.8849
1984	1.4686	1.5285	0.9608	3.3174	3.8513	0.8614	0.8276

Annual Growth Rates in %

Period	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957-84	3.7	2.3	1.4	5.0	7.6	-2.4	-1.1
1961-84	3.5	2.5	0.9	5.6	8.8	-3.0	-2.1
1962-84	3.3	2.7	0.7	6.0	9.2	-2.9	-2.3
1962-83	3.4	2.6	0.8	6.1	9.2	-2.8	-2.1
1957-72	4.3	1.2	3.1	0.2	3.3	-3.0	-0.03
1962-72	2.5	0.9	1.6	-1.5	3.9	-5.1	-3.7
1973-83	6.1	2.7	3.3	0.8	12.6	-10.5	-7.6
1973-84	5.2	2.6	2.6	1.0	11.6	-9.5	-7.1

Table 5-5. Indexes of Grain Output, Inputs, Prices, and Productivity, Alberta Gray Soil Zone, 1957 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957	0.5140	0.8947	0.5745	1.0466	0.6732	1.5547	0.8932
1958	0.3949	0.8948	0.4413	1.0944	0.6759	1.6192	0.7145
1959	0.6835	0.9086	0.7523	1.1205	0.6925	1.6181	1.2173
1960	0.6235	0.9107	0.6846	1.2109	0.7010	1.7274	1.1826
1961	0.7402	0.9110	0.8125	1.4302	0.7151	2.0000	1.6250
1962	0.6951	0.9136	0.7608	1.3292	0.7366	1.8045	1.3729
1963	0.5200	0.9346	0.5564	1.3331	0.7601	1.7538	0.9758
1964	0.7283	0.9569	0.7611	1.3395	0.7752	1.7279	1.3151
1965	0.5756	0.9740	0.5910	1.3877	0.8064	1.7209	1.0170
1966	0.8450	1.0047	0.8410	1.4208	0.8398	1.6918	1.4228
1967	0.6792	1.0556	0.6434	1.2417	0.8930	1.3905	0.8946
1968	0.9972	1.0049	0.9923	1.1031	0.9272	1.1897	1.1806
1969	0.7946	0.9955	0.7982	0.9754	0.9659	1.0098	0.8061
1970	0.8026	0.9637	0.8328	1.0465	0.9742	1.0742	0.8946
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9859	1.0302	0.9570	1.6299	1.0795	1.5099	1.4449
1973	0.9326	1.0768	0.8661	3.2812	1.1865	2.7654	2.3952
1974	0.7790	1.1567	0.6735	3.1767	1.4220	2.2340	1.5046
1975	1.1256	1.3007	0.8654	2.9355	1.7532	1.6744	1.4490
1976	1.1731	1.3853	0.8468	2.5349	1.9617	1.2922	1.0942
1977	1.2004	1.2191	0.9847	2.3411	2.1755	1.0761	1.0597
1978	1.6151	1.2779	1.2639	2.5080	2.2573	1.1111	1.4043
1979	1.6590	1.3602	1.2197	2.9169	2.5471	1.1452	1.3968
1980	1.9282	1.3605	1.4173	3.3568	2.9333	1.1444	1.6219
1981	1.7871	1.4261	1.2531	3.0098	3.3140	0.9082	1.1381
1982	1.7633	1.3727	1.2845	2.5687	3.4836	0.7374	0.9472
1983	2.1068	1.3810	1.5256	3.1187	3.5802	0.8711	1.3289
1984	2.0974	1.4287	1.4680	3.0461	3.5487	0.8584	1.2601

Annual Growth Rates in %

1957-84	5.4	2.0	3.3	4.7	7.2	-2.4	0.9
1961-84	5.7	2.2	3.4	5.1	8.3	-3.0	0.3
1962-84	6.1	2.2	3.7	5.5	8.6	-2.9	0.7
1962-83	6.2	2.3	3.7	5.6	8.7	-2.8	0.8
1957-72	4.4	1.0	3.3	0.01	3.3	-3.1	0.2
1962-72	5.1	0.9	4.2	-1.6	3.8	-5.3	-1.3
1973-83	9.6	2.1	7.3	-0.2	11.5	-10.5	-4.0
1973-84	9.0	2.0	6.8	0.1	10.6	-9.5	-3.3

Figure 5-1. Indexes of Output, Input, and Total Factor Productivity, Alberta Grain Sector, 1957 to 1984 (1971=1.000)

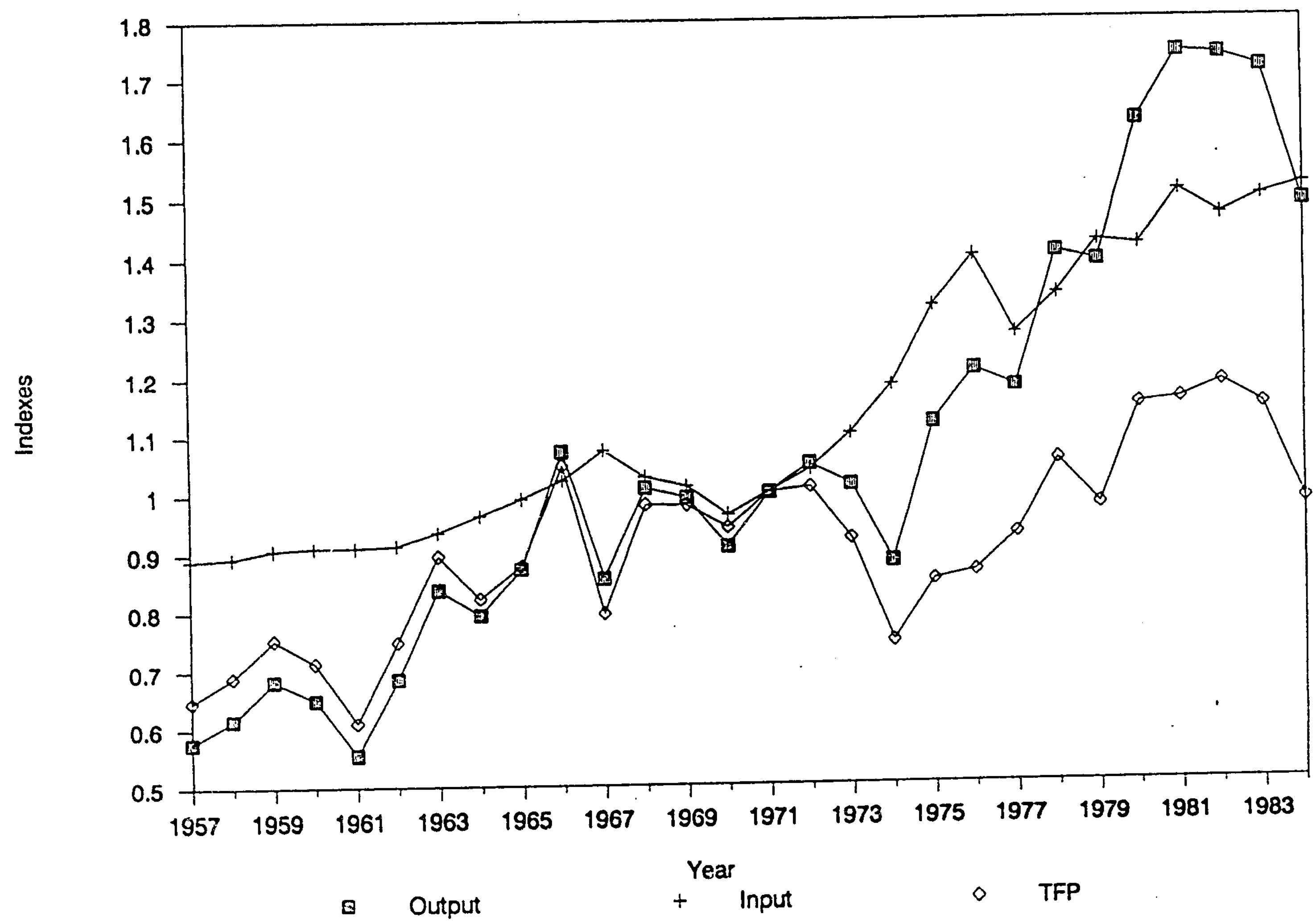


Figure 5-2. Indexes of Grain Output, Input and Total Factor Productivity, Brown Soil Zone, Alberta, 1957 to 1984 (1971=1.000)

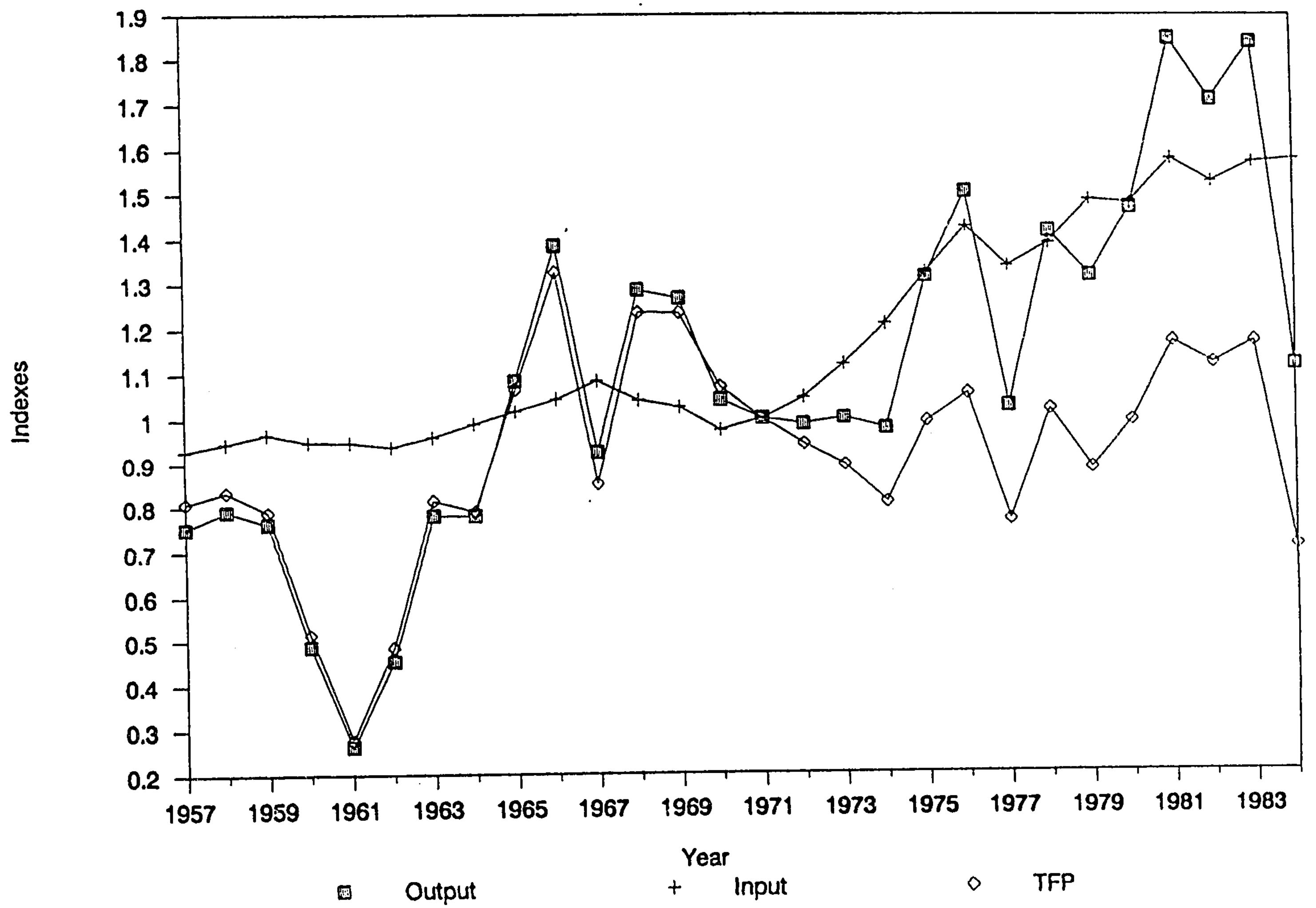


Figure 5-3. Indexes of Grain Output, Input and Total Factor Productivity, Dark Brown Soil Zone, Alberta, 1957 to 1984 (1971=1.000)

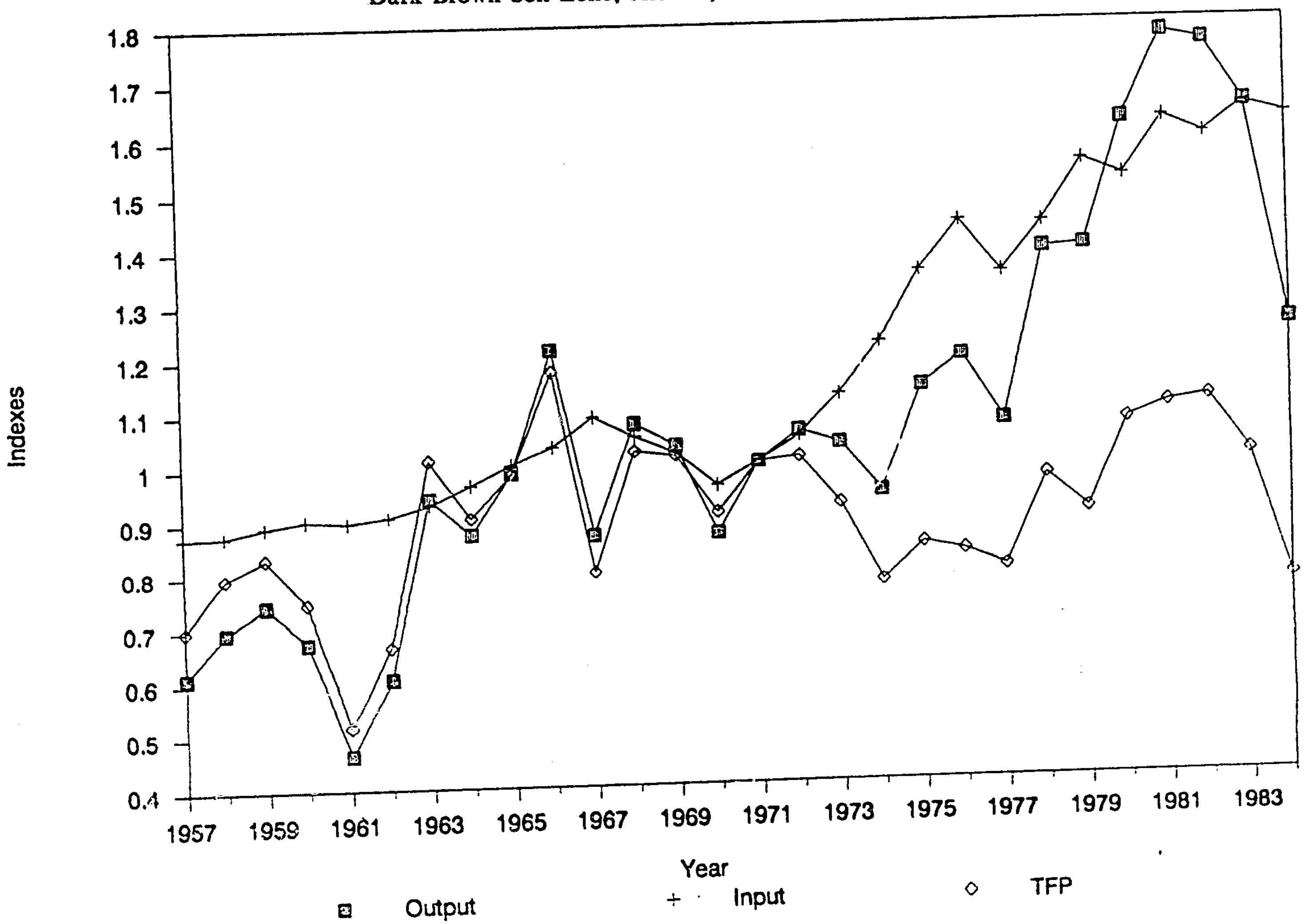


Figure 5-4. Indexes of Grain Output, Input and Total Factor Productivity, Black Soil Zone, Alberta, 1957 to 1984 (1971=1.000)

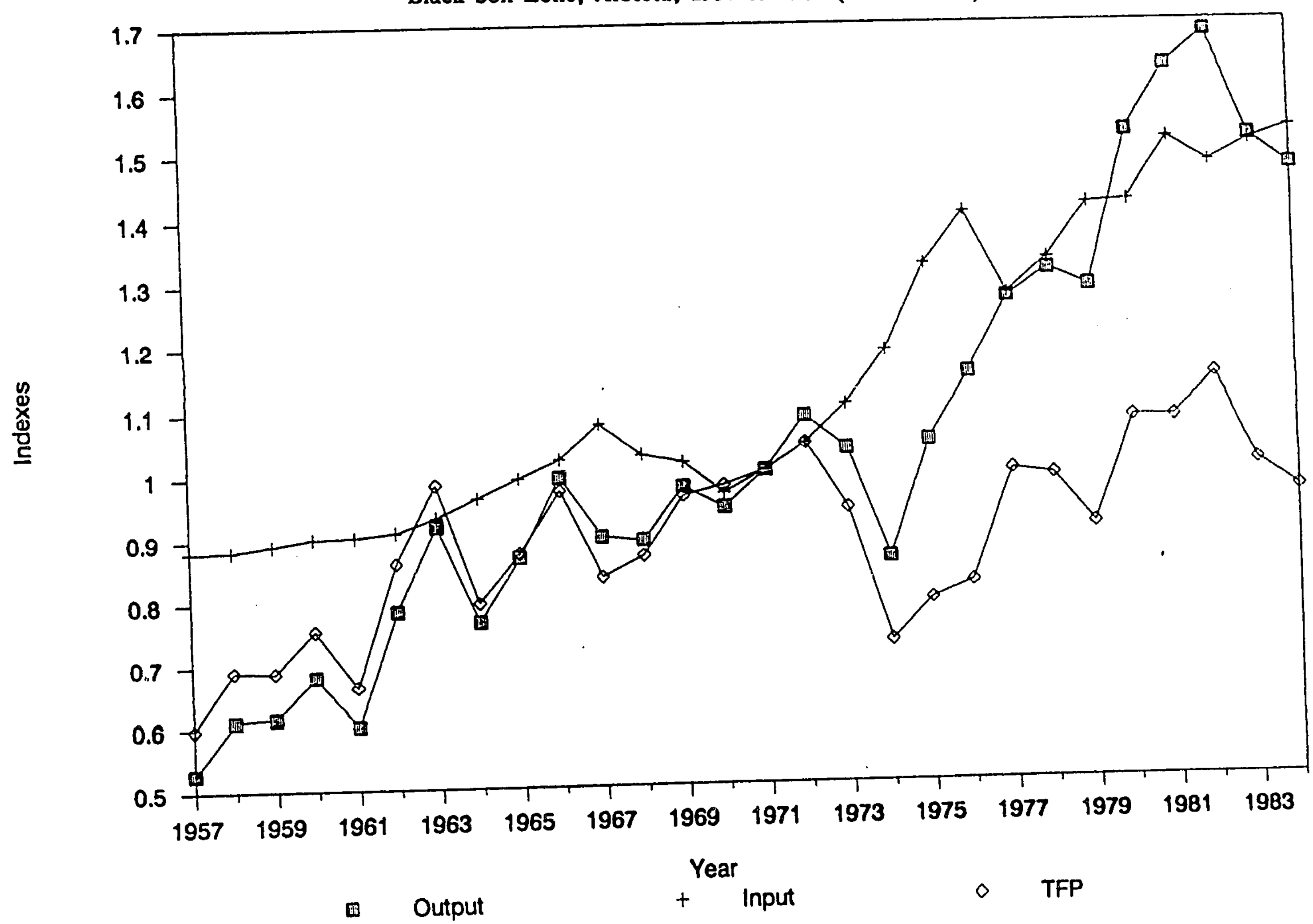
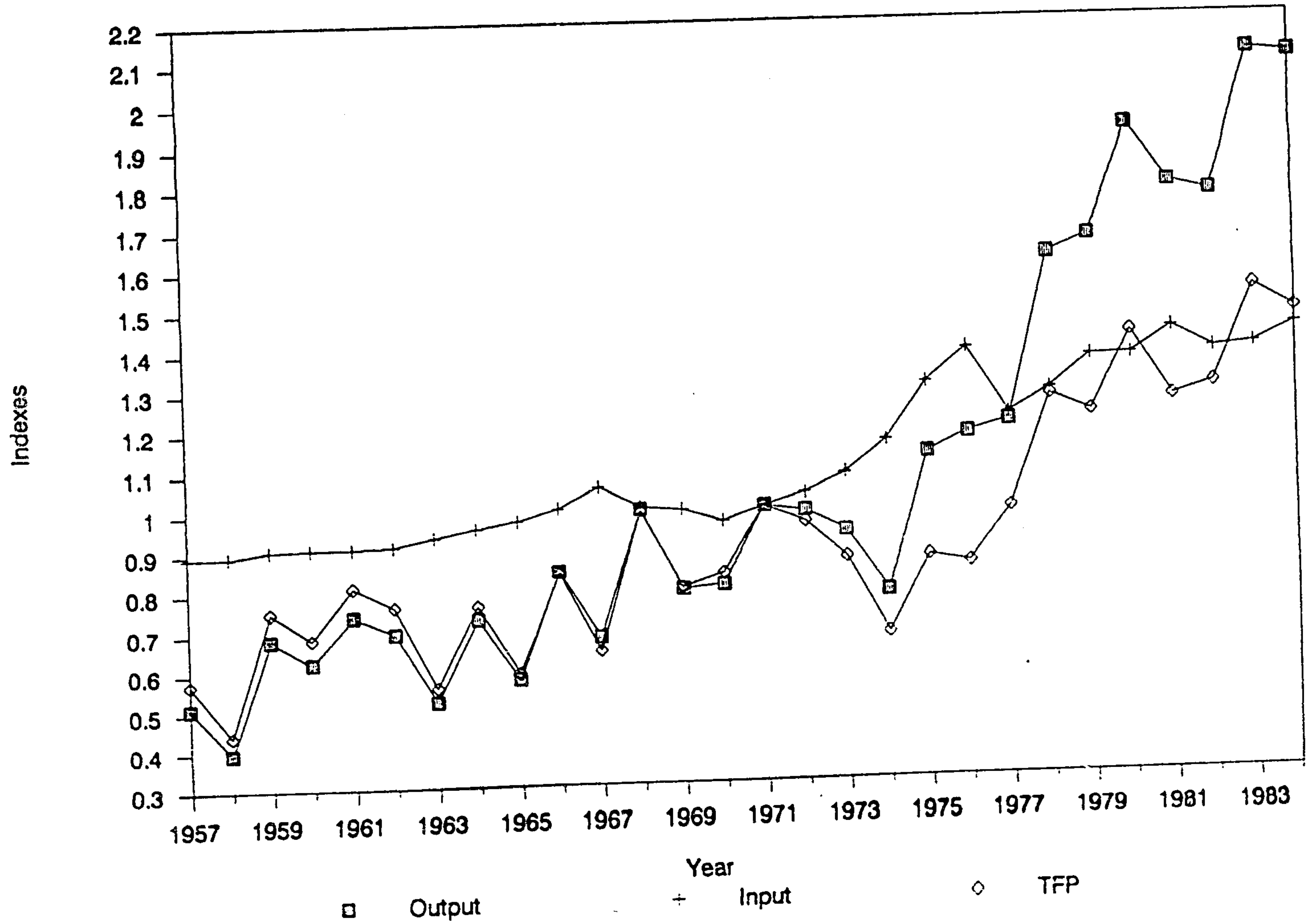


Figure 5-5. Indexes of Grain Output, Input and Total Factor Productivity, Gray Soil Zone, Alberta, 1957 to 1984 (1971=1.000)



trade alone, but must also involve consideration of the change in technical efficiency with which inputs are converted into outputs or, more simply, the growth rate of TFP. Therefore, one has to bring the growth rate of TFP into the picture to determine the returns to cost ratio, a crude measure of profitability. The relationship between changes in productivity , farmers' terms of trade, and the returns to cost ratio, as outlined by Lawrence and McKay (1980), can be written as:

$$\text{Growth rate of returns to cost ratio} = \text{Growth rate of TFP} + \text{Growth rate of terms of trade}$$

This relationship tells us that if the growth rate of TFP is higher than the absolute value of growth rate associated with declining the (negative) terms of trade, the social profitability as indicated by the returns to cost ratio has nevertheless improved, i.e. the returns generated by farmers are greater than the costs paid to produce that output. However, if the growth rate of TFP is insufficient to compensate for the deterioration in the terms of trade, then the rate of growth of the returns to cost ratio is negative and the welfare position of farmers is declining.

As seen in Tables 5-1 through 5-5, improvements in productivity between 1957 and 1984 were able to more than compensate for deterioration in the terms of trade for the brown and gray soil zones in Alberta, but not for the black and dark brown soil zones. In Alberta grain production as a whole, the returns to cost ratio declined slightly at 0.5 percent per year between 1957 and 1984, as improvements in productivity (1.7 percent per year) were less than the negative fall (2.2 percent per year) in the terms of trade. The considerable deterioration in the returns to cost ratio since 1973 is partly due to the relatively rapid increases in input prices since that date but also due to the statistical artifact that 1973 is an abnormal peak year with respect to output prices, terms of trade, and returns to cost.

5.3 Estimates for Manitoba

The results of the estimated output, input, and total factor productivity indexes for Manitoba, as well as their corresponding growth rates for different period of time, will be presented, analyzed, and discussed in this section. The terms of trade and returns to cost ratios were derived and also will be discussed in this section.

5.3.1 Output, Input, and Productivity Indexes

The output and input data which have been described in Chapters 3 and 4 of this thesis, together with the Divisia-related index approaches which were outlined in Chapter 2, were used to derive output and input quantity indexes for the Manitoba grain sector. The TFP index is obtained by dividing the output quantity index by the input quantity index. The results are reported in Columns 1, 2, and 3 of Table 5-6 for output, input, and TFP indexes, respectively. It can be seen from this table that the output quantity index for the Manitoba grain sector rose from 0.475 in 1957 to 1.592 in 1984. Meanwhile, as in the Alberta grain sector, the Maanitoba grain output is characterized by wide fluctuations which are largely attributed to the weather variable. The output of the grain sector in Manitoba grew by an annual compound rate of 4.1 percent for the period of 1957-84, 4.4 percent over 1961-84, and only 3.2 percent for the period from 1962 to 1984. This later result is yet another example of how the inclusion of the drought year 1961 affects the annual growth rate. Furthermore, the output growth rate in Manitoba grain production rose from 4.3 percent in the sub-period, 1957-72, to 6.0 percent in the sub-period, 1973-84.

The input quantity index, on the other hand, for the Manitoba grain sector increased from 0.939 in 1957 to 1.42 in 1984, an increase at an annual compound growth rate of 2.0 percent over this entire period of study. The growth rate of input quantity rose from -0.4 percent per year over 1957-72 to 3.2 percent in the sub-period, 1973-84. This increased input use since 1973 reflects various factors including intensified use of mechanical and biochemical technology and increased land costs in the grain production process in Manitoba.

As portrayed in Table 5-6, Column 3, the TFP index increased from 0.506 in 1957 to 1.114 in 1984, generating an annual compound growth rate of 2.4 percent for the period of 1957-84. This result shows that the growth rate of TFP in the Manitoba grain sector is higher than those in Alberta and its major soil zones, except for the gray soil zone. Whether or not the rate of productivity growth in Manitoba grain production fell or rose after 1973 is problematic. The growth rate of TFP declined from 4.1 percent from 1957 to 1972 to 2.7 percent in the sub-period between 1973 and 1984. This decline in the growth rate of TFP is caused by the remarkable increase in the growth rate of input quantity during the sub-period of 1973-84. However, if a shorter earlier sub-period from 1962 to 1972 is considered, then the growth rate of TFP increased from 2.5 percent per year over 1962-72 to 2.7 percent over 1973-84.

Output, input, and TFP indexes for Manitoba are depicted in Figure 5-6. This figure gives a clear picture concerning the respective time paths for output, input, and TFP indexes in the Maitoba grain sector during the entire period of study. The output index is characterized by wide fluctuations during the period of study. Moreover, the effect of the drought year 1961 can be seen very clearly in this graph; output and TFP indexes reached their lowest levels in 1961. The input quantity index, on the other hand, shows a stable pattern in the period of 1957-72, then starts to rise more rapidly during the period 1973-84. Prior to 1973, the time paths of output and productivity are very similar; after 1973, these two indexes move in similar directions, but the gap between the two indexes tends to widen.

5.3.2 Terms of Trade and Return to Cost

The output and input price indexes for the Manitoba grain sector are constructed by using the Divisia-related index number procedure. Terms of trade and the returns to cost ratios are also derived. The resultant output price index, input price index, terms of trade, and returns to cost ratios are reported in Columns 4, 5, 6, and 7 of Table 5-6, respectively. The output price index grew by an annual compound rate of 5.0 percent for the period of study, while the input price index grew by an annual compound rate of 7.3 percent during the same period. The grain output price index, as seen in the case of Alberta, peaked

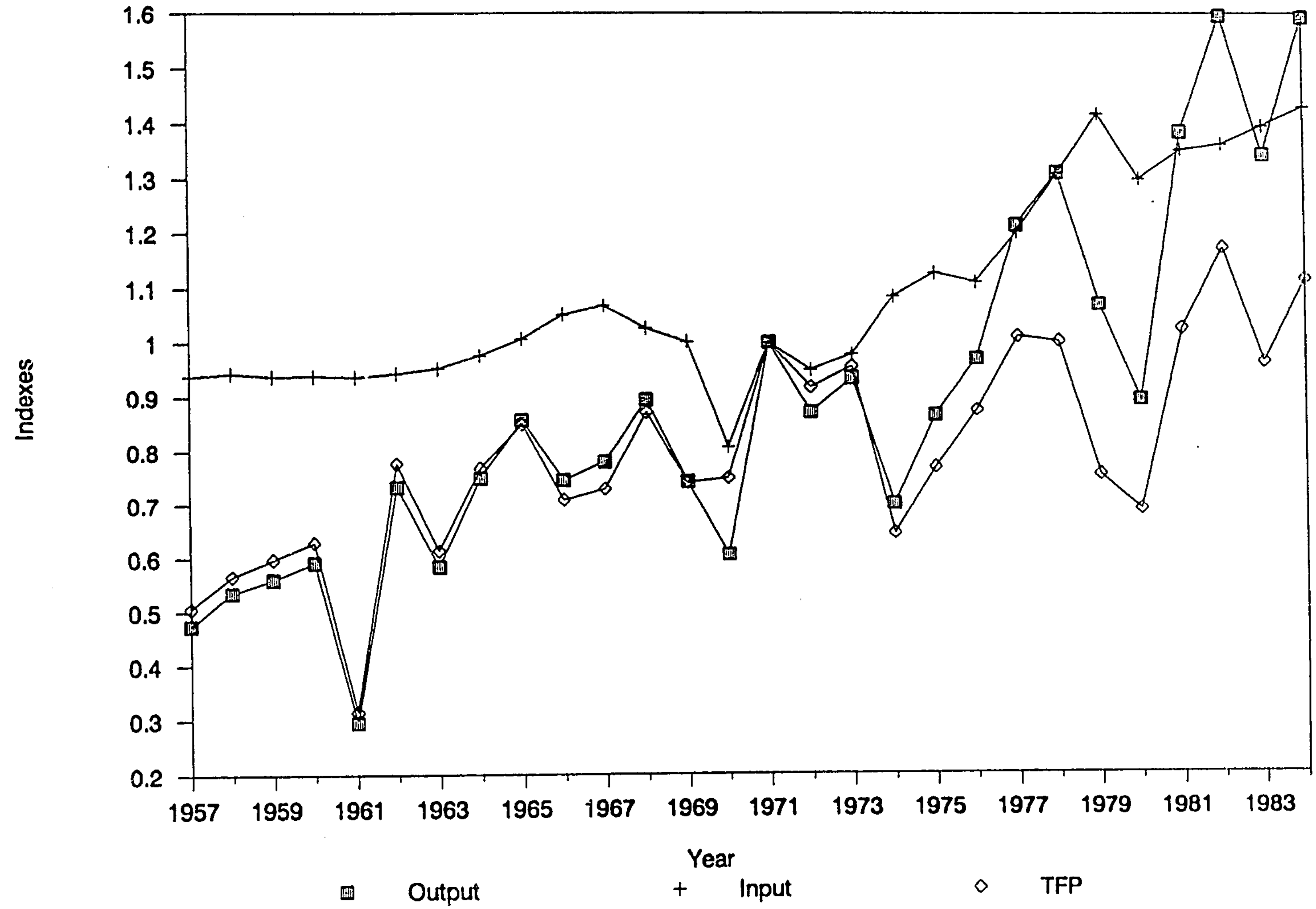
Table 5-6. Indexes of Grain Output, Inputs, Prices, and Productivity, Manitoba Grain Sector, 1957 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1957	0.4745	0.9387	0.5054	1.0454	0.6467	1.6165	0.8170
1958	0.5344	0.9439	0.5662	1.1059	0.6883	1.6068	0.9097
1959	0.5604	0.9382	0.5973	1.1133	0.7003	1.5898	0.9496
1960	0.5912	0.9397	0.6291	1.2314	0.7192	1.7122	1.0772
1961	0.2955	0.9379	0.3150	1.4100	0.7337	1.9218	0.6054
1962	0.7329	0.9441	0.7763	1.3217	0.7310	1.8080	4.4036
1963	0.5836	0.9526	0.6126	1.3294	0.7426	1.7902	1.0967
1964	0.7501	0.9773	0.7675	1.2806	0.7753	1.6518	1.2678
1965	0.8566	1.0075	0.8502	1.3406	0.8048	1.6657	1.4162
1966	0.7457	1.0516	0.7091	1.3798	0.8503	1.6227	1.1507
1967	0.7794	1.0682	0.7297	1.2879	0.9019	1.4280	1.0420
1968	0.8946	1.0269	0.8712	1.0957	0.9378	1.1684	1.0178
1969	0.7421	1.0023	0.7404	0.9860	0.9601	1.0269	0.7603
1970	0.6051	0.8075	0.7493	1.0438	0.9721	1.0737	0.8046
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.8703	0.9491	0.9170	1.6039	1.0831	1.4809	1.3579
1973	0.9338	0.9776	0.9552	3.3883	1.1967	2.8314	2.7046
1974	0.7004	1.0843	0.6460	3.2252	1.4243	2.2644	1.4628
1975	0.8646	1.1258	0.7680	2.8488	1.7438	1.6337	1.2546
1976	0.9691	1.1095	0.8734	2.4056	1.9957	1.2054	1.0528
1977	1.2139	1.2007	1.0110	2.2274	2.2067	1.0094	1.0205
1978	1.3095	1.3065	1.0023	2.6585	2.3752	1.1193	1.1219
1979	1.0691	1.4168	0.7546	3.2342	2.5844	1.2514	0.9443
1980	0.8937	1.2971	0.6890	3.6828	2.9578	1.2451	0.8579
1981	1.3841	1.3504	1.0250	3.3499	3.3667	0.9950	1.0198
1982	1.5962	1.3616	1.1723	2.9052	3.4800	0.8348	0.9787
1983	1.3421	1.3938	0.9629	3.3475	3.5289	0.9486	0.9134
1984	1.5927	1.4290	1.1146	3.2309	3.5962	0.8984	1.0013

Annual Growth Rates in %

1957-84	4.1	-1.6	2.4	5.0	7.3	-2.1	0.3
1961-84	4.4	1.9	2.4	5.6	8.4	-2.6	-0.3
1962-84	3.6	2.0	1.6	6.0	8.7	-2.5	-1.0
1962-83	3.4	2.0	1.4	6.2	8.8	-2.3	-1.0
1957-72	4.3	0.2	4.1	0.01	3.3	-3.1	0.9
1962-72	2.1	-0.4	2.5	-1.5	4.0	-5.2	-2.9
1973-83	5.8	3.4	2.3	1.1	11.4	-9.2	-7.1
1973-84	5.9	3.2	2.7	1.2	10.5	-8.5	-6.0

Figure 5-6. Indexes of Output, Input and Total Factor Productivity, Manitoba Grain Sector, 1957 to 1984 (1971=1.000)



sharply in 1973 and as a consequence the terms of trade also reached its highest level in 1973.

Since the input price index grew faster than the output price index for the entire period of study, the terms of trade in Manitoba grain production declined by an annual compound rate of 2.1 percent per year between 1957 and 1984. This decline in the terms of trade was more than offset by increases in productivity in Manitoba grain production. As a consequence, the returns to cost ratio rose slightly between 1957 and 1984. The welfare situation for Manitoba grain farmers since 1973, however, has been deteriorating as the returns to cost ratio has been falling.

The above discussion suggested that productivity advance in the grain sector in Manitoba (black soil zone) has been relatively strong by provincial standards. The output and TFP growth rates were higher in Manitoba than in Alberta between 1957 and 1984. The growth in productivity historically more than offset the declining terms of trade which gave rise to a small increase in the returns to cost ratio in Manitoba. Of course, productivity growth has clearly not compensated for the adverse movements in the terms of trade for Manitoba grain farmers since 1973.

5.4 Estimates for Saskatchewan

The following part of this chapter is concerned with the estimation, reporting, and discussion of the output, input, and productivity indexes for the grain sector in Saskatchewan and its major soil zones (brown, dark brown, and black) for the period of 1961 to 1984. Output data by crop district prior to 1961 for the province of Saskatchewan were not readily available to the author.

5.4.1 Indexes of Output, Input, and Productivity

The Divisia-related index number procedures were utilized to construct output and input quantity indexes for Saskatchewan and its major soil zones for the period 1961-84. The TFP indexes were obtained by dividing the output quantity indexes by the input quantity indexes. The resultant output, input, and total factor productivity indexes are reported in Columns 1, 2 and 3 of Tables 5-7, 5-8, 5-9, and 5-10 for Saskatchewan, and its brown, dark brown, and black soil zones, respectively.

The output quantity index in Saskatchewan is also characterized by wide fluctuations, typically due to weather, around the trend. The output quantity index for the Saskatchewan grain sector rose from 0.279 in 1961 to 0.992 in 1984. The high level of output was achieved in 1982 in Saskatchewan and its major soil zones; in the black soil zone, high levels of output were achieved in all years between 1981 and 1984. The devastating effect of drought in 1961 in all soil zones in the province can be recognized clearly from these tables. The output quantity indexes at the zonal level rose from extreme lows of 0.267, 0.244, and 0.314 in 1961 to 0.780, 0.682, and 1.143 in 1984 for the brown, dark brown, and black soil zones, respectively (1984 also being a year of drought in the brown and dark brown soil zones). The output quantity indexes for Saskatchewan and its brown, dark brown, and black soil zones grew by annual compound rates of 2.3, 1.6, 2.0 znd 3.0 percent, respectively, over 1962-84, eliminating 1961, a year which imparts undue bias to productivity calculations. When the end year 1984 is also excluded, the growth rates of the output quantity index are 2.5, 2.1, 2.4, and 2.9 percent for Saskatchewan, and its brown, dark brown, and black soil zones, respectively.

It can be seen also from these tables that the growth rates of output quantity indexes for Saskatchewan and its soil zones vary considerably when the data is divided into two sub-periods. The output quantity index showed a higher growth rate in the sub-period 1973-84 for the Saskatchewan aggregate and the black soil zone, while the output growth rate is lower for the brown and dark brown soil zones for the same sub-period than in the earlier sub-period of 1962-72. If 1984 is eliminated from the second sub-period, the output growth rates in Saskatchewan and all its soil zones are higher between 1973-83 than between 1962-72.

The input quantity indexes for Saskatchewan and its major soil zones (brown, dark brown, and black) increased from 0.992, 0.961, 0.935, and 0.976 in 1961 to 1.370, 1.298, 1.466, and 1.353 in 1984, respectively. The dark brown soil zone shows the highest input quantity increases during the period of study. The growth rates associated with these input quantity indexes are estimated to be 1.5, 1.3, 2.2, and 1.9 percent per year over 1961-84 for Saskatchewan and its brown, dark brown and black soil zones, respectively. Further, the input quantity indexes grew by an annual compound rates of -0.1, -0.4, 0.2 and 0.2 percent for the sub-period of 1961-72, while these rates increased to 2.0, 1.6, 2.5 and 2.0 percent for the subperiod of 1973-84 for Saskatchewan and its brown, dark brown, and black soil zones, respectively. The considerable increases in the growth rates of these respective input quantity indexes clearly indicates, among other things, that mechanical and biochemical technology were increasingly applied in the Saskatchewan grain sector in the sub-period of 1973-84.

Total factor productivity in Saskatchewan grain production grew at the annual rate of 0.7 percent over 1962-84 or at 1.0 percent over 1962-83 (eliminating the downward bias associated with 1984 being a drought year in the brown and dark brown zones in the province). The respective zonal productivity growth rates for the brown, dark brown, and black soil zones were 0.3, 0.2 and 1.6 percent per year over 1962 to 1984 and 0.8, 0.3 and 1.6 percent per year over 1962 to 1983. These results suggest that the dark brown soil zone has the lowest growth rate of TFP which is associated with the higher increase in the growth rate of its input quantity index.

The brown and dark brown soil zones in Saskatchewan, like their counterparts in Alberta, seem to be characterized by slow TFP growth rates in the 1970s and early 1980s. For example, the TFP indexes grew by annual compound rates of 1.9 and 2.5 percent for the sub-period of 1962-72 for the brown and dark brown soil zones. However, these rates decreased to -0.4 and -1.0 percent for the sub-period of 1973-84 and changed to 1.4 and 0.6 percent for 1973-83. The black soil zone follows the same pattern as the black soil zone in Alberta and Manitoba which are characterized by a higher growth rate of TFP in the second sub-period (1973-84) than in the first sub-period (1962-72).

Output, input, and total factor productivity indexes are depicted graphically in Figures 5-7, 5-8, 5-9 and 5-10 for Saskatchewan (aggregate) and its brown, dark brown, and black soil zones, respectively. It can be seen from these graphs that input quantity indexes show a more stable trend and tend to increase smoothly over time. On the other hand, output and TFP indexes fluctuate widely and have essentially similar time trends over the period of study. The increase in input use in the Saskatchewan grain sector which occurred since 1973 can also be seen in these graphs.

The preceeding discussion suggests that TFP in the grain sector in Saskatchewan increased at approximately one percent per year across all soil zones over 1962 to 1983 with somewhat differential performance across respective soil zones. The productivity performance of grain production in the black soil zone is ranked first, followed in turn by the brown and dark brown soil zones. Moreover, productivity growth in grain production in the Saskatchewan black soil zone is higher than its counterpart in Alberta and less than that in Manitoba. The evidence on whether productivity growth in Saskatchewan grain production slowed down after 1973 is not conclusive, though it clearly increases in the black soil zone.

5.4.2 Terms of Trade and Returns to Cost

As in Alberta and Manitoba, Divisia-related index procedures were used to derive output and input price indexes for Saskatchewan. The terms of trade, it will be recalled, is obtained as a ratio of the output price index to the input price index, and the returns to cost ratio relates the terms of trade and TFP. The resultant output price, input price, terms of trade and returns to cost indexes are reported in Columns 4, 5, 6 and 7 of Table 5-7 for Saskatchewan grain production and of Tables 5-8, 5-9 and 5-10 for the brown, dark brown and black soil zones in Saskatchewan.

As shown from these tables, the output price indexes grew by annual compound rates of 6.2, 6.4, 6.2 and 5.9 percent for Saskatchewan and its soil zones, respectively, for the period of 1961-84. Corresponding input price indexes, on the other hand, increased at annual compound rates of 8.4, 8.6, 8.6, and 8.3 percent. In general, then, input price indexes in Saskatchewan grew faster than the output price indexes for the entire period of study except for the years of 1972 and 1973. In these two years output prices rose more

Table 5-7. Indexes of Grain Output, Inputs, Prices, and Productivity, Saskatchewan Grain Sector, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.2787	0.9918	0.2810	1.3472	0.7415	1.8169	0.5105
1962	0.6644	0.9918	0.6699	1.2788	0.7575	1.6882	1.1309
1963	0.9232	1.0045	0.9191	1.3255	0.7730	1.7147	1.5760
1964	0.6153	1.0298	0.5975	1.2470	0.7921	1.5743	0.9406
1965	0.7537	1.0628	0.7092	1.3125	0.8111	1.6182	1.1476
1966	1.0351	1.1002	0.9408	1.3563	0.8777	1.5453	1.4539
1967	0.6542	1.0864	0.6022	1.2317	0.9373	1.3141	0.7913
1968	0.7462	1.0518	0.7095	1.0271	0.9737	1.0548	0.7484
1969	0.9494	1.0905	0.8706	0.9951	0.9836	1.0117	0.8808
1970	0.6797	0.9346	0.7273	1.0852	0.9723	1.1161	0.8117
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.8334	1.0211	0.8162	1.5249	1.0598	1.4389	1.1744
1973	0.8433	1.0372	0.8131	3.4110	1.1976	2.8482	2.3157
1974	0.7269	1.0934	0.6648	3.2505	1.4292	2.2743	1.5120
1975	0.8899	1.2468	0.7137	2.8176	1.7561	1.6045	1.1452
1976	1.0998	1.2043	0.9132	2.3155	2.0063	1.1541	1.0540
1977	1.1129	1.2637	0.8807	2.2314	2.2069	1.0111	0.8904
1978	1.1540	1.3473	0.8565	2.7835	2.3716	1.1737	1.0053
1979	0.9297	1.3825	0.6725	3.3886	2.5922	1.3072	0.8791
1980	0.9526	1.2670	0.7519	3.9876	3.0140	1.3230	0.9947
1981	1.1652	1.2974	0.8981	3.6077	3.4050	1.0595	0.9516
1982	1.3332	1.3223	1.0082	3.2486	3.6695	0.8853	0.8926
1983	1.2403	1.3439	0.9229	3.5333	3.7652	0.9384	0.8661
1984	0.9921	1.3695	0.7244	3.4448	3.8498	0.8948	0.6482

Annual Growth Rates in %

1961-84	3.2	1.5	1.7	6.2	8.4	-2.1	-0.04
1962-84	2.3	1.6	0.7	6.6	8.8	-2.0	-1.3
1962-83	2.5	1.6	1.0	6.8	8.7	-1.8	-0.9
1961-72	5.5	0.05	5.4	-1.5	3.5	-4.8	-0.04
1962-72	1.7	-0.1	1.9	-1.4	3.5	-4.7	-2.9
1973-83	4.4	2.2	2.1	2.2	11.9	-8.7	-6.8
1973-84	3.2	2.0	1.2	2.1	11.2	-8.2	-7.1

Table 5-8. Indexes of Grain Output, Inputs, Prices, and Productivity, Saskatchewan Brown Soil Zone, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.2667	0.9614	0.2774	1.3320	0.7394	1.8015	0.4997
1962	0.7393	1.0174	0.7267	1.2621	0.7422	1.7005	1.2357
1963	1.0675	1.0307	1.0357	1.3136	0.7571	1.7350	1.7970
1964	0.6626	1.0500	0.6310	1.2192	0.7789	1.5653	0.9878
1965	0.9235	1.0826	0.8530	1.2897	0.8004	1.6113	1.3745
1966	1.1780	1.1083	1.0629	1.3367	0.8731	1.5310	1.6273
1967	0.6365	1.0878	0.5851	1.2250	0.9339	1.3117	0.7675
1968	0.7578	1.0532	0.7195	1.0127	0.9713	1.0426	0.7502
1969	1.0892	1.0982	0.9918	0.9768	0.9761	1.0007	0.9925
1970	0.8892	0.9483	0.9377	1.0674	0.9589	1.1132	1.0438
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9263	1.0208	0.9074	1.4759	1.0542	1.4000	1.2704
1973	0.8806	1.0335	0.8521	3.4091	1.1946	2.8538	2.4316
1974	0.8180	1.0907	0.7500	3.2337	1.4195	2.2781	1.7085
1975	1.0432	1.2411	0.8405	2.7695	1.7390	1.5926	1.3386
1976	1.3108	1.2298	1.0659	2.2042	1.9563	1.1267	1.2009
1977	1.1393	1.2678	0.8986	2.1412	2.1875	0.9788	0.8796
1978	1.2116	1.3383	0.9053	2.8341	2.3604	1.2007	1.0870
1979	1.0788	1.3647	0.7905	3.5766	2.5875	1.3823	1.0927
1980	1.0105	1.2595	0.8023	4.2222	3.0156	1.4001	1.1233
1981	1.1085	1.2734	0.8705	3.7860	3.4581	1.0948	0.9530
1982	1.3929	1.2863	1.0829	3.4362	3.7604	0.9138	0.9895
1983	1.2629	1.2954	0.9749	3.6102	3.8528	0.9370	0.9135
1984	0.7800	1.2975	0.6012	3.5529	3.9750	0.8938	0.5373

Annual Growth Rates in %

1961-84	2.7	1.3	1.4	6.4	8.6	-2.0	-0.06
1962-84	1.6	1.3	0.3	6.9	8.9	-2.0	-1.6
1962-83	2.1	1.4	0.8	7.1	8.9	-1.7	-0.1
1961-72	5.9	0.02	5.9	-1.5	3.6	-4.9	-0.07
1962-72	1.5	-0.4	1.9	-1.4	3.7	-4.9	-3.1
1973-83	3.3	2.7	0.6	3.0	12.4	-8.3	-7.0
1973-84	1.2	1.6	-0.4	2.8	11.6	-7.9	-8.3

Table 5-9. Indexes of Grain Output, Inputs, Prices, and Productivity, Saskatchewan Dark Brown Soil Zone, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.2435	0.9351	0.2604	1.3652	0.7444	1.8340	0.4776
1962	0.5696	0.9618	0.5922	1.2937	0.7639	1.6935	1.0030
1963	0.8135	0.9776	0.8321	1.3394	0.7795	1.7183	1.4299
1964	0.5194	1.0056	0.5165	1.2520	0.7992	1.5666	0.8091
1965	0.5880	1.0417	0.5645	1.3234	0.8193	1.6153	0.9118
1966	0.9515	1.0903	0.8727	1.3693	0.8759	1.5633	1.3643
1967	0.5903	1.0770	0.5481	1.2516	0.9341	1.3399	0.7344
1968	0.6695	1.0479	0.6389	1.0395	0.9710	1.0705	0.6840
1969	0.8797	1.0820	0.8130	0.9971	0.9835	1.0138	0.8243
1970	0.5679	0.9214	0.6163	1.0865	0.9878	1.0999	0.6779
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.7509	1.0331	0.7268	1.5223	1.0587	1.4379	1.0451
1973	0.8381	1.0589	0.7915	3.4863	1.1990	2.9077	2.3014
1974	0.6318	1.1230	0.5626	3.2938	1.4361	2.2936	1.2904
1975	0.7570	1.2892	0.5872	2.8553	1.7657	1.6171	0.9495
1976	0.9837	1.2612	0.7800	2.3085	2.0252	1.1399	0.8891
1977	1.0249	1.3395	0.7651	2.2232	2.2249	0.9992	0.7646
1978	0.9488	1.4332	0.6620	2.8327	2.4033	1.1787	0.7803
1979	0.7999	1.4792	0.5408	3.4943	2.6347	1.3263	0.7172
1980	0.7348	1.3638	0.5388	4.1183	3.0872	1.3340	0.7187
1981	0.9691	1.3959	0.6942	3.7084	3.5229	1.0527	0.7308
1982	1.1766	1.4241	0.8262	3.3444	3.8096	0.8779	0.7253
1983	1.0638	1.4371	0.7402	3.5783	3.9292	0.9107	0.6741
1984	0.6817	1.4655	0.4652	3.5050	4.0164	0.8727	0.4059
Annual Growth Rates in %							
1961-84	2.9	2.1	0.8	6.2	8.6	-2.2	-1.4
1962-84	1.9	2.1	-0.2	6.6	8.9	-2.1	-2.3
1962-83	2.4	2.1	0.2	6.9	8.9	-1.9	-1.6
1961-72	6.3	0.5	5.8	-1.6	3.4	-4.8	0.07
1962-72	2.7	0.2	2.5	-1.5	3.5	-4.8	-2.4
1973-83	3.3	2.7	0.6	2.4	12.5	-8.6	-8.5
1973-84	1.5	2.5	-1.0	2.2	11.7	-8.4	-9.3

Table 5-10. Indexes of Grain Output, Inputs, Prices, and Productivity, Saskatchewan Black Soil Zone, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.3136	0.9756	0.3214	1.3454	0.7421	1.8130	0.5828
1962	0.6943	0.9965	0.6967	1.2796	0.7610	1.6815	1.1715
1963	0.9193	1.0067	0.9132	1.3239	0.7771	1.7036	1.5557
1964	0.6624	1.0337	0.6408	1.2639	0.7943	1.5912	1.0197
1965	0.7899	1.0656	0.7413	1.3213	0.8112	1.6288	1.2074
1966	1.0051	1.1011	0.9128	1.3609	0.8814	1.5440	1.4094
1967	0.7131	1.0903	0.6540	1.2214	0.9409	1.2981	0.8490
1968	0.7977	1.0529	0.7576	1.0274	0.9766	1.0520	0.7970
1969	0.9142	1.0911	0.8379	1.0071	0.9874	1.0200	0.8546
1970	0.6491	0.9363	0.6933	1.0977	0.9693	1.1325	0.7851
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.8498	1.0145	0.8377	1.5611	1.0636	1.4678	1.2295
1973	0.8223	1.0276	0.8002	3.3448	1.1978	2.7925	2.2346
1974	0.7558	1.0795	0.7001	3.2210	1.4293	2.2536	1.5778
1975	0.9141	1.2276	0.7446	2.8163	1.7581	1.6019	1.1928
1976	1.0663	1.1613	0.9182	2.4004	2.0185	1.1892	1.0919
1977	1.1644	1.2216	0.9532	2.3015	2.2051	1.0437	0.9948
1978	1.2940	1.3062	0.9907	2.7238	2.3574	1.1554	1.1446
1979	0.9400	1.3398	0.7016	3.1973	2.5685	1.2448	0.8734
1980	1.1114	1.2189	0.9118	3.7484	2.9685	1.2627	1.1514
1981	1.3767	1.2553	1.0967	3.4218	3.3102	1.0337	1.1337
1982	1.4214	1.2844	1.1067	3.0619	3.5438	0.8640	0.9562
1983	1.3737	1.3178	1.0424	3.4522	3.6265	0.9519	0.9923
1984	1.4125	1.3525	1.0444	3.3410	3.6958	0.9040	0.9441

Annual Growth Rates in %

1961-84	3.8	1.4	2.4	5.9	8.3	-2.2	0.02
1962-84	3.0	1.4	1.6	6.3	8.6	-2.1	-0.05
1962-83	2.9	1.4	1.6	6.5	8.6	-1.9	-0.04
1961-72	4.7	0.1	4.6	-1.4	3.4	-4.6	-0.02
1962-72	1.2	-0.2	1.5	-1.2	3.5	-4.6	-3.2
1973-83	5.8	2.0	3.7	1.6	11.5	-8.9	-5.5
1973-84	5.5	2.0	3.5	1.6	10.7	-8.2	-5.1

Figure 5-7. Indexes of Output, Input and Total Factor Productivity,

Saskatchewan Grain Sector, 1961 to 1984 (1971=1.000)

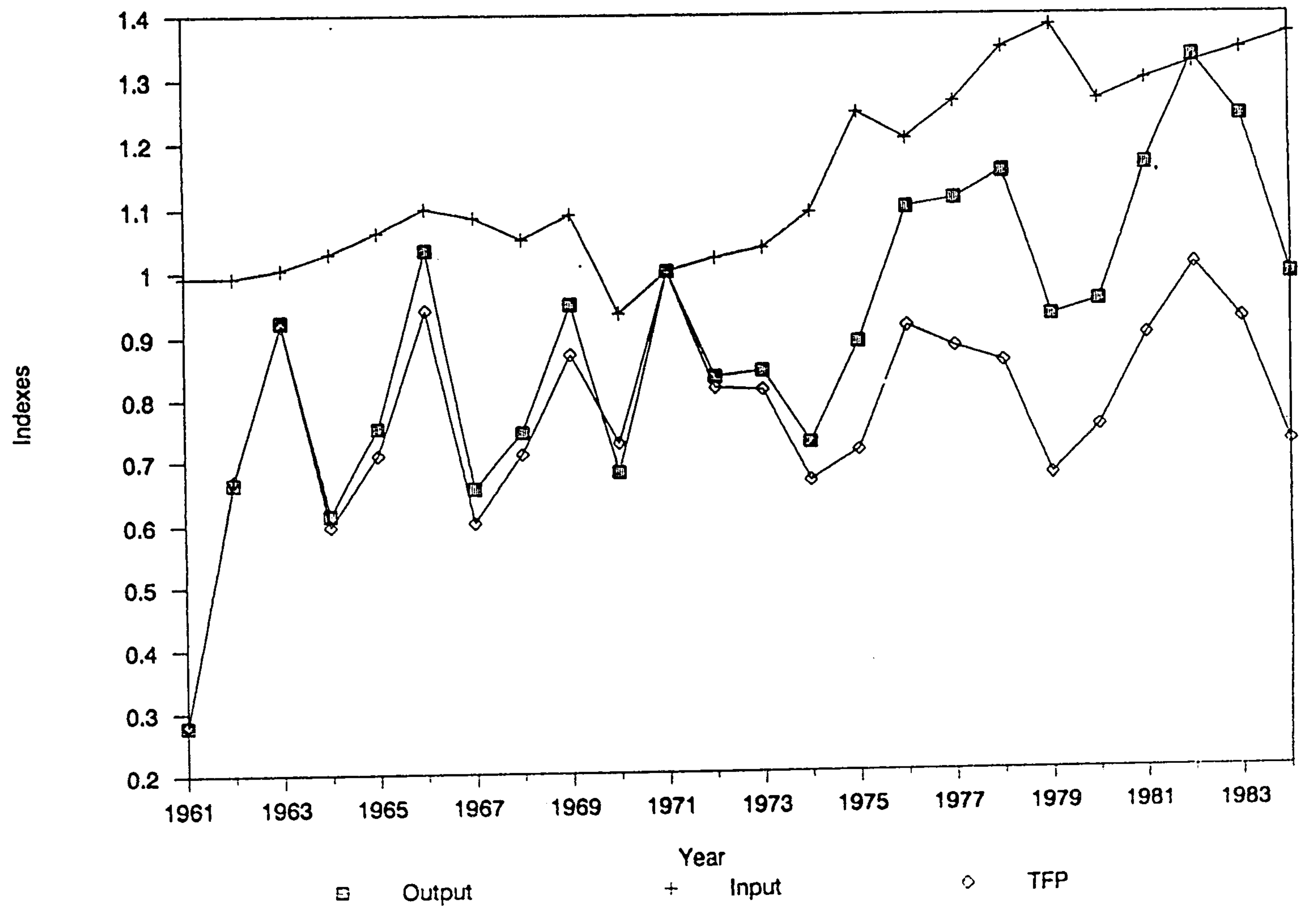


Figure 5-8. Indexes of Grain Output, Input and Total Factor Productivity, Brown Soil Zone, Saskatchewan, 1961 to 1984 (1971=1.000)

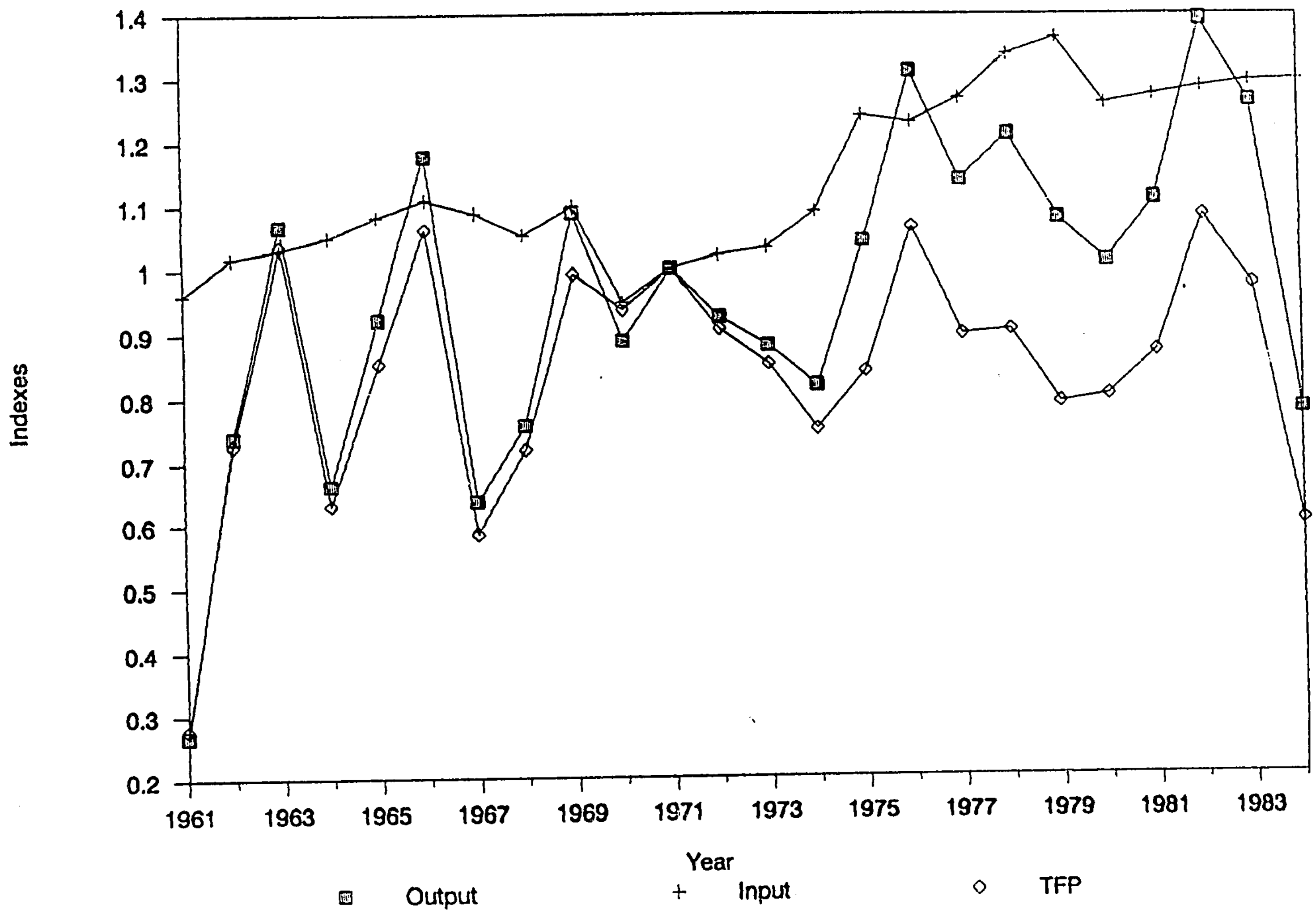


Figure 5-9. Indexes of Grain Output, Input and Total Factor Productivity, Dark Brown Soil Zone, Saskatchewan, 1961 to 1984 (1971=1.000)

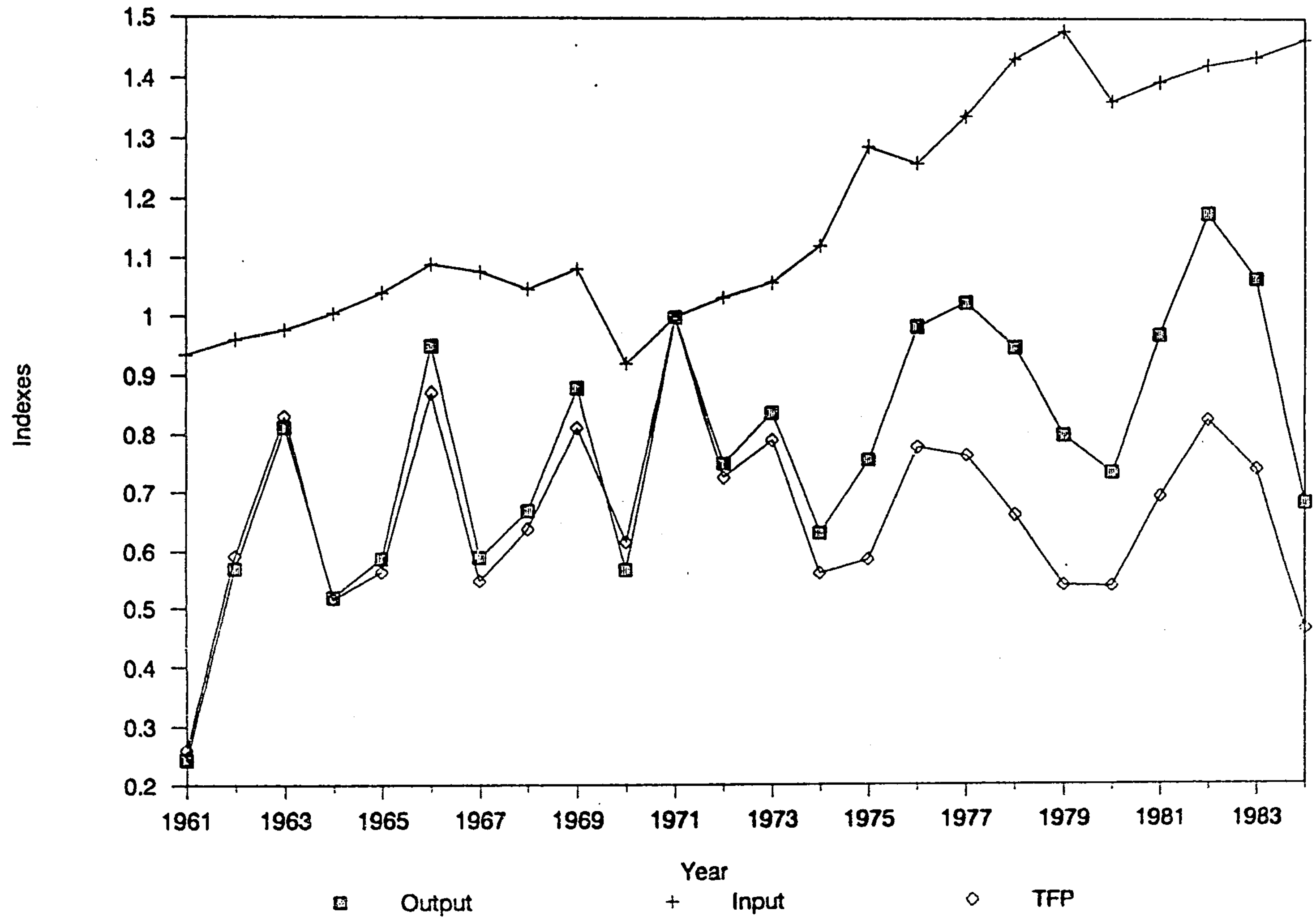
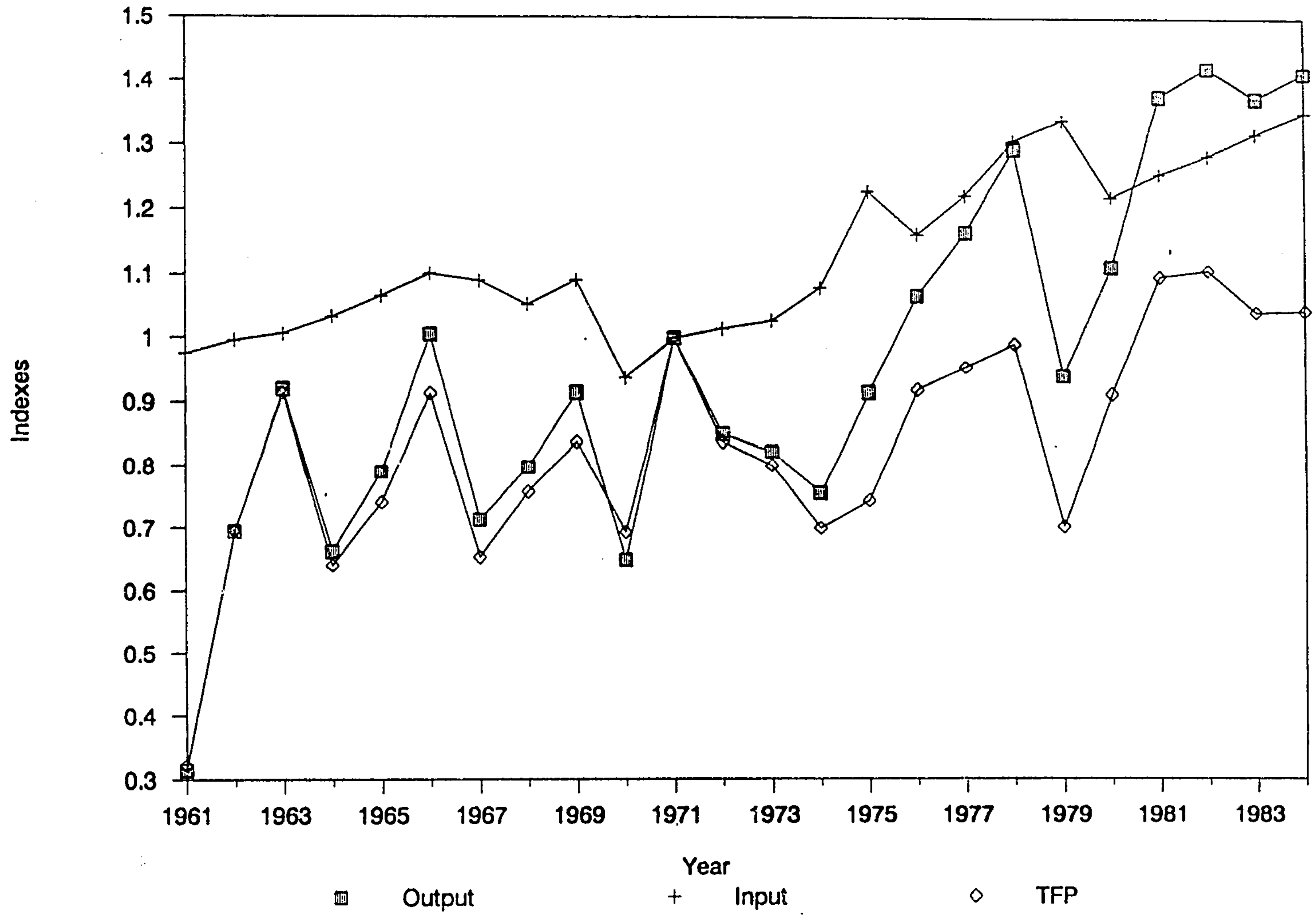


Figure 5-10. Indexes of Grain Output, Input and Total Factor Productivity, Black Soil Zone, Saskatchewan, 1961 to 1984 (1971=1.000)



rapidly than input prices causing significant increases in terms of late 1970s and early 1980s the considerable increases in input prices which occurred led to general deterioration in the terms of trade for Saskatchewan grain farmers. This deterioration, in turn, was a factor worsening the income position of grain producers.

These tables also indicate that the terms of trade for Saskatchewan farmers declined by an annual compound rate of approximately 2 percent over the period of study. However, the income position of farmers can not be determined by the terms of trade (cost price squeeze) alone without taking into consideration the impact of productivity growth which also is an influence on returns to cost. In general, productivity growth in Saskatchewan grain production was not quite sufficient to overcome adverse movements in the terms of trade during the period of study. As a consequence, the returns to cost ratio generally fell except, perhaps, for the black soil zone. In all soil zones since 1973, however, the returns to cost ratio declined considerably. This was caused primarily by deterioration in the terms of trade (led by steadily escalating input prices), although slow down in productivity growth in the brown and dark brown soil zones was also apparent.

5.5 Prairie Estimates

The last part of this chapter is devoted to reporting and discussion of estimated output, input, and productivity growth for the entire prairie region, including the major soil zones of the prairies. The main reasons for estimating grain productivity at the aggregate level is to provide a composite picture of trends in grain output, grain input use, and productivity for the prairie grain sector as a whole as well as for its major soil zones. The output and input levels are aggregated at the zonal level by adding up the respective provincial soil zones figures; for example, the outputs and inputs of the prairie brown soil zone are obtained by adding up the outputs and inputs of the Alberta and Saskatchewan brown soil zones. The prairie aggregate output and input figures were obtained by adding up the respective output and input levels of Alberta, Saskatchewan, and Manitoba.

5.5.1 Output, Input, and Productivity Indexes

Having aggregated the output and input data for the prairies and its zonal grain sectors, the Divisia-related index number procedure was used to derive output and input quantity indexes. The total factor productivity indexes were again obtained as ratio of output quantity indexes to corresponding input quantity indexes. The resultant output, input, and TFP indexes are reported in Columns 1, 2 and 3 of Tables 5-11, 5-12, 5-13, and 5-14 and are depicted graphically in Figures 5-11 through 5-14 for the prairie aggregate grain sector, the prairie brown soil zone, the prairie dark brown soil zone and the prairie black soil zone, respectively.[11] These tables show that the grain output quantity index grew over the period from 1962 to 1984 at an annual compound rate of 2.9 percent for the prairie as a whole, at 2.0 percent for the prairie brown soil zone, at 2.3 percent for the prairie dark brown soil zone, at 3.2 percent for the prairie black soil zone, and at 6.1 percent for the gray soil zone, assumed to be entirely in Alberta. When the year, 1984, another drought year in the southern prairies, is also excluded, these respective output growth rates are 3.1, 2.5, 2.7, 3.2, and 6.2 percent per year over 1962-83.

Aggregate input use in grain production in the prairie region increased by 1.9 percent per annum over 1962-84 with the dark brown zone (2.4 percent) and gray soil zone (2.2 percent) registering input growth rates above the prairie average and the brown zone (1.7 percent) and black zone (1.4 percent) having rates somewhat below the prairie average. The higher input growth rate in the dark brown soil zone, for instance, is partially attributable to a lower level of labor decline and to a higher rate of increase in the opportunity cost of land than in the brown zone. When the period of study is divided into sub-periods (eliminating the end years, 1961 and 1984, which are drought years), the annual rate of input growth is much higher in the second sub-period, 1973-83, than in the initial sub-period, 1962-72 (2.4 percent versus 0.2 percent). This, in part, might be attributed to the heavy reliance of the prairie grain sector on mechanical and, to a lesser extent, biochemical technology in the later 1970s and early 1980s and the associated increases in

[11]The estimates of output, input, and total factor productivity for the prairie gray soil zone are the same as those estimated for the gray soil zone in Alberta; see Table 5-5 earlier in this chapter.

specialization and size of grain farms in the prairie region during this time. It is also due to the greater rate of increase in the service flows (opportunity costs) of land calculated for the 1973-83 sub-period.

Total factor productivity (TFP) in the prairie grain sector shows considerable variation from year to year, its fluctuations closely mirroring those of the output quantity index and also being heavily influenced by weather variables. The measurement and assessment of trends in productivity, as a consequence, are very sensitive to the specific time periods involved. For example, the inclusion of the very adverse drought year, 1961, in the period of study leads to upwardly biased estimates of productivity performance whereas the inclusion of 1984, also a year of drought in the southern prairies, tends to bias productivity estimates in a downward direction. As a result, the period of 1962 to 1983 likely provides the fairest period of assessment of productivity performance in the prairie region. Over the period from 1962 to 1983, total factor productivity in the prairie grain sector increased by 1.2 percent per year. The brown and dark brown zones (see Figure 5-15) evidence annual productivity growth below the prairie norm (0.8 and 0.3 percent, respectively) whereas the black and gray soil zones register productivity advances above the prairie average (1.8 and 3.7 percent, respectively). The sub-period estimates suggest that productivity grew more rapidly in grain production in the black and gray soil zones in the latter half of the period (1973-83) than in the initial half (1962-72), whereas exactly the opposite occurred in the brown and dark brown soil zones.

5.5.2 Terms of Trade and Returns to Cost

A useful by-product of productivity measurement is the information which can be generated on the terms of trade and returns-to-cost for prairie grain farmers (see the latter Columns of Tables 5-11 through 5-14). The aggregate grain input price index (comprising both actual and imputed prices) grew more rapidly than the grain output price index, particularly in the latter half of the period. As a consequence, the terms of trade for prairie grain farmers tended to decline by some 2 to 3 percent per year over the study period. No marked differences in changes in terms of trade occur across soil zones,

Table 5-11. Indexes of Grain Output, Inputs, Prices, and Productivity, Prairie Grain Sector, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.3603	0.9545	0.3775	1.3597	0.7311	1.8598	0.7020
1962	0.6831	0.9563	0.7143	1.2869	0.7361	1.7483	1.2488
1963	0.8450	0.9711	0.8701	1.3175	0.7456	1.7670	1.5376
1964	0.6892	0.9971	0.6912	1.2688	0.7595	1.6706	1.1547
1965	0.8052	1.0260	0.7848	1.3210	0.8070	1.6369	1.2847
1966	0.9987	1.0609	0.9414	1.3744	0.8522	1.6128	1.5182
1967	0.7336	1.0757	0.6820	1.2446	0.9060	1.3737	0.9368
1968	0.8474	1.0332	0.8202	1.0372	0.9273	1.1185	0.9174
1969	0.9279	1.0438	0.8890	0.9880	0.9617	1.0273	0.9133
1970	0.7292	0.9248	0.7885	1.0575	0.9616	1.0997	0.8671
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9004	1.0102	0.8913	1.5518	1.0860	1.4289	1.2736
1973	0.9064	1.0411	0.8706	3.3511	1.1890	2.8184	2.4538
1974	0.7655	1.1159	0.6860	3.1902	1.4278	2.2343	1.5327
1975	0.9495	1.2423	0.7643	2.8116	1.7614	1.5962	1.2200
1976	1.1081	1.2483	0.8877	2.3719	1.9795	1.1982	1.0637
1977	1.1463	1.2389	0.9253	2.2165	2.1951	1.0097	0.9343
1978	1.2480	1.3141	0.9497	2.6509	2.3480	1.1290	1.0722
1979	1.0753	1.3822	0.7780	3.2191	2.6110	1.2329	0.9591
1980	1.1232	1.3047	0.8609	3.7817	3.0072	1.2575	1.0826
1981	1.3541	1.3571	0.9978	3.4160	3.4163	0.9999	0.9977
1982	1.4834	1.3527	1.0966	3.0020	3.6184	0.8296	0.9098
1983	1.3850	1.3784	1.0048	3.4093	3.6756	0.9275	0.9320
1984	1.2225	1.4051	0.8700	3.3135	3.7301	0.8883	0.7729

Annual Growth Rates in %

1961-84	3.6	1.8	1.7	5.8	8.5	-2.4	-0.1
1962-84	2.9	1.9	1.0	6.2	8.9	-2.4	-1.4
1962-83	3.1	1.9	1.2	6.4	8.9	-2.3	-1.2
1961-72	4.9	0.3	4.6	-1.5	3.8	-5.1	-0.1
1962-72	2.2	0.2	2.0	-1.4	4.0	-5.1	-3.3
1973-83	5.4	2.4	2.9	1.6	11.9	-9.2	-6.6
1973-84	4.5	2.3	2.2	1.6	11.0	-8.5	-6.5

Table 5-12. Indexes of Grain Output, Inputs, Prices, and Productivity, Prairie Brown Soil Zone, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.2654	0.9549	0.2779	1.3444	0.7261	1.8515	0.5146
1962	0.6818	0.9968	0.6840	1.2756	0.7225	1.7655	1.2076
1963	1.0092	1.0125	0.9967	1.3238	0.7342	1.8031	1.7972
1964	0.6844	1.0353	0.6611	1.2341	0.7526	1.6398	1.0840
1965	0.9533	1.0673	0.8932	1.2969	0.7986	1.6240	1.4505
1966	1.2168	1.0933	1.1130	1.3548	0.8515	1.5911	1.7708
1967	0.6924	1.0872	0.6369	1.2424	0.9063	1.3708	0.8730
1968	0.8606	1.0516	0.8184	1.0238	0.9317	1.0989	0.8993
1969	1.1221	1.0807	1.0383	0.9686	0.9558	1.0134	1.0522
1970	0.9164	0.9539	0.9607	1.0554	0.9525	1.1080	1.0645
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9399	1.0270	0.9152	1.4829	1.0730	1.3820	1.2648
1973	0.9064	1.0526	0.8611	3.3821	1.1754	2.8774	2.4777
1974	0.8504	1.1178	0.7608	3.1882	1.3961	2.2836	1.7374
1975	1.0988	1.2607	0.8716	2.7757	1.7167	1.6169	1.4092
1976	1.3506	1.2780	1.0568	2.2291	1.9036	1.1710	1.2375
1977	1.1172	1.2855	0.8691	2.1425	2.1326	1.0046	0.8731
1978	1.2527	1.3518	0.9267	2.8018	2.3092	1.2133	1.1244
1979	1.1256	1.3947	0.8071	3.5816	2.5665	1.3955	1.1263
1980	1.1016	1.3125	0.8393	4.1834	2.9704	1.4084	1.1821
1981	1.2559	1.3460	0.9331	3.7661	3.4000	1.1077	1.0335
1982	1.4564	1.3435	1.0840	3.3968	3.6576	0.9287	1.0067
1983	1.3786	1.3613	1.0127	3.6056	3.7065	0.9728	0.9851
1984	0.8482	1.3640	0.6218	3.5178	3.7983	0.9262	0.5759

Annual Growth Rates in %

1961-84	3.1	1.7	1.4	6.3	8.6	-2.0	-0.1
1962-84	2.0	1.7	0.3	6.8	8.9	-2.0	-1.7
1962-83	2.5	1.7	0.8	7.0	8.9	-1.8	-1.0
1961-72	6.6	0.2	6.4	-1.6	3.8	-5.3	-0.1
1962-72	2.2	-0.2	2.4	-1.5	4.1	-5.4	-3.1
1973-83	3.9	2.2	1.1	3.0	12.3	-8.2	-6.5
1973-84	1.8	1.9	-0.1	2.8	11.4	-7.8	-7.9

Table 5-13. Indexes of Grain Output, Inputs, Prices, and Productivity, Prairie Dark Brown Soil Zone, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.3049	0.9209	0.3311	1.3633	0.7282	1.8722	0.6198
1962	0.5810	0.9441	0.6154	1.2933	0.7377	1.7532	1.0789
1963	0.8513	0.9623	0.8847	1.3330	0.7507	1.7757	1.5709
1964	0.6173	0.9934	0.6214	1.2581	0.7669	1.6405	1.0194
1965	0.6988	1.0300	0.6784	1.3159	0.8109	1.6228	1.1010
1966	1.0267	1.0744	0.9556	1.3724	0.8521	1.6106	1.5391
1967	0.6690	1.0808	0.6190	1.2522	0.9056	1.3827	0.8559
1968	0.7832	1.0505	0.7455	1.0390	0.9322	1.1146	0.8310
1969	0.9253	1.0630	0.8705	0.9822	0.9628	1.0201	0.8880
1970	0.6485	0.9304	0.6970	1.0555	0.9764	1.0810	0.7535
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.8336	1.0372	0.8037	1.5307	1.0789	1.4188	1.1403
1973	0.8903	1.0768	0.8268	3.4046	1.1823	2.8796	2.3809
1974	0.7146	1.1499	0.6214	3.2231	1.4168	2.2749	1.4137
1975	0.8576	1.3044	0.6575	2.8242	1.7517	1.6123	1.0600
1976	1.0366	1.3122	0.7900	2.3374	1.9743	1.1839	0.9353
1977	1.0303	1.3398	0.7690	2.2133	2.1816	1.0145	0.7802
1978	1.0593	1.4321	0.7397	2.7332	2.3545	1.1608	0.8587
1979	0.9499	1.4967	0.6347	3.3692	2.6240	1.2840	0.8149
1980	0.9598	1.4077	0.6818	3.9356	3.0643	1.2843	0.8757
1981	1.1748	1.4613	0.8039	3.5545	3.4974	1.0163	0.8171
1982	1.3246	1.4721	0.8998	3.1666	3.7280	0.8494	0.7643
1983	1.2129	1.4970	0.8102	3.4927	3.7867	0.9224	0.7473
1984	0.8264	1.5118	0.5466	3.3910	3.8702	0.8762	0.4790

Annual Growth Rates in %

1961-84	3.1	2.4	0.7	6.1	8.7	-2.4	1.7
1962-84	2.3	2.4	-0.1	6.4	9.0	-2.3	-2.4
1962-83	2.7	2.4	0.3	6.6	8.9	-2.2	-1.9
1961-72	5.8	0.7	5.0	-1.6	3.7	-5.2	-0.04
1962-72	2.7	0.4	2.2	-1.5	3.9	-5.2	-3.1
1973-83	4.4	2.9	1.4	2.0	12.4	-9.2	-7.9
1973-84	2.6	2.7	-0.1	1.9	11.5	-8.6	-8.7

Table 5-14. Indexes of Grain Output, Inputs, Prices, and Productivity, Prairie Black Soil Zone, 1961 to 1984 (1971=1.000)

Year	Output Quantity (Y)	Input Quantity (X)	Total Prod'y (Y/X)	Output Price P_Y	Input Price P_X	Terms of Trade (P_Y/P_X)	Return to Cost (TFP.TT)
1961	0.3760	0.9766	0.3850	1.3624	0.7225	1.8857	0.7260
1962	0.7264	0.9863	0.7365	1.2885	0.7276	1.7709	1.3042
1963	0.8072	0.9964	0.8101	1.3091	0.7360	1.7787	1.4409
1964	0.7124	1.0166	0.7008	1.2830	0.7469	1.7178	1.2038
1965	0.8267	1.0333	0.8001	1.3311	0.7956	1.6731	1.3386
1966	0.9137	1.0631	0.8595	1.3811	0.8461	1.6323	1.4029
1967	0.7778	1.0670	0.7290	1.2441	0.9014	1.3802	1.0061
1968	0.8511	1.0241	0.8311	1.0404	0.9207	1.1300	0.9391
1969	0.8710	1.0727	0.8120	0.9982	0.9578	1.0422	0.8462
1970	0.7028	0.9165	0.7668	1.0589	0.9552	1.1086	0.8501
1971	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9130	1.0213	0.8940	1.5822	1.0923	1.4485	1.2949
1973	0.9099	1.0311	0.8825	3.3245	1.1965	2.7785	2.4519
1974	0.7622	1.0921	0.6979	3.1791	1.4377	2.2112	1.5433
1975	0.9289	1.2455	0.7458	2.8155	1.7808	1.5810	1.1791
1976	1.0524	1.1837	0.8891	2.4283	2.0123	1.2067	1.0729
1977	1.2038	1.2075	0.9969	2.2381	2.2342	1.0017	0.9987
1978	1.3031	1.2812	1.0171	2.5919	2.3922	1.0835	1.1020
1979	1.0605	1.3207	0.8030	3.0867	2.6408	1.1689	0.9386
1980	1.1331	1.1971	0.9465	3.6439	3.0014	1.2141	1.1492
1981	1.4309	1.2410	1.1530	3.2946	3.3701	0.9776	1.1272
1982	1.5320	1.2575	1.2183	2.8589	3.5450	0.8065	0.9825
1983	1.3914	1.2695	1.0960	3.3514	3.5980	0.9315	1.0209
1984	1.4778	1.3008	1.1361	3.2545	3.6554	0.8903	1.0115

Annual Growth Rates in %

1961-84	3.8	1.3	2.5	5.7	8.6	-2.7	-0.1
1962-84	3.2	1.4	1.8	6.0	8.9	-2.6	-0.1
1962-83	3.2	1.4	1.8	6.2	9.0	-2.5	-0.8
1961-72	4.5	0.1	4.4	-1.5	3.9	-5.2	-1.0
1962-72	1.8	-0.8	1.9	-1.3	4.1	-5.2	-3.5
1973-83	5.8	1.6	4.2	1.1	11.5	-9.3	-5.5
1973-84	5.5	1.5	4.0	1.2	10.6	-8.5	-4.9

zones suffered slightly less adverse movements in these cost/price squeeze pressures. Productivity growth, of course, partially compensated for such adverse changes in grain farmers' terms of trade. In the prairie grain sector as a whole, the returns-to-cost ratio declined by some 1.2 percent per year, with a slightly higher rate of decline occurring in the dark brown zone and a slight increase in this ratio occurring in the gray soil zone over the period from 1962 to 1983. As anticipated, the returns-to-cost ratio deteriorated considerably in all soil zones in the sub-period since 1973.

5.5.3 Productivity and Factor Intensity

The final empirical issue which will be addressed are trends in labor productivity, total factor productivity, and factor intensity. Factor intensity is the difference between labor productivity, defined in this study in terms of output per man-hour, and total factor productivity, obtained as the ratio of output to all inputs combined. Change in factor intensity can be defined as the weighted sum of growth in the capital-labor ratio and growth in the materials-labor ratio (Capalbo and Denny, 1986). The growth rates of labor productivity, TFP, and factor intensity for the prairie grain sector and its key soil zone, the

Table 5-15. Annual Compound Growth Rates of Labor Productivity, Total Factor Productivity, and Factor Intensity. Prairie Grain Sector and Black Soil Zone, Various Time Periods (Percent).

	Labor Productivity		Total Factor Productivity		Factor Intensity	
	Prairies	Black	Prairies	Black	Prairies	Black
1962-84	4.3	4.9	1.0	1.8	3.3	3.1
1962-83	4.4	4.8	1.2	1.8	3.2	3.0
1962-72	3.7	3.3	2.0	1.9	1.7	1.4
1973-83	8.1	9.3	2.9	4.2	5.2	5.1
1973-84	7.0	8.9	2.2	4.0	4.8	4.9

Figure 5-11. Indexes of Output, Input and Total Factor Productivity, The Prairie Grain Sector, 1961 to 1984 (1971=1.000)

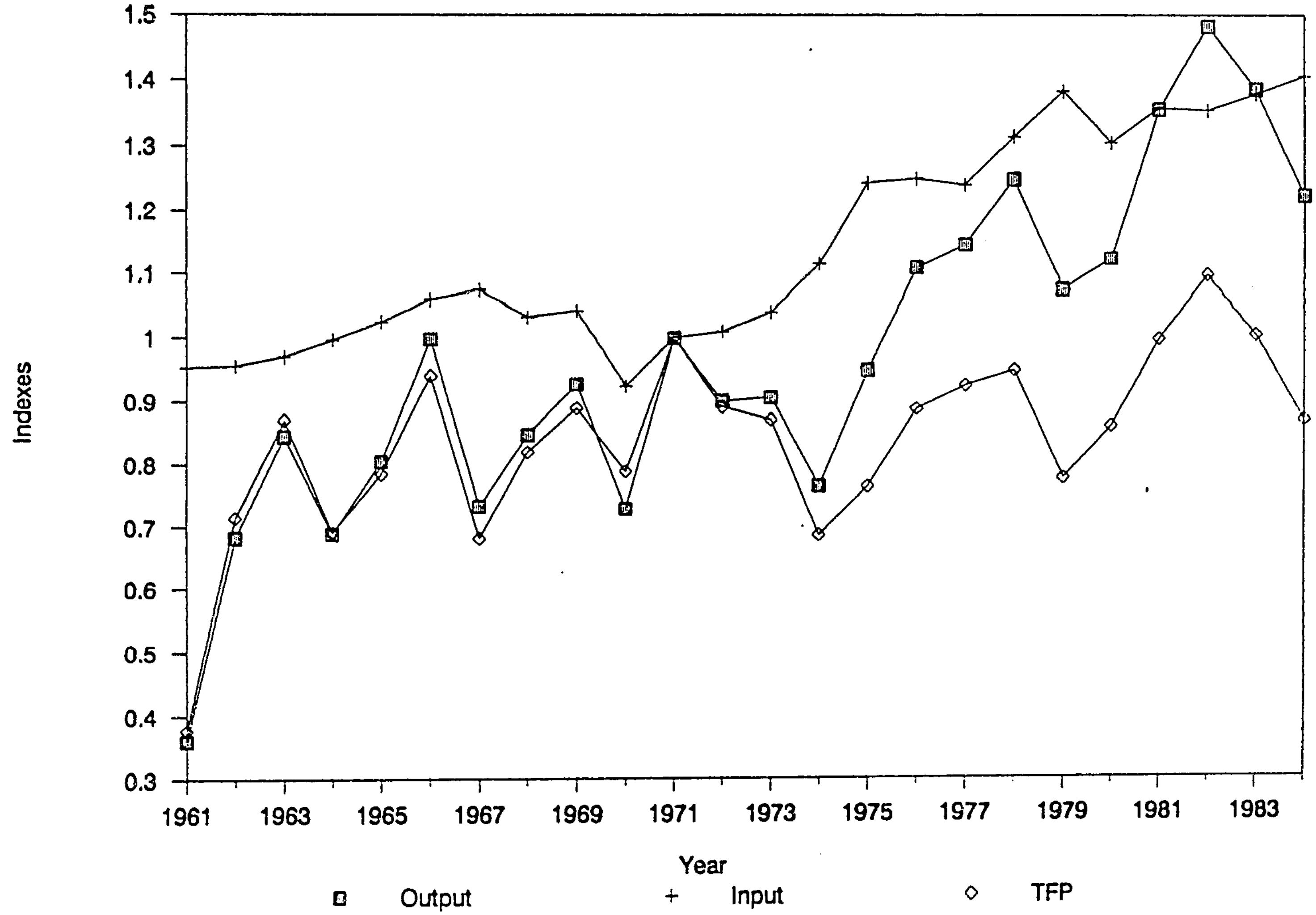


Figure 5-12. Indexes of Grain Output, Input and Total Factor Productivity, Brown Soil Zone, Prairies, 1961 to 1984 (1971=1.000)

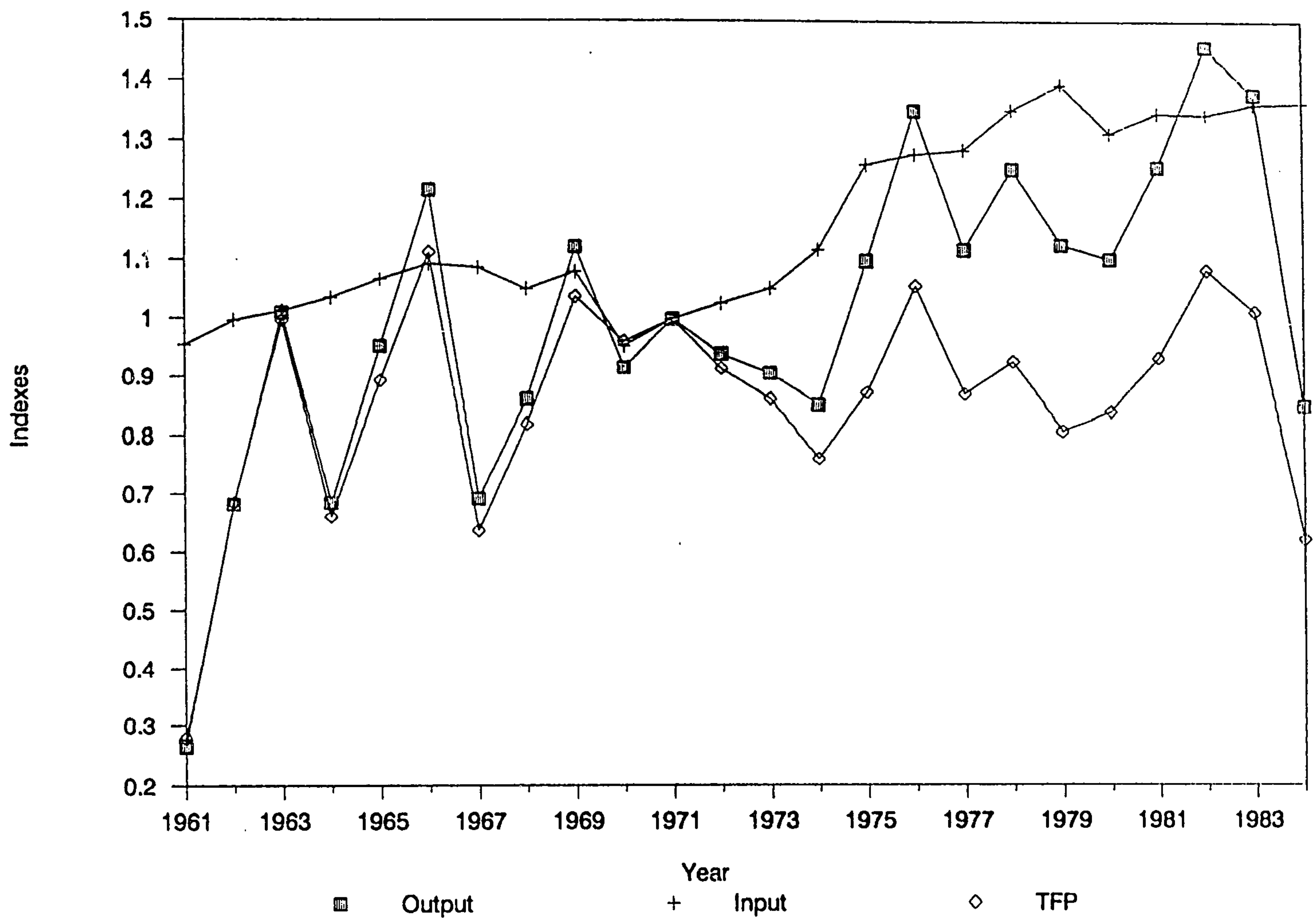


Figure 5-13. Indexes of Grain Output, Input and Total Factor Productivity, Dark Brown Soil Zone, Prairies, 1961 to 1984 (1971=1.000)

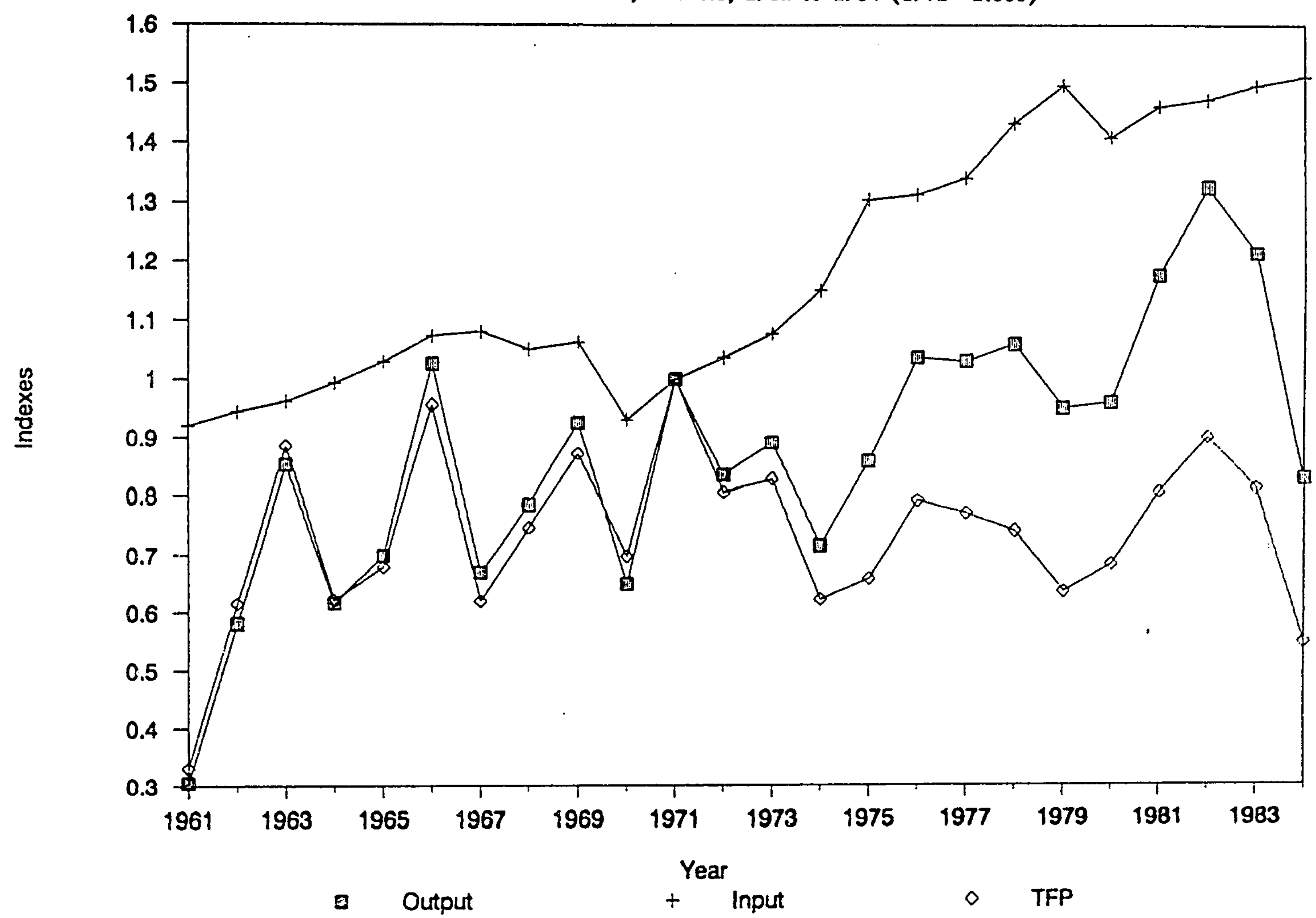


Figure 5-14. Indexes of Grain Output, Input and Total Factor Productivity, Black Soil Zone, Prairies, 1961 to 1984 (1971=1.000)

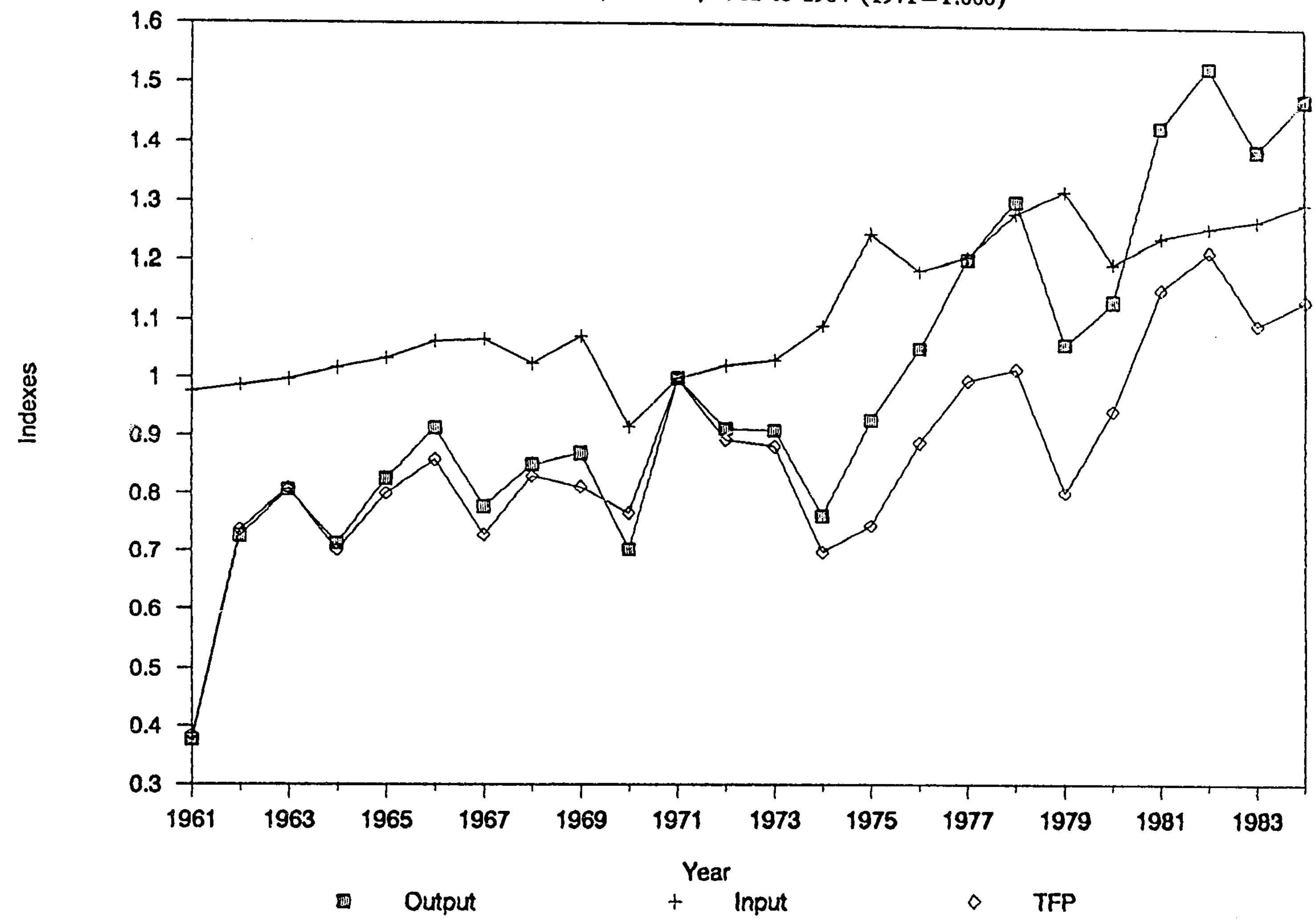
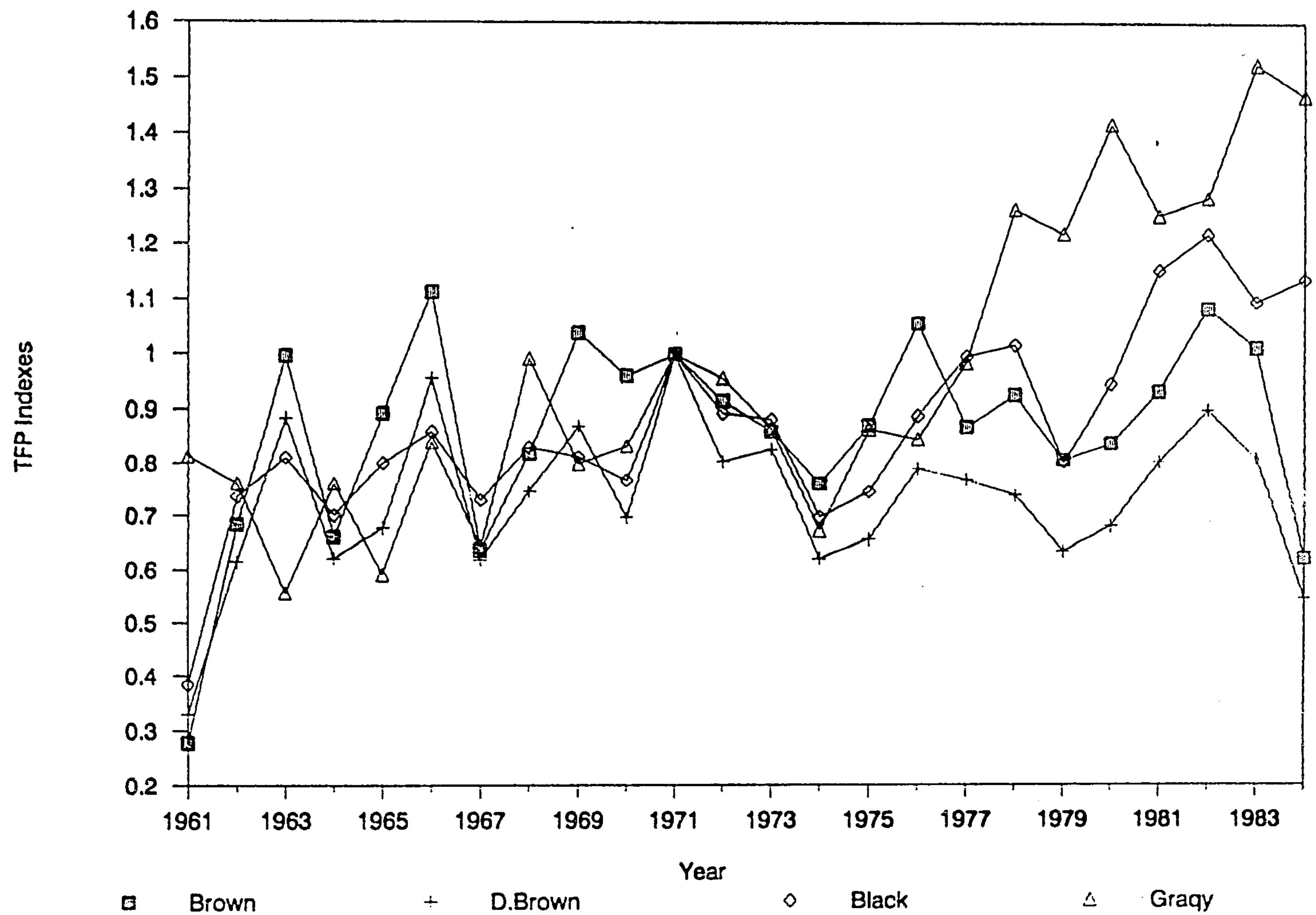


Figure 5-15. Total Factor Productivity by Soil Zone,

The Prairie Region, 1961 to 1984



black zone, are reported in the Table 5-15. Over 1962 to 1983, labor productivity in prairie grain production increased by 4.4 percent per year, considerably higher than the annual change of 1.2 percent in total factor productivity. Factor intensity in prairie grain production, the residual difference, rose by 3.2 percent annually. Both labor productivity and factor intensity in grain production grew more rapidly in the latter half of the study period as prairie grain farmers continued to rely heavily on mechanical technology, to substitute capital for labor, and to increase fertilizer and chemical use at relatively rapid rates.

5.6 Summary

From the preceding discussion one can summarize the major empirical results of this chapter in the following points:

1. One of the most important results of this chapter is the sensitivity of the growth rates of output, input and total factor productivity to the chosen period of time. The inclusion or exclusion of drought years such as 1961 and 1984, for example, has major effects on estimated growth rates.
2. Total factor productivity in the Alberta grain sector grew by an annual compound rate of 1.3 percent over the period from 1962 to 1983. Moreover, TFP grew at annual compound rates of 2.3 percent over the first sub-period 1962-72, and 4.2 percent over the second sub-period 1973-83. Accordingly, one can conclude that growth rates of TFP in the Alberta grain sector as a whole did not decline in the late 1970s and early 1980s, as has some time been suggested. The respective zonal productivity growth rates for the brown, dark brown, black, and gray soil zones were 1.2, 0.5, 0.8 and 3.7 percent per year over the period from 1962 to 1983. In general, the productivity growth rates for soil zones in the Alberta grain sector show the gray zone exibiting the highest rate, followed by the brown, black and dark brown soil zones.
3. Total factor productivity in the Manitoba grain sector grew at annual rate of 1.4 percent per year over 1962-83. This result shows that the growth rate of TFP in the Manitoba grain sector is higher than those in Alberta and its major soil zones except

for the gray soil zone. However, the growth rate of TFP in the Manitoba grain sector declined from 6.3 percent in the first sub-period (1962-72) to 2.7 percent in the second sub-period (1973-83).

4. Total factor productivity in the Saskatchewan grain sector increased at an annual rate of 1.0 percent over 1962-83. The respective zonal productivity growth rates for the brown, dark brown, and black soil zones were 0.8, 0.2 and 1.6 per year, respectively, over this same period. The brown and dark brown soil zones in Saskatchewan seem to be characterized by slower TFP growth rates in the 1970s and early 1980s. However, the Saskatchewan black soil zone follows the same pattern as the black soil zone in Alberta and Manitoba which are characterized by a higher growth rates of TFP in the second sub-period (1973-83) than in the first sub-period (1962-72).

5. The rate of productivity advance in the prairie grain sector as a whole is estimated at 1.2 percent per year over the period 1962 to 1983. Further, productivity growth rates at the zonal level grew by annual rates of 0.8, 0.3, 1.8, and 3.7 percent for the brown, dark brown, black, and gray soil zones, respectively, over the same period of time. The sub-period estimates of TFP growth rates suggest that productivity grew more rapidly in grain production in the black and gray soil zones in the sub-period of 1973-83, than in the initial sub-period (1962-72), whereas exactly the opposite occured in the brown and dark brown soil zones.

6. The terms of trade for prairie grain farmers tended to decline by some 2 to 3 percent per year over the study period. The returns to cost ratio, on the other hand, for the prairie as a whole declined by some 1.2 percent per year, with a slightly higher rate of decline occuring the dark brown zone and a slight increase in this ratio occuring in the gray soil zone over the period from 1962 to 1983. As anticipated, the returns to cost ratio deteriorated considerably in all soil zones in the second sub-period (1973-84).

6. Production Technology in the Alberta Grain Sector

6.1 Introduction

The prairie grain sector is a very significant sub-sector of Canadian agriculture and a key industry in Western Canada. It is important that we understand the characteristics of production relations in this critical, but changing sector. Given our time series data base on input quantities and prices, as well as output quantities and prices, the analysis of production technology in the grain sector can be undertaken. This, in turn, can be carried out through the use of either the production function or the cost function approach, employing improved production/cost specification and aspects of duality.

Since the production function defines the physical relationship between inputs and outputs, it has been extensively utilized in economics to understand the economics of production in both manufacturing and the agricultural sector. An improved understanding of features of production structure such as returns to scale, substitutability and complementarity among input factors, distributional or factor shares, and the nature of technical change provides a basis for policy information. Most of the previous studies dealing with production technology in Canadian agriculture (Islam and Veeman, 1980; Lopez, 1980; and Adamowicz, 1986) have been concerned with estimation of an aggregate cost function for the entire sector. Studies can be criticized on the ground that one can not separate the influence of a particular subsector such as grain or livestock on the whole agricultural sector. Therefore, the information obtained from such aggregate studies are mixed and might not be as helpful as guidelines for short and long run planning for either of these two agricultural subsectors. Unlike previous studies which have generally been concerned with the estimation of production structure in Canadian agriculture at the aggregate level, in this study we try to estimate and analyze the production relations on a more disaggregated level. To be specific, the translog cost function will be utilized to study the production technology of the grain sector in the province of Alberta. Alberta has been chosen as a representative in studying the grain sector in the prairie provinces mainly because the data set for Alberta was more complete and extended back to 1957 which gives us more flexibility in terms of degrees of freedom which are required for estimation of the model.

In this chapter, the rationale for choosing a flexible form production/cost specification will be briefly examined, the essential production relationships for the Alberta grain sector will be defined and estimated, and the results and conclusions with respect to the production technology of the grain sector will be presented.

6.2 The Production Function Approach

A production function is a mathematical form expressing the relationship between inputs and outputs in physical terms. A simple form of a single output production funtion can be expressed as:

$$Y = f(X_i) \tag{6-1}$$

where: (Y) is the amount of output produced, (f) denotes a function, and X_i are the variable inputs. This mathematical expression can take different forms: linear, quadratic, logarithmic, etc. Historically, the well known production functions which have been widely utilized in studying the production relations in manufacturing and agriculture have been the Cobb-Douglas, Leontief, and constant elasticity of substitution (CES) functions.

This class of production functions have come to be known in the literature as inflexible functional forms, which means that the estimation of these forms involves *a priori* restriction on the elasticity of substitution. However, the wide applicability of these functional forms can be attributed to some of their useful properties. In the case of the Cobb-Douglas function, the input coefficients are often specified to sum to one, which indicates constant returns to scale. These coefficients also represent factor shares and can be viewed as the cost shares of respective inputs in the total cost of production. Finally, a Cobb-Douglas coefficient represents the elasticity of output with respect to the particular input in question. More importantly, the Cobb-Douglas function can be transformed into a logarithmic form and estimated very easily. However, these attractive properties are offset by some highly restrictive properties. First, the Cobb-Douglas function restricts the elasticities of substitutions between a pair of inputs to unity, and the production surface to be homothetic. Secondly, it can not be used when complementarity takes place between factor inputs; in other words, the Cobb-Douglas function can not handle negative values of the elasticities of substitution.

In the early 1960's the CES production function was introduced into the literature by Arrow, Chenery, Minhas, and Solow (1961). The CES function does not impose *a priori* restrictions on the values of elasticities of substitution to be unity, and it can be reduced to the Cobb-Douglas function by imposing certain restrictions on its coefficients. Hence, the founders of this function consider the Cobb-Douglas function as a special case of the CES function. Like the Cobb-Douglas function, the CES function has some serious limitations when it is applied in the real world. First, the CES function restricts the elasticities of substitution between factor inputs to be constant. Second, the estimation of the CES production function becomes too complicated when more than two inputs are used in the production process. Third, it is not linear in logarithms. Fourth, it can not handle the negative value of the elasticities of substitution which implies, in turn, the input pairs must be substitutes and cannot be complements.

Because of the limitations of these two types of production functions, economists in the last two decades have developed improved production and cost specifications which are now known in the literature as flexible functional forms. These functional forms can be estimated with fewer *a priori* restrictions on the elasticities of substitutions and allow one to study homothetic as well as non-homothetic production structure. Among these flexible functional forms are the transcendental logarithmic (translog) production function (Christensen, Jorgenson and Lau, 1971), the generalized Leontief function, and the generalized Cobb-Douglas function (Diewert, 1971, 1973). The common feature of these flexible forms is the ability of each of them to provide a second order local approximation to any twice differentiable production or cost function. Moreover, these varieties of flexible forms involve similar estimation procedures which makes it extremely difficult to differentiate among them on theoretical or econometrical grounds. However, in recent years, some economists have tried to discriminate between these three flexible forms. Berndt, Darrough and Diewert (1977) compared the translog, generalized Leontief and the generalized Cobb-Douglas functions on the basis of a Baysian testing technique and on the basis of their comformity with *a priori* information. The conclusion of this study was in favor of the translog function. The same conclusion was found by Kiefer (1975) when she discriminated between the translog and generalized Leontief functions by using a Box-Cox transformation. On the other hand, some authors have argued that the generalized Leontief and the square rooted quadratic function are preferable to the translog function. Appelbaum (1979), for example, compared a variety of generalized forms of production functions which were generated by imposing certain restrictions on the parameters of the Box-Cox transformation function on the basis of parametric testing procedures. He utilized the 1929-71 U.S. manufacturing data of Berndt and Christensen (1974). The conclusion of his study shows that the generalized Leontief and the square-rooted quadratic function were preferable over the translog function.

In agricultural research studies which have been conducted to examine and analyze production relations in agriculture, the translog production/cost function has been much more widely used than other flexible forms. Binswanger (1973), Brown (1978), Chotigeat (1978), Islam and Veeman (1980), Ray (1982), Furtan (1981), and Adamowicz (1985) have all used translog forms to study agricultural production relations. These authors have typically concluded that translog functions are preferabie over inflexible forms and fit the agricultural data relatively well. The Cobb-Douglas and CES are regarded to be less appropriate functional forms to study agricultural production technology by most of these authors.

In common with most past flexible form work on the agricultural sector, the translog cost function will be used in this study to examine the characteristics of production relations in the Alberta grain sector. Moreover, the Cobb-Douglas specification will be empirically tested, to see whether it is an appropriate representation of production relations in the Alberta grain sector, as opposed to the translog specification.

6.3 Literature Review

The introduction of the translog production function in the early 1970's and the application of the duality theorem have attracted many agricultural economists in the last decade to study production relations in the agricultural sector. In the following part of this chapter, we shall briefly introduce several selected studies which utilize flexible functional forms to examine and analyze production technology in agriculture.

The earliest study in this context was done by Binswanger (1973). He used a homothetic translog cost function to study the production relations in U.S. agriculture. The input set in his study was composed of land, labor, machinery, fertilizer, and other inputs. Binswanger's conclusions show that land-labor, land-machinery, land-fertilizer, labor-machinery, labor-other inputs, machinery-other inputs, and fertilizer-other inputs are substitutes in the production process. Complementarity relationships were found for the land-other inputs, labor-fertilizer and machinery-fertilizer input pairs. Binswanger also rejected the Cobb-Douglas specification, finding it to be an inapproriate function to study the production technology in U.S. agriculture.

Brown (1978) used a homothetic translog cost function to study factor substitution and productivity in U.S. agriculture for the period 1947-74. Capital, hired labor, and material are the input factors in Brown's study. The main conclusion of his study indicated substitutability between both the capital-labor and labor-material input pairs but complementarity between the capital-material pair.

Lopez (1980) used the generalized Leontief function to examine and analyze the structure of production and the derived demand for inputs in Canadian agriculture. The following results are reported in his study. First, all inputs are substitutes in the production process. Second, relative factor prices do play an important role in the determination of the demand for the different inputs. Third, Leontief and Cobb-Douglas types of production functions have been rejected as appropriate specifications to study production structure in Canadian agriculture. Fourth, the hypothesis of constant returns to scale in Canadian agriculture is rejected.

Islam and Veeman (1980) utilized the translog cost function as a framework to study the change in input use and technical change in Canadian agriculture for the period 1961-78. Land, labor, machinery, fertilizer, and energy are the major input factors considered in their study. Their conclusion indicates that substitutability was found among land-labor, land-machinery, labor-machinery, labor-energy, machinery-fertilizer, and machinery-energy pairs. In contrast, complementarity relationships are reported between energy-fertilizer and between labor-fertilizer. The authors also concluded that the translog cost function is a more appropriate specification to study production technology in Canadian agriculture than the Cobb-Douglas.

Ray (1982) used a translog cost function to analyze U.S. agricultural production in a multi-output context. In Ray's study, crops and livestock were treated as two distinct outputs. The conclusion of this study shows a declining trend in the degree of substitutability between capital and labor in U.S. agriculture for the period 1939-77, and an increase in the input price elasticities of demand for all inputs.

Kunimoto (1983) examined the characteristics of Canadian agricultural production technology by utilizing a multiple-input, multiple-output, non-homothetic translog cost function for the period 1961-79. The major input groups in his study were land, labor, capital and materials. The presence of substitutability among all input pairs except land-labor is one of the main conclusions of his study. The other interesting conclusion in his study is the complementarity between labor and capital in Western Canada.

Adamowicz (1985) analyzed the effect of disaggregation on the estimation of production technology in Canadian agriculture. He used a non-homothetic translog cost function as a framework for his study. The author indicated that disaggregation of input data into more variables will enhance the estimation of production technology relations. He also shows a decline in substitutability over time among input factors in Canadian agriculture.

6.4 Translog Cost Function Approach

The translog cost function is defined as a mathematical relationship which expresses the production cost as a function of the prices of inputs and the amount of output produced. Such functional forms were introduced into the economic literature in the early 1970's. Since then, the translog cost function has been widely used by agricultural economists and researchers in other areas of economics. The wide use of this functional form, in turn, is attributed to one of the most useful mathematical concepts known in the economics literature: the concept of duality.[12] The most important contribution of the duality theorem to the economics discipline lies in the fact that one can estimate and analyze production relations by using the cost function approach which is dual to the production function.

There are many reasons for using the dual function approach in economic analysis. First, use of flexible functional forms involving the dual function permits imposing less restrictive assumptions on the parameters of the production technology (such as the elasticities of substitution) than do the Cobb-Douglas and CES functions. Second, estimation of the translog cost function with price data may permit more precise econometric estimation of production technology. This is because there is often less multicolliniarity among factor prices. Third, data on input prices are sometimes more readily available and more accurate than data on input quantities. Fourth, by taking the first derivative of the translog cost function with respect to the price of a certain input, one can easily obtain the derived demand equation for that particular input.

The specification of the cost function can be written as:

$$C = f\,[P_L, P_N, P_K, P_F, P_M, Q, T] \qquad (6\text{-}2)$$

where: C = total cost of producing the output quantity Q, P_L = the price of land, P_N = the labor wage per hour, P_K = the price of machinery, P_F = the price of fertilizer and pesticides, and P_M = the price of other materials. All these prices are in index forms. T is the time trend which is used as a proxy for technical change.

[12]For more detailed information on duality, see Diewert (1971), Varian (1978) and Beattie and Taylor (1985).

Mathematically, equation (6-2) can be expressed in a non-homothetic form as:

$$\ln C = B_0 + \sum_i^n B_i \ln P_i + B_q \ln Q + B_t T + 1/2 \sum_i^n \sum_j^n B_{ij} \ln P_i \ln P_j + \sum_i^n B_{iq} \ln P_i \ln Q + B_{qt} \ln QT + \sum_i^n B_{it} \ln P_i T + 1/2\, B_{qq} (\ln Q)^2 + 1/2\, B_{tt} T^2 \qquad (6\text{-}3)$$

where: $P = (P_i, \ldots\ldots, P_n)$ are input prices, and B's are the parameters of the translog cost function to be estimated. This translog cost function must satisfy the following requirements: non-negative at all prices and output levels, continuous and linear in prices, monotonically increasing in input prices, non-decreasing in output, and concave in prices.[13] The non-homothetic translog cost function expressed in Equation 6-3 is considered to be the general class of translog cost functions. The homothetic case can be obtained by setting $B_{iq} = 0$, and the Cobb-Douglas cost function can be generated by imposing the restrictions that $B_{iq} = 0$, $B_{it} = 0$ and $B_{ij} = 0$.

As in previous translog cost function studies, the only restrictions which must be imposed *a priori* to estimate equation 6-3 are continuity, symmetry, and linear homogeneity in input prices (see, for example, Capalbo 1988). The other restrictions can be tested and verified in a nested fashion as sequential hypotheses. Therefore, their acceptance or rejection will depend on the actual values of the estimated parameters of the translog cost function. Homogeneity and symmetry conditions require that the following restrictions are imposed on the cost function.

1. Symmetry condition requires:

$$B_{ij} = B_{ji} \qquad (6\text{-}4)$$

2. Homogeneity condition requires:

$$\sum_i^n B_i = 1, \quad \sum_i^n B_{ij} = \sum_j^n B_{ji} = 0 \qquad (6\text{-}5)$$

Applying Shephard's lemma to equation (6-3), the cost-minimizing derived demands for various inputs can be obtained. Differentiating equation (6-3) with respect to input

[13]For more information on the mathematical proof of these conditions, see Diewert (1977) and Varian (1978).

price P_i, one can generate the demand equation for input i:

$$\frac{\partial \ln C}{\partial \ln P_i} = S_i = B_i + \sum_{ij}^{n} \ln P_j + B_{iq} \ln Q + B_{it} T \qquad (6\text{-}6)$$

where: S_i is the cost share of the i-th input in total cost of producing the output quantity Q. S_i also can be derived from the cost equation (6-3) as:

$$S_i = \partial \ln C / \partial \ln P_i = P_i X_i / \Sigma P_i X_i \qquad (6\text{-}7)$$

where P_i is the price of input i, X_i is the quantity of input i and $\Sigma P_i X_i$ = total cost. The sum of the cost shares across all inputs is equal to one.

6.4.1 Elasticities of Substitution

The elasticity of substitution (σ_{ij}) is a concept which measures the ease with which one member of an input pair can be substituted for the other in the production process. Allen partial elasticities of substitution can be calculated from the parameters of the translog cost function as follows:

a. Own elasticities of substitution:

$$\sigma_{ii} = (B_{ii} + S_i^2 - S_i) / S_i^2 \qquad (6\text{-}8)$$

where: σ_{ii} is the own elasticity of substitution, B_{ii} is the estimated coefficient of the i-th input, and S_i is the cost share of the i-th input.

b. Cross elasticities of substitution:

$$\sigma_{ij} = 1 + (B_{ij} / S_i S_j) \qquad (6\text{-}9)$$

where: B_{ij} is the estimated coefficient of the interaction term P_i and P_j, and S_j is the cost share of the j-th input.

Whether substitutability or complementarity exists between input pairs will be determined by the sign of (σ_{ij}). If σ_{ij} has a positive value, that means the two inputs of the input pair are substitutes throughout the production process. On the other hand, a negative value indicates that the input pair are complements in the production process. The value of (σ_{ij}) also indicates the degree of flexibility that producers have in adjusting their input mix in response to relative input price change (Debertin, 1985). In other words, a high value of elasticity of substitution between two input factors will indicate that farmers have a high degree of flexibility to substitute one for another when the price of either input is changed. Moreover, the elasticity of substitution is defined as a measure of the proportionate change in the input ratio, relative to the proportionate change in the marginal rate of substitution. Therefore, the value of (σ_{ij}) has a great influence in determining the shape of the isoquant. If (σ_{ij}) is equal to zero, there is no possibility of substitution between the two inputs at all, and the corresponding isoquant is a right angle shape. If the value σ_{ij} is equal to infinity, the two inputs are perfect substitutes, and the isoquant will be a diagonal straight line.

6.4.2 Own and Cross Price Elasticities

Own and cross price elasticities of demand for various input factors can also be computed from the parameters of the translog cost function. The own price elasticity of demand, which is defined as the responsiveness of quantity demanded of a particular input to change in its own price, can be computed as:

$$\eta_{ii} = \sigma_{ii} S_i \qquad (6\text{-}10)$$

where: σ_{ii} is the own elasticity of substitution of the i-th input and S_i is the cost share of the i-th input. The cross price elasticity of demand, which is defined as the responsiveness of quantity demanded of the i-th input to a change in the price of the j-th input, can be obtained from the parameters of the translog cost function as:

$$\eta_{ij} = \sigma_{ij} S_j \qquad (6\text{-}11)$$

where: σ_{ij} is the elasticity of substitution between the i-th and j-th inputs, and S_j is the cost share of the j-th input.

Knowing own and cross price elasticities of demand, and the elasticities of substitutions among input factors, will permit better understanding of the production structure of the Alberta grain sector which, in turn, is related to the nature of productivity growth in this important subsector.

6.5 Price Indexes and Cost Shares

To estimate the parameters of the translog cost function, one needs to derive input price indexes, cost shares for different input factors, and an aggregate output index (in our case, for grain output encompassing, wheat, barley, oats, flaxseed, and canola). The derivation of output and input data for the purpose of studying productivity growth in the Alberta grain sector was described in Chapters 3 and 4 in this thesis. This data set -- specifically, that part of it relating to the province of Alberta -- will be utilized to estimate a translog cost function for the Alberta grain sector. The model is formally specified in Section 6.7.

Five major input groups have been chosen to study production relations in the Alberta grain sector. These input groups are classified as: land and buildings; labour (owner operator, family labor and hired labor); machinery (depreciation, and opportunity cost); fertilizer (fertilizer lime and pesticides); and materials (seeds, irrigation equipment, electricity, and fuel and oil). The major sources of these input data are the published material and a few unpublished series from Statistics Canada.

The cost share of each factor input is derived by dividing the cost of the i-th input by the total cost of all inputs. As shown in Equation 6-7, the cost share of the i-th input is:

$$S_i = P_iX_i / \Sigma P_iX_i$$

where P_i and X_i are the price and the quantity of the i-th input, and ΣP_iX_i is the total cost of all inputs.

Detailed descriptions of the cost shares of the various input factors have been given in Appendix 5 of this thesis. The Divisia-related index procedure which has been used in the previous chapters to derive input and output indexes is used to construct price indexes for different input factors. Briefly, as outlined in Chapter 2, the respective discrete approximations to the Divisia price and quantity indexes, often called Tornqvist or Tornqvist-Theil indexes, can be written in the following form:

$$\text{Log } P_t - \text{Log } P_{t-1} = \Sigma \bar{w}_{it} (\text{Log } P_{it} - \text{Log } P_{i,t-1}) \qquad (6\text{-}12)$$

$$\text{Log } Q_t - \text{Log } Q_{t-1} = \Sigma \bar{w}_{it} (\text{Log } Q_{it} - \text{Log } Q_{i,t-1}) \qquad (6\text{-}13)$$

where: P's and Q's are the prices and quantities, respectively, and w_{it} is the share of i-th input factor in total cost or the share of i-th output in total value product. As has been argued previously, the wide applicability of the Divisia index can be attributed to its close relationship to the translog cost function. Diewert (1976) has shown that the Tornqvist-Theil index exactly corresponds to the linearly homogenous translog cost function.

Equation (6-7) is used to construct cost shares for the different input factors, equation (6-12) is utilized to derive input price indexes, and equation (6-13) is used to construct the aggregate output quantity index. The cost share tables and the input price indexes are provided in Appendices 4 and 5. However, graphical representation of these input price indexes is shown in Figure 6-1, while the cost shares of land, labor, machinery, fertilizer, and materials in Alberta grain production are depicted in Figure 6-2.

In Figure 6-1, it is evident that input prices were more stable up to 1972. In other words, during this period all input prices show low rates of increase. This phenomenom might partially explain the lower growth rate of input quantity (0.07 percent) during this period. As shown in Table D-1, Appendix 4, after 1972 input prices rose much more rapidly. These sharp increases in input prices may be attributed largely to the so called oil crisis in 1973 and the ensuing period of higher inflation. During 1973 to 1984, the growth rate of the overall input quantity index increased considerably to approximately 3 percent per year. The price of land recorded the highest increase of any input price during the period of 1973-84. This rapid increase in the price of land, especially prior to 1982, could be related to the fact that the role of land might be viewed as a hedge against inflation and as a source of current and expected capital gains (Veeman and Fantino 1985). It can be seen also from Figure 6-1 that the price of the machinery input rose by a lower rate than did the labor wage per hour. This supports the generalization that farmers in the Alberta grain sector are acting rationally when they substitute a relatively cheaper input (machinery) for a more expensive input (labor). The price indexes of fertilizer and material increased in a similar pattern. The relationship between these two input groups can be explained in terms of cause and effect. That is, the increase in energy prices which is the main component of material inputs might also cause the price of fertilizer to move in the same

Figure 6-1. Input Price Indexes of Major Input Groups, Alberta Grain Sector, 1957 to 1984 (1971=1.000)

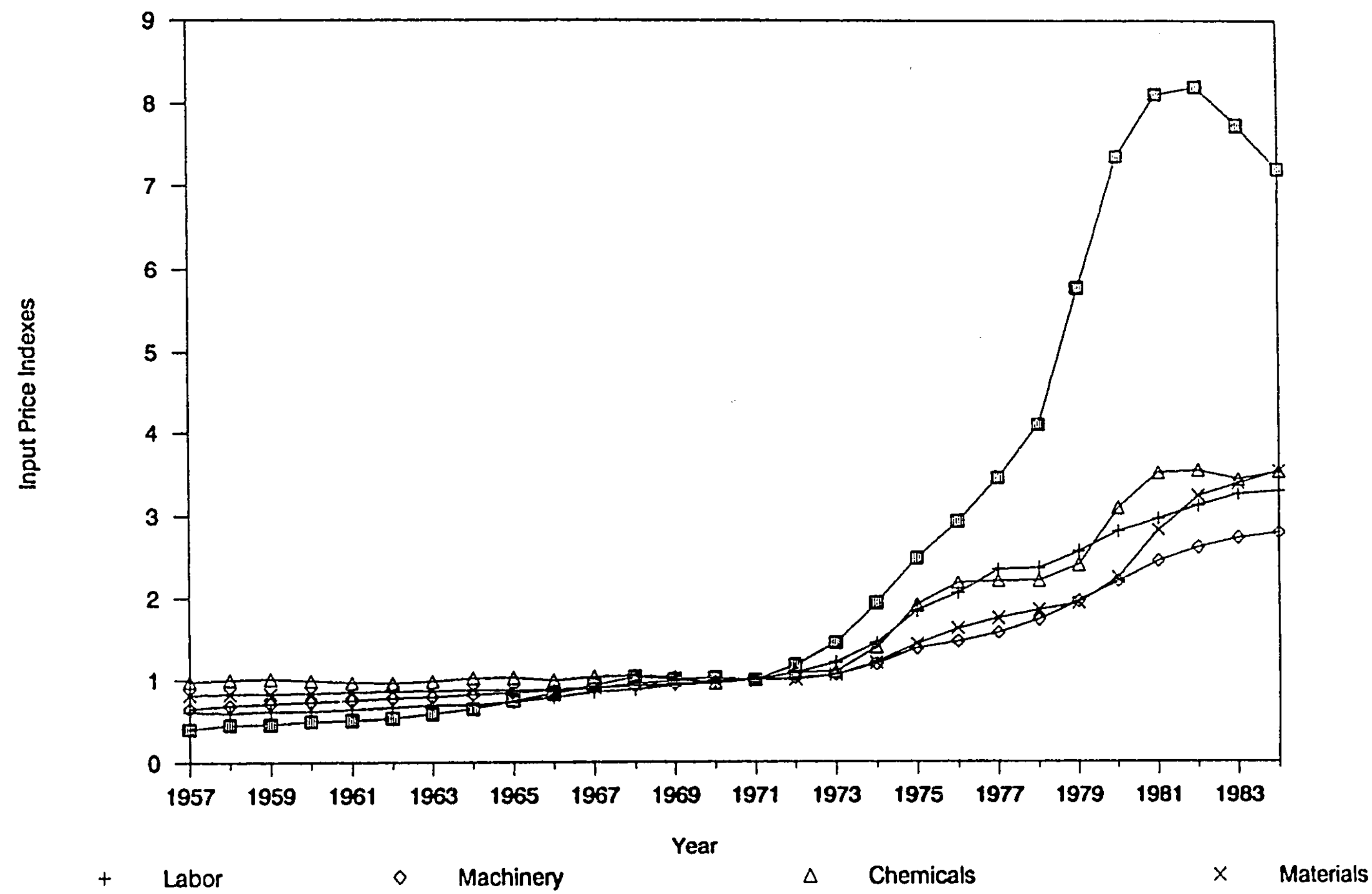
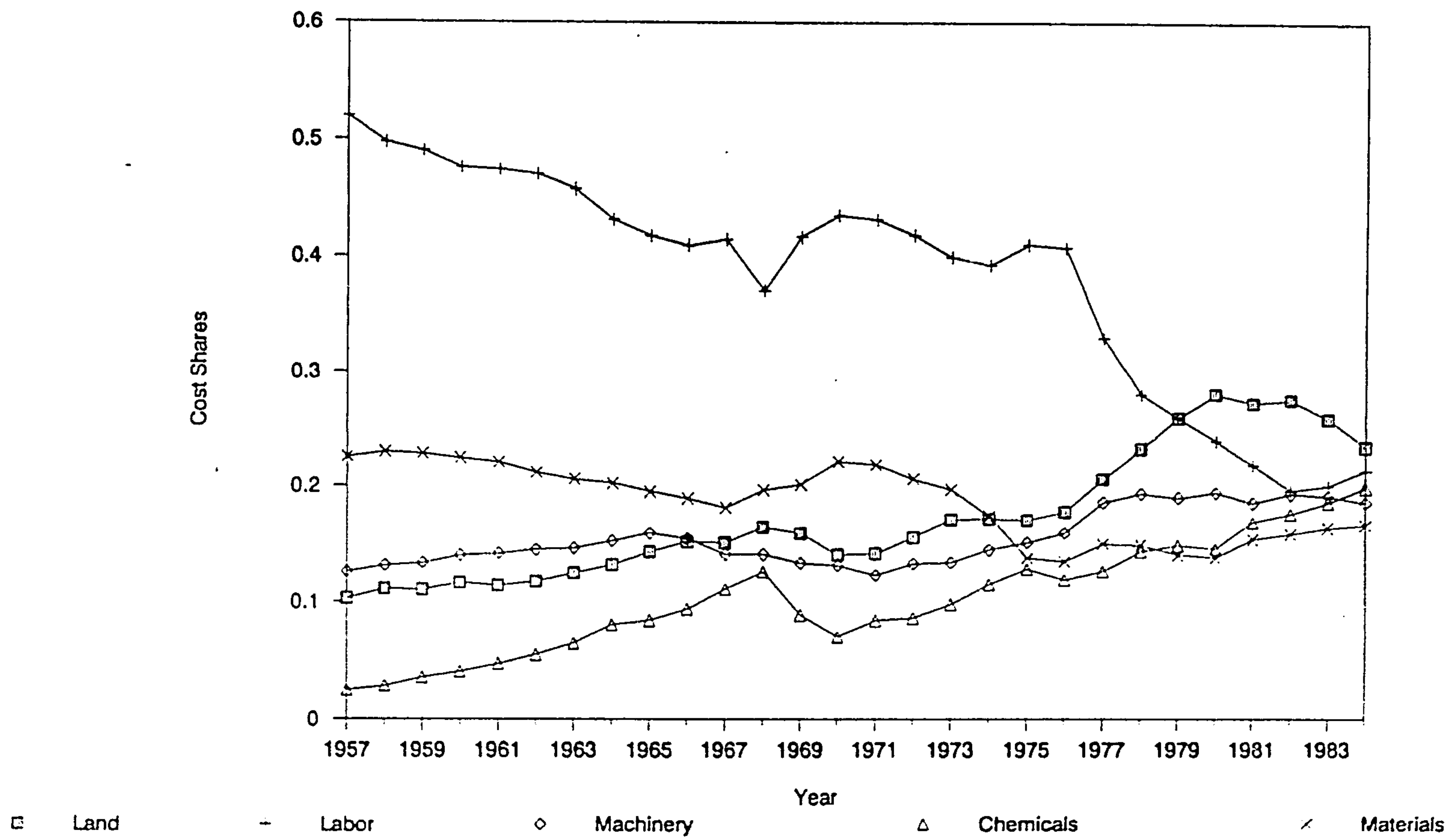


Figure 6-2. Cost Shares of Major Input Groups in Total Cost, Alberta Grain Sector, 1957 to 1984



direction after 1973 .

The cost shares of the various input groups which are given in Figure 6-2 show a steady decline in the share of labor input for the period of 1957-84. The magnitude of the decline in the labor share can be seen from Table E-1 in Appendix 5 of this thesis, ranging from 52.4 percent in 1957 to 21.5 percent in 1984. The remarkable decrease in the cost share of labor might be attributed to structural change in the Canadian economy in general and Alberta in particular. This structural change is characterized by a decrease in the number of farms in Alberta, a decline in labor force enrolled in agriculture, and the tendency of Alberta farmers to make more intensive use of capital in their production process.

The cost share of land increased from 10 percent in 1957 to 23 percent in 1984, which can be attributed to the sharp increase in the price of land since 1973. Meanwhile, the cost share of machinery rose from 12 percent in 1957 to 18.7 percent in 1984. This moderate increase in the cost share might be partially explained in terms of the existence of the substitutability relationship between machinery and fertilizer and pesticides, which will be verified empirically later in this chapter. The cost share of fertilizer increased sharply from 2.5 percent in 1957 to 20 percent in 1984. This can be attributed to the heavier reliance of Alberta grain farmers on fertilizer use especially since 1973. It can be seen also from Table E-1, Appendix 5 and Figure 6-2 that the cost share of material inputs shows a decline from 22 percent in 1957 to 16.3 percent in 1984.

The input price indexes along with the respective cost shares of land, labor, machinery, fertilizer, and material were utilized to estimate the production structure of the Alberta grain sector. The next part of this chapter is concerned with the model specification and the estimation technique which was utilized in this study to analyze production structure in Alberta grain farming.

6.6 Model Specification, Estimation Techniques, and Basic Hypothesis Testing

The non-homothetic translog cost function was estimated along with the cost share equations by using Zellner's iterative procedure. The estimated non-homothetic translog cost function can be represented as follows:

$$\ln C = \gamma_0 + \sum_i^n \gamma_i \ln P_i + \gamma_q \ln Q + \gamma_t T + 1/2 \sum_i^n \sum_j^n \gamma_{ij} \ln P_i \ln P_j + \sum_i^n \gamma_{iq} \ln P_i \ln Q + \sum_i^n \gamma_{it} \ln P_i\, T + \gamma_{qt} \ln Q\, T + 1/2\gamma_{qq} (\ln Q)^2 + 1/2\, \gamma_{tt} (T^2) + v \quad (6\text{-}14)$$

where: C is the total cost of grain production in Alberta, P's are the prices of land, labor, machinery, chemicals, and materials, Q is the grain output quantity index, T is the time trend, γ's are parameters of the cost function to be estimated, and v is the error term.

The cost share equations for land, labor, machinery, fertilizer, and materials can be obtained by taking the first derivative of equation (6-14) with respect to P_i. The form of share equations which was used in our estimation can be written as:

$$S_i = \gamma_i + \sum_{ij}^n \gamma_{ij} \ln P_j + \gamma_{iq} \ln Q + \gamma_{it}\, T + \epsilon_i \quad (6\text{-}15)$$

$$i = (L, N, K, F, M)$$

where: S_i is the share equation of the i-th input, and ϵ_i is the error term.

Many authors of previous studies have estimated production relations by utilizing the cost share equations (Binswanger, 1974). Such a procedure is criticized on the ground that it does not provide satisfactory estimation. The estimation of the cost function jointly with the cost share equations leads to much higher efficiency in the estimated results (Christensen and Green 1976, Ray 1982). However, one must keep in mind that the most limiting factor which affects the choice between these two estimation techniques is the availability of the number of observations in the data set (the degrees of freedom). Therefore, if the degrees of freedom are insufficient to estimate the whole system, then estimation of the cost share equations alone appears to yield reasonable results (Binswanger 1974, Islam and Veeman 1980, and Taher 1983). In this study, for more efficient estimation, the translog cost function was estimated jointly with the cost share equations.

In our model, we have five cost share equations for land, labor, machinery, fertilizer, and materials. Therefore, to estimate these five share equations along with the cost function, we had to utilize the restriction that the sum of the cost shares must equal to one. Hence, to overcome the over-identification problem in our model, one of the cost share equations (that relating to material) was eliminated, and the remaining n-1 cost share equations was estimated by using Zellner's Seemingly Unrelated Regression Procedure (Zellner, 1962).

Equation (6-14) along with four share equations are estimated. Several specifications of the basic model are generated by imposing certain restrictions on the non-homothetic translog cost function. First, the homotheticity specification is obtained by imposing the following restriction: $\gamma_{iq} = 0$. The second specification is the imposition of Hicks neutral technical change which is estimated by imposing the restriction that $\gamma_{it} = 0$. The third specification is the imposition of constant returns to scale which is derived by imposing the following set of restrictions on the non-homothetic translog cost function: $\gamma_q = 1$, $\gamma_{qq} = 0$, $\gamma_{iq} = 0$, and $\gamma_{qt} = 0$. The fourth specification is the Cobb-Douglas which is obtained by setting the following parameters of the non-homothetic translog cost function equal to zero: $\gamma_{ij} = 0$, $\gamma_{iq} = 0$, $\gamma_{it} = 0$, $\gamma_{tt} = 0$, $\gamma_{qt} = 0$ and $\gamma_{qq} = 0$.

These four specifications were estimated and the following hypotheses were tested statistically to select the appropriate specification for the Alberta grain sector. The first hypothesis is that the structure of production technology in the Alberta grain sector is homothetic in nature. Homotheticity of production structure implies the separability[14] of the cost function in output and input prices. However, if the production structure is non-homothetic then output expansion or reduction has an effect on the cost shares of different input factors. In other words, the change in output has an impact on the respective derived demands for input factors. The second hypothesis is that technical change is Hicks-neutral. Technical change can be defined as the production of the same amount of output from a lesser level of inputs, or the production of more output from the same level of inputs. In other words, technical change is portrayed as the inward shift of the isoquant associated with the production function. If the hypothesis of neutrality of

[14]For more detailed discussion of separability, see Berndt and Christensen (1978), Denny and May (1978), Taher (1983), and Green (1979).

technical change is not rejected, this implies that the marginal rate of technical substitution between two inputs is constant over time as technical change occurs and the level of output changes. And if the hypothesis of neutral technical change is rejected, then the technical change is said to be biased. Technical change is proxied in the share equations as a time variable (T). By examining the estimated coefficient of this variable one can make some inference about the nature, but not the magnitude, of technical change. That is to say, if the time coefficient in a particular share equation has a negative sign, this will indicate that technical change is factor saving. On the other hand, if the time coefficient is positive, this implies that technical change is factor using.

The third hypothesis concerns the presence of constant returns to scale. If this hypothesis is rejected, this will imply that scale economies or diseconomies are present in the Alberta grain sector.

The fourth hypothesis deals with the Cobb-Douglas specification. Rejection of this hypothesis implies that the Cobb-Douglas function is not an appropriate specification for Alberta grain production.

A likelihood ratio test was utilized to derive test statistics to test the four hypotheses decribed above. The likelihood ratio test (LR) can be defined as:

$$LR = 2 \text{ (Log Lv - Log Lvn)} \sim X^2 \text{ (q)} \qquad (6\text{-}17)$$

where: LR = likelihood ratio, Lv is the likelihood value of the unrestricted model, Lvn is the likelihood value of the restricted model, and q is the number of restrictions (degrees of freedom).

LR has a Chi-square distribution with q degrees of freedom. In this study the unrestricted model was the non-homothetic translog cost function and the restricted models were, respectively, the homothetic cost function, Hicks neutral technical change, constant returns to scale, and the Cobb-Douglas specification. All these models were estimated and the likelihood ratio test was conducted for each hypothesis.

The results of the tests of these hypotheses are presented in Table 6-1. It can be seen from this table that all specifications which are tested against the non-homothetic cost function are rejected at the 1 percent level. The rejection of other specifications leads us to conclude that the non-homothetic translog cost function is the appropriate specification to study the production structure in the Alberta grain sector. This strong conclusion implies, first, production structure in the Alberta grain sector is not homothetic; this implies that a change in output level has a direct effect on the demand for different input factors. Second, production technology in the Alberta grain sector is not Hicks neutral. Third, economies of scale in Alberta grain production do exist, and fourth, the Cobb-Douglas specification is not an appropriate form to study production technology in the Alberta grain sector.

6.7 Comparative Static Results

The selected specification which is the non-homothetic cost function, along with the four share equations relating to land, labor, machinery, and materials, were estimated. The results are presented in Table 6-2. These estimated coefficients are used to analyze the production relations, such as the elasticities of substitution, own and cross price elasticities of demand, the nature of technical change, and the scale effect in the Alberta grain sector.

The goodness of fit statistics of the estimated non-homothetic cost function and the four share equations are presented in Table 6-3. The values of R^2, D.W., and SSE indicate that the estimated model performed very well.

6.7.1 Elasticities of Substitution

The estimated parameters of the non-homothetic translog cost function are transformed into Allen partial elasticities of substitution (AES) for the Alberta grain sector. These elasticities are calculated at the mean value of the cost shares for the entire period and are also calculated for different points of time to examine changes in substitutability and complementarity over time. The results of these calculations are presented in Table 6-4. The table shows substitutability relationships between the following input pairs: land-machinery, land-fertilizer, land-materials, labor-machinery, labor-materials, and machinery-fertilizer. On the other hand, complementarity relationships were found between land-labor, land-materials, labor-fertilizer, machinery-materials and fertilizer-materials.

Table 6-1. Likelihood Ratio Test for Various Specifications of Production Technology in the Alberta Grain Sector.

Hypothesis	No. of restrictions	X^2 (1 percent)	X^2 (5 percent)	X^2 calculated
(1) Homotheticity	5	15.1	11.0	34.5
(2) Hicks neutral technical change	5	15.1	11.0	40.6
(3) Constant returns to scale	7	18.5	14.0	123.9
(4) Cobb-Douglas specification	21	38.9	32.7	243.7

Table 6-3. Goodness of Fit Statistics.

	R^2	D.W.	SEE
(1) The cost function	0.9625	1.2727	0.040
(2) Cost share of land	0.9782	1.0968	0.008
(3) Cost share of labor	0.9619	1.3993	0.020
(4) Cost share of machinery	0.8053	0.9132	0.010
(5) Cost share of fertilizer	0.9183	0.8685	0.010
(6) Cost share of material	0.9625	0.5904	0.009

Notes:
Since this equation is dropped from the system, the value of R^2, D.W. and SEE are obtained by injecting this equation into the system and dropping the cost share equation of fertilizer.

Table 6-2. Estimated Parameters of the Non-homothetic Translog Cost Function, Alberta Grain Sector, 1957-84.

Variable name	Estimated Coefficient	Assymptotic T. Ratio
γ_o	13.0000	484.12*
γ_l	0.1445	19.24*
γ_n	0.4583	40.52*
γ_k	0.1212	12.07*
γ_f	0.0751	7.33*
γ_m	0.2009	18.99*
γ_q	-0.0078	-0.13
γ_t	-0.0812	-2.46*
γ_{ll}	0.1426	5.81*
γ_{ln}	-0.0868	-4.65*
γ_{lk}	-0.0081	-0.30
γ_{lf}	0.0364	1.86**
γ_{lm}	-0.0841	-3.22*
γ_{nn}	0.1777	5.71*
γ_{nk}	-0.0540	-2.182**
γ_{nf}	-0.0401	-1.82**
γ_{nm}	0.0032	1.47***
γ_{kk}	0.0195	3.38
γ_{kf}	0.0979	3.65**
γ_{km}	-0.0553	-1.18***
γ_{ff}	-0.0206	-0.73
γ_{fm}	-0.0736	-4.89*
γ_{mm}	0.2098	3.75*
γ_{qq}	0.2450	2.10**
γ_{tt}	0.0086	5.36*

Notes:

- L = Land, N = Labor, K Machinery, F = Fertilizer, and M = Materials.
- The interaction between time and output is believed to be a source of multicolliniarity. In addition, the coefficient of this interaction term γtq is small and insignificant. The empirical results were improved by removing this variable from the regression (for a similar argument, see Banskota 1984).

  * = significant at 1% level

  ** = significant at 5% level

  *** = significant at 10% level
- The degrees of freedom in this model are calculated as follows:

  d.F = N X M - K

  where: N = Number of observations = 28

  M = Number of equations = 5 equations (one cost equation and 4 share equations).

  K = Total number of variables in the cost equations and share equations = 55

  d.F = 140-55 = 85

  (See Johnston, 1984, p. 339).

Table 6-4. Allen Partial Elasticities of Substitution, Alberta Grain Sector.

Variable Name	Mean	1957-63	1964-70	1971-77	1978-84
L-N	-0.300**	-0.548	-0.391	-0.265	-0.449
L-K	0.704	0.498	0.633	0.684	0.838
L-F	3.018**	8.355	3.575	2.984	1.833
L-M	-1.644*	-2.397	-1.886	-1.865	-1.154
N-K	0.100**	0.206	0.111	0.092	-0.224
N-F	-0.010**	-0.912	-0.025	0.800	-0.035
N-M	1.045***	1.030	1.039	1.046	-1.091
K-F	7.100*	17.334	8.119	7.105	4.045
K-M	-0.940***	-0.847	-0.954	-1.180	-0.928
F-M	-2.900*	-6.965	-3.035	-2.957	-1.920

where: L = Land, N = Labor, K = Machinery, F = Fertilizer, and M = Material.

$\sigma_{ij} > 0$ indicates that the i-th and j-th input factors are substitutes.

$\sigma_{ij} < 0$ indicates that the i-th and j-th input factors are complements.

*, **, *** denotes the values of AES obtained from gamma coefficients significant at 1%, 5% and 10% level, respectively (see Islam 1982).

Most of these relationships among input pairs appear sensible and are expected on *a priori* grounds.

The substitutability between land and machinery as well as that between land and fertilizer found in this study are confirmed in most previous cost function studies[15] in Canadian and U.S. agriculture. The declining trend of the substitutability between labor and machinery in the Alberta grain sector is confirmed in this study. A similar conclusion is reported in Ray's study of U.S. agriculture. Furthermore, the complementarity between labor and capital which was reported in Western Canadian agriculture (Kunimoto 1983) is not found here (except for the 1978-84 sub-period). A major conclusion of this study is the strong degree of substitutability between machinery and fertilizer, or in the broad sense, between mechanical and biochemical technology. The magnitude of the AES between machinery and fertilizer, however, has declined over time.

The complementarity between land and labor and between labor and fertilizer seems to be sensible and expected, and is confirmed in many translog cost function studies in Canadian and American agriculture.[16] The complementarity between fertilizer and labor is also reported by Baanante (1980) in Punjab, India. Complementarity between machinery and materials is expected on *a priori* grounds because energy is the main component of materials input. Therefore, one expects that heavy machinery use requires more energy.

6.7.2 Own and Cross Price Elasticities

Own and cross price elasticities are measures of the responsiveness of the quantity demanded of a particular input, respectively, to the change in its own price P_i or to the price of another input P_j. The parameters of the estimated non-homothetic cost function were used to calculate the own and cross price elasticities, by applying the following

[15]For more detailed discussion, see Binswanger (1973), Lopez (1980), Islam and Veeman (1980), and Kunimoto (1983).

[16]For more detailed information about the complementarity between land and labor, and between labor and fertilizer, see Aun (1983), Kunimoto (1983), Islam (1982), Baanante (1980), and Adamowicz (1985).

Table 6-5. Own and Cross Price Elasticities of Input Demand for Alberta Grain Sector.[17]

	L	N	K	F	M
L	-0.007	-0.115	-0.110	0.312	-0.300
N	-0.052	-0.153	-0.016	-0.002	0.191
K	0.123	0.038	-0.719	0.730	-0.172
F	0.526	-0.004	1.102	-1.095	-0.530
M	0.286	0.401	-0.147	-0.300	0.333

where: L = Land, N = Labor, K = Machinery, F = Fertilizer, and M = Machinery.

$\eta_{ij} > 0$ = input factors i and j are substitutes.

$\eta_{ij} < 0$ = input factors i and j are complements.

[17]The standard errors of the elasticities of substitution, own and cross price elasticities are not reported because the standard errors are generally calculated under the assumption that the cost shares are constant (nonstochastic) and this is not true.

formula:

$$\eta_{ii} = G_{ii}\ S_i \tag{6-18}$$

$$\eta_{ij} = G_{ii}\ S_j \tag{6-19}$$

where: η_{ii} is the own price elasticity, G_{ij} is the own elasticity of substitution, S_i is the cost share of the i-th input, η_{ij} is the cross price elasticity of demand, G_{ii} is the elasticity of substitution between the i-th and j-th inputs, and S_j is the cost share of the j-th input.

The results of these calculations are presented in Table 6-5.[18] The lowest own price elasticity occurs for land which implies that the demand for land is highly price inelastic. A similar finding is obtained by Islam (1982), Binswanger (1975), and Adamowicz (1985). It can also be seen that the demands for labor and machinery are inelastic and they have the correct sign. However, the demand for labor shows a smaller response to the change in the wage rate per hour compared to the demand for machinery vis-a-vis a change in the price of machinery. The demand for fertilizer has the highest negative sign, indicating that fertilizer is the most price-elastic factor. Contrary to expectations, the own price elasticity of demand for materials is positive.[19] The cross price elasticities indicate substitutability if the sign of the coefficient is positive and complementarity if the sign is negative. Fertilizer and machinery showed the highest degree of substitutability, while fertilizer and labor have the lowest degree of complementarity.

6.7.3 Technological and Scale Effects

In this study technical change and scale economies are introduced as a time variable T and output quantity Q, respectively, into the cost function. By examining the sign of the estimated coeffecient of the interaction of the time and output variables with the i-th input price index, one can infer certain conclusions about the direction of technical change and scale effects. The estimated coefficients of these two variables are presented in Table 6-6.

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[18]The estimation of own and cross price elasticities is not symmetric, i.e., the cross price elasticity N_{ij} is not equal to the cross price elasticity N_{ji}; this is mainly due to differences in the value of cost shares.

[19]An estimated positive value of own price elasticity of demand for a farm input is not uncommon. See Chotigeat (1978), Baanante and Sidhu (1980), and Islam (1982).

Table 6-6. Technical Change and Scale Effects.

Input	Technical Effect	Scale Effect
Land	γ_{LT} = -0.0017	γ_{LQ} = 0.0261***
	(-0.23)	(1.36)
Labor	γ_{NT} = -0.0441*	γ_{NQ} = -0.1098*
	(-4.99)	(-3.99)
Machinery	γ_{KT} = (0.0186)	γ_{KQ} = 0.0321**
	(1.788)	(1.62)
Fertilizer	γ_{FT} = 0.0263*	γ_{FQ} = 0.0278***
	(3.18)	(1.21)
Materials	γ_{MT} = 0.0009	γ_{MQ} = 0.0238***
	(0.49)	(1.23)

where: t values are in parentheses

* = significant at 1% level

** = significant at 5% level

*** = significant at 10% level

(γ_{iT}) > 0 → input using technical change.

(γ_{iT}) < 0 → input saving technical change.

(γ_{iT}) = 0 → Hicks neutral technical change.

(γ_{iQ}) > 0 → scale effect are input using.

(γ_{iQ}) < 0 → scale effect are input saving.

(γ_{iQ}) = 0 → neutral.

It can be seen from this table that the general direction of technical change in the Alberta grain sector has been labor saving, and machinery and fertilizer using. The coefficient of labor is negative and highly significant which indicates that technical change has been labor-saving. This finding is consistent with the result which is reported by Furtan and Lee (1978) for Saskatchewan wheat production. This conclusion is sensible and expected on *a priori* grounds, because the wage rate per hour has shown remarkable increases since the early 1970s. Therefore, grain farmers have employed relatively less expensive input factors in their production process. The coefficient of land is negative, but it is not statistically significant, which implies that technical change has been neither land-saving nor land-using. The coefficients of machinery and fertilizer use are both positive and significant which implies that technical change in Alberta grain production has been both machinery and fertilizer using. Finally, the coefficient of materials input is positive but not significant which means that there is no strong conclusion which can be made with respect to the effects of technical change on the use of materials input over time.

The scale effects or the effects of the change in output level on the demand for various input factors also can be examined from Table 6-6. From this table one can notice that the coefficient of the interaction term between labor and output is negative and highly significant which implies that the scale effect with respect to labor is labor saving. This latter result indicates that both technical change and the scale effect operate in the same direction towards labor saving. Further, the coefficient of the interaction term between machinery and output is positive and significant which implies that this scale effect is machinery using. These two strong results with regard to the effect of scale economies on labor and machinery are expected on a *priori* grounds, since labor and machinery are substitutes in the production process. Therefore, any expansion or reduction in output level will effect the demands of labor and machinery in opposite directions. The remaining scale coefficients with respect to land, fertilizer, and materials are positive and significant at only the 10 percent level of significance, which indicates that the remaining scale effects are weakly land, fertilizer, and materials using.

6.8 Summary

The main objective of this chapter was to select an appropriate form of cost function to study the production structure of the Alberta grain sector. A general form of cost function (non-homothetic) was initially estimated. Several models such as the homothetic, Hicks neutral, constant returns to scale, and Cobb-Douglas were generated by imposing certain restrictions on this general form. The log likelihood ratio test was conducted to test different hypotheses concerning the production structure of the Alberta grain sector. The non-homothetic translog cost function can not be rejected statistically while the other specifications are rejected at the 1 percent level of significance. Therefore, the non-homothetic form was chosen as an appropriate specification to study the production relations in the Alberta grain sector.

The preceding results imply that the production structure in the Alberta grain sector, first, does not involve Hicks neutral technical change. Second, it is not characterized by constant returns to scale. Third, scale economies or diseconomies exist. In other words a change in output level has a great impact on the demand for different input factors and, as a consequence, affects the cost shares and total cost. Fourth, the Cobb-Douglas specification is not an appropriate form to study the production structure in the Alberta grain sector.

The estimated coefficients of the non-homothetic cost function were used to calculate such production relations as the elasticities of substitution, as well as the own and cross price elasticities of demand for various inputs. Several conclusions emerged from the results obtained from these calculations. First, there is strong evidence supporting our conclusion that substitutability does exist between land-fertilizer, labor-machinery and machinery-fertilizer. However, the substitutability among input pairs has declined over time. Second, complementarity relationships were found between the land-labor, land-material, labor-fertilizer, and fertilizer-material input pairs. The complementarity between labor and fertilizer which exists in Canada is also evident in studies of American and Indian agriculture. Third, the own price elasticity of demand for land has the smallest value, followed by labor and machinery which implies that the demands for land, labor and machinery are inelastic. On the other hand, the own price elasticity of the demand for fertilizer is negative and greater than one which indicates that the demand for fertilizer is price elastic. In other words, the quantity demanded of fertilizer is relatively responsive to change in its own price. Fourth, the general direction of technical change in the Alberta grain sector is strongly labor saving and capital and fertilizer using. Finally, the scale effect is highly labor saving and machinery using.

7. Summary and Conclusion

The growth potential and productivity performance of the prairie grain sector continues to be of vital importance to prairie farmers and policy makers. Improvements in agriculture productivity are essential to overcoming cost-price-squeeze pressures and to retaining competitiveness in world markets. In this study total factor productivity was measured and analyzed for a specific, but very critical sub-sector in prairie agriculture -- the prarie grain sector. In addition, the measurement of productivity was diaggregated to the provincial level and to the major soil zones of the prairie grain growing region. Further, in this study, the production relations were also estimated and analyzed for the Alberta grain sector which was taken as a representative grain producing area in the prairie region.

7.1 Grain Output, Input, and Productivity

The prairie grain sector was defined in this study to include five major cereals and oilseeds (wheat, oats, barley, canola, and flaxseed) grown in the prairie region of Alberta, Saskatchewan, and Manitoba. The production of these major grains takes place in four major soil zones: the brown, dark brown, black, and gray zones. These soil zones are delineated on the basis of soil organic matter content, moisture availability, and other distinguishing soil-agronomic characteristics. The following simplifying assumptions were made: grain production in Manitoba was considered to be entirely in the black zone; the relatively narrow gray soil zone across northern Saskatchewan was subsumed into the black soil zone; in Alberta, where census divisions clearly overlapped two soil zones, portions of these census divisions were allocated to respective soil zones.

Data on grain production and average prices paid to farmers were obtained for each year from various statistical sources for the period of 1961-84. Zonal output and zonal cropped land data were derived according to the location of census divisions (or crop districts) in respective soil zones. Zonal output prices for wheat and barley were also derived by utilizing the average grade distribution (over a recent seven year period), the average zonal shares of wheat and barley production in total production, and the CWB prices of wheat and barley by grade. This procedure permitted the generation of a wheat price series for the brown soil zone, for example, which was higher than that for the black soil zone, reflecting the typically higher quality of wheat (relatively more CWRS 1 and 2 and less CWRS 3 and feed) produced in the brown zone.

The basic input categories in the grain sector included land, labor, machinery, chemicals, and materials. Most of these input classes are used in both grain and livestock production; therefore, a major empirical problem involved the separation of input use figures attributable to grain operation when many prairie farms, in fact, are mixed crop and livestock enterprises. The difficulty arises because input use figures are not collected or published explicity for either the crops or livestock sector in Canada. Moreover, Statistics Canada does not provide systematic time series data on representative farm types such as exist in the Australian BAE Surveys. Given these data constraints, the procedure adopted in this study was to allocate input use, between major productive uses and among soil zones, on the basis of census information.

In this study, input use is considered to comprise two distinctive components. First, there are those inputs that are readily and directly attributable to grain production, such as cropped land, fertilizer, pesticides, energy, and seeds. Second, there are those input categories that are extremely difficult to attribute either to grain or livestock production. Such inputs include machinery which is used jointly in grain and livestock production, labor, and buildings. The estimation of input use attributable to grain in the latter categories necessarily involves some arbitrary assumptions. One option is to use respective total cash receipts from grain and livestock as a basis for allocating total input use between crops and livestock (Weaver *et. al.*, 1982). The other alternative which was actually used in this study is to use the proportional share of the number of crop farms to total farms in each province as the basis to allocate labor, machinery, and depreciation on buildings between crops and livestock. Input use was then allocated among soil zones according to the soil zone shares of total expenditure on major input classes in respective censuses. Finally, the zonal prices of the land input were derived by utilizing the zonal quantities of cropped land and the zonal values of cropped land and buildings.

The methodological approach to productivity measurement which is taken in this study rests on some important conceptual foundations. In the first place, productivity analysis is conducted in terms of the concept of total factor productivity (the ratio of aggregate output over the weighted aggregate of all inputs used in the production process) rather than in terms of partial productivity (for example, yield per acre). Secondly, improvements in production/cost function specification and in index number procedures now permit the aggregation of outputs and inputs through the use of flexible weight, rather than fixed base weight, methods. In essence, rather than using Laspeyres index number methods, the Tornqvist approximation to the Divisia Index was used to aggregate individual grains into a grain output index and to aggregate individual grain inputs into a grain input index.

The empirical estimates show that grain output in the prairie region grew by 3.6 percent per year over the 1961-84 (or alternatively 2.9 percent annually over the 1962-84 period). These results indicate the inclusion or exclusion of the drought year, 1961, has a direct effect on the estimated growth rate of grain output. On the zonal level, grain output increased somewhat less rapidly in the brown zone (2.0 percent per year) and the dark brown zone (2.3 percent per year) during the 1962-84 period. On the other hand, grain output rose by 3.2 percent per annum in the black soil zone and by a remarkable 6.2 percent per year in the Alberta gray soil zone. Whereas, on the provincial level, the growth rate of the grain output quantity index is higher in Manitoba, followed by Alberta and Saskatchewan. When the period of study is divided into two sub-periods (eliminating the end years, 1961 and 1984, which are drought years), the annual growth rates of grain output on the provincial, zonal, and the prairie aggregate levels are much higher in the second sub-period, 1973-83, than in the initial sub-period, 1962-72. For example, these rates rose to 5.4 percent for the prairie aggregate, and to 3.9, 4.4, 5.9 and 9.6 percent for the prairie brown, dark brown, black, and gray soil zones, respectively, over the sub-period since 1973.

Aggregate input use in grain production in the prairie region increased by 1.8 percent per annum over 1961-84 with the dark brown zone (2.4 percent) and gray soil zone

(2.2 percent) registering input growth rates above the prairie average and the brown zone (1.7 percent) and black zone (1.3 percent) having rates somewhat below the prairie average. The higher input growth rate in the dark brown soil zone (in Alberta, Saskatchewan and the prairie aggregate), for instance, is partially attributable to a lower level of labor decline and to a higher rate of increase in the opportunity costs of land than in the brown zone. Aggregate grain input use on the provincial level, on the other hand, grew by annual compound rates of 2.5, 1.9 and 1.5 percent for Alberta, Manitoba, and Saskatchewan, respectively, over the period 1961-84. When the period of study is divided into two sub-periods (again eliminating the end drought years, 1961 and 1984), the annual rates of input growth on the provincial, zonal, and prairie aggregate levels are much higher in the second sub-period, 1973-83, than in the initial sub-period, 1962-72. This, in part, might be attributed to the heavy reliance of the prairie grain sector on mechanical and, to a lesser extent, biochemical technology in the later 1970s and early 1980s and the associated increases in specialization and size of grain farms in the prairie region during this time. It is also due to the greater rate of increase in the service flows (opportunity costs) of land calculated for the 1973-83 subperiod.

Total factor productivity (TFP) shows considerable variation from year to year, its fluctuations closely mirroring those of the output quantity index and also being heavily influenced by weather variables. The measurement and assessment of trends in productivity, as a consequence, are very sensitive to the specific time periods involved. For example, the inclusion of the very adverse drought year, 1961, in the period of study leads to upwardly biased estimates of productivity performance whereas the inclusion of 1984, also a year of drought in the southern prairies, tends to bias productivity estimates in a downward direction. As a result, we have chosen to focus on the period from 1962 to 1983 which we feel provides the fairest assessment of productivity performance in the prairie region.

Total factor productivity in the Alberta grain sector grew by an annual compound rate of 1.3 percent over the period 1962 to 1983. Moreover, TFP grew at an annual compound rate of 2.3 percent over the first subperiod 1962-72, and 4.2 percent over the second sub-period 1973-83. Accordingly, one can conclude that growth rates of TFP in the Alberta grain sector as a whole did not decline in the late 1970s and early 1980s, as has some time been suggested. The respective zonal productivity growth rates for the brown, dark brown, black, and gray soil zones were 1.2, 0.5, 0.8 and 3.7 percent per year over the period from 1962 to 1983. In general, the productivity growth rates for soil zones in the Alberta grain sector show the gray zone exibiting the highest rate, followed by the brown, black, and dark brown soil zones. Grain productivity for Manitoba, on the other hand, grew at an annual rate of 1.4 percent per year over 1962-83. This result shows that the growth rate of TFP in the Manitoba grain sector is higher than those in Alberta and its major soil zones except for the gray soil zone. However, the growth rate of TFP in the Manitoba grain sector declined from 6.3 percent in the first sub-period (1962-72) to 2.7 percent in the second sub-period (1973-83).

Total factor productivity in the Saskatchewan grain sector increased at an annual rate of 1.0 percent over 1962-83. The respective zonal productivity growth rates for the brown, dark brown, and black soil zones were 0.8, 0.2, and 1.6 per year, respectively, over this same period. The brown and dark brown soil zones in Saskatchewan seem to be characterized by slower TFP growth rates in the 1970s and early 1980s. However, the Saskatchewan black soil zone follows the same pattern as the black soil zone in Alberta and Manitoba which are characterized by higher growth rates of TFP in the second sub-period (1973-83) than in the first sub-period (1962-72).

Further, over the period from 1962 to 1983, TFP in the prairie grain sector increased by 1.2 percent per year. The brown and dark brown zones evidence annual productivity growth below the prairie norm (0.8 and 0.3 percent, respectively) whereas the black and gray soil zones register productivity advances above the prairie average (1.8 and 3.7 percent, respectively). Our estimates suggest that productivity grew more rapidly in grain production in the black and gray soil zones in the latter half of the period (1973-83) than in the inital half (1962-72), whereas exactly the opposite occurred in the brown and dark brown soil zones.

A useful by-product of productivity measurement is the information which can be generated on the terms of trade and returns-to-cost for prairie grain farmers. The empirical estimates of this study indicate that the aggregate input price index (comprising both actual and imputed prices) grew more rapidly than the grain output price index, particularly in the later half of the period. As a consequence, the terms of trade for prairie grain farmers tended to decline by some 2 to 3 percent per year over the study period. The returns-to-cost ratio, on the other hand, for the prairie grain sector as a whole, declined by some 1.2 percent per year. As anticipated, the returns-to-cost ratio deteriorated considerably in all soil zones in the second sub-period (1973-84).

The major conclusions, therefore, which emerge from the preceding discussion are that the rate of productivity advance for the prairie aggregate crop sector is estimated at 1.2 percent per year over the period 1962 to 1983, with Manitoba having the highest provincial rate of productivity growth, followed by Alberta and Saskatchewan. The productivity growth rates for soil zones show the gray zone exhibiting the highest rate, followed by black, brown and dark brown zones. The result that the brown soil zone has a slightly higher rate of productivity growth than the dark brown zone is tentative; further research is needed on how sensitive this conclusion is to such factors as irrigation, summer fallow, relative land values, and labor input methodology. The study of agriculture productivity at the sectoral level is not an easy task, but it is useful in gaining a deeper understanding of the anatomy of growth in the grains sector and across soil zones.

7.2 Production Relations in the Grain Sector

The grain and oilseed production process involves inputs such as land, labor, machinery, chemicals, and materials which are used to produce grains (wheat, oats, and barley) and oilseeds (flaxseed and canola). Knowing the production relations among these input factors -- such as substitutability between input pairs, own and cross-price elasticities of demand for each input factor, and the nature of technical change in the grain sector -- is one of several issues which have been addressed in this study. Alberta was chosen as a representative sub-unit in studying the grain sector in the prairie provinces, mainly because the data set for Alberta was more complete and extended back to 1957 which gives more flexibility in terms of degrees of freedom which are required for estimation of our model.

The development of duality theory since the early 1970s allows us to estimate the production relations either by using a production function or cost function approach. In this study, a specific flexible functional form --- namely, the translog cost function -- was utilized to estimate the production relations in the Alberta grain sector. The translog cost function was specified as a function of the input prices of land, labor, machinery, chemicals, and materials. Therefore, our model involved five cost share equations, one each for land, labor, machinery, chemicals, and materials. The translog cost function was estimated jointly with the share equations. Therefore, to estimate these five share equation along with the cost function, we had to utilize the restriction that the sum of the cost shares must equal to one. Hence, to overcome the over-identification problem in our model, one of the cost share equations (that relating to materials) was eliminated, and the remaining n-1 cost share equations were estimated jointly with the translog cost function by using Zellner's Seemingly Unrelated Regression Procedure.

A general form of cost function (non-homothetic) was initially estimated. Several models such as the homothetic, Hicks neutral, constant returns to scale, and Cobb-Douglas were generated by imposing certain restrictions on this general form. The log likelihood ratio test was conducted to test different hypotheses concerning the production structure in Alberta grain sector. The non-homothetic translog cost function could not be rejected statistically while the other specifications were rejected at the 1 percent level of significance. Therefore, the non-homothetic form was chosen as an appropriate specification to study the production relations in the Alberta grain sector.

The preceeding results imply that the production structure in the Alberta grain sector does not involve Hicks neutral technical change and is not characterized by constant returns to scale; further, the Cobb-Douglas specification is not an appropriate form to study the production structure in the Alberta grain sector. Moreover, the estimated coefficients of the non-homothetic cost function were used to calculate such production relations as the elasticities of substitution as well as own-price and cross-price elasticities of demand for various inputs. Several conclusions emerged from the results obtained from these calculations. First, there is strong evidence supporting our conclusion that substitutability does exist between land-fertilizer, labor-machinery and machinery-fertilizer. However, the substitutability among input pairs has declined over time. Second, complementarity relationships were found between the land-labor, land-materials, labor-fertilizer, and fertilizer-materials input pairs. Third, the own price elasticity of demand for land, labor, and machinery each has an absolute value less than one which implies that the demand for each of these inputs is inelastic. On the other hand, the own price elasticity of the demand for fertilizer is negative and greater than one which indicates that the demand for fertilizer is price elastic. Fourth, the general direction of technical change in the Alberta grain sector is strongly labor saving and machinery and chemical using. Finally, the scale effects are highly labor saving and machinery using.

7.3 Limitations and Suggestions for Future Research

In this study, estimates of levels and trends in grain output, aggregate grain input use, and total factor productivity in provincial, zonal, and prairie grain production over the period from 1961 to 1984 have been provided. Our estimates on the grain output side for the five major crops are relatively accurate, subject to the difficulties of matching up census divisions (or crop districts) with respective soil zones. A useful start has also been made in this study in providing estimates of wheat and barley prices on a soil zone basis. The grain input side, on the other hand, is more troublesome and fraught with difficulties in data availability, quality of data, and conceptual issues. There is also a need for simplifying assumptions in allocating input use, first, between crops and livestock and second, among the various soil zones. As a consequence, considerable further refinement and revision of grain input figures and resultant productivity estimates is certainly possible.

Given these difficulties and problems which are associated with the input side, it is recommended that particular attention be paid in future to improvement and refinement of input series data. It is desirable and will facilitate future sectoral TFP studies in Canadian agriculture, if Statistics Canada provides systematic time series data on representative farm types. Further, providing yearly data on quantity and prices of fertilizer (N, P, K) and pesticides are essential for studying productivity and production structure in Canadian agriculture.

Several useful extensions of the work reported here might be suggested: (1) the separation of output and input data in the brown soil zone into that associated with irrigated grain production and that associated with dry land grain production; (2) more explicit modelling of the impact of summer fallow, either by including summer fallow as a component of the stock of land or by treating summer fallow as a lagged input in the production process; (3) the need to move beyond opportunity cost approaches in making more refined estimates of the service flows of durable inputs such as land and machinery; (4) the development of a land price series which more accurately reflects the role of land as a source of production services and which abstracts from the role of land as a source of expected capital gains (which, in turn, would lead to lower price weights for land and reduced cost shares for land from 1973 to 1981); (5) the consideration of grain output market distortions, including subsidies, in the design of appropriate time series for grain output prices (an issue which would be particularly relevant in updating this study past 1984); and (6) the more explicit treatment of location and transportation factors which influence grain production in various provinces and soil zones. Finally, it is highly desirable in future research to identify and analyze the sources of productivity growth in the prairie grain sector.

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Appendix 1

Table A-1. Annual Production of Major Grains and Oilseeds, Alberta, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1957	2532.1	1119.4	2088.4	143.8	28.5
1958	2664.8	1219.4	2242.1	165.5	23.6
1959	3131.7	1367.5	2307.7	169.2	10.4
1960	2882.6	1434.4	2068.9	162.6	56.7
1961	2419.3	1326.4	1678.5	109.2	119.4
1962	3036.2	1992.1	1995.9	88.1	60.3
1963	4054.8	1923.5	2412.3	94.0	80.7
1964	3981.6	1223.1	2345.6	109.4	146.5
1965	4137.3	1613.0	2504.5	121.4	215.5
1966	5166.4	1559.2	3426.5	140.1	249.5
1967	3926.4	1222.9	3038.2	43.2	276.7
1968	4527.7	1453.9	3877.4	109.2	170.1
1969	3820.4	1511.4	4134.5	160.0	265.4
1970	1958.5	1809.3	4115.1	269.2	578.3
1971	2476.1	1557.6	4877.7	88.9	725.8
1972	3211.5	1595.3	5007.8	68.6	544.3
1973	3456.4	1711.8	4289.7	73.7	487.6
1974	2767.9	1233.8	4309.9	63.5	424.1
1975	3674.2	1449.7	4964.2	81.3	691.7
1976	4953.3	1660.2	5346.2	30.2	335.7
1977	3263.7	1388.0	5552.2	50.8	805.1
1978	4220.7	1163.9	4949.9	50.8	1406.2
1979	4059.7	1160.4	4681.2	111.8	1456.3
1980	5388.8	1185.0	6082.9	83.8	1134.0
1981	6222.3	1225.3	6967.3	55.9	760.7
1982	5985.1	1357.0	6575.0	80.8	963.3
1983	6803.5	1049.0	4991.3	28.3	1078.2
1984	4358.0	987.0	4638.0	33.0	1290.8

Table A-2. Annual Production of Major Grains and Oilseeds, Brown Soil Zone, Alberta, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1957	572.6	51.1	148.1	32.3	0.1
1958	542.4	68.6	220.7	34.1	0.1
1959	543.9	87.3	188.4	24.0	0.0
1960	364.2	46.9	106.8	15.5	0.2
1961	211.0	22.2	53.9	3.3	0.5
1962	342.2	83.8	94.9	1.8	0.2
1963	625.6	100.2	139.8	5.7	0.2
1964	660.2	46.7	132.4	6.5	0.4
1965	871.6	108.8	190.4	14.5	0.6
1966	1133.4	92.8	266.7	14.9	0.7
1967	755.7	64.5	191.0	4.4	0.8
1968	1000.5	97.5	309.8	12.1	0.5
1969	874.1	102.1	367.2	36.3	0.8
1970	528.1	130.3	356.7	87.9	1.7
1971	591.8	110.6	445.4	16.1	2.2
1972	698.3	108.3	308.2	9.3	1.6
1973	774.0	112.1	234.4	8.5	1.5
1974	714.2	85.8	314.9	5.6	1.3
1975	1061.2	98.5	310.8	6.6	2.1
1976	1290.2	93.0	301.0	1.7	1.0
1977	797.9	56.3	296.0	5.0	2.4
1978	1170.0	55.7	321.8	6.0	4.6
1979	1047.1	90.0	307.4	12.6	6.0
1980	1195.8	86.0	343.5	5.0	3.9
1981	1564.3	74.9	372.2	7.7	3.0
1982	1442.2	106.5	314.1	9.7	3.9
1983	1616.5	93.2	268.7	3.4	3.7
1984	988.3	25.9	167.7	4.4	4.4

Table A-3. Annual Production of Grains and Oilseeds, Dark Brown Soil Zone, Alberta, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1957	962.1	129.6	332.9	70.2	7.1
1958	986.5	178.8	460.7	91.5	5.9
1959	1107.1	202.8	410.6	99.0	2.6
1960	982.3	204.6	328.5	97.2	14.2
1961	712.5	140.2	177.1	53.1	29.8
1962	900.8	275.3	309.5	40.4	15.1
1963	1528.1	341.4	435.4	44.7	20.2
1964	1506.3	162.6	333.7	51.9	36.6
1965	1579.2	247.2	450.8	56.8	53.9
1966	1984.8	240.7	565.4	67.8	62.4
1967	1385.5	164.9	475.6	22.7	69.2
1968	1593.2	236.5	722.3	56.0	42.5
1969	1302.7	281.8	798.9	78.2	66.3
1970	597.2	312.4	870.0	121.2	144.6
1971	827.5	254.0	1108.2	52.6	181.4
1972	1164.4	282.9	971.8	38.8	136.1
1973	1277.0	289.8	789.9	39.9	121.9
1974	1139.2	212.4	825.3	32.9	106.0
1975	1387.5	240.5	878.2	40.5	172.9
1976	1724.0	242.0	927.7	16.5	83.9
1977	1083.8	161.6	952.4	29.4	201.3
1978	1509.5	199.8	913.8	29.1	320.9
1979	1471.4	189.8	846.2	65.2	335.5
1980	1843.8	184.0	1065.7	49.1	305.8
1981	2208.7	153.0	1263.8	35.1	203.4
1982	2132.5	198.0	1082.0	53.9	269.1
1983	2205.1	133.2	742.3	17.9	272.2
1984	1465.8	100.1	505.6	19.7	313.6

Table A-4. Annual Production of Major Grains and Oilseeds, Black Soil Zone, Alberta, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1957	765.2	662.2	1071.5	18.6	12.0
1958	921.3	753.2	1194.1	25.9	9.9
1959	1047.7	677.8	1150.8	24.0	4.4
1960	1124.3	862.0	1146.5	27.3	23.8
1961	1011.0	784.3	902.9	23.3	50.1
1962	1293.0	1271.3	1115.2	16.2	25.3
1963	1590.6	1206.0	1435.0	18.7	33.9
1964	1341.1	714.6	1307.7	21.9	61.5
1965	1366.7	1052.4	1409.0	22.7	90.5
1966	1549.8	957.7	1867.5	23.1	104.8
1967	1381.6	809.1	1767.7	6.1	116.2
1968	1293.4	851.4	1878.9	15.4	71.4
1969	1206.1	923.6	2230.8	23.1	111.4
1970	637.6	1108.5	2177.6	41.5	242.9
1971	750.3	916.4	2440.6	12.3	304.8
1972	971.5	936.5	2795.3	10.6	228.6
1973	1046.9	1000.9	2425.3	13.4	204.8
1974	745.2	707.1	2281.1	12.8	178.1
1975	943.8	815.4	2583.4	13.5	290.5
1976	1453.3	938.6	2785.0	6.6	141.0
1977	1065.9	879.5	3207.7	9.7	338.2
1978	1172.5	636.8	2684.8	11.0	554.0
1979	1118.2	608.6	2518.4	22.4	587.0
1980	1586.2	677.6	3352.9	12.8	417.1
1981	1731.1	680.4	3842.7	7.0	326.4
1982	1762.8	733.4	3663.8	9.7	449.1
1983	1881.4	546.4	2708.9	3.0	475.8
1984	1536.3	567.0	2603.7	3.8	585.3

Table A-5. Annual Production of Major Grains and Oilseeds, Gray Soil Zone, Alberta, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1957	232.1	276.5	535.8	22.7	9.3
1958	214.6	218.9	366.6	14.1	7.7
1959	432.9	399.6	557.9	22.2	3.4
1960	411.8	320.8	487.1	22.6	18.5
1961	484.8	379.6	544.7	29.6	39.0
1962	500.3	361.8	476.3	29.7	19.7
1963	310.5	275.9	402.0	24.9	26.4
1964	474.0	299.2	571.8	29.0	47.9
1965	319.7	204.7	454.3	27.4	70.5
1966	498.5	268.0	726.9	34.3	81.6
1967	403.6	184.4	603.9	10.0	90.5
1968	640.7	268.5	966.4	25.7	55.6
1969	437.6	203.8	737.5	22.4	86.8
1970	195.6	258.1	710.8	18.6	189.0
1971	306.6	276.5	883.4	7.9	237.3
1972	377.2	267.6	932.5	9.9	178.0
1973	358.5	309.0	840.1	11.9	159.5
1974	169.3	228.4	888.6	12.2	138.7
1975	281.7	295.3	1191.9	20.7	226.2
1976	485.8	386.6	1332.6	5.4	109.8
1977	316.1	290.6	1096.0	6.7	263.3
1978	368.7	271.5	1029.5	4.7	526.7
1979	422.9	271.9	1009.2	11.6	527.8
1980	763.0	237.4	1320.9	17.0	407.2
1981	718.3	317.0	1488.6	6.2	227.9
1982	647.6	319.0	1515.1	7.5	241.2
1983	1100.4	276.2	1271.3	4.0	326.5
1984	867.6	294.0	1361.0	5.1	387.5

Table A-6. Annual Production of Major Grains and Oilseeds, Manitoba, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1957	1333.6	740.3	718.5	88.9	7.8
1958	1660.2	771.1	958.0	19.4	5.7
1959	1678.4	771.1	718.5	116.8	4.1
1960	1796.3	863.6	522.6	162.6	10.9
1961	925.3	370.1	196.0	109.2	8.2
1962	2177.3	1372.6	457.2	198.1	13.2
1963	1660.2	956.2	348.4	236.2	17.2
1964	2313.4	1125.8	348.4	269.3	33.3
1965	2449.4	1141.2	479.0	411.5	54.4
1966	2150.1	987.0	609.6	266.7	47.6
1967	2449.4	1017.9	718.5	144.8	52.2
1968	2476.7	1249.2	936.2	264.2	43.1
1969	1741.8	1064.1	914.5	259.1	79.4
1970	830.1	817.4	1110.4	292.1	163.3
1971	2014.0	1172.1	2046.7	149.9	272.2
1972	1877.9	848.2	1850.7	149.9	192.8
1973	2095.6	971.6	1807.2	193.1	174.6
1974	1605.7	633.1	1153.9	167.7	192.8
1975	2122.8	771.1	1110.4	213.5	283.5
1976	2803.2	940.8	1458.7	160.0	102.1
1977	2748.8	894.5	2046.6	330.1	290.3
1978	2830.4	632.3	1850.7	317.5	578.3
1979	2041.2	308.4	1262.8	444.5	567.0
1980	1905.1	277.6	1567.6	211.0	294.8
1981	3326.1	462.7	2330.0	261.0	306.0
1982	3701.0	571.0	2373.0	424.0	420.0
1983	3410.0	401.0	1589.0	297.0	397.0
1984	3743.0	447.0	1938.0	419.0	544.0

Table A-7. Annual Production of Major Grains and Oilseeds, Saskatchewan, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	3800.0	291.0	436.0	143.0	126.0
1962	9273.0	1694.0	1030.0	112.0	59.0
1963	12947.0	1818.0	1680.0	194.0	90.0
1964	9040.0	. 832.0	737.0	122.0	120.0
1965	10099.0	1448.0	1413.0	197.0	242.0
1966	14615.0	1501.3	1776.4	152.4	288.0
1967	9226.2	850.0	1277.4	40.6	231.3
1968	10125.8	1265.5	1617.5	106.7	226.8
1969	12109.8	1785.7	2153.0	287.3	412.8
1970	5715.4	1837.9	2787.4	652.8	702.2
1971	9422.6	2498.5	4701.2	326.7	969.6
1972	8872.4	1929.1	3460.7	228.6	562.5
1973	9344.4	1788.5	3306.9	203.0	544.3
1974	8274.9	1332.9	2740.9	119.4	526.2
1975	10532.8	1445.3	2711.5	137.4	748.4
1976	14853.3	1574.6	2847.6	80.9	387.8
1977	12851.2	1638.9	3445.3	267.4	839.1
1978	12931.5	1193.7	2755.2	211.4	1451.5
1979	10010.0	876.0	2356.0	263.8	1281.4
1980	10808.0	895.0	2539.0	165.3	997.9
1981	13953.0	1099.0	3116.0	153.0	759.9
1982	16136.0	1281.0	3349.0	223.9	793.8
1983	15203.0	882.0	2296.0	115.3	1088.2
1984	10658.0	658.0	2347.0	221.3	1315.0

Table A-8. Annual Production of Major Grains and Oilseeds, Brown Soil Zone, Saskatchewan, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	939.0	24.0	78.0	49.0	1.0
1962	2764.0	210.0	198.0	32.0	1.0
1963	3961.0	212.0	348.0	68.0	1.0
1964	2568.9	88.0	134.0	31.0	1.0
1965	3377.0	230.0	307.0	57.0	2.0
1966	4487.3	334.2	205.5	40.2	1.9
1967	2449.0	190.8	96.5	9.7	1.8
1968	2837.3	260.8	136.5	28.9	1.9
1969	3904.5	454.2	226.2	83.2	5.0
1970	2612.0	511.2	323.4	236.2	26.5
1971	2817.2	1051.3	264.6	98.8	104.8
1972	3000.9	659.2	266.1	51.6	49.8
1973	2999.6	471.1	209.4	46.6	48.9
1974	2901.4	349.7	173.4	24.3	40.9
1975	3768.3	342.2	223.1	29.4	50.9
1976	5067.7	342.7	202.9	9.4	5.2
1977	4183.4	512.1	163.0	38.7	12.1
1978	4526.6	376.7	140.9	25.0	41.6
1979	3991.0	373.0	134.0	40.2	27.5
1980	3792.0	383.0	110.0	13.3	14.0
1981	4214.0	366.0	112.0	10.7	7.6
1982	5223.0	486.0	181.0	30.1	12.4
1983	4861.0	324.0	110.0	8.5	14.1
1984	2996.0	203.0	31.0	17.1	13.4

Table A-9. Annual Production of Major Grains and Oilseeds, Dark Brown Soil Zone, Saskatchewan, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	1303.0	80.0	85.0	53.0	4.0
1962	2996.0	542.0	195.0	43.0	3.0
1963	4330.0	591.0	324.0	76.0	3.0
1964	2891.0	255.0	117.0	53.0	6.0
1965	3030.0	430.0	245.0	82.0	12.0
1966	5236.9	415.1	401.3	66.7	6.5
1967	3309.3	207.0	279.5	15.6	4.4
1968	3575.3	320.0	385.8	47.8	5.0
1969	4350.9	509.7	668.4	131.0	14.7
1970	1780.2	481.7	960.9	291.8	65.6
1971	3575.1	537.4	1850.8	168.5	254.9
1972	3067.1	372.8	1123.0	125.1	110.2
1973	3709.3	432.0	1002.6	121.3	88.4
1974	2917.4	331.0	693.1	51.5	71.2
1975	3623.1	378.1	657.9	47.7	107.4
1976	5069.5	437.8	742.7	24.4	64.9
1977	4668.2	433.8	1019.3	105.9	148.9
1978	4210.1	288.9	794.3	82.6	270.1
1979	3515.0	189.0	567.0	109.8	258.0
1980	3367.0	153.0	637.0	53.5	149.5
1981	4648.0	247.0	759.0	48.5	101.2
1982	5607.0	277.0	941.0	86.3	118.3
1983	5206.0	169.0	625.0	39.4	171.0
1984	3130.0	102.0	435.0	57.6	170.1

Table A-10. Annual Production of Major Grains and Oilseeds, Black Soil Zone, Saskatchewan, 1957-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	1558.0	187.0	273.0	41.0	121.0
1962	3513.0	942.0	637.0	37.0	55.0
1963	4656.0	1015.0	1008.0	50.0	86.0
1964	3581.0	489.0	486.0	38.0	113.0
1965	3692.0	788.0	861.0	58.0	228.0
1966	4890.7	752.0	1169.7	45.6	279.6
1967	3467.9	452.1	901.3	15.3	225.2
1968	3713.3	684.7	1095.3	30.1	219.9
1969	3854.3	821.8	1258.4	73.1	393.0
1970	1323.2	845.0	1503.1	124.8	610.1
1971	3030.3	909.9	2585.8	59.5	609.9
1972	2804.4	897.0	2071.7	51.9	402.5
1973	2635.5	885.3	2094.9	35.1	407.0
1974	2456.1	652.3	1874.5	43.6	414.1
1975	3141.5	725.0	1830.4	60.3	590.1
1976	4716.1	794.1	1902.0	47.1	317.7
1977	3999.6	693.0	2263.0	122.8	678.1
1978	4194.8	528.1	1820.0	103.8	1139.8
1979	2504.0	314.0	1655.0	113.8	995.9
1980	3649.0	359.0	1792.0	98.5	834.4
1981	5091.0	486.0	2245.0	93.8	651.1
1982	5306.0	518.0	2227.0	107.5	663.1
1983	5136.0	389.0	1561.0	67.4	903.1
1984	4532.0	353.0	1881.0	146.6	1131.5

Table A-11. Annual Production of Major Grains and Oilseeds, Prairies, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	7144.6	1987.5	2310.5	361.4	253.6
1962	14486.5	5058.7	3483.1	398.2	132.5
1963	18662.0	4697.7	4440.7	524.2	187.9
1964	15335.0	3180.9	3431.0	500.7	299.8
1965	16685.7	4202.2	4396.5	729.9	511.9
1966	21931.5	4047.5	5812.5	559.2	585.1
1967	15602.0	3090.8	5034.1	228.6	560.2
1968	17130.2	3968.6	6431.1	480.1	440.0
1969	17672.0	4361.2	7202.0	706.4	757.6
1970	8504.0	4464.6	8102.9	1214.1	1443.8
1971	13912.7	5228.2	11625.6	565.5	1967.6
1972	13961.8	4372.6	10319.2	447.1	1299.6
1973	14896.4	4471.9	9403.8	469.8	1206.5
1974	12648.5	3199.8	8204.7	350.6	1143.1
1975	16329.8	3666.1	8786.1	432.2	1723.6
1976	22609.8	4175.6	9652.5	271.1	825.6
1977	18863.7	3921.4	11044.1	648.3	1934.5
1978	19982.6	2989.9	9555.8	579.7	3436.0
1979	16110.9	2344.8	8300.0	820.1	3304.7
1980	18101.9	2357.6	10189.5	460.1	2426.7
1981	23501.4	2787.0	12413.3	469.9	1826.6
1982	25822.1	3209.0	12297.0	728.7	2177.1
1983	25416.5	2332.0	8876.3	440.6	2563.4
1984	19259.0	2092.0	8923.0	673.3	3148.8

Table A-12. Annual Production of Major Grains and Oilseeds, Brown Soil Zone, Prairies, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	1150.0	64.2	131.9	52.3	1.5
1962	3106.2	293.8	292.9	33.8	1.2
1963	4586.6	312.2	487.8	73.7	1.2
1964	3228.2	134.7	266.4	37.5	1.4
1965	4248.6	338.8	497.4	71.5	2.6
1966	5620.7	427.0	472.2	55.1	2.6
1967	3204.7	255.3	287.5	14.1	2.6
1968	3837.8	358.3	446.3	41.0	2.4
1969	4778.6	556.3	593.4	119.5	5.8
1970	3140.1	641.5	680.1	324.1	28.2
1971	3409.0	1161.9	710.0	114.9	107.2
1972	3699.2	767.5	574.3	60.9	51.4
1973	3773.6	583.2	443.8	55.1	50.4
1974	3615.6	435.5	488.3	29.9	42.2
1975	4829.5	440.7	533.9	36.0	53.0
1976	6357.9	435.7	503.9	11.1	6.2
1977	4981.3	568.4	459.0	43.7	14.5
1978	5696.6	432.4	462.7	31.0	46.2
1979	5038.1	463.0	441.4	52.8	33.5
1980	4987.8	469.0	453.5	18.3	17.9
1981	5778.3	440.9	484.2	18.4	10.6
1982	6665.2	592.5	495.1	39.8	16.3
1983	6477.5	417.2	378.7	11.9	17.8
1984	3984.3	228.9	198.7	21.5	17.8

Table A-13. Annual Production of Major Grains and Oilseeds, Dark Brown Soil Zone, Prairies, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	2015.5	220.2	262.1	106.1	33.8
1962	3896.8	817.3	504.5	83.4	18.1
1963	5858.1	932.4	759.4	120.7	23.2
1964	4397.3	417.6	450.7	104.9	42.6
1965	4609.2	677.2	695.8	138.8	65.9
1966	7221.7	655.8	966.7	134.5	68.5
1967	4694.8	371.9	755.1	38.3	73.6
1968	5168.5	556.5	1108.1	103.8	47.5
1969	5653.6	791.5	1467.3	209.2	81.0
1970	2377.4	794.1	1830.9	413.0	210.2
1971	4402.6	791.4	2959.0	221.1	436.3
1972	4231.5	655.7	2094.8	163.9	246.3
1973	4986.3	721.7	1792.5	161.2	210.3
1974	4056.6	543.4	1518.4	84.4	177.2
1975	5010.6	618.6	1536.1	88.2	280.3
1976	6793.5	679.8	1670.4	40.9	148.8
1977	5752.0	595.4	1971.7	135.3	350.2
1978	5719.6	488.7	1708.1	111.7	591.0
1979	4986.4	378.8	1413.2	175.0	593.5
1980	5210.8	337.0	1702.7	102.6	455.3
1981	6856.7	400.0	2022.8	83.6	304.6
1982	7739.5	475.0	2023.0	140.2	387.4
1983	7411.1	302.2	1367.3	57.3	443.2
1984	4595.8	202.1	940.6	77.3	483.7

Table A-14. Annual Production of Major Grains and Oilseeds, Black Soil Zone, Prairies, 1961-84 ('000 tonnes)

Year	Wheat	Oats	Barley	Flax	Canola
1961	3494.3	1341.4	1371.9	173.5	179.3
1962	6983.3	3585.9	2209.4	251.3	93.5
1963	7906.8	3177.2	2791.4	304.9	137.7
1964	7235.5	2329.4	2142.1	329.2	207.8
1965	7508.1	2981.6	2749.0	492.2	372.9
1966	8590.6	2696.7	3646.8	335.4	432.0
1967	7298.9	2279.1	3387.5	166.2	393.0
1968	7483.4	2785.3	3910.4	309.7	334.4
1969	6802.2	2809.5	4403.7	355.3	583.8
1970	2790.9	2770.9	4791.1	458.4	1016.3
1971	5794.6	2998.4	7073.1	221.7	1186.9
1972	5653.8	2681.7	6717.7	212.4	823.9
1973	5778.0	2857.8	6327.4	241.6	786.4
1974	4807.0	1992.5	5309.5	224.1	785.0
1975	6208.1	2311.5	5524.2	287.3	1164.7
1976	8972.6	2673.5	6145.7	213.7	560.8
1977	7814.3	2467.0	7517.3	462.6	1306.0
1978	8197.7	1797.2	6355.5	432.3	2272.7
1979	5663.4	1231.0	5436.2	580.7	2149.9
1980	7140.3	1314.2	6712.5	322.3	1546.3
1981	10148.2	1629.1	8417.7	361.8	1283.5
1982	10769.8	1822.4	8263.8	541.2	1532.2
1983	10427.4	1336.4	5858.9	367.4	1775.9
1984	9811.3	1367.0	6422.7	569.4	2260.8

Appendix 2

Table B-1. Provincial and Derived Zonal Wheat Prices, Alberta, 1957-84 (dollars/tonne)

Year	Alberta	Brown	Dark Brown	Black	Gray
1957	45.20	46.96	45.74	44.38	42.44
1958	48.14	50.01	48.71	47.27	45.20
1959	45.93	47.72	46.48	45.10	43.13
1960	56.22	58.41	56.89	55.21	52.79
1961	63.20	65.66	63.96	62.06	59.34
1962	59.52	61.85	60.24	58.45	55.89
1963	63.57	66.04	64.33	62.42	59.69
1964	56.95	59.17	57.64	55.93	53.48
1965	60.26	62.61	60.98	59.18	56.58
1966	63.57	66.05	64.33	62.42	59.69
1967	59.16	61.47	59.87	58.09	55.55
1968	48.14	50.01	48.71	47.27	45.20
1969	42.99	44.67	43.51	42.22	40.37
1970	49.60	51.54	50.20	48.71	46.58
1971	47.77	49.63	48.34	46.91	44.85
1972	67.61	70.25	68.42	66.39	63.48
1973	155.80	161.87	157.66	152.99	146.29
1974	145.51	151.18	147.25	142.89	136.63
1975	128.97	134.00	130.52	126.65	121.10
1976	102.88	106.90	104.12	101.03	96.61
1977	101.05	104.99	102.26	99.23	94.88
1978	134.48	139.73	136.10	132.06	126.28
1979	178.57	185.53	180.71	175.35	167.67
1980	196.95	104.63	199.31	193.40	184.93
1981	185.00	192.21	187.22	181.67	173.71
1982	167.00	173.51	169.00	163.99	156.81
1983	173.00	179.75	175.08	169.89	162.45
1984	163.00	169.36	164.96	160.07	153.06

Table B-2. Provincial and Derived Zonal Wheat Prices, Saskatchewan, 1957-84
(dollars/tonne)

Year	Saskatchewan	Brown	Dark Brown	Black
1957	47.40	48.21	47.92	46.03
1958	48.50	49.33	49.04	47.10
1959	48.50	49.33	49.04	47.10
1960	58.05	59.04	58.69	56.37
1961	64.30	65.40	65.01	62.44
1962	61.36	62.41	62.04	59.58
1963	64.30	65.40	65.01	62.44
1964	58.79	59.79	59.44	57.09
1965	62.46	63.53	63.15	60.65
1966	65.04	66.14	65.75	63.15
1967	59.52	60.54	60.18	57.80
1968	49.24	50.07	49.78	47.81
1969	47.40	48.21	47.92	46.03
1970	53.28	54.18	53.87	51.73
1971	49.60	50.45	50.15	48.17
1972	69.08	70.25	69.84	67.08
1973	169.02	171.90	170.88	164.12
1974	159.10	161.81	160.85	154.49
1975	135.22	137.52	136.71	131.30
1976	106.56	108.37	107.73	103.47
1977	104.72	106.50	105.87	101.68
1978	141.46	143.87	143.02	137.36
1979	178.94	181.99	180.91	173.75
1980	209.81	213.37	212.12	203.72
1981	188.00	191.20	190.07	182.55
1982	172.00	174.92	173.89	167.01
1983	179.00	182.04	180.97	173.81
1984	176.00	178.99	177.94	170.90

Table B-3. Prairie Aggregate and Derived Zonal Wheat Prices, Prairies, 1957-84
(dollars/tonne)

Year	Prairies	Brown	Dark Brown	Black	Gray
1957	47.03	48.68	48.07	45.57	43.83
1958	48.50	50.20	49.57	47.00	45.20
1959	48.14	49.82	49.19	46.64	44.86
1960	57.69	59.71	58.96	55.90	53.77
1961	63.93	66.17	65.34	61.95	59.59
1962	61.00	63.13	62.34	59.10	56.85
1963	63.93	66.17	65.34	61.95	59.59
1964	58.42	60.47	59.71	56.61	54.45
1965	61.73	63.89	63.09	59.82	57.53
1966	64.67	66.93	66.09	62.66	60.27
1967	59.52	61.61	60.83	57.68	55.48
1968	48.87	50.58	49.95	47.36	45.55
1969	46.30	47.92	47.32	44.86	43.15
1970	52.18	54.00	53.32	50.56	48.63
1971	49.24	50.96	50.32	47.71	45.89
1972	68.71	71.12	70.22	66.58	64.04
1973	164.61	170.37	168.23	159.51	153.42
1974	154.69	160.11	158.10	149.90	144.17
1975	133.01	137.67	135.94	128.89	123.97
1976	105.45	109.15	107.78	102.19	98.28
1977	103.25	106.86	105.52	100.05	96.23
1978	138.89	143.75	141.95	134.59	129.45
1979	177.84	184.07	181.75	172.33	165.75
1980	205.40	212.59	209.92	199.03	191.43
1981	185.23	191.71	189.30	179.48	172.63
1982	169.54	175.47	173.27	164.28	158.01
1983	176.72	182.91	180.61	171.24	164.71
1984	171.94	177.96	175.73	166.61	160.25

Table B-4. Provincial and Derived Zonal Barley Prices, Alberta, 1957-84 (dollars/tonne)

Year	Alberta	Brown	Dark Brown	Black	Gray
1957	33.99	36.10	35.59	33.65	33.14
1958	34.45	36.59	36.07	34.11	33.59
1959	33.53	35.61	35.11	33.19	32.69
1960	36.28	38.53	37.99	35.92	35.37
1961	48.68	51.70	50.97	48.19	47.46
1962	43.17	45.85	45.20	42.74	42.09
1963	42.71	45.36	44.72	42.28	41.64
1964	45.01	47.80	47.13	44.56	43.88
1965	46.85	49.75	49.05	46.38	45.68
1966	47.31	50.24	49.53	46.84	46.13
1967	38.58	40.97	40.39	38.19	37.62
1968	37.20	39.51	38.95	36.83	36.27
1969	28.48	30.25	29.82	28.20	27.77
1970	31.69	33.65	33.18	31.37	30.90
1971	30.77	32.68	32.22	30.46	30.00
1972	57.87	61.46	60.59	57.29	56.42
1973	114.82	121.94	120.22	113.67	111.95
1974	101.05	107.32	105.80	100.04	98.52
1975	106.10	112.68	111.09	105.04	103.45
1976	86.00	91.33	90.04	85.14	83.85
1977	74.00	78.59	77.48	73.26	72.15
1978	79.00	83.90	82.71	78.21	77.02
1979	106.00	112.57	110.98	104.94	103.35
1980	139.00	147.62	145.53	137.61	135.52
1981	115.00	122.13	120.40	113.85	112.12
1982	90.00	95.58	94.23	89.10	87.75
1983	116.00	123.19	121.45	114.84	113.10
1984	121.00	128.50	126.69	119.79	117.97

Table B-5. Provincial and Derived Zonal Barley Prices, Saskatchewan, 1957-84 (dollars/tonne)

Year	Saskatchewan	Brown	Dark Brown	Black
1957	34.91	36.80	36.27	33.90
1958	34.45	36.31	35.79	33.45
1959	33.53	35.34	34.84	32.56
1960	36.29	38.25	37.71	35.24
1961	48.22	50.82	50.10	46.82
1962	42.25	44.53	43.90	41.02
1963	43.63	45.99	45.33	42.36
1964	46.85	49.38	48.68	45.49
1965	47.77	50.35	49.63	46.38
1966	48.23	50.83	50.11	46.83
1967	39.04	41.15	40.56	37.91
1968	35.83	37.76	37.23	34.79
1969	30.77	32.43	31.97	29.88
1970	36.28	38.24	37.69	35.23
1971	30.31	31.95	31.49	29.43
1972	56.49	59.54	58.69	54.85
1973	115.74	121.99	120.25	112.38
1974	100.13	105.54	104.04	97.23
1975	106.56	112.31	110.72	103.47
1976	90.00	94.86	93.51	87.39
1977	78.00	82.21	81.04	75.74
1978	83.00	87.48	86.24	80.59
1979	112.00	118.05	116.37	108.75
1980	147.00	154.94	152.73	142.74
1981	132.00	139.13	137.15	128.17
1982	108.00	113.83	112.21	104.87
1983	125.00	131.75	129.87	121.37
1984	125.00	131.75	129.87	121.37

Table B-6. Prairie Aggregate Derived Zonal Barley Prices, Prairies, 1957-84 (dollars/tonne)

Year	Prairies	Brown	Dark Brown	Black	Gray
1957	34.85	37.18	37.05	34.47	33.35
1958	34.97	37.31	37.17	34.59	33.47
1959	33.89	36.16	36.03	33.52	32.43
1960	36.58	39.03	38.88	36.18	35.01
1961	48.56	51.81	51.62	48.03	46.47
1962	43.02	45.90	45.73	42.55	41.17
1963	43.19	46.08	45.91	42.71	41.33
1964	45.74	48.80	48.62	45.24	43.77
1965	47.29	50.46	50.27	46.77	45.26
1966	47.93	51.14	50.95	47.40	45.87
1967	39.03	41.65	41.49	38.60	37.35
1968	36.71	39.17	39.02	36.31	35.13
1969	29.59	31.57	31.45	29.26	28.32
1970	33.70	35.96	35.82	33.33	32.25
1971	30.80	32.86	32.74	30.46	29.48
1972	57.37	61.21	60.98	56.74	54.90
1973	115.25	122.97	122.51	113.98	110.29
1974	101.05	107.82	107.42	99.94	96.70
1975	106.98	114.15	113.72	105.80	102.38
1976	88.19	94.10	93.75	87.22	84.40
1977	75.33	80.38	80.08	74.50	72.09
1978	79.92	85.27	84.95	79.04	76.48
1979	107.02	114.19	113.76	105.84	102.42
1980	141.00	150.45	149.88	139.45	134.94
1981	120.17	128.22	127.74	118.85	115.00
1982	95.05	01.42	01.04	94.00	90.96
1983	118.94	126.91	126.43	117.63	113.83
1984	122.06	130.24	129.75	120.72	116.81

Appendix 3

Table C-1.Provincial and Zonal Quantities of Cropped Land, Alberta and Manitoba, 1957-84 ('000 hectares)

Year	Alberta					Manitoba
	Total	Brown	Dark Brown	Black	Gray	
1957	4596.8	664.8	1121.1	1971.4	839.5	2635.8
1958	4636.0	695.8	1140.0	1968.4	831.7	1927.1
1959	4820.1	741.0	1189.2	1935.0	954.9	2455.5
1960	4766.7	700.2	1206.7	1986.3	973.6	2396.9
1961	4655.2	668.0	1107.8	1976.0	803.3	2417.3
1962	4773.6	700.5	1149.6	2019.7	903.8	2284.9
1963	4974.3	726.0	1159.9	2094.5	993.8	2495.0
1964	5067.6	728.4	1205.6	2135.7	997.8	2518.2
1965	5159.0	749.5	1271.7	2228.2	909.6	2682.0
1966	5422.3	780.0	1287.3	2300.5	1054.6	2775.7
1967	5521.9	786.0	1306.0	2354.5	1075.4	2806.8
1968	5585.3	792.6	1283.7	2352.9	1183.7	2790.7
1969	5524.7	807.4	1279.5	2382.1	1055.7	2856.8
1970	4548.0	641.7	1018.2	1967.7	920.5	2641.3
1971	5400.0	718.8	1236.0	2282.2	1162.5	2290.9
1972	5180.4	691.2	1200.7	2244.7	1043.7	2878.1
1973	5364.2	724.4	1269.4	2318.2	1052.2	2755.2
1974	5038.6	711.6	1238.1	2126.7	961.8	2994.9
1975	5463.5	742.4	1281.1	2281.1	1158.9	2832.3
1976	5581.2	795.4	1336.8	2286.4	1162.6	2914.5
1977	5450.0	795.5	1293.8	2247.3	1113.5	3005.0
1978	5936.3	790.0	1447.2	2330.1	1368.4	2995.0
1979	5969.4	803.5	1501.9	2310.7	1353.3	3118.0
1980	6139.0	796.7	1452.1	2444.2	1446.0	3035.0
1981	6494.6	866.9	1532.5	2634.2	1461.4	2975.0
1982	6613.4	863.1	1564.8	2664.1	1520.4	3295.0
1983	6589.0	916.3	1630.9	2658.0	1383.7	3478.0
1984	6457.8	893.3	1425.2	2606.9	1552.4	3481.0

Table C-2. Provincial and Zonal Quantity of Cropped Land, Saskatchewan, 1961-84 ('000 hectares)

Year	Saskatchewan	Brown	Dark Brown	Black
1961	7687.0	2616.0	2030.0	3041.0
1962	8905.0	2715.0	2750.0	3440.0
1963	9000.0	2818.0	2799.0	3383.0
1964	9017.0	277.0	2807.0	3440.0
1965	9191.0	2808.0	2836.0	3547.0
1966	9971.1	2890.5	3358.2	3722.4
1967	9869.1	2850.0	3318.4	3700.7
1968	9794.5	2822.5	3294.5	3677.5
1969	9335.8	2762.6	3086.8	3486.6
1970	8660.9	2172.7	1971.7	2716.5
1971	9760.4	2730.8	3260.0	3769.6
1972	8839.0	2547.0	2979.9	3311.9
1973	9590.9	2685.5	3151.1	3754.4
1974	9145.8	2560.1	2936.0	3649.7
1975	9226.7	2580.6	2956.2	3690.0
1976	9540.0	3023.5	3005.4	3511.2
1977	9447.0	2689.9	3086.8	3670.2
1978	9699.6	2799.7	3166.1	3733.8
1979	9768.7	2845.3	3221.1	3702.3
1980	9527.4	2736.4	3071.4	3719.5
1981	10359.5	2776.5	3238.1	4344.9
1982	10504.2	2749.6	3311.8	4442.8
1983	10707.7	2848.9	3354.0	4504.8
1984	11046.7	2769.0	3492.8	4784.9

Table C-3. Total Quantity of Cropped Land for the Prairie Region and its Major Soil Zones, 1961-84 ('000 hectares)

Year	Prairies	Brown	Dark Brown	Black	Gray
1961	14883.4	3280.8	3151.1	7648.2	803.3
1962	15963.4	3415.5	3899.6	7744.5	903.8
1963	16469.3	3543.9	3959.0	7972.6	993.8
1964	16602.7	3498.4	4012.6	8093.9	997.8
1965	17032.0	3557.5	4107.7	8457.2	909.6
1966	18169.1	3670.5	4645.4	8798.6	1054.6
1967	18197.7	3636.0	4624.4	8861.9	1075.4
1968	18170.5	3615.0	4578.3	8793.5	1183.7
1969	17717.1	3569.9	4366.2	8725.4	1055.6
1970	14050.3	2814.5	2989.9	7325.5	920.4
1971	17450.7	3449.6	4496.0	8342.6	1162.5
1972	16897.4	3238.3	4180.7	8434.7	1043.7
1973	17710.4	3409.9	4420.5	8827.8	1052.2
1974	17179.0	3271.8	4174.1	8771.3	961.8
1975	17522.4	3323.0	4237.3	8803.3	1158.9
1976	18035.8	3818.8	4342.2	8712.1	1162.7
1977	17902.0	3485.4	4380.6	8922.5	1113.5
1978	18630.9	3589.8	4613.3	9059.4	1368.4
1979	18856.1	3648.9	4722.9	9131.0	1353.3
1980	18701.3	3533.1	4523.5	9198.7	1446.0
1981	19829.1	3643.4	4770.1	9954.2	1461.4
1982	20412.6	3612.7	4877.6	10401.9	1520.4
1983	20774.6	3765.2	4984.9	10640.8	1383.7
1984	20985.4	3642.3	4917.9	10872.8	1552.4

Table C-4. Provincial and Zonal Capital Value of Land and Buildings, Alberta and Manitoba, 1957-84 (million dollars)

	Alberta					Manitoba
Year	Total	Brown	Dark Brown	Black	Gray	Black
1957	318.1	54.3	60.5	157.8	44.5	221.9
1958	366.6	61.5	70.3	182.1	51.9	171.4
1959	381.1	62.9	73.6	189.5	54.5	212.4
1960	412.3	66.8	80.2	205.2	59.7	225.1
1961	414.1	65.9	81.2	206.4	55.6	238.9
1962	448.2	70.0	88.6	223.9	66.4	225.8
1963	516.3	79.0	102.8	258.2	77.4	265.1
1964	576.0	86.5	115.5	288.4	87.3	304.9
1965	675.7	99.5	136.5	338.7	103.5	371.1
1966	790.5	114.7	160.9	396.8	122.5	425.3
1967	914.2	129.3	187.4	459.4	143.2	492.4
1968	1021.3	141.4	210.9	513.7	161.7	537.9
1969	982.9	133.2	204.4	495.0	157.2	522.4
1970	820.4	108.7	174.8	413.5	132.6	476.5
1971	947.3	122.8	199.8	477.6	154.7	407.6
1972	1075.3	137.4	224.9	538.9	174.2	547.6
1973	1378.6	173.6	286.1	697.7	221.4	626.4
1974	1743.0	216.1	358.5	860.8	277.5	888.1
1975	2430.1	296.7	495.7	1253.9	383.7	986.8
1976	2937.6	353.4	594.3	1530.5	460.0	1217.1
1977	3380.4	400.2	678.1	1778.1	524.6	1477.7
1978	4386.0	510.9	871.5	2328.5	675.0	1828.0
1979	6254.4	716.7	1232.7	3351.7	953.8	2242.1
1980	8252.5	930.0	1612.5	4462.9	1247.8	2654.9
1981	9629.3	1065.9	1865.2	5255.7	1442.5	3014.1
1982	9903.5	1077.5	1901.5	5454.8	1470.7	3004.5
1983	9264.4	990.4	1763.0	5148.2	1362.8	3076.8
1984	8441.7	886.4	1591.3	4733.3	1230.8	2890.2

Table C-5. Provincial and Zonal Capital Value of Land and Buildings, Saskatchewan, 1961-84 (million dollars)

Year	Saskatchewan	Brown	Dark Brown	Black
1961	551.2	163.7	144.7	242.3
1962	682.2	202.1	179.7	299.7
1963	778.4	230.0	205.7	341.9
1964	891.3	262.8	236.3	391.4
1965	1067.5	314.0	283.9	468.5
1966	1330.5	390.5	355.1	583.8
1967	1512.0	442.7	404.8	663.2
1968	1597.4	466.6	429.1	700.3
1969	1407.2	410.0	379.3	616.7
1970	1017.2	295.7	274.9	445.6
1971	1423.0	412.6	386.6	623.1
1972	1310.5	379.8	363.9	565.7
1973	1682.7	487.1	478.2	716.2
1974	2033.9	588.4	591.3	853.0
1975	2667.6	771.2	792.8	1102.2
1976	3347.6	967.1	1016.6	1344.7
1977	3781.8	1091.4	1172.7	1516.1
1978	4745.8	1368.7	1502.5	1873.2
1979	5817.6	1676.6	1879.7	2260.7
1980	7816.3	2250.3	2576.3	2988.9
1981	9778.9	2813.4	3286.7	3678.8
1982	10616.6	3052.2	3637.1	3929.1
1983	10504.5	3016.9	3667.1	3822.6
1984	10400.3	2984.8	3698.4	3720.2

Table C-6. Total Capital Value of Land and Buildings for the Prairie Region and its Major Soil Zones, 1961-84 (million dollars)

Year	Prairies	Brown	Dark Brown	Black	Gray
1961	1198.7	229.6	225.9	687.6	55.6
1962	1356.3	272.1	268.3	749.5	66.4
1963	1560.1	309.1	308.4	865.2	77.4
1964	1773.1	349.4	351.8	984.6	87.3
1965	2115.8	413.5	420.4	1178.4	103.5
1966	2548.9	504.6	515.9	1405.9	122.5
1967	2922.4	572.0	592.2	1615.0	143.2
1968	3161.3	607.9	639.9	1751.9	161.6
1969	2918.2	543.3	583.6	1634.1	157.2
1970	2319.4	404.4	446.8	1335.6	132.6
1971	2785.0	535.5	586.4	1508.4	154.7
1972	2932.6	517.2	588.9	1652.3	174.2
1973	3686.6	660.7	764.3	2040.2	221.4
1974	4663.8	804.5	949.8	2631.9	277.6
1975	6083.3	1067.9	1288.6	3343.1	383.7
1976	7483.7	1320.5	1610.9	4092.3	460.0
1977	8639.0	1491.7	1850.8	4771.9	524.6
1978	10958.4	1879.7	2374.0	6029.7	675.0
1979	14314.1	2393.3	3112.4	7854.6	953.8
1980	18723.8	3180.4	4188.8	10106.8	1247.8
1981	22422.7	3879.7	5151.9	11948.6	1442.5
1982	23527.4	4129.7	5538.6	12388.4	1470.7
1983	22847.8	4007.3	5430.1	12047.6	1362.8
1984	21735.4	3871.3	5289.6	11343.7	1230.8

Table C-7. Derived Zonal Prices of Cropped Land for Alberta's Soil Zones, 1957-84
(dollars/hectare)

Year	Brown	Dark Brown	Black	Gray
1957	82	54	80	53
1958	88	62	92	62
1959	85	65	98	57
1960	95	67	103	68
1961	99	73	104	69
1962	100	77	110	74
1963	108	89	123	78
1964	119	96	135	88
1965	133	107	152	114
1966	146	125	173	116
1967	165	144	195	133
1968	178	164	220	137
1969	165	160	208	149
1970	169	169	210	144
1971	171	162	209	133
1972	199	187	240	167
1973	240	225	301	210
1974	304	290	419	289
1975	400	387	550	331
1976	444	445	669	396
1977	503	524	791	471
1978	647	602	999	493
1979	892	821	1451	705
1980	1168	1110	1826	863
1981	1230	1217	1995	987
1982	1248	1214	2048	967
1983	1081	1081	1936	985
1984	1015	1116	1815	793

Table C-8. Derived Zonal Prices of Cropped Land for Saskatchewan's Soil Zones, 1961-84
(dollars/hectare)

Year	Brown	Dark Brown	Black
1961	62	71	80
1962	75	65	87
1963	82	74	101
1964	95	84	113
1965	112	100	132
1966	135	106	157
1967	155	122	179
1968	165	130	191
1969	149	123	177
1970	136	140	164
1971	151	119	165
1972	149	122	171
1973	182	152	191
1974	230	202	234
1975	298	268	299
1976	320	338	383
1977	406	380	413
1978	489	475	502
1979	589	583	610
1980	822	839	804
1981	1013	1015	847
1982	1110	1098	884
1983	1059	1093	849
1984	1078	1059	777

Table C-9. Derived Zonal Prices of Cropped Land for the Prairie Soil Zones, 1961-84
(dollars/hectare)

Year	Brown	Dark Brown	Black	Gray
1961	70	72	90	69
1962	80	69	97	74
1963	87	78	109	78
1964	100	88	122	88
1965	116	102	139	114
1966	138	111	160	116
1967	157	128	182	133
1968	168	140	199	137
1969	152	134	187	149
1970	144	149	182	144
1971	155	130	181	133
1972	160	141	196	167
1973	194	173	231	210
1974	246	228	300	289
1975	321	304	380	331
1976	346	371	470	396
1977	427	423	534	471
1978	524	515	666	493
1979	656	659	860	705
1980	900	926	1099	863
1981	1065	1080	1200	987
1982	1143	1136	1191	967
1983	1064	1089	1132	985
1984	1063	1076	1043	793

Appendix 4

Table D-1. Input Price Indexes for the Major Input Groups, Alberta, 1957-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1957	0.4115	0.6154	0.6511	0.9785	0.8203
1958	0.4626	0.6036	0.6853	1.0078	0.8278
1959	0.4636	0.6272	0.7169	1.0176	0.8328
1960	0.5034	0.6272	0.7343	0.9965	0.8405
1961	0.5157	0.6450	0.7538	0.9725	0.8529
1962	0.5422	0.6686	0.7783	0.9682	0.8635
1963	0.5968	0.6982	0.8002	0.9844	0.8684
1964	0.6521	0.7041	0.8249	1.0281	0.8788
1965	0.7470	0.7337	0.8450	1.0303	0.8785
1966	0.8295	0.7870	0.8734	0.9959	0.8872
1967	0.9387	0.8521	0.8982	1.0350	0.9015
1968	1.0350	0.8876	0.9281	1.0584	0.9597
1969	1.0114	0.9349	0.9548	1.0301	0.9862
1970	1.0247	0.9586	0.9777	0.9665	0.9826
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.1799	1.0888	1.0286	1.0941	1.0082
1973	1.4552	1.2130	1.0655	1.1033	1.0608
1974	1.9424	1.4556	1.1913	1.4028	1.2079
1975	2.4807	1.8521	1.3830	1.9153	1.4417
1976	2.9320	2.0592	1.4755	2.1863	1.6370
1977	3.4461	2.3491	1.5848	2.2117	1.7615
1978	4.0942	2.3669	1.7426	2.2165	1.8575
1979	5.7649	2.5680	1.9635	2.4074	1.9430
1980	7.3577	2.8047	2.2102	3.0946	2.2505
1981	8.1128	2.9645	2.4538	3.5135	2.8281
1982	8.2031	3.1243	2.6158	3.5457	3.2361
1983	7.7304	3.2544	2.7300	3.4338	3.3851
1984	7.1998	3.2959	2.7965	3.5245	3.5382

Table D-2. Input Price Indexes for the Major Input Groups, Brown Soil Zone, 1957-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1957	0.5377	0.6154	0.6477	0.9785	0.8128
1958	0.5601	0.6036	0.6740	1.0078	0.8206
1959	0.5519	0.6272	0.7020	1.0176	0.8264
1960	0.5958	0.6272	0.7217	0.9965	0.8348
1961	0.6049	0.6450	0.7384	0.9725	0.8471
1962	0.6105	0.6686	0.7604	0.9681	0.8581
1963	0.6546	0.6982	0.7823	0.9842	0.8638
1964	0.7066	0.7041	0.8089	1.0282	0.8751
1965	0.7726	0.7337	0.8340	1.0303	0.8760
1966	0.8426	0.7870	0.8644	0.9957	0.8856
1967	0.9308	0.8521	0.8854	1.0351	0.9000
1968	1.0030	0.8876	0.9359	1.0586	0.9596
1969	0.9622	0.9349	0.9660	1.0301	0.9862
1970	0.9807	0.9586	0.9827	0.9664	0.9825
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.1498	1.0888	1.0129	1.0928	1.0083
1973	1.3635	1.1230	1.0338	1.1020	1.0613
1974	1.6688	1.4556	1.1342	1.4290	1.2108
1975	2.0928	1.8521	1.3207	1.9540	1.4464
1976	2.3394	2.0592	1.4259	2.2080	1.6405
1977	2.6278	2.3491	1.5318	2.2373	1.7643
1978	3.2589	2.3669	1.6738	2.2519	1.8593
1979	4.3020	2.5680	1.8651	2.4435	1.9445
1980	5.3979	2.8047	2.1001	3.1071	2.2574
1981	5.7188	2.9645	2.3326	3.5107	2.8515
1982	5.8508	3.1243	2.5254	3.5847	3.2605
1983	5.2906	3.2544	2.6416	3.5044	3.4086
1984	5.0256	3.2959	2.7174	3.5970	3.5610

Table D-3. Input Price Indexes for the Major Input Groups, Alberta Dark Brown Soil Zone, 1957-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1957	0.4190	0.6154	0.6406	0.9785	0.8715
1958	0.4541	0.6036	0.6696	1.0078	0.8778
1959	0.4583	0.6272	0.6988	1.0176	0.8787
1960	0.4836	0.6272	0.7174	0.9965	0.8828
1961	0.5128	0.6450	0.7347	0.9725	0.8955
1962	0.5302	0.6686	0.7570	0.9681	0.9046
1963	0.5886	0.6982	0.7787	0.9843	0.9054
1964	0.6309	0.7041	0.8053	1.0281	0.9103
1965	0.6892	0.7337	0.8306	1.0303	0.8991
1966	0.7799	0.7870	0.8611	0.9958	0.9003
1967	0.8718	0.8521	0.8815	1.0351	0.9162
1968	0.9779	0.8876	0.9359	1.0585	0.9604
1969	0.9803	0.9349	0.9668	1.0301	0.9835
1970	1.0200	0.9586	0.9826	0.9665	0.9798
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.1463	1.0888	1.0128	1.0934	1.0159
1973	1.3572	1.2130	1.0322	1.1026	1.0843
1974	1.6772	1.4556	1.1303	1.4162	1.2593
1975	2.1105	1.8521	1.3174	1.9351	1.5078
1976	2.4192	2.0592	1.4316	2.1974	1.7048
1977	2.7888	2.3491	1.5380	2.2248	1.8347
1978	3.1666	2.3669	1.6756	2.2347	1.9321
1979	4.0969	2.5680	1.8571	2.4259	2.0200
1980	5.2167	2.8047	2.0915	3.1009	2.3622
1981	5.7109	2.9645	2.3234	3.5118	3.0851
1982	5.7708	3.1243	2.5319	3.5657	3.5048
1983	5.3783	3.2544	2.6510	3.4701	3.6538
1984	5.4983	3.2959	2.7312	3.5618	3.8129

Table D-4. Input Price Indexes for the Major Input Groups, Alberta Black Soil Zone, 1957-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1957	0.4612	0.6154	0.6405	0.9784	0.8724
1958	0.5041	0.6036	0.6689	1.0078	0.8788
1959	0.5262	0.6272	0.6979	1.0176	0.8800
1960	0.5487	0.6272	0.7167	0.9965	0.8843
1961	0.5500	0.6450	0.7338	0.9724	0.8971
1962	0.5725	0.6686	0.7559	0.9682	0.9067
1963	0.6209	0.6982	0.7777	0.9845	0.9071
1964	0.6713	0.7041	0.8044	1.0281	0.9119
1965	0.7360	0.7337	0.8299	1.0302	0.9010
1966	0.8176	0.7870	0.8606	0.9959	0.9021
1967	0.9041	0.8521	0.8808	1.0350	0.9177
1968	1.0057	0.8876	0.9361	1.0584	0.9611
1969	0.9834	0.9349	0.9671	1.0301	0.9841
1970	0.9904	0.9586	0.9828	0.9666	0.9804
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.1379	1.0888	1.0124	1.0944	1.0152
1973	1.3886	1.2130	1.0314	1.1036	1.0836
1974	1.8174	1.4556	1.1283	1.3962	1.2590
1975	2.2573	1.8521	1.3153	1.9055	1.5056
1976	2.6976	2.0592	1.4314	2.1808	1.7029
1977	3.1149	2.3491	1.5378	2.2052	1.8331
1978	3.7805	2.3669	1.6737	2.2075	1.9320
1979	5.1229	2.5680	1.8511	2.3983	2.0205
1980	6.1719	2.8047	2.0849	3.0916	2.3564
1981	6.7392	2.9645	2.3163	3.5146	3.0642
1982	6.9644	3.1243	2.5340	3.5358	3.4750
1983	6.8022	3.2544	2.6548	3.4157	3.6216
1984	6.4630	3.2959	2.7384	3.5058	3.7815

Table D-5. Input Price Indexes for the Major Input Groups, Alberta Gray Soil Zone, 1957-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1957	0.4765	0.6154	0.6429	0.9784	0.8722
1958	0.5268	0.6036	0.6737	1.0077	0.8785
1959	0.5003	0.6272	0.7037	1.0175	0.8796
1960	0.5662	0.6272	0.7219	0.9964	0.8837
1961	0.5572	0.6450	0.7399	0.9724	0.8965
1962	0.5918	0.6686	0.7628	0.9682	0.9054
1963	0.6214	0.6982	0.7846	0.9845	0.9061
1964	0.6836	0.7041	0.8106	1.0280	0.9109
1965	0.8281	0.7337	0.8344	1.0302	0.8997
1966	0.8533	0.7870	0.8644	0.9959	0.9008
1967	0.9529	0.8521	0.8860	1.0349	0.9165
1968	0.9844	0.8876	0.9337	1.0583	0.9604
1969	1.0762	0.9349	0.9635	1.0301	0.9834
1970	1.0486	0.9586	0.9813	0.9666	0.9800
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.2175	1.0888	1.0172	1.0947	1.0158
1973	1.4918	1.2130	1.0413	1.1038	1.0837
1974	1.9327	1.4556	1.1468	1.3915	1.2564
1975	2.1789	1.8521	1.3352	1.8986	1.5030
1976	2.5693	2.0592	1.4439	2.1769	1.7014
1977	2.9824	2.3491	1.5512	2.2006	1.8323
1978	3.1711	2.3669	1.6941	2.2011	1.9309
1979	4.2471	2.5680	1.8859	2.3918	2.0191
1980	5.0088	2.8047	2.1237	3.0895	2.3567
1981	5.6695	2.9645	2.3587	3.5154	3.0727
1982	5.6502	3.1243	2.5552	3.5287	3.4900
1983	5.8413	3.2544	2.6730	3.4027	3.6391
1984	4.9461	3.2959	2.7497	3.4925	3.7988

Table D-6. Input Price Indexes for the Major Input Groups, Manitoba, 1957-84
(1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1957	0.5022	0.5806	0.6461	0.9785	0.8663
1958	0.5256	0.6323	0.6820	1.0078	0.8730
1959	0.5515	0.6452	0.7142	1.0176	0.8750
1960	0.5535	0.6645	0.7309	0.9965	0.8802
1961	0.5760	0.6774	0.7510	0.9725	0.8931
1962	0.5762	0.6645	0.7732	0.9681	0.9059
1963	0.6155	0.6710	0.7939	0.9842	0.9058
1964	0.6922	0.7032	0.8166	1.0284	0.9104
1965	0.7788	0.7355	0.8361	1.0305	0.9012
1966	0.8563	0.8000	0.8658	0.9959	0.9040
1967	0.9669	0.8581	0.8936	1.0351	0.9201
1968	1.0568	0.8839	0.9195	1.0585	0.9634
1969	1.0202	0.9290	0.9460	1.0301	0.9863
1970	1.0073	0.9613	0.9733	0.9664	0.9804
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0733	1.1290	1.0341	1.0932	1.0134
1973	1.2757	1.2903	1.0747	1.1042	1.0885
1974	1.6386	1.4839	1.2092	1.4158	1.3081
1975	1.9086	1.8194	1.3998	1.9345	1.5747
1976	2.2762	2.1548	1.4909	2.1975	1.7390
1977	2.6608	2.5032	1.6005	2.2250	1.8420
1978	3.2668	2.6710	1.7560	2.2358	1.9248
1979	3.8312	2.8387	1.9810	2.4269	2.0103
1980	4.5959	2.9161	2.2334	3.1054	2.3900
1981	5.2947	3.1355	2.4751	3.5162	3.0586
1982	4.8260	3.3032	2.6363	3.5871	3.3954
1983	4.7222	3.4387	2.7472	3.5004	3.5016
1984	4.4486	3.5548	2.8130	3.5929	3.6474

Table D-7. Input Price Indexes for the Major Input Groups, Saskatchewan, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.5196	0.7320	0.7481	0.9727	0.8920
1962	0.5492	0.7451	0.7723	0.9681	0.9023
1963	0.6113	0.7516	0.7941	0.9840	0.9032
1964	0.6891	0.7582	0.8192	1.0284	0.9082
1965	0.7936	0.7647	0.8404	1.0305	0.8970
1966	0.9004	0.8627	0.8692	0.9958	0.8987
1967	1.0203	0.9346	0.8929	1.0353	0.9153
1968	1.0848	0.9673	0.9291	1.0588	0.9607
1969	1.0236	0.9869	0.9566	1.0301	0.9839
1970	1.0088	0.9608	0.9784	0.9660	0.9795
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0264	1.0915	1.0266	1.0894	1.0159
1973	1.2091	1.3007	1.0619	1.0987	1.0855
1974	1.5113	1.5621	1.1853	1.4734	1.2673
1975	1.9243	1.9412	1.3767	2.0193	1.5202
1976	2.3198	2.2810	1.4719	2.2452	1.7162
1977	2.6346	2.5686	1.5809	2.2823	1.8440
1978	3.1861	2.6928	1.7366	2.3139	1.9365
1979	3.8456	2.8366	1.9530	2.5081	2.0231
1980	5.1522	3.0523	2.1986	3.1712	2.3843
1981	5.8970	3.2680	2.4412	3.5758	3.1274
1982	6.3078	3.5425	2.6140	3.6740	3.5558
1983	6.1856	3.7451	2.7299	3.6049	3.7084
1984	5.9526	3.9216	2.7991	3.7002	3.8650

Table D-8. Input Price Indexes for the Major Input Groups, Saskatchewan Brown Soil Zone, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.6036	0.7320	0.7471	0.9728	0.8934
1962	0.5196	0.7451	0.7712	0.9679	0.8981
1963	0.5642	0.7516	0.7930	0.9836	0.8999
1964	0.6452	0.7582	0.8181	1.0286	0.9051
1965	0.7445	0.7647	0.8396	1.0306	0.8920
1966	0.8818	0.8627	0.8686	0.9956	0.8923
1967	1.0001	0.9346	0.8920	1.0356	0.9089
1968	1.0631	0.9673	0.9294	1.0592	0.9552
1969	0.9780	0.9869	0.9570	1.0301	0.9786
1970	0.9063	0.9608	0.9786	0.9657	0.9783
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	0.9989	1.0915	1.0260	1.0863	1.0193
1973	1.2062	1.3007	1.0608	1.0958	1.0832
1974	1.5072	1.5621	1.1834	1.5274	1.2308
1975	1.9195	1.9412	1.3746	2.0993	1.4725
1976	2.0693	2.2810	1.4704	2.2897	1.6829
1977	2.5839	2.5686	1.5793	2.3346	1.8208
1978	3.0846	2.6928	1.7345	2.3855	1.9184
1979	3.6909	2.8366	1.9498	2.5812	2.0050
1980	5.0028	3.0523	2.1950	3.2025	2.3469
1981	6.0908	3.2680	2.4373	3.5809	3.1048
1982	6.6525	3.5425	2.6117	3.7537	3.5632
1983	6.4211	3.7451	2.7277	3.7415	3.7315
1984	6.5210	3.9216	2.7974	3.8405	3.8907

Table D-9. Input Price Indexes for the Major Input Groups, Saskatchewan Dark Brown Soil Zone, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.5050	0.7320	0.7488	0.9727	0.8926
1962	0.5726	0.7451	0.7730	0.9681	0.9028
1963	0.6348	0.7516	0.7948	0.9839	0.9036
1964	0.7174	0.7582	0.8198	1.0284	0.9086
1965	0.8342	0.7647	0.8408	1.0305	0.8974
1966	0.8808	0.8627	0.8696	0.9958	0.8991
1967	1.0025	0.9346	0.8934	1.0353	0.9156
1968	1.0681	0.9673	0.9289	1.0588	0.9608
1969	1.0263	0.9869	0.9563	1.0301	0.9839
1970	1.1467	0.9608	0.9783	0.9659	0.9796
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0376	1.0915	1.0269	1.0889	1.0158
1973	1.2773	1.3007	1.0623	1.0983	1.0852
1974	1.6632	1.5621	1.1858	1.4819	1.2657
1975	2.1636	1.9412	1.3773	2.0318	1.5175
1976	2.6999	2.2810	1.4728	2.2521	1.7142
1977	3.0227	2.5686	1.5819	2.2905	1.8424
1978	3.7276	2.6928	1.7374	2.3252	1.9356
1979	4.5410	2.8366	1.9531	2.5197	2.0224
1980	6.3204	3.0523	2.1987	3.1764	2.3808
1981	7.5705	3.2680	2.4414	3.5770	3.1196
1982	8.1756	3.5425	2.6173	3.6868	3.5462
1983	8.2051	3.7451	2.7338	3.6265	3.6986
1984	7.9616	3.9216	2.8041	3.7223	3.8556

Table D-10. Input Price Indexes for the Major Input Groups, Saskatchewan Black Soil Zone, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.4843	0.7320	0.7483	0.9727	0.8908
1962	0.5509	0.7451	0.7725	0.9682	0.9041
1963	0.6275	0.7516	0.7943	0.9841	0.9046
1964	0.6988	0.7582	0.8194	1.0283	0.9095
1965	0.7964	0.7647	0.8405	1.0304	0.8992
1966	0.9290	0.8627	0.8694	0.9959	0.9017
1967	1.0483	0.9346	0.8930	1.0352	0.9184
1968	1.1126	0.9673	0.9290	1.0586	0.9635
1969	1.0545	0.9869	0.9565	1.0301	0.9866
1970	0.9874	0.9608	0.9784	0.9661	0.9800
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0410	1.0915	1.0268	1.0904	1.0143
1973	1.1642	1.3007	1.0623	1.0997	1.0869
1974	1.4124	1.5621	1.1861	1.4557	1.2870
1975	1.7715	1.9412	1.3775	1.9931	1.5465
1976	2.2425	2.2810	1.4722	2.2305	1.7344
1977	2.4224	2.5686	1.5812	2.2650	1.8565
1978	2.9126	2.6928	1.7374	2.2901	1.9460
1979	3.5155	2.8366	1.9548	2.4838	2.0325
1980	4.5201	3.0523	2.2006	3.1600	2.4053
1981	4.7778	3.2680	2.4433	3.5729	3.1434
1982	4.9973	3.5425	2.6132	3.6466	3.5573
1983	4.8495	3.7451	2.7286	3.5593	3.7019
1984	4.4730	3.9216	2.7969	3.6534	3.8570

Table D-11. Input Price Indexes for the Major Input Groups, Prairies, 1961-84
(1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.5521	0.6875	0.7481	0.9726	0.8914
1962	0.5535	0.6875	0.7722	0.9681	0.9020
1963	0.6033	0.6875	0.7940	0.9842	0.9028
1964	0.6740	0.6875	0.8191	1.0282	0.9080
1965	0.7840	0.7500	0.8405	1.0304	0.8979
1966	0.8651	0.8125	0.8694	0.9959	0.9000
1967	0.9783	0.8750	0.8930	1.0351	0.9161
1968	1.0457	0.8750	0.9299	1.0586	0.9613
1969	1.0268	0.9375	0.9576	1.0301	0.9845
1970	1.0222	1.9375	0.9789	0.9664	0.9801
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.1064	1.1250	1.0254	1.0926	1.0148
1973	1.3368	1.2500	1.0592	1.1019	1.0842
1974	1.7234	1.5000	1.1800	1.4279	1.2695
1975	2.1266	2.8750	1.3710	1.9522	1.5224
1976	2.5058	2.1250	1.4683	2.2073	1.7120
1977	2.9149	2.4375	1.5771	2.2369	1.8351
1978	3.4207	2.5625	1.7309	2.2521	1.9275
1979	4.4001	2.7500	1.9431	2.4439	2.0142
1980	5.6284	3.8750	2.1875	3.1190	2.3697
1981	6.4020	3.1250	2.4291	3.5303	3.0800
1982	6.5807	3.3125	2.6078	3.5950	3.4832
1983	6.4173	3.4375	2.7243	3.5049	3.6238
1984	6.0107	3.5625	2.7949	3.5975	3.7786

Table D-12. Input Price Indexes for the Major Input Groups, Prairie Brown Soil Zone, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.6136	0.6875	0.7442	0.9727	0.8790
1962	0.5445	0.6875	0.7678	0.9680	0.8862
1963	0.5883	0.6875	0.7896	0.9839	0.8892
1964	0.6623	0.6875	0.8151	1.0284	0.8964
1965	0.7523	0.7500	0.8375	1.0305	0.8879
1966	0.8713	0.8125	0.8668	0.9956	0.8911
1967	0.9808	0.8750	0.8896	1.0354	0.9069
1968	1.0463	0.8750	0.9307	1.0589	0.9571
1969	0.9757	0.9375	0.9590	1.0301	0.9814
1970	0.9293	0.9375	0.9794	0.9661	0.9799
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0401	1.1250	1.0233	1.0896	1.0151
1973	1.2489	1.2500	1.0548	1.0990	1.0751
1974	1.5522	1.5000	1.1722	1.4827	1.2236
1975	1.9656	1.8750	1.3625	2.0331	1.4632
1976	2.1354	2.1250	1.4623	2.2527	1.6669
1977	2.5886	2.4375	1.5708	2.2908	1.7997
1978	3.1133	2.5625	1.7220	2.3265	1.8961
1979	3.8333	2.7500	1.9298	2.5200	1.9821
1980	5.0568	2.8750	2.1727	3.1564	2.3146
1981	5.9159	3.1250	2.4127	3.5443	3.0173
1982	6.3406	3.3125	2.5949	3.6756	3.4569
1983	6.0239	3.4375	2.7117	3.6358	3.6174
1984	6.0090	3.5625	2.7838	3.7320	3.7741

Table D-13. Input Price Indexes for the Major Input Groups, Prairie Dark Brown Soil Zone, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.5269	0.6875	0.7449	0.9726	0.8936
1962	0.5590	0.6875	0.7687	0.9681	0.9034
1963	0.6199	0.6875	0.7904	0.9841	0.9042
1964	0.6876	0.6875	0.8159	1.0283	0.9092
1965	0.7821	0.7500	0.8381	1.0304	0.8980
1966	0.8439	0.8125	0.8674	0.9958	0.8995
1967	0.9549	0.8750	0.8902	1.0352	0.9158
1968	1.0359	0.8750	0.9308	1.0587	0.9606
1969	1.0144	0.9375	0.9592	1.0301	0.9838
1970	1.1104	0.9375	0.9795	0.9663	0.9797
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0850	1.1250	1.0228	1.0917	1.0158
1973	1.3131	1.2500	1.0535	1.1010	1.0849
1974	1.6777	1.5000	1.1694	1.4452	1.2634
1975	2.1548	1.8750	1.3596	1.9778	1.5140
1976	2.5962	2.1250	1.4609	2.2217	1.7108
1977	2.9341	2.4375	1.5693	2.2540	1.8396
1978	3.5091	2.5625	1.7192	2.2757	1.9342
1979	4.3919	2.7500	1.9239	2.4681	2.0214
1980	5.8885	2.8750	2.1662	3.1324	2.3741
1981	6.8003	3.1250	2.4056	3.5375	3.1073
1982	7.1579	3.3125	2.5930	3.6183	3.5315
1983	6.9900	3.4375	2.7106	3.5404	3.6828
1984	6.9051	3.5625	2.7844	3.6340	3.8404

Table D-14. Input Price Indexes for the Major Input Groups, Prairie Black Soil Zone, 1961-84 (1971=1.0000)

Year	Land	Labor	Machinery	Chemicals	Materials
1961	0.5502	0.6875	0.7450	0.9726	0.8935
1962	0.5647	0.6875	0.7686	0.9682	0.9055
1963	0.6224	0.6875	0.7904	0.9843	0.9057
1964	0.6877	0.6875	0.8160	1.0282	0.9105
1965	0.7707	0.7500	0.8385	1.0304	0.9004
1966	0.8697	0.8125	0.8679	0.9959	0.9026
1967	0.9755	0.8750	0.8906	1.0351	0.9188
1968	1.0601	0.8750	0.9320	1.0585	0.9628
1969	1.0224	0.9375	0.9605	1.0301	0.9857
1970	0.9989	0.9375	0.9801	0.9664	0.9802
1971	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.0873	1.1250	1.0226	1.0930	1.0143
1973	1.2744	1.2500	1.0531	1.1022	1.0864
1974	1.6124	1.5000	1.1686	1.4204	1.2860
1975	1.9834	1.8750	1.3588	1.9411	1.5442
1976	2.4168	2.1250	1.4602	2.2011	1.7262
1977	2.7311	2.4375	1.5685	2.2296	1.8436
1978	3.3246	2.5625	1.7181	2.2419	1.9333
1979	4.1918	2.7500	1.9221	2.4335	2.0199
1980	5.1814	2.8750	2.1641	3.1145	2.3847
1981	5.6584	3.1250	2.4033	3.5290	3.0879
1982	5.6681	3.3125	2.5903	3.5857	3.4717
1983	5.4997	3.4375	2.7077	3.4890	3.6020
1984	5.1254	3.5625	2.7813	3.5811	3.7548

Appendix 5

Table E-1. Alberta Grain Sector, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1957	0.8839	1.1673	0.9431	0.1816	0.7610	0.1030	0.5199	0.1263	0.0251	0.2257
1958	0.9112	1.1522	0.9440	0.2037	0.7708	0.1112	0.4980	0.1320	0.0287	0.2301
1959	0.9479	1.1374	0.9562	0.2634	0.7925	0.1107	0.4905	0.1345	0.0360	0.2284
1960	0.9084	1.1228	0.9958	0.3122	0.8025	0.1169	0.4761	0.1409	0.0411	0.2250
1961	0.8957	1.1084	0.9996	0.3812	0.7930	0.1144	0.4739	0.1425	0.0480	0.2212
1962	0.8917	1.0942	1.0259	0.4548	0.7884	0.1179	0.4697	0.1455	0.0552	0.2117
1963	0.9273	1.0802	1.0697	0.5557	0.8135	0.1253	0.4570	0.1470	0.0647	0.2060
1964	0.9486	1.0663	1.1426	0.6980	0.8411	0.1328	0.4314	0.1530	0.0806	0.2023
1965	0.9628	1.0525	1.2389	0.7752	0.8813	0.1441	0.4169	0.1596	0.0842	0.1951
1966	1.0079	1.0390	1.2546	0.9650	0.9150	0.1522	0.4093	0.1555	0.0940	0.1891
1967	1.0255	1.0835	1.2352	1.2220	0.9499	0.1517	0.4139	0.1418	0.1108	0.1818
1968	1.0318	0.9322	1.2008	1.3670	0.9697	0.1650	0.3703	0.1417	0.1265	0.1965
1969	1.0206	1.0064	1.1156	1.0003	0.9659	0.1593	0.4164	0.1340	0.0891	0.2013
1970	0.8476	0.9863	1.0311	0.8078	1.0016	0.1412	0.4349	0.1323	0.0702	0.2214
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1424	0.4313	0.1235	0.0843	0.2186
1972	0.9632	0.9976	1.1718	1.0478	1.0860	0.1560	0.4181	0.1337	0.0862	0.2060
1973	1.0052	0.9939	1.3216	1.3688	1.1418	0.1717	0.3991	0.1348	0.0977	0.1967
1974	0.9501	1.0539	1.6375	1.6440	1.1683	0.1718	0.3927	0.1457	0.1153	0.1745
1975	1.0249	1.1981	2.0466	1.8664	1.1357	0.1709	0.4099	0.1517	0.1290	0.1386
1976	1.0483	1.2783	2.4156	1.8040	1.2059	0.1780	0.4072	0.1599	0.1192	0.1358
1977	1.0310	0.9121	2.6409	1.9105	1.2621	0.2060	0.3297	0.1865	0.1271	0.1508
1978	1.1211	0.8574	2.8051	2.4136	1.3284	0.2327	0.2801	0.1934	0.1443	0.1495
1979	1.1291	0.8929	2.9890	2.8079	1.4560	0.2593	0.2594	0.1902	0.1494	0.1416
1980	1.1620	0.8816	3.1501	2.5043	1.4548	0.2806	0.2394	0.1941	0.1467	0.1393
1981	1.2305	0.9086	3.2575	3.0385	1.4881	0.2724	0.2183	0.1857	0.1692	0.1544
1982	1.2501	0.7910	3.2431	3.2133	1.4051	0.2755	0.1958	0.1930	0.1765	0.1592
1983	1.2464	0.7976	3.1827	3.6080	1.4190	0.2582	0.1998	0.1914	0.1864	0.1642
1984	1.2228	0.8564	3.0789	3.8130	1.3982	0.2343	0.2135	0.1865	0.1987	0.1670

Table E-2. Alberta Brown Soil Zone, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1957	0.9443	1.1685	0.7752	0.2047	0.8123	0.1452	0.4011	0.1361	0.0220	0.2956
1958	0.9959	1.1535	0.7717	0.2237	0.8195	0.1513	0.3775	0.1398	0.0241	0.3073
1959	1.0596	1.1386	0.8040	0.2874	0.8392	0.1479	0.3718	0.1424	0.0300	0.3079
1960	0.9887	1.1240	0.8007	0.3426	0.8476	0.1558	0.3666	0.1515	0.0350	0.2910
1961	0.9491	1.1096	0.8163	0.4122	0.8341	0.1500	0.3651	0.1534	0.0403	0.2913
1962	0.9781	1.0954	0.8441	0.4825	0.8260	0.1550	0.3696	0.1600	0.0465	0.2690
1963	1.0126	1.0814	0.8711	0.5730	0.8482	0.1619	0.3607	0.1620	0.0531	0.2623
1964	0.0194	1.0674	0.9045	0.7011	0.8735	0.1678	0.3394	0.1681	0.0642	0.2605
1965	1.0462	1.0537	0.9370	0.7751	0.9111	0.1787	0.3283	0.1756	0.6692	0.2506
1966	1.0856	1.0401	0.9424	0.9745	0.9401	0.1859	0.3239	0.1719	0.0757	0.2425
1967	1.0935	1.0835	0.9427	1.2193	0.9693	0.1844	0.3324	0.1593	0.0896	0.2343
1968	1.0965	0.9322	0.9520	1.3678	0.9840	0.1952	0.2957	0.1582	0.1021	0.2488
1969	1.1158	1.0064	0.9514	1.0091	0.9749	0.1857	0.3346	0.1506	0.0729	0.2562
1970	0.8966	0.9863	0.9505	0.8170	1.0060	0.1615	0.3504	0.1491	0.0577	0.2813
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1606	0.3507	0.1404	0.0692	0.2792
1972	0.9661	0.9986	1.1240	1.0610	1.0840	0.1736	0.3406	0.1522	0.0716	0.2620
1973	1.0231	0.9949	1.3548	1.4013	1.1369	0.1881	0.3245	0.1532	0.0819	0.2524
1974	1.0126	1.0562	1.5374	1.6625	1.1590	0.1870	0.3226	0.1671	0.0983	0.2250
1975	1.0465	1.2019	1.5467	1.8783	1.1207	0.1864	0.3430	0.1769	0.1115	0.1821
1976	1.1200	1.2837	1.5871	1.8500	1.1863	0.1907	0.3404	0.1860	0.1037	0.1791
1977	1.1470	0.9160	1.5615	1.9567	1.2366	0.2123	0.2692	0.2120	0.1080	0.1985
1978	1.1466	0.8620	1.5895	2.4776	1.2976	0.2348	0.2278	0.2188	0.1229	0.1957
1979	1.1739	0.8986	1.5578	2.8886	1.4199	0.2586	0.2121	0.2161	0.1280	0.1852
1980	1.1779	0.8873	1.6591	2.6148	1.4092	0.2749	0.1957	0.2203	0.1260	0.1831
1981	1.2852	0.9144	1.7816	3.1852	1.4364	0.2627	0.1788	0.2113	0.1455	0.2016
1982	1.2592	0.7961	1.6583	3.3674	1.3489	0.2603	0.1598	0.2189	0.1531	0.2079
1983	1.3284	0.8028	1.6755	3.7403	1.3593	0.2405	0.1636	0.2178	0.1620	0.2161
1984	1.2822	0.8619	1.5687	3.9728	1.3354	0.2153	0.1757	0.2132	0.1744	0.2215

Table E-3. Alberta Dark Brown Soil Zone, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1957	0.9289	1.2248	0.8945	0.1933	0.7058	0.1165	0.4604	0.1473	0.0338	0.2420
1958	0.9416	1.2050	0.8942	0.2138	0.7161	0.1263	0.4382	0.1536	0.0380	0.2440
1959	0.9745	1.1855	0.9122	0.2756	0.7378	0.1264	0.4291	0.1560	0.0474	0.2411
1960	0.9999	1.1663	0.9394	0.3276	0.7435	0.1335	0.4121	0.1623	0.0538	0.2382
1961	0.9484	1.1474	0.9466	0.3969	0.7315	0.1317	0.4087	0.1641	0.0624	0.2330
1962	0.9830	1.1289	0.9733	0.4689	0.7218	0.1361	0.4021	0.1670	0.0708	0.2240
1963	1.0044	1.1107	1.0124	0.5645	0.7423	0.1452	0.3885	0.1680	0.0815	0.2168
1964	1.0549	1.0925	1.0739	0.6996	0.7613	0.1538	0.3628	0.1735	0.0994	0.2105
1965	1.1241	1.0748	1.1520	0.7752	0.7906	0.1674	0.3476	0.1802	0.1031	0.2017
1966	1.1397	1.0573	1.1649	0.9698	0.8255	0.1772	0.3384	0.1747	0.1151	0.1946
1967	1.1428	1.0988	1.1508	1.2206	0.8712	0.1779	0.3409	0.1592	0.1348	0.1871
1968	1.1183	0.9421	1.1290	1.3674	0.9019	0.1920	0.2995	0.1567	0.1519	0.1998
1969	1.0963	1.0135	1.0682	1.0048	0.9117	0.1900	0.3417	0.1509	0.1093	0.2081
1970	0.9054	0.9897	1.0078	0.8125	0.9691	0.1715	0.3593	0.1506	0.0871	0.2315
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1737	0.3543	0.1402	0.1038	0.2280
1972	1.0620	0.9962	1.1582	1.0545	1.0398	0.1877	0.3411	0.1510	0.1063	0.2138
1973	1.1393	0.9911	1.3317	1.3853	1.0802	0.2035	0.3227	0.1512	0.1201	0.2024
1974	1.1825	1.0487	1.6090	1.6533	1.0691	0.2009	0.3155	0.1627	0.1418	0.1791
1975	1.2848	1.1905	1.9009	1.8724	0.9823	0.1989	0.3299	0.1698	0.1588	0.1426
1976	1.3818	1.2684	2.1740	1.8274	1.0158	0.2056	0.3277	0.1792	0.1476	0.1399
1977	1.3831	0.9038	2.3258	1.9339	1.0495	0.2309	0.2592	0.2046	0.1539	0.1514
1978	1.5191	0.8484	2.4507	2.4461	1.1015	0.2543	0.2165	0.2088	0.1727	0.1477
1979	1.5837	0.8816	2.5725	2.8489	1.2204	0.2795	0.1989	0.2042	0.1779	0.1394
1980	1.5587	0.8692	2.7161	2.5605	1.1982	0.2988	0.1827	0.2076	0.1744	0.1366
1981	1.6362	0.8958	2.8278	3.1130	1.2208	0.2858	0.1656	0.1975	0.1998	0.1513
1982	1.6609	0.7798	2.7819	3.2917	1.1330	0.2849	0.1476	0.2040	0.2085	0.1550
1983	1.7042	0.7864	2.7441	3.6751	1.1534	0.2653	0.1510	0.2029	0.2206	0.1602
1984	1.5239	0.8443	2.6395	3.8942	1.1417	0.2394	0.1620	0.1985	0.2368	0.1633

Table E-4. Alberta Black Soil Zone, Input Quantity Indexes and Cost Shares

	Input Indexes					Input Cost Shares				
Year	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1957	0.9202	1.1659	0.9146	0.1759	0.6871	0.1074	0.5385	0.1215	0.0263	0.2063
1958	0.9198	1.1511	0.9142	0.1987	0.6979	0.1163	0.5168	0.1273	0.0303	0.2093
1959	0.9139	1.1362	0.9302	0.2575	0.7195	0.1158	0.5090	0.1296	0.0381	0.2074
1960	0.9427	1.1219	0.9606	0.3047	0.7254	0.1222	0.4929	0.1355	0.0433	0.2061
1961	0.9406	1.1075	0.9664	0.3735	0.7163	0.1197	0.4903	0.1369	0.0508	0.2023
1962	0.9635	1.0933	0.9926	0.4479	0.7087	0.1231	0.4840	0.1393	0.0585	0.1951
1963	1.0008	1.0796	1.0327	0.5514	0.7311	0.1307	0.4702	0.1404	0.0690	0.1897
1964	1.0355	1.0656	1.0972	0.6972	0.7520	0.1385	0.4434	0.1460	0.0863	0.1858
1965	1.0930	1.0521	1.1801	0.7753	0.7830	0.1504	0.4280	0.1521	0.0903	0.1793
1966	1.1217	1.0386	1.1933	0.9626	0.8195	0.1586	0.4193	0.1479	0.1003	0.1739
1967	1.1300	1.0831	1.1773	1.2226	0.8666	0.1578	0.4227	0.1344	0.1181	0.1670
1968	1.1080	0.9320	1.1513	1.3668	0.8976	0.1718	0.3783	0.1343	0.1348	0.1808
1969	1.1075	1.0062	1.0830	0.9982	0.9102	0.1663	0.4259	0.1272	0.0949	0.1858
1970	0.9389	0.9863	1.0151	0.8056	0.9680	0.1479	0.4461	0.1259	0.0749	0.2052
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1489	0.4415	0.1173	0.0900	0.2023
1972	1.0726	0.9972	1.1616	1.0445	1.0410	0.1622	0.4280	0.1271	0.0919	0.1909
1973	1.1366	0.9931	1.3279	1.3608	1.0808	0.1799	0.4073	0.1278	0.1035	0.1815
1974	1.1344	1.0526	1.6153	1.6394	1.0667	0.1811	0.3993	0.1377	0.1216	0.1604
1975	1.2711	1.1961	1.9402	1.8636	0.9815	0.1810	0.4144	0.1425	0.1354	0.1267
1976	1.3353	1.2757	2.2403	1.7926	1.0138	0.1901	0.4112	0.1501	0.1247	0.1238
1977	1.3585	0.9099	2.4130	1.8990	1.0473	0.2222	0.3328	0.1751	0.1329	0.1370
1978	1.4223	0.8550	2.5486	2.3978	1.0994	0.2522	0.2814	0.1808	0.1501	0.1354
1979	1.4406	0.8900	2.6877	2.7878	1.2146	0.2821	0.2590	0.1768	0.1545	0.1275
1980	1.5254	0.8784	2.8358	2.4768	1.1948	0.3068	0.2380	0.1797	0.1508	0.1247
1981	1.6346	0.9053	2.9458	3.0019	1.2152	0.3001	0.2167	0.1716	0.1737	0.1379
1982	1.6518	0.7881	2.9095	3.1750	1.1293	0.3058	0.1940	0.1781	0.1804	0.1418
1983	1.6462	0.7947	2.8650	3.5751	1.1497	0.2890	0.1978	0.1766	0.1905	0.1461
1984	1.6134	0.8533	2.7611	3.7732	1.1389	0.2647	0.2116	0.1721	0.2030	0.1486

Table E-5. Alberta Gray Soil Zone, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1957	0.7754	1.1389	0.8208	0.1718	0.6979	0.0722	0.5799	0.1146	0.0178	0.2155
1958	0.7743	1.1263	0.8186	0.1952	0.7082	0.0785	0.5605	0.1207	0.0208	0.2195
1959	0.8542	1.1139	0.8453	0.2533	0.7298	0.0838	0.5510	0.1224	0.0260	0.2167
1960	0.8202	1.1012	0.8540	0.2994	0.7357	0.0847	0.5392	0.1292	0.0298	0.2172
1961	0.8425	1.0892	0.8663	0.3681	0.7249	0.0865	0.5361	0.1302	0.0350	0.2122
1962	0.8534	1.0772	0.8937	0.4431	0.7165	0.0881	0.5328	0.1331	0.0407	0.2053
1963	0.9255	1.0671	0.9254	0.5484	0.7379	0.0980	0.5198	0.1344	0.0483	0.1995
1964	0.9503	1.0533	0.9699	0.6967	0.7578	0.1041	0.4959	0.1413	0.0614	0.1974
1965	0.9166	1.0417	1.0203	0.7753	0.7879	0.1061	0.4864	0.1494	0.0652	0.1930
1966	1.0238	1.0302	1.0287	0.9610	0.8238	0.1207	0.4761	0.1448	0.0721	0.1864
1967	1.0313	1.0760	1.0234	1.2231	0.8703	0.1213	0.4820	0.1320	0.0853	0.1794
1968	1.0999	0.9274	1.0207	1.3667	0.9012	0.1425	0.4330	0.1322	0.0976	0.1948
1969	0.9921	1.0031	0.9966	0.9966	0.9113	0.1257	0.4843	0.1241	0.0680	0.1979
1970	0.8777	0.9844	0.9728	0.8040	0.9688	0.1145	0.4981	0.1205	0.0526	0.2143
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1225	0.4922	0.1118	0.0631	0.2104
1972	1.0002	0.9990	1.1368	1.0422	1.0400	0.1269	0.4842	0.1227	0.0651	0.2011
1973	1.0362	0.9964	1.3451	1.3551	1.0807	0.1383	0.4682	0.1252	0.0743	0.1940
1974	1.0264	1.0582	1.5635	1.6363	1.0705	0.1361	0.4654	0.1366	0.0882	0.1738
1975	1.2440	1.2043	1.6813	1.8617	0.9845	0.1449	0.4806	0.1405	0.0976	0.1363
1976	1.3009	1.2867	1.8110	1.7845	1.0168	0.1481	0.4795	0.1484	0.0901	0.1338
1977	1.2925	0.9195	1.8535	1.8910	1.0502	0.1727	0.3990	0.1777	0.0986	0.1520
1978	1.5175	0.8653	1.9186	2.3866	1.1011	0.2149	0.3390	0.1841	0.1115	0.1505
1979	1.5266	0.9025	1.9464	2.7737	1.2182	0.2407	0.3168	0.1824	0.1163	0.1438
1980	1.6224	0.8920	2.0635	2.4574	1.1983	0.2702	0.2910	0.1851	0.1132	0.1405
1981	1.6463	0.9193	2.1812	2.9762	1.2199	0.2571	0.2703	0.1804	0.1331	0.1591
1982	1.6946	0.8003	2.0886	3.1479	1.1322	0.2651	0.2434	0.1882	0.1387	0.1646
1983	1.5666	0.8070	2.0843	3.5520	1.1520	0.2329	0.2536	0.1906	0.1497	0.1732
1984	1.6922	0.8665	1.9789	3.7452	1.1403	0.2289	0.2639	0.1808	0.1551	0.1713

Table E-6. Manitoba Grain Sector, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1957	0.6628	1.2447	1.1412	0.1446	0.6755	0.0688	0.5456	0.1606	0.0206	0.2044
1958	0.8732	1.2265	1.1011	0.1349	0.6743	0.0885	0.5484	0.1527	0.0185	0.1919
1959	0.8511	1.2083	1.0784	0.1747	0.6824	0.0836	0.5451	0.1549	0.0239	0.1925
1960	0.8692	1.1905	1.0855	0.1981	0.6992	0.0891	0.5375	0.1550	0.0257	0.1927
1961	0.8390	1.1727	1.0844	0.2846	0.6940	0.0882	0.5288	0.1563	0.0355	0.1912
1962	0.9076	1.1553	1.0853	0.2831	0.7245	0.0950	0.5078	0.1607	0.0350	0.2015
1963	0.9245	1.1384	1.1045	0.3510	0.7418	0.1002	0.4943	0.1628	0.0428	0.1999
1964	0.9896	1.1214	1.5592	0.4049	0.7931	0.1122	0.4764	0.1630	0.0486	0.1999
1965	1.0388	1.1050	1.2724	0.5018	0.8234	0.1253	0.4504	0.1737	0.0564	0.1942
1966	1.0470	1.0885	1.2351	0.9544	0.8624	0.1253	0.4394	0.1576	0.0936	0.1841
1967	1.0384	1.0911	1.2255	1.0987	0.8808	0.1304	0.4376	0.1500	0.1041	0.1779
1968	1.0476	0.9395	1.1822	1.4065	0.8970	0.1441	0.3799	0.1492	0.1366	0.1901
1969	0.9469	1.0407	1.0832	0.8442	0.9293	0.1256	0.4528	0.1405	0.0796	0.2014
1970	0.8200	0.9555	0.7454	0.7651	0.9464	0.1284	0.5098	0.0372	0.0809	0.2437
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1243	0.4479	0.1303	0.0875	0.2100
1972	0.9622	0.8552	1.0590	1.1170	1.0384	0.1251	0.4163	0.1391	0.1041	0.2154
1973	1.0476	0.7815	1.1653	1.6099	1.0641	0.1422	0.3768	0.1398	0.1329	0.2083
1974	1.0159	0.8873	1.4191	1.7833	1.1373	0.1340	0.3757	0.1449	0.1430	0.2024
1975	1.0563	0.8827	1.7245	2.0744	1.0349	0.1273	0.3608	0.1598	0.1783	0.1738
1976	1.0879	0.7929	1.9322	2.0625	1.0788	0.1379	0.3394	0.1683	0.1777	0.1766
1977	1.0909	0.8780	1.9675	2.4035	1.1511	0.1347	0.3713	0.1532	0.1746	0.1662
1978	1.1398	0.8818	1.9993	3.2636	1.2925	0.1473	0.3374	0.1457	0.2032	0.1663
1979	1.1154	0.9229	2.0598	3.9955	1.4652	0.1437	0.3158	0.1439	0.2294	0.1673
1980	1.1067	0.8400	2.1091	3.2959	1.3254	0.1638	0.2728	0.1591	0.2319	0.1723
1981	1.2195	0.8545	2.1575	3.5267	1.3358	0.1768	0.2420	0.1533	0.2389	0.1890
1982	1.2627	0.8007	2.2020	3.7486	1.3575	0.1611	0.2219	0.1610	0.2501	0.2059
1983	1.2502	0.7749	2.1510	4.1290	1.4406	0.1498	0.2185	0.1573	0.2581	0.2163
1984	1.2835	0.7783	2.1132	4.5189	1.4308	0.1395	0.2137	0.1523	0.2791	0.2154

Table E-7. Saskatchewan Grain Sector, Input Quantity Indexes and Cost Shares

	Input Indexes					Input Cost Shares				
Year	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.8135	1.1570	0.8527	0.5564	0.7433	0.0730	0.5537	0.2051	0.0221	0.1462
1962	0.9307	1.1410	0.8526	0.5930	0.7333	0.0864	0.5440	0.2039	0.0229	0.1428
1963	0.9562	1.1251	0.8859	0.7043	0.7572	0.0956	0.5236	0.2113	0.0268	0.1428
1964	0.9721	1.1095	0.9402	0.9351	0.7885	0.1043	0.4959	0.2220	0.0354	0.1423
1965	1.0095	1.0944	1.0147	1.0519	0.8356	0.1180	0.4668	0.2364	0.0378	0.1410
1966	1.0875	1.0792	1.0519	1.5584	0.8729	0.1288	0.4636	0.2276	0.0483	0.1317
1967	1.0797	1.0460	1.0172	1.8877	0.9062	0.1374	0.4617	0.2111	0.0577	0.1321
1968	1.0614	0.9565	1.0407	1.9700	0.9270	0.1428	0.4344	0.2206	0.0612	0.1410
1969	0.9829	1.1356	0.9983	1.1353	0.9733	0.1190	0.5019	0.2018	0.0327	0.1446
1970	0.7399	0.9469	0.9398	0.7276	0.9794	0.1042	0.4807	0.2211	0.0232	0.1709
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1269	0.4802	0.2011	0.0300	0.1619
1972	0.9088	1.0130	1.0877	1.2005	1.0577	0.1094	0.4906	0.2030	0.0362	0.1608
1973	0.9842	0.9448	1.2364	1.8224	1.0742	0.1216	0.4751	0.2030	0.0483	0.1520
1974	0.9574	0.9721	1.5173	2.2133	1.0094	0.1177	0.4673	0.2196	0.0626	0.1327
1975	0.9884	1.1590	1.7947	2.4826	0.9362	0.1105	0.4946	0.2207	0.0688	0.1055
1976	1.0222	0.9690	2.0096	2.4795	1.0062	0.1248	0.4402	0.2499	0.0692	0.1160
1977	1.0167	1.0163	2.0951	2.7969	1.0980	0.1221	0.4505	0.2408	0.0687	0.1178
1978	1.0505	1.0332	2.2382	4.1431	1.2093	0.1333	0.4194	0.2381	0.0902	0.1190
1979	1.0629	1.0013	2.3591	5.1309	1.3045	0.1452	0.3820	0.2451	0.1080	0.1197
1980	1.0675	0.8210	2.4810	4.4127	1.2411	0.1833	0.3160	0.2646	0.1102	0.1259
1981	1.1573	0.8176	2.6981	4.9465	1.2021	0.1966	0.2912	0.2535	0.1204	0.1383
1982	1.1716	0.8415	2.7144	5.2795	1.2449	0.1939	0.2958	0.2419	0.1202	0.1482
1983	1.1785	0.7951	2.7604	6.6311	1.3006	0.1836	0.2836	0.2356	0.1422	0.1550
1984	1.2065	0.8131	2.6594	7.1511	1.2876	0.1737	0.2918	0.2296	0.1512	0.1537

Table E-8. Saskatchewan Brown Soil Zone, Input Quantity Indexes and Cost Shares

	Input Indexes					Input Cost Shares				
Year	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.4432	1.1731	0.8668	0.6234	0.7616	0.0569	0.5493	0.2275	0.0169	0.1494
1962	1.0058	1.1554	0.8656	0.6492	0.7551	0.1054	0.5196	0.2181	0.0165	0.1405
1963	1.0565	1.1379	0.8993	0.7225	0.7770	0.1163	0.4995	0.2260	0.0181	0.1402
1964	1.0566	1.1202	0.9550	0.8811	0.8080	0.1269	0.4733	0.2380	0.0220	0.1399
1965	1.0918	1.1034	1.0319	0.9752	0.8546	0.1428	0.4438	0.2528	0.0230	0.1376
1966	1.1243	1.0867	1.0697	1.4352	0.8947	0.1560	0.4416	0.2441	0.0293	0.1291
1967	1.1122	1.0520	1.0320	1.7064	0.9310	0.1667	0.4411	0.2274	0.0345	0.1303
1968	1.0909	0.9607	1.0553	1.8122	0.9502	0.1726	0.4141	0.2373	0.0372	0.1388
1969	1.0338	1.1386	1.0094	1.1135	0.9855	0.1435	0.4775	0.2171	0.0212	0.1406
1970	0.8256	0.9482	0.9466	0.7574	0.9817	0.1252	0.4562	0.2376	0.0159	0.1651
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1522	0.4555	0.2162	0.0198	0.1563
1972	0.9331	1.0130	1.0852	1.2213	1.0552	0.1318	0.4680	0.2196	0.0244	0.1562
1973	0.9848	0.9443	1.2308	1.8595	1.0795	0.1464	0.4532	0.2197	0.0327	0.1480
1974	0.9576	0.9716	1.5084	2.1939	1.0446	0.1420	0.4469	0.2382	0.0429	0.1299
1975	0.9878	1.1580	1.7877	2.4093	0.9741	0.1339	0.4751	0.2405	0.0465	0.1040
1976	1.1418	0.9682	2.0086	2.5454	1.0419	0.1496	0.4186	0.2697	0.0480	0.1141
1977	1.0320	1.0149	2.0928	2.9089	1.1287	0.1465	0.4287	0.2602	0.0486	0.1160
1978	1.0792	1.0318	2.2313	4.1505	1.2310	0.1607	0.4013	0.2587	0.0622	0.1171
1979	1.1009	0.9996	2.3466	5.0654	1.3190	0.1755	0.3665	0.2672	0.0735	0.1173
1980	1.0916	0.8196	2.4619	4.3296	1.2629	0.2192	0.3004	0.2857	0.0724	0.1222
1981	1.1117	0.8158	2.6623	4.9956	1.2289	0.2344	0.2761	0.2732	0.0806	0.1357
1982	1.1015	0.8396	2.6740	5.2726	1.2718	0.2310	0.2804	0.2607	0.0812	0.1468
1983	1.1244	0.7934	2.7122	6.4806	1.3196	0.2207	0.2717	0.2565	0.0965	0.1547
1984	1.0900	0.8113	2.6174	6.9517	1.2948	0.2104	0.2817	0.2519	0.1029	0.1532

Table E-9. Saskatchewan Dark Brown Soil Zone, Input Quantity Indexes and Cost Shares

	Input Indexes					Input Cost Shares				
Year	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.4999	1.1260	0.8611	0.5668	0.7391	0.0466	0.5249	0.2351	0.0211	0.1723
1962	0.8661	1.1136	0.8603	0.6018	0.7299	0.0873	0.5015	0.2267	0.0211	0.1633
1963	0.8956	1.1009	0.8949	0.7071	0.7542	0.0965	0.4823	0.2341	0.0243	0.1629
1964	0.9118	1.0888	0.9519	0.9267	0.7859	0.1053	0.4562	0.2450	0.0316	0.1618
1965	0.9403	1.0766	1.0302	1.0400	0.8333	0.1189	0.4284	0.2596	0.0335	0.1596
1966	1.0919	1.0647	1.0691	1.5392	0.8711	0.1303	0.4272	0.2503	0.0428	0.1494
1967	1.0829	1.0350	1.0316	1.8595	0.9049	0.1396	0.4271	0.2322	0.0511	0.1500
1968	1.0653	0.9488	1.0559	1.9454	0.9261	0.1447	0.4006	0.2413	0.0540	0.1593
1969	0.9721	1.1296	1.0102	1.1319	0.9724	0.1212	0.4649	0.2212	0.0292	0.1636
1970	0.6477	0.9446	0.9475	0.7322	0.9790	0.1054	0.4423	0.2400	0.0207	0.1916
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1292	0.4436	0.2186	0.0266	0.1819
1972	0.9185	1.0352	1.0933	1.2037	1.0577	0.1126	0.4583	0.2184	0.0319	0.1787
1973	0.9746	0.9862	1.2503	1.8282	1.0744	0.1267	0.4482	0.2160	0.0421	0.1670
1974	0.9308	1.0356	1.5454	2.2101	1.0103	0.1243	0.4457	0.2314	0.0542	0.1445
1975	0.9617	1.2602	1.8461	2.4708	0.9373	0.1184	0.4779	0.2308	0.0589	0.1139
1976	0.9820	1.0748	2.0874	2.4898	1.0061	0.1345	0.4268	0.2571	0.0586	0.1231
1977	1.0114	1.1495	2.1922	2.8146	1.0973	0.1329	0.4406	0.2451	0.0577	0.1237
1978	1.0463	1.1912	2.3587	4.1440	1.2079	0.1468	0.4144	0.2402	0.0747	0.1238
1979	1.0706	1.1761	2.5046	5.1201	1.3029	0.1618	0.3811	0.2451	0.0885	0.1234
1980	1.0557	0.9823	2.6556	4.3992	1.2402	0.2055	0.3168	0.2610	0.0887	0.1280
1981	1.1151	0.9961	2.9160	4.9537	1.2007	0.2226	0.2945	0.2476	0.0963	0.1390
1982	1.1397	1.0252	2.9349	5.2778	1.2434	0.2227	0.2978	0.2353	0.0958	0.1484
1983	1.1416	0.9687	2.9867	6.6064	1.2989	0.2153	0.2861	0.2296	0.1135	0.1555
1984	1.1806	0.9906	2.8761	7.1185	1.2862	0.2075	0.2942	0.2236	0.1205	0.1541

Table E-10. Saskatchewan Black Soil Zone, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.5410	1.1643	0.8408	0.5345	0.7370	0.0408	0.6027	0.1906	0.0264	0.1396
1962	0.9309	1.1475	0.8416	0.5747	0.7248	0.0766	0.5781	0.1851	0.0270	0.1332
1963	0.9345	1.1307	0.8738	0.6983	0.7492	0.0849	0.5571	0.1922	0.0324	0.1335
1964	0.9620	1.1144	0.9259	0.9528	0.7805	0.0927	0.5278	0.2021	0.0440	0.1333
1965	1.0087	1.0985	0.9970	1.0770	0.8276	0.1053	0.4985	0.2161	0.0474	0.1328
1966	1.0563	1.0827	1.0331	1.5986	0.8633	0.1145	0.4937	0.2076	0.0605	0.1237
1967	1.0526	1.0486	1.0014	1.9470	0.8948	0.1219	0.4901	0.1920	0.0725	0.1235
1968	1.0359	0.9584	1.0246	2.0216	0.9162	0.1270	0.4625	0.2013	0.0768	0.1324
1969	0.9547	1.1371	0.9858	1.1424	0.9678	0.1057	0.5336	0.1841	0.0402	0.1364
1970	0.7564	0.9475	0.9319	0.7179	0.9785	0.0930	0.5135	0.2028	0.0281	0.1626
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1131	0.5120	0.1842	0.0368	0.1539
1972	0.8832	1.0028	1.0859	1.1937	1.0589	0.0964	0.5195	0.1865	0.0444	0.1532
1973	0.9930	0.9256	1.2314	1.8104	1.0714	0.1062	0.5009	0.1877	0.0595	0.1456
1974	0.9811	0.9427	1.5060	2.2201	0.9917	0.1018	0.4896	0.2038	0.0772	0.1275
1975	1.0131	1.1124	1.7693	2.5079	0.9169	0.0943	0.5137	0.2052	0.0855	0.1014
1976	0.9701	0.9202	1.9664	2.4576	0.9888	0.1052	0.4596	0.2360	0.0863	0.1129
1977	1.0125	0.9548	2.0414	2.7596	1.0835	0.1032	0.4674	0.2285	0.0856	0.1152
1978	1.0358	0.9602	2.1739	4.1413	1.1996	0.1112	0.4315	0.2265	0.1137	0.1171
1979	1.0319	0.9206	2.2835	5.1541	1.2984	0.1197	0.3902	0.2340	0.1375	0.1185
1980	1.0627	0.7466	2.3924	4.4416	1.2310	0.1507	0.3236	0.2560	0.1433	0.1264
1981	1.2272	0.7352	2.5937	4.9322	1.1901	0.1602	0.2970	0.2470	0.1567	0.1391
1982	1.2499	0.7567	2.6109	5.2838	1.2327	0.1558	0.3025	0.2364	0.1564	0.1489
1983	1.2493	0.7149	2.6576	6.6847	1.2926	0.1441	0.2881	0.2287	0.1841	0.1549
1984	1.3116	0.7311	2.5588	7.2216	1.2853	0.1336	0.2953	0.2220	0.1954	0.1536

Table E-12. The Prairie Grain Sector, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.8260	1.1422	1.0090	0.3996	0.7322	0.0746	0.5515	0.1736	0.0310	0.1693
1962	0.9081	1.1268	1.0078	0.4438	0.7277	0.0815	0.5392	0.1766	0.0340	0.1688
1963	0.9371	1.1116	1.0510	0.5385	0.7492	0.0892	0.5172	0.1838	0.0407	0.1691
1964	0.9638	1.0963	1.1254	0.6808	0.7807	0.0980	0.4878	0.1933	0.0515	0.1695
1965	1.0015	1.0815	1.2273	0.7721	0.8175	0.1083	0.4801	0.1975	0.0535	0.1605
1966	1.0573	1.0668	1.2580	1.1123	0.8539	0.1156	0.4699	0.1924	0.0682	0.1539
1967	1.0594	1.0664	1.2103	1.3575	0.8889	0.1215	0.4693	0.1776	0.0803	0.1513
1968	1.0549	0.9449	1.2094	1.5302	0.9112	0.1315	0.4230	0.1858	0.0942	0.1655
1969	0.9878	1.0745	1.1238	0.9927	0.9411	0.1153	0.4915	0.1695	0.0567	0.1669
1970	0.7873	0.9616	0.9164	0.7761	0.9688	0.1033	0.4964	0.1604	0.0469	0.1931
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1141	0.4896	0.1598	0.0556	0.1808
1972	0.9392	0.9789	1.0860	1.1048	1.0474	0.1081	0.4916	0.1639	0.0612	0.1752
1973	1.0104	0.9314	1.2063	1.5476	1.0763	0.1245	0.4606	0.1677	0.0766	0.1705
1974	0.9864	0.9843	1.4685	1.8249	1.0599	0.1220	0.4546	0.1793	0.0911	0.1530
1975	1.0437	1.1219	1.8078	2.0772	0.9759	0.1161	0.4719	0.1856	0.1033	0.1231
1976	1.0761	1.0412	2.1157	2.0437	1.0270	0.1248	0.4394	0.2050	0.1018	0.1290
1977	1.0720	0.9563	2.2234	2.2667	1.0944	0.1315	0.4207	0.2099	0.1040	0.1339
1978	1.1285	0.9468	2.3176	3.0816	1.1892	0.1433	0.3863	0.2101	0.1255	0.1348
1979	1.1502	0.9510	2.4023	3.7184	1.3080	0.1607	0.3563	0.2098	0.1406	0.1325
1980	1.1729	0.8454	2.4696	3.2031	1.2464	0.1927	0.3043	0.2243	0.1421	0.1366
1981	1.2618	0.8556	2.4999	3.6560	1.2411	0.1995	0.2832	0.2123	0.1554	0.1496
1982	1.2804	0.8175	2.4769	3.8839	1.2301	0.1972	0.2718	0.2129	0.1592	0.1589
1983	1.2722	0.7927	2.4255	4.5215	1.2779	0.1848	0.2645	0.2098	0.1748	0.1661
1984	1.2819	0.8218	2.3765	4.8571	1.2664	0.1687	0.2750	0.2037	0.1865	0.1661

Table E-13. The Prairie Brown Soil Zone, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.5903	1.1616	0.9982	0.5120	0.7892	0.0795	0.5023	0.2114	0.0226	0.1842
1962	1.0288	1.1445	0.9933	0.5613	0.7615	0.1186	0.4768	0.2082	0.0237	0.1726
1963	1.0748	1.1276	1.0363	0.6436	0.7824	0.1297	0.4551	0.2160	0.0268	0.1724
1964	1.0793	1.1106	1.1122	0.7859	0.8131	0.1399	0.4278	0.2273	0.0327	0.1724
1965	1.1164	1.0943	1.2189	0.8694	0.8498	0.1503	0.4203	0.2332	0.0331	0.1631
1966	1.1482	1.0782	1.2615	1.1916	0.8842	0.1639	0.4108	0.2293	0.0401	0.1559
1967	1.1359	1.0578	1.2007	1.4488	0.9213	0.1725	0.4100	0.2133	0.0479	0.1563
1968	1.1168	0.9555	1.2156	1.5772	0.9355	0.1819	0.3725	0.2235	0.0537	0.1684
1969	1.0702	1.1144	1.1323	1.0582	0.9605	0.1541	0.4414	0.2032	0.0332	0.1681
1970	0.8606	0.9551	1.0267	0.7889	0.9775	0.1342	0.4300	0.2153	0.0264	0.1941
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1525	0.4363	0.1956	0.0315	0.1841
1972	0.9640	1.0104	1.0748	1.1364	1.0505	0.1388	0.4501	0.1976	0.0354	0.1782
1973	1.0203	0.9536	1.1915	1.6167	1.0908	0.1571	0.4204	0.2029	0.0452	0.1745
1974	1.0120	0.9871	1.4429	1.9122	1.0689	0.1537	0.4145	0.2200	0.0572	0.1545
1975	1.0610	1.1661	1.7677	2.1267	0.9928	0.1472	0.4416	0.2244	0.0630	0.1238
1976	1.2101	1.0260	2.0753	2.1780	1.0507	0.1622	0.3916	0.2498	0.0635	0.1328
1977	1.1319	0.9968	2.1756	2.4075	1.1291	0.1633	0.3873	0.2493	0.0634	0.1367
1978	1.1719	1.0007	2.2730	3.2734	1.2145	0.1786	0.3592	0.2491	0.0769	0.1361
1979	1.1973	0.9810	2.3490	3.9257	1.3131	0.1960	0.3297	0.2529	0.0872	0.1342
1980	1.1889	0.8319	2.4085	3.4309	1.2742	0.2357	0.2681	0.2691	0.0876	0.1396
1981	1.2270	0.8338	2.4327	4.0465	1.2670	0.2424	0.2488	0.2559	0.0988	0.1542
1982	1.2162	0.8315	2.3953	4.2738	1.2614	0.2398	0.2450	0.2506	0.1008	0.1638
1983	1.2476	0.7950	2.3396	5.0486	1.3014	0.2278	0.2369	0.2482	0.1148	0.1723
1984	1.2036	0.8204	2.3034	5.3955	1.2826	0.2137	0.2469	0.2440	0.1227	0.1727

Table E-14. The Prairie Dark Brown Soil Zone, Input Quantity Indexes and Cost Shares

Year	Input Indexes					Input Cost Shares				
	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.6434	1.1312	0.9983	0.4598	0.7364	0.0715	0.4886	0.2159	0.0331	0.1908
1962	0.9041	1.1174	0.9952	0.5181	0.7270	0.1028	0.4649	0.2131	0.0358	0.1835
1963	0.9309	1.1034	1.0382	0.6173	0.7500	0.1131	0.4426	0.2199	0.0418	0.1826
1964	0.9580	1.0898	1.1139	0.7836	0.7772	0.1225	0.4146	0.2299	0.0527	0.1804
1965	0.9993	1.0762	1.2201	0.8731	0.8182	0.1326	0.4074	0.2353	0.0536	0.1711
1966	1.1085	1.0630	1.2611	1.1803	0.8550	0.1447	0.3977	0.2302	0.0639	0.1634
1967	1.1029	1.0504	1.2027	1.4569	0.8930	0.1524	0.3959	0.2124	0.0767	0.1626
1968	1.0833	0.9472	1.2148	1.5812	0.9176	0.1623	0.3568	0.2207	0.0851	0.1751
1969	1.0127	1.1017	1.1313	1.0517	0.9509	0.1421	0.4252	0.2024	0.0527	0.1777
1970	0.7294	0.9555	1.0270	0.7829	0.9755	0.1262	0.4153	0.2127	0.0414	0.2044
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1416	0.4212	0.1931	0.0497	0.1943
1972	0.9695	1.0258	1.0803	1.1095	1.0513	0.1331	0.4344	0.1931	0.0538	0.1855
1973	1.0335	0.9873	1.1988	1.5484	1.0764	0.1509	0.4084	0.1959	0.0666	0.1783
1974	1.0195	1.0387	1.4539	1.8586	1.0311	0.1489	0.4035	0.2098	0.0821	0.1557
1975	1.0745	1.2434	1.7835	2.0926	0.9532	0.1438	0.4309	0.2119	0.0903	0.1231
1976	1.1203	1.1214	2.0945	2.0719	1.0096	0.1593	0.3884	0.2339	0.0886	0.1299
1977	1.1435	1.0902	2.2019	2.2600	1.0805	0.1629	0.3839	0.2338	0.0869	0.1325
1978	1.2080	1.1086	2.3031	3.0783	1.1703	0.1785	0.3560	0.2309	0.1037	0.1309
1979	1.2447	1.1051	2.3852	3.6959	1.2738	0.1978	0.3271	0.2313	0.1159	0.1279
1980	1.2254	0.9549	2.4504	3.2458	1.2254	0.2375	0.2688	0.2445	0.1176	0.1315
1981	1.2911	0.9718	2.4793	3.7986	1.2078	0.2439	0.2510	0.2308	0.1312	0.1432
1982	1.3161	0.9660	2.4433	4.0315	1.2046	0.2438	0.2463	0.2262	0.1326	0.1512
1983	1.3298	0.9246	2.3873	4.7703	1.2477	0.2331	0.2370	0.2229	0.1488	0.1582
1984	1.3070	0.9552	2.3473	5.0994	1.2354	0.2194	0.2461	0.2177	0.1583	0.1584

Table E-15. The Prairie Black Soil Zone, Input Quantity Indexes and Cost Shares

	Input Indexes					Input Cost Shares				
Year	Land	Labor	Machinery	Fertilizer	Material	Land	Labor	Machinery	Fertilizer	Material
1961	0.7487	1.1473	1.0180	0.3746	0.7158	0.0656	0.5628	0.1698	0.0346	0.1672
1962	0.9350	1.1340	1.0161	0.4107	0.7199	0.0800	0.5447	0.1710	0.0371	0.1673
1963	0.9522	1.1206	1.0595	0.5045	0.7412	0.0861	0.5229	0.1781	0.0451	0.1678
1964	0.9934	1.1038	1.1330	0.6402	0.7763	0.0954	0.4921	0.1868	0.0571	0.1686
1965	1.0440	1.0784	1.2320	0.7346	0.8127	0.1057	0.4842	0.1904	0.0601	0.1597
1966	1.0740	1.0675	1.2559	1.1049	0.8498	0.1093	0.4733	0.1843	0.0799	0.1532
1967	1.0720	1.0501	1.2144	1.3388	0.8814	0.1136	0.4715	0.1712	0.0935	0.1502
1968	1.0619	0.9507	1.2061	1.5327	0.9039	0.1221	0.4242	0.1781	0.1114	0.1643
1969	0.9978	1.1199	1.1187	0.9694	0.9369	0.1085	0.4955	0.1631	0.0657	0.1672
1970	0.8301	0.9531	0.8231	0.7693	0.9641	0.1029	0.5048	0.1409	0.0559	0.1955
1971	1.0000	1.0000	1.0000	1.0000	1.0000	0.1060	0.4924	0.1542	0.0660	0.1814
1972	0.9660	1.0042	1.0839	1.1076	1.0463	0.1047	0.4856	0.1592	0.0734	0.1770
1973	1.0573	0.9394	1.2031	1.5632	1.0717	0.1224	0.4493	0.1631	0.0927	0.1724
1974	1.0472	0.9721	1.4667	1.8297	1.0657	0.1198	0.4422	0.1732	0.1080	0.1567
1975	1.1148	1.1477	1.8081	2.0951	0.9780	0.1149	0.4525	0.1813	0.1243	0.1270
1976	1.1298	0.9935	2.1090	2.0526	1.0282	0.1229	0.4176	0.2020	0.1237	0.1337
1977	1.1587	0.9769	2.2078	2.2981	1.0967	0.1299	0.4079	0.2018	0.1249	0.1356
1978	1.2027	0.9837	2.2914	3.1461	1.2023	0.1384	0.3732	0.2003	0.1511	0.1370
1979	1.2007	0.9579	2.3704	3.8174	1.3319	0.1504	0.3441	0.1997	0.1702	0.1356
1980	1.2306	0.7944	2.4322	3.2581	1.2535	0.1801	0.2938	0.2144	0.1721	0.1395
1981	1.3688	0.7894	2.4576	3.6572	1.2489	0.1913	0.2710	0.2017	0.1844	0.1516
1982	1.3993	0.7899	2.4439	3.8911	1.2455	0.1899	0.2594	0.2022	0.1881	0.1604
1983	1.3959	0.7443	2.3968	4.5154	1.3014	0.1789	0.2506	0.1986	0.2045	0.1674
1984	1.4263	0.7686	2.3451	4.8692	1.2922	0.1655	0.2576	0.1918	0.2181	0.1670