TESTING FOR STRUCTURE IN A MULTI-PRODUCT INDUSTRY WITH PRICE EXPECTATIONS: THE CANADIAN CATTLE INDUSTRY

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENT FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

Department of Economics

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA
August, 1984

Department of Economics

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Date: August 20, 1984

ABSTRACT

The aim of this research is to develop a theoretical profit maximizing model of a cow-calf farm and then to determine and to estimate empirically the dynamic short run supply response and investment behaviour of cattle producers. The theory of duality is used here to provide a consistent model of the cow-calf industry. The model is consistent in that the estimated equations are derived from the profit maximizing farm model.

A comparative static analysis is carried out to determine short run supply response of cow-calf farmers. (Past studies have argued the existence of negative short run supply elasticities.) In this model, the sign of the short run elasticity of cattle supply depends on three factors: i) the technological structure of the industry; ii) the substitution possibilities between production today and production tomorrow; and iii) farmers' expectations of cattle prices. Consequently, a short run negative supply elasticity in the cow-calf industry is not a prediction from economic theory. Rather the sign of the elasticity is unknown and will depend on price expectations of producers.

The estimated coefficients of the profit function are used to test for certain characteristics of the underlying transformation function. It is determined that the technological structure of cow-calf production in western Canada is defined by a non-homothetic, non-homogeneous transformation function subject to decreasing returns to scale

and joint production between crops and cattle.

Other characteristics of the cow-calf industry are determined by calculating elasticities of choice. These elasticities conform to all a priori expectations with output supply functions having non-negative slopes, derived input demand functions having non-postive slopes, and a substitute relationship predicted between cattle supply and end-of-period inventory demand.

The total elasticity of cattle supply is also calculated. This elasticity measure takes account not only of the effect of cattle price fluctuations, but also the effect of changing expectations of cattle prices on cattle supply. It is determined that accounting for adjustments in expectations of cattle prices caused by changes in current cattle prices will always decrease the elasticity of cattle supply. However, there is no evidence to indicate that this tendency is significantly strong enough to decrease short run elasticities of cattle supply to zero or less.

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ACKNOWLEDGEMENTS

I would like to express my appreciation to Rick Barichello, Chuck Blackorby, John Cragg, and Bill Schworm for their comments, suggestions, and encouragements over the course of this study. Without their assistance, this dissertation would not have been completed.

This dissertation also benefited from discussions with other individuals. Specifically, I would like to thank Erwin Diewert, John Graham, Tim Hazledine, Kurt Klein, Ralph Lattimore, Rick Lymer, and Cameron Short for their constructive criticisms and cooperation and Ray Bollman for his comments and assistance in obtaining the data.

I am grateful to the members and students in the departments of Economics and Agricultural Economics for providing an excellent environment in which to study economics.

Finally, I would like to thank my parents for encouraging me to continue my education and my wife, Gloria, for her love and continued support during many, sometimes turbulent, years of graduate studies. This dissertation is dedicated to her.

1. INTRODUCTION

A number of economic studies have analyzed the structure and characteristics of the Canadian cow-calf industry and the decision-making behavior of cattle producers[1] (Kerr 1968, Tryfos 1974, Kulshreshtha 1976, Haack, Martin, and MacAulay 1978, Pugh 1978, Agriculture Canada 1983, and others). The interest in this industry is generated first of all by the need for economists to have knowledge of the structural characteristics in order to determine the consequences of changes in policy and other parameters. Second, there is evidence, both theoretical and empirical, which suggests that the elasticity of supply in the short run is negative and gradually becomes positive over a long adjustment period (Marshall 1964, Reutlinger 1966, Jarvis 1969, Yver 1971, and Nelson and Spreen 1978). Three reasons are put forward to explain negative short run supply responses in the cattle industry: 1) the price expectations of cattle producers (i.e., changing price expectations will initiate changes in investment decisions and cattle inventories); 2) the beef animal is both an input into the production process as well as the output (i.e., additional output requires that cows and heifers be retained in the breeding herd in order to produce more animals: this implies lower current output); and 3) the biological characteristics of cattle reproduction (i.e., the existence of a time lag in the reproduction process between when producers decide to increase their herd and when new animals are brought to market).

Existing studies however, have had some problems in modelling and predicting the dynamic short run supply response and investment behavior of cattle producers. Knight (1961), in describing these problems, stated that "Research workers have probably had more difficulty deriving meaningful and realistic supply-price elasticities for beef than for any of the other commodities". In addition, Nelson and Spreen (1978) have argued that previous empirical studies of the cattle industry have generated contradictory results, "and a controversy still exists about the proper specification of a short-run supply relation for slaughter cattle". These problems can be attributed to three factors. 1) Theoretical studies (Jarvis 1969, Yver 1971) which demonstrate the existence of negative short run supply response allude to the importance of price expectations of cattle producers but do not explicitly take account of expectations in their theoretical analysis. It will be shown in this study that price expectations of cattle producers are the major causal factor generating negative supply responses in the short run. 2) Empirical attempts to model the cow-calf industry are complicated by the fact that beef animals are simultaneously an investment good and an output good. 3) Most empirical studies are static with some form of lag structure appended to the model in order to introduce dynamic elements into the analysis. Intertemporal analysis is required to model consistently the dynamic response and investment behavior of cattle producers. This will allow improved specification of the econometric equations and presumably more accurate results.

The development of duality theory (Shepard 1953, Gorman 1968, and McFadden 1978) offers the economist new tools with which to approach the problem of modelling dynamic short run supply responses and investment[2] behavior of cattle producers. Generally, duality theory demonstrates that under certain regularity conditions[3] and with the assumption of profit maximization, the production possibilities available to a farm can be completely characterized by a profit function.[4] A dual relationship between this profit function and a transformation function allows either to be derived from the knowledge of the other. Theoretically, therefore, the technological parameters of the cow-calf industry can be recovered either directly by estimating the transformation function (the primal approach) or indirectly by estimating the profit function (the dual approach).

There are however, several disadvantages to estimating the transformation function directly[5] (Woodland 1976). If the vector of inputs in the transformation function are chosen by the farm, such inputs are endogenous in an econometric model and unlikely to be independent of the error structure. In this case, ordinary least squares regression would be inappropriate and alternative and more complicated econometric techniques, such as instrumental variables, would be required. If time-series data are used, it is likely that the inputs will be multicollinear, causing the standard errors of the regression coefficients to be larger (or smaller) than they otherwise would be in the absence of multicollinearity.

Finally, if the farm maximizes profits, this behavior is not used in estimating the transformation function unless it is modelled directly.

If one is willing to assume both profit maximizing and price-taking behavior, then empirical factor demand and output supply equations can be derived as solutions to the first order conditions in the maximization of profits subject to the transformation function. However, because of the difficulty involved in solving first order conditions, one is forced to posit very restrictive functional forms for the transformation function (e.g., Cobb-Douglas or C.E.S.).[6]

By using a dual approach to recover the parameters of the technology, many of the problems associated with direct estimation of the transformation function can be overcome. Under the maintained assumptions of profit maximization and price-taking market conditions, the dual approach specifies an (optimal) profit function directly and thereby avoids the necessity of solving first order conditions in a maximizing problem. Certain restrictions are imposed on the profit function to ensure that it satisfies the conditions of a "well-behaved" transformation function (Diewert 1973).

Besides circumventing the need to solve first order conditions, there are two other principal advantages of duality theory in applied economics (Diewert 1974). First, the derived input demand and output supply equations that are consistent with farm profit maximization can be obtained by differentiating the profit function with respect to input and output prices. Because of the ease in deriving input demand

and output supply equations, duality theory allows a direct and consistent relationship between the theoretical model and the econometric model. Second, comparative static results can easily be generated from the estimated derived input demand and output supply equations.

A number of recent contributions to the theory of cost and production have enhanced and extended the use of duality theory in empirical work. The introduction of flexible functional forms (FFF) by Diewert (1971) and Christensen, Jorgensen, and Lau (1973) allowed generalizations away from previous more restrictive functional forms. In fact, FFF can be used to test statistically for the existence of the more restrictive forms. FFF provide a second order approximation to the underlying transformation function and do not a priori impose homotheticity, separability, or restrictions on substitution elasticities.[7] Moreover, FFF can be used to test statistically for these restrictions on the underlying technology. The extension of duality theory and FFF to allow for multiple outputs and inputs enables the researcher to model firms which employ a number of inputs and produce a number of outputs (Lau 1972, Hall 1973, and Diewert 1973).[8] This generalization eliminates the need to associate certain expenses with the production of certain outputs. In addition, joint production possibilities can be tested statistically. Finally, the development of variable or restrictive profit functions takes account of the Marshallian notion that in the short run, some factors are variable (i.e., the farm is optimizing with respect to the quantity employed of each variable input) whereas other factors are fixed (i.e., the farm may not be in equilibrium with respect to quantities employed of these fixed factors) (Gorman 1968). Using this procedure, the shadow price of each fixed factor can be derived by differentiating the variable profit function with respect to the fixed factor.

There are a number of econometric advantages to using the dual approach combined with FFF. The coefficients of the profit function can be estimated from the derived input demand and output supply equations. These functions are reduced form equations with output and input quantities as functions of output and input prices and the quantity of any fixed factors. If prices are exogenous, less complicated econometric techniques can be used to estimate the coefficients. Additionally, many types of FFF that are used to approximate the profit function are linear in their coefficients and this allows the use of linear regression techniques in estimating these coefficients. However, because the independent variables are monotonic transforms of prices or price ratios, multicollinearity can be a serious problem. Finally, it should be noted that although one might expect prices to be independent of the error structure in an econometric equation, it is likely that because of the symmetry restrictions imposed across equations, the error structure is correlated across equations in a system of input and output equations. This would indicate that a systems method which accounts for this error structure should be used when estimating the coefficients from the derived input demand and output supply equations.[9]

1.1 OBJECTIVES

The aim of this research is to develop a theoretical profit maximizing model of a cow-calf farm and then to determine and to estimate empirically the dynamic short run supply response and investment behavior of cattle producers.

Specifically, the objectives are as follows: i) to characterize the structure of the Canadian cow-calf industry using a discrete time, intertemporal model (ignoring other sectors of the beef industry, such as feedlot production and meat processing); ii) to demonstrate theoretically the importance of cattle producers' price expectations in generating the time path of the supply adjustment process and to determine empirically cattle producers' expectations about future beef prices; iii) to recover the parameters of the technology using the output supply and input demand equations that uniquely define the transformation function over the economically relevant region; iv) to undertake a comparative static analysis of the changes in the optimal values of output supply and input demand as a result of changes in the exogenous variables; v) to generate a number of summary statistics of output and input flexibility including the short run elasticity of output supply and input demand and measures of substitutability of outputs and of inputs.

1.2 EXISTING LITERATURE

The present study differs from previous studies of the cow-calf industry in four ways. First, previous studies (Jarvis 1969 and Yver 1971) have developed theoretical models of cattle production which maximize the net present discounted value of an animal at birth or for its remaining lifetime. The endogenous variables, optimal input quantities and optimal slaughter age, are specified as functions of the exogenous parameters. However, the empirical models do not fully reflect the theoretical results: they do not include equations that represent the endogenous variables as functions of the exogenous variables. Rather, the estimated equations are arbitrarily specified to determine average slaughter weight, number of animals slaughtered in each category, and export and domestic demand. In contrast, the theory of duality is used here to provide a rigorous and consistent model of the cow-calf industry. Because duality theory allows one to manage complicated functions more easily, the technology of cattle production can be modelled in greater detail and with more precision than before. The model is consistent in that the estimated equations are derived from the profit maximizing farm model.

Second, Reutlinger (1966) argued that to achieve more accurate results when estimating cattle production models, it is necessary to estimate output supply and cattle inventory equations simultaneously. Previous studies have either assumed cattle inventories to be exogenous (Langemeir and Thompson 1967) or have arbitrarily specified inventory equations to be functions of expected beef prices and feed costs (Tryfos 1974). These studies generally allow inventories to approach an optimal level using a partial adjustment process (Ospina and Shumway 1978). In this study, cattle inventories are determined endogenously.

The importance of price expectations in the cattle industry has been well documented in the literature (Marshall 1964 and Elam 1975). However, little has been done to demonstrate in a rigorous manner the theoretical importance of price expectations for the time path of adjustment adopted by cattle producers. Therefore, a third innovation of this study is that price expectations will be introduced into the theoretical model. The consequences of price expectations for the dynamic short run response of cattle producers will be determined.

Finally, existing studies have focused on estimating inventory, investment, or slaughter equations but have ignored the demands by producers for factor inputs (Kulshreshtha and Wilson 1972, and Ospina and Shumway n.d.). In this study output supply equations, cattle inventory equations, and derived input demand equations will be estimated simultaneously. The results of the estimation will provide information on structural parameters of this industry making it potentially more useful to policy makers.

1.3 THESIS OUTLINE

The remainder of this thesis is organized as follows. The characteristics of the Canadian cattle industry are described in Chapter Two. This discussion indicates the importance of cattle production within Canadian agriculture and the implications for Canadian cattle prices of relatively free international trade in beef animals and meat products. This chapter includes a review of past theoretical attempts to model cattle production.

In Chapter Three, a theoretical profit maximizing model of a cow-calf producer is developed. Initially a number of simplifying assumptions are imposed on the model in order to focus on the dynamic elements of cattle production and to determine the theoretical implications of price expectations on short run supply behavior. Subsequently, the model is extended to account for a multi-output, multi-input production technology from which an econometric model can be postulated. A comparative static analysis is undertaken and a number of elasticity measurements for the multi-output, multi-input model are discussed.

The data required to estimate the output supply and derived input demand equations are reported in Chapter Four. Data include the quantity of different outputs produced by cow-calf farms and associated output prices, the quantity of different inputs used on farms and associated input prices, and the inventories of cattle on farms. The transformation of the data, in order to obtain the appropriate variables required for empirical analysis in this dissertation, are also described.

Additionally, Chapter Four includes a discussion of the issues involved in estimating the coefficients of the profit function model. Functional forms for the profit function are specified and the estimating equations are derived. Finally, the econometric methodology used to estimate the system of equations is detailed as are the assumptions about the stochastic framework of the equations.

The results of the regression analyses are reported in Chapter Five. In addition, a number of elasticity measurements are presented and the hypotheses to be postulated in Chapter Three are tested.

The main conclusions of the study are summarized in Chapter Six.

FOOTNOTES TO CHAPTER ONE

1 A cattle producer is defined as a farmer who owns a beef cow breeding herd and produces calves for sale. The cattle producer may also retain calves on the farm and sell heavier animals at a later date. The economic choices available to the cattle producer will be discussed in Chapter Two.

2 The investment behavior that is of interest here is the expansion or reduction of the breeding herd.

3 These regularity conditions will be discussed in Chapter Three.

4 Diewert (1974) states that the essence of duality theory rests on a mathematical theorem by Minkowski: "every closed convex set in R^n can be characterized as the intersection of its supporting halfspaces".

5 Some of these disadvantages apply equally to estimation of profit functions.

6 These functional forms are restrictive in the sense that they impose homotheticity, separability, or constant elasticities of substitution on the estimating function.

7 One can distinguish two types of approximation: i) the Diewert approximation, where a functional form is flexible if the parameters of the functional form can be chosen to make the values of its first and second order derivatives equal to the first and second order derivatives of the function being approximated at some point; and ii) the Taylor series approximation, where the function is

approximated with a Taylor series expansion around some point. See Blackorby, Primont, and Russell (1978) pp.290-300 for the distinction between the two definitions.

8 Given the multi-product nature of Canadian agriculture, this extension will prove valuable in modelling the cow-calf industry. See Mundlak (1963) for an initial attempt at modelling multi-product production functions.

9 It should be noted that the use of duality in applied economics has gained wide popularity. For examples of applied duality in both agricultural and non-agricultural markets see Berndt, Fuss, and Waverman (1979), Binswanger (1974), Caves and Christensen (1980), Caves, Christensen, and Swanson (1981), Fuss (1977), Lopez (1980), McKay, Lawrence, and Vlastium (1982), Sidhu and Baanante (1981), Woodland (1975), Woodland (1977). One common feature of almost all of these studies is the use of highly aggregated sectoral data (i.e., total agriculture or total manufacturing). This study will use a more disaggregated industry-level data series to estimate the model.

2. THE CANADIAN CATTLE INDUSTRY

2.1 INTRODUCTION

The Canadian cattle industry is characterized by a large number of small producers, cyclical trends in production, and an open market for international trade in live cattle and beef. These and other characteristics of the cattle industry are discussed in Section (2.2) of this chapter. The economic options available to cow-calf producers when determining production strategy are outlined in Section (2.3). Finally, Section (2.4) consists of an examination of past attempts to model the economic behavior of cow-calf producers.

2.2 SOME CHARACTERISTICS OF THE CATTLE INDUSTRY

The cattle industry is an important sector of agricultural production in Canada. Table 2.1 lists farm cash receipts for Canada from the sale of cattle and calves for selected years between 1970 to 1982. Cattle and calf sales for this period represent from 18.4% to 34.9% of total farm cash receipts, second only to the grains (wheat, barley, etc.) industry.

In 1982, the receipts from the sale of cattle and calves accounted for 30.5%, 12.6%, and 17.6% of total farm cash receipts for Alberta, Saskatchewan, and Manitoba respectively.[1]

Another indication of the importance of the Canadian cattle industry is that international trade in beef animals and meat products has increased significantly in recent years.

TABLE 2.1

Canadian Farm Cash Receipts from the Sale of Cattle and Calves

Year	1970	1975	1980	1981	1982
Receipts from the Sale of Cattle and Calves ($ million)	1,469.6	1,873.9	3,665.0	3,537.0	3,586.0
Total Farm CAsh Receipts ($ million)	4,208.4	10,142.4	15,837.0	18,835.0	18,840.0
Receipts from the Sale of Cattle and Calves as a Percentage of Total Receipts	34.9	18.4	23.0	18.8	19.0

Source: Statistics Canada, Farm Cash Receipts, Cat. No. 21-001, Ottawa, Queen's Printer, annual.

Table 2.2 lists the numbers of cattle and calves and pounds of dressed beef and veal exported and imported for selected years between 1970 to 1982. This table indicates that throughout this period, Canada has been a net exporter of live animals and that these exports have been increasing at a significantly greater rate than imports. Furthermore, in 1970 and 1975 Canada was a net importer of dressed beef and veal but in the late '70's and early '80's, Canada changed to a net exporter in this category as well. The significance of international trade to the Canadian cattle industry is demonstrated in Table 2.3 which lists, in millions of dollars, the value of exports and imports of live animals and meat products. Throughout this period, the value of live animal exports exceeded imports but the value of imports increased at a significantly greater rate than exports. These figures represent the fact that Canada exports large quantities of low quality beef and imports high quality beef from the U.S.[2] Finally, in 1977-78 the value of imports of meat products exceeded exports but this has changed significantly. In recent years, the value of meat products exports has increased to more than twice the value of imports.

The U.S. is Canada's largest trading partner in beef products accounting for approximately 90% of total exports of cattle and calves and 85% of total dressed beef and veal.

Canada's success in international trade in live animals and meat products depends on low trade barriers with its major trading partners.[3] Except for a few periods where high tariffs or import restrictions were imposed, beef producers have

TABLE 2.2

Canadian Exports and Imports of Live Animals and Dressed Beef and Veal

Year	1970	1975	1980	1981	1982
EXPORTS					
Cattle and Calves (thousand Head)	247.0	223.6	357.8	353.0	504.9
Dressed Beef and Veal (million lbs.)	119.1	45.1	114.3	174.7	183.5
IMPORTS					
Cattle and Calves (thousand head)	53.3	92.6	52.7	171.1	83.9
Dressed Beef and Veal (million lbs.)	157.4	139.8	129.7	133.8	140.6

Sources: Statistics Canada, Livestock and Animal Products Statistics, Cat. No. 23-203, Ottawa, Queen's Printer, annual.

Agriculture Canada, Livestock Market Review, Ottawa, Queen's Printer, annual.

TABLE 2.3

Value of Canadian Exports and Imports of Live Animals and Meat Products

Year	1977	1978	1979	1980	1981	1982
EXPORTS ($ million)						
Live Animals	135.0	196.0	224.0	229.0	201.0	299.0
Meat Products	222.0	309.0	428.0	514.0	620.0	776.0
IMPORTS ($ million)						
Live Animals	30.0	57.0	48.0	88.0	170.0	105.0
Meat Products	295.0	331.0	332.0	287.0	301.0	297.0

Source: Statistics Canada, Selected Agriculture Statistics Canada and the Provinces, Ottawa, Queen's Printer, 1983.

enjoyed relatively free trade in beef products. In Table 2.4, an example of the 1982 tariff structure is presented for Canada and its major trading partners for different categories of animals and meat products. Canadian import tariffs for different categories of livestock and meat and for different countries are either zero or approximately $.02 per pound. U.S. tariff on Canadian products varies from zero to 10% of the price per pound. But for the two important categories of live animals and dressed beef and veal, the tariff is $.01 and $.02 per pound respectively.

Canada produces approximately 10% of total North American beef output. Because of the size and proximity of the U.S. market and the virtual free trade in beef cattle between the two countries, Canadian beef prices are closely related to U.S. beef prices. Figure 2.1 illustrates this relationship with quarterly choice steer prices in Canadian funds, in Calgary and Omaha, for the period 1977 to 1982. If changes in supply or demand conditions for beef in Canada result in Canadian prices becoming significantly higher than U.S. beef prices, arbitrage will result in U.S. cattle entering the Canadian market and consequently decreasing Canadian beef prices. One would expect that U.S. cattle would be imported to Canada if the Canadian beef price is greater than the U.S. price plus transportation costs to Canadian markets plus transaction costs, which include a small import tariff.

The relationship between price variations and shipments of cattle between Canada and the U.S. can be represented in a simple diagram.[4] In Figure 2.2, DD' represents the Canadian

TABLE 2.4

Canadian Tariff Structure for Different Categories of Animals and Meat Products

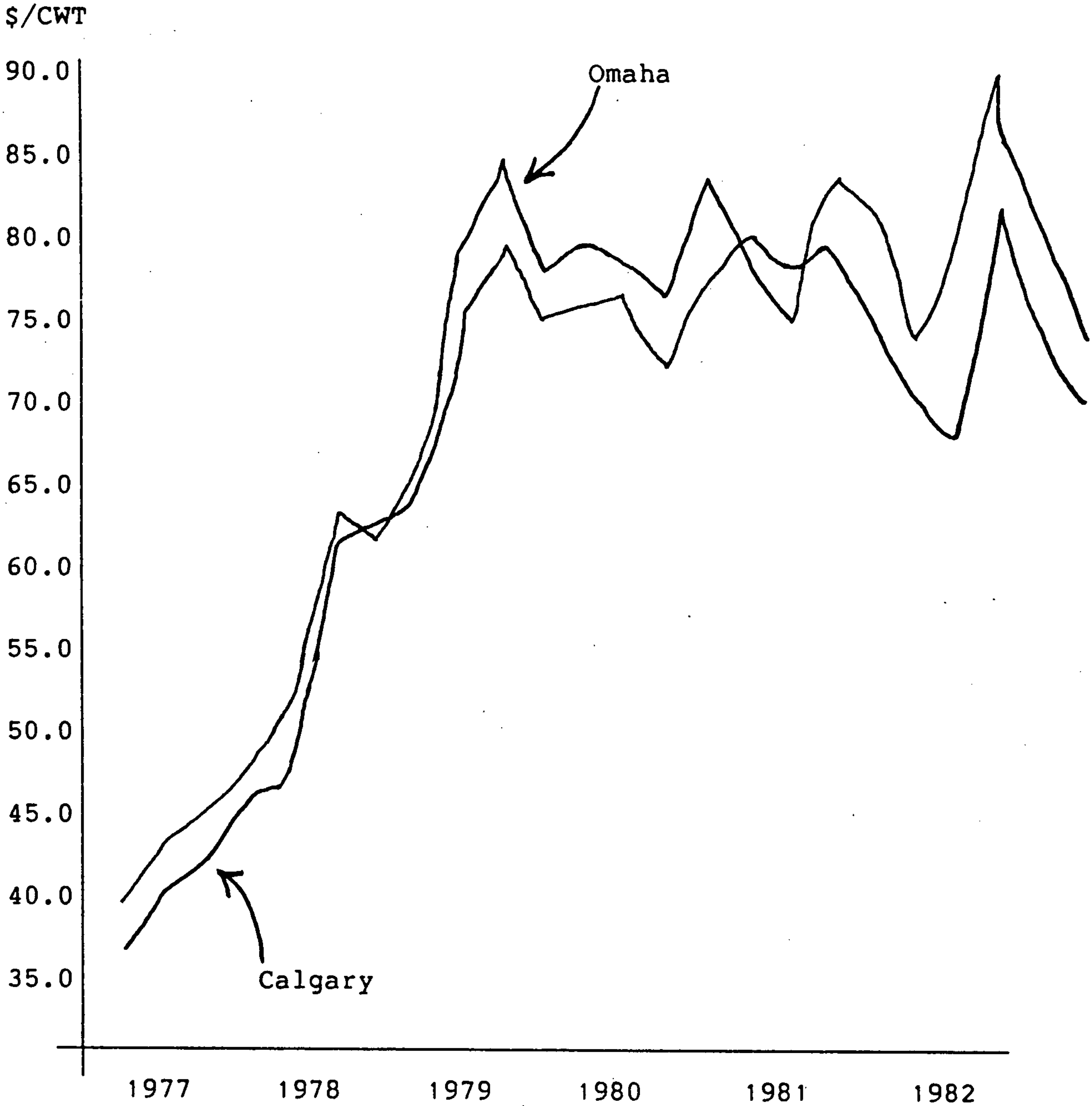
Commodity	British	Australia New Zealand	M.F.N.* U.S.	U.S. Tariff on Candian Goods
Breeding Animals	Free	Free	Free	Free
Live Cattle (excludes dairy cows)	Free	Free	$.01/lb	$.01/lb
Beef and Veal Fresh and Frozen	$.02/lb	$.02/lb	$.02/lb	$.02/lb
Prime or Choice Prepared for Retail	$.02/lb	$.02/lb	$.02/lb	4.0%
Beef Prepared and Preserved	Free	Free	$.01/lb	$.02 or 10.0%**
Beef Canned	15.0%	Free	15.0%	3.0%
Beef Salted in Barrels	Free	Free	Free	$.022 or 10.0%***
Cattle Hides	Free	Free	Free	Free

* Most Favorite Nation
** $.02/lb when price is $.30/lb or less; 10.0% when price is over $.30/lb.
*** $.022/lb when price is $.30/lb or less; 10.0% when price is over $.30/lb.

Source: Agriculture Canada, Livestock Market Review, Ottawa, Queen's Printer, 1982.

FIGURE 2.1

Choice Steer Prices, in Canadian
Funds, Calgary and Omaha



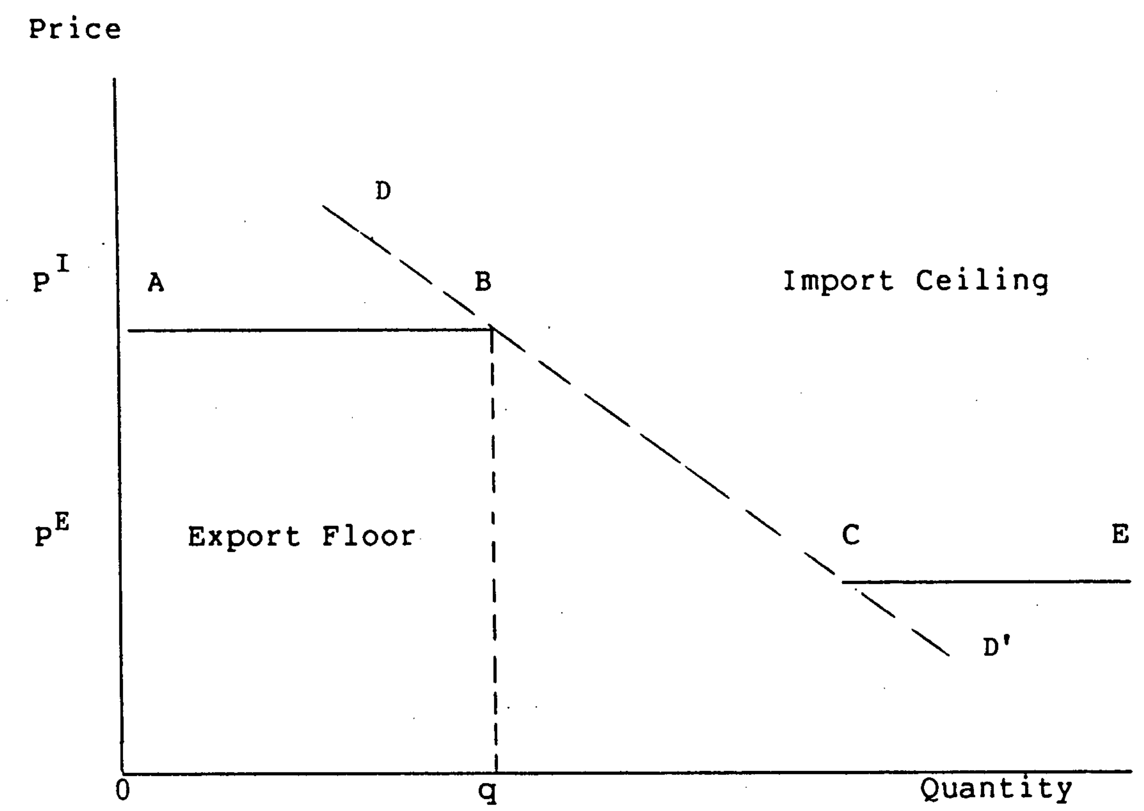
Source: Agriculture Canada, Canadian Livestock and Meat Trade Report, Ottawa, Queen's Printer, annual.

domestic demand function for beef products. The import ceiling price (P^I) represents the price of beef products in the U.S. plus transportation costs to Canadian markets plus a small import duty. The export floor price (P^E) represents the price of beef products in the U.S. less transportation costs to U.S. markets less U.S. import duty. P^I and P^E represent the range in which the Canadian price will change relative to that of the U.S. beef price. The large size of the U.S. market relative to the Canadian market has a number of important implications for the shape of the total demand curve facing Canadian cattle producers. If Canadian prices vary within the range P^I to P^E, the relevant demand curve is domestic demand. If Canadian prices fall below P^E, then Canadian beef becomes competitive in U.S. markets and the relevant demand curve for Canadian producers is the domestic demand plus U.S. demand for Canadian beef. This demand is drawn as horizontal at price P^E (segment CE) to indicate the assumption that Canadian exports to the U.S. will not affect U.S. beef prices. On the other hand, if Canadian prices rise above price P^I, U.S. beef becomes competitive on Canadian markets. A reduction in Canadian beef supply below Oq would result in U.S. beef entering the Canadian market and prices being reduced to P^I. Consequently, the relevant demand curve for Canadian producers is horizontal at price P^I (segment AB). Therefore, the demand curve facing Canadian beef producers is represented as ABCE in Figure 2.2.

This diagram has three important implications for this study. First, only variations within a certain output range

FIGURE 2.2

Aggregate Demand Facing Canadian
Cattle Producers



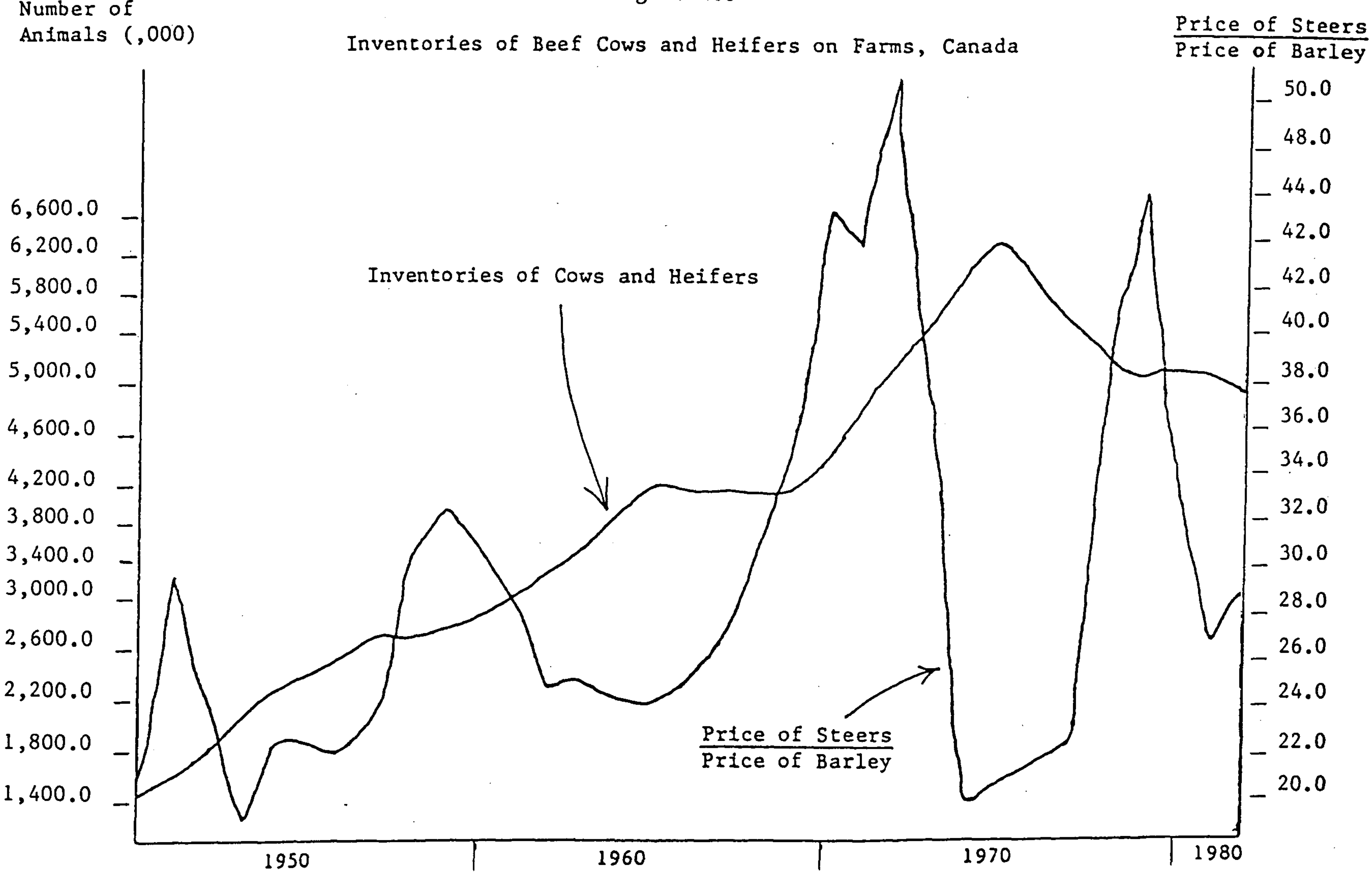
in the quantity of beef supplied by Canadian producers will alter the price of beef in Canada. Otherwise, changes in output supply have no effect on beef prices. Second, since Canadian beef prices are not the prices at which Canadian demand and supply are equalized but are largely determined exogenously by the U.S. market, demand and supply functions are independent functions and may be estimated separately. Finally, because one can treat Canadian beef prices as predetermined, such prices can be assumed to be exogenous not only at the farm level but also exogenous at the Canadian industry level. This simplifies the econometric model.

One distinctive feature of the cattle industry is large variations over time in cattle production. This has become known as the "beef cycle". The beef cycle is represented in Figure 2.3 by the inventories of cows and heifers on farms in Canada for the period 1950-82. Female inventories were at a cyclical low point in 1950 (the previous peak was 1945): they reached a peak in 1965, a relative low point in 1968, and again peaked in 1975. Included in Figure 2.3 is a curve representing the ratio of choice steer prices to the price of feed barley over the period 1950-82. Generally, the price ratio is the reciprocal of inventory movements, but prices precede the turning points of inventories by several years. The response lag of inventories following changes in prices reflects the biological lag between when cow-calf farmers make production plans and when such plans are reflected in herd size.

A better description of the beef cycle is gained from

Figure 2.3

Inventories of Beef Cows and Heifers on Farms, Canada



Sources: Statistics Canada, Livestock and Animal Product Statistics, Cat. No. 23-203, Ottawa, Queen's Printer, annual.

Statistics Canada, Handbook of Agricultural Statistics, Cat. No. 21-516, Part 1, Ottawa, Queen's Printer, annual.

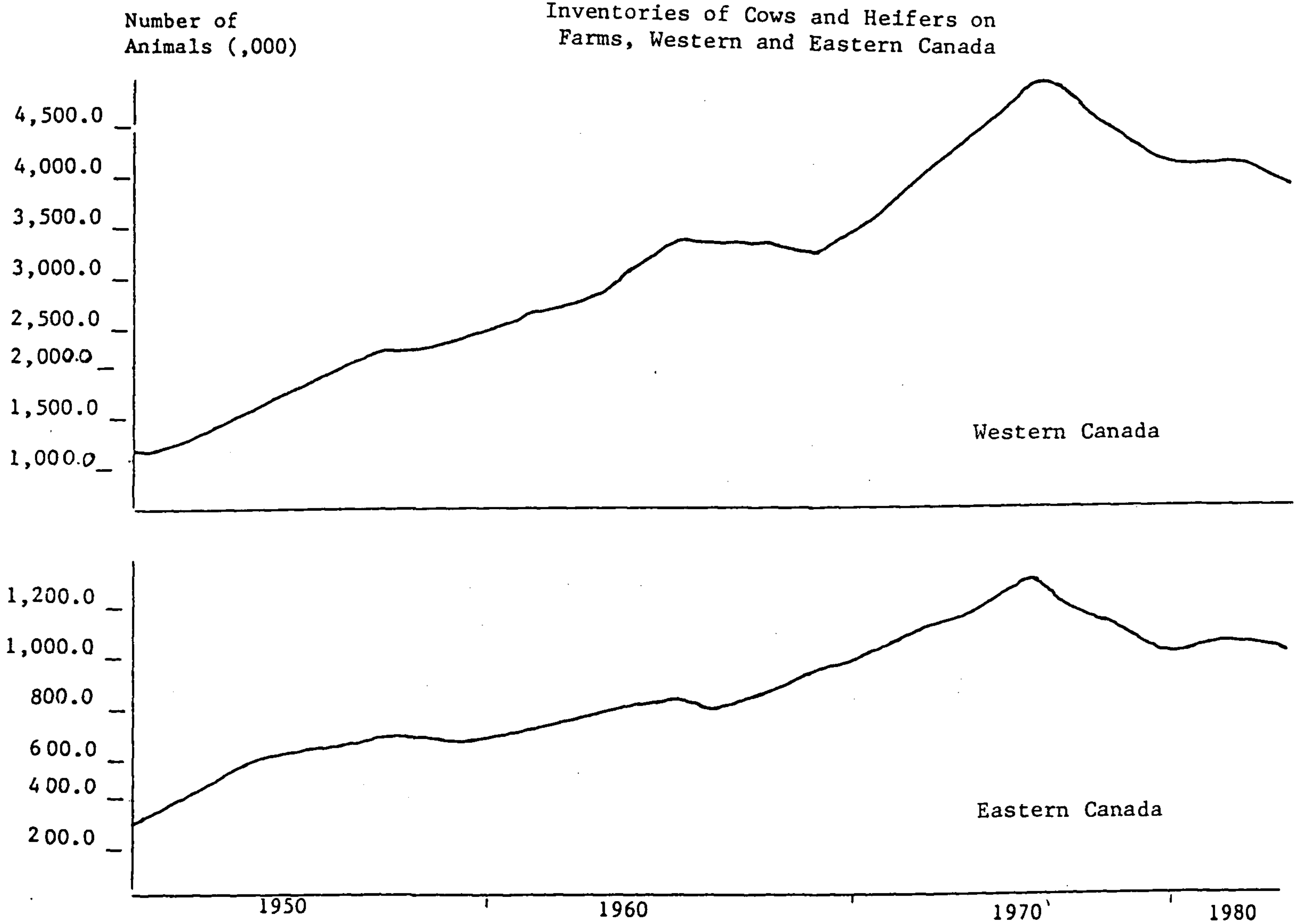
examining changes in female inventories in the beef herds in western Canada compared to herds in eastern Canada. Figure 2.4 shows changes in female inventories for the two regions for the period 1950-1982. Although there are some cyclical trends in the eastern beef herd, the more pronounced variations occur in the western herd. This reflects the fact that 80 percent of the Canadian beef breeding herd is in western Canada. Consequently, changes in Canadian beef production are due primarily to inventory changes in the beef herd in western Canada.[5]

To gain some insight into the causes of the beef cycle, consider Figure 2.5 which illustrates steer and female slaughter for the period 1960-82. Steer slaughter is more stable than female slaughter. This indicates that as the herd expanded (say between 1970 and 1975), female animals were held back from the market and retained in the breeding herd to produce new animals. Consequently, during this period of the cycle, female slaughter is less than steer slaughter. However, the decline in the herd after 1975 coincides with farmers reducing their breeding herds (culling cows and slaughtering heifers) resulting in a large female slaughter.

The position of the beef industry along a cycle can generally be identified by the slaughter of females as a ratio of steer slaughter. Figure 2.6 shows this ratio for the period 1960-82. During an expansionary phase of the cycle, for example between 1970 and 1975, female slaughter is significantly less than steer slaughter whereas during a contractionary phase of the cycle, after 1975, female

Figure 2.4

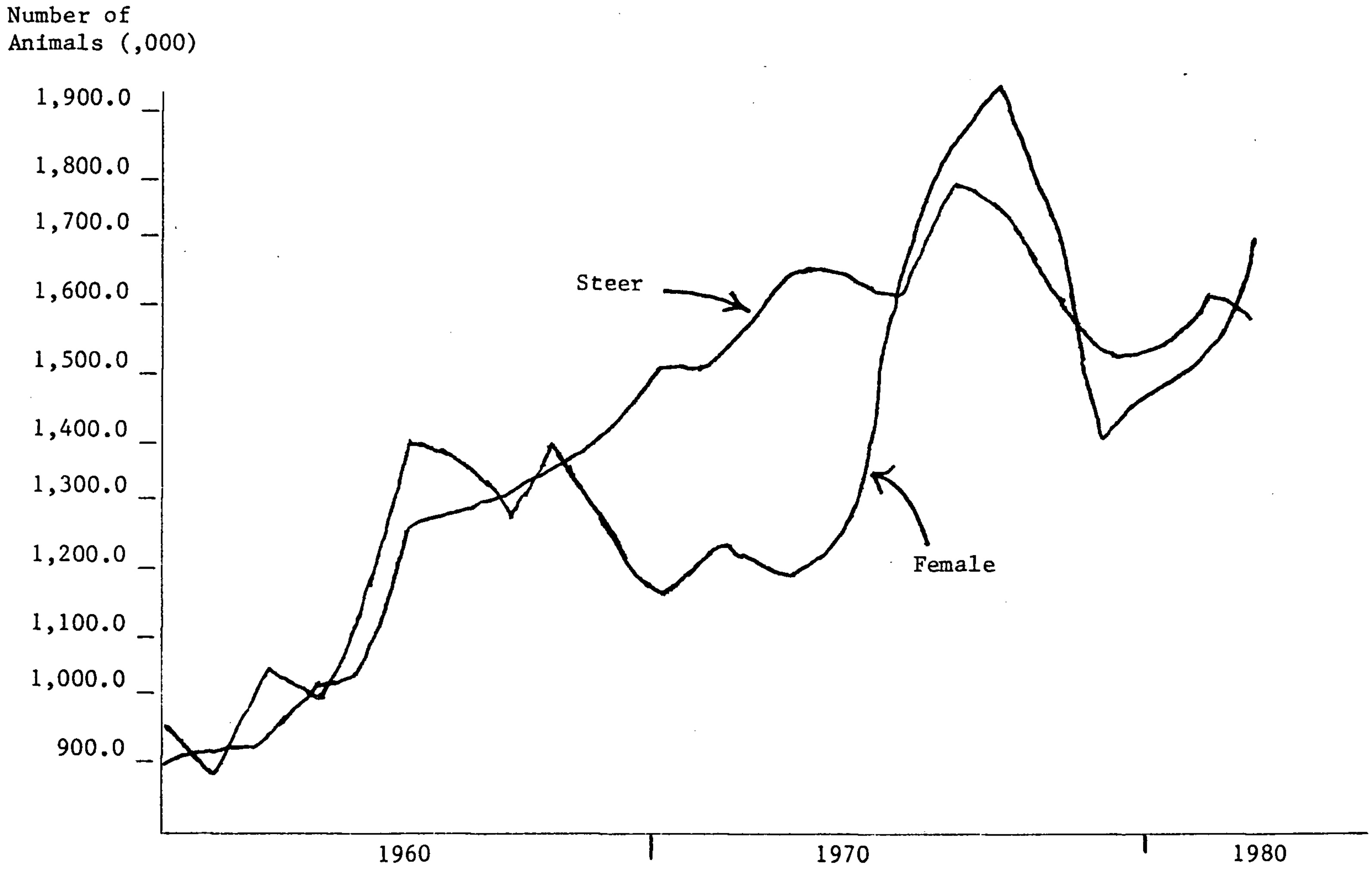
Inventories of Cows and Heifers on Farms, Western and Eastern Canada



Source: Statistics Canada, Livestock and Animal Product Statistics, Cat. No. 23-203, Ottawa, Queen's Printer. annual.

Figure 2.5

Steer and Female Slaughter, Canada



Source: Statistics Canada, Livestock and Animal Product Statistics, Cat. No. 23-203, Ottawa, Queen's Printer, annual.

Figure 2.6

Female Slaughter as a Percentage of
Steer Slaughter, Canada

Source: Statistics Canada, Livestock and Animal Product Statistics, Cat. No. 23-203, Ottawa, Queen's Printer, annual.

slaughter is significantly greater than steer slaughter. A ratio of female to steer slaughter of less than one indicates an expansionary phase. Conversely, a ratio of more than one indicates a contractionary phase.

Both Figure 2.5 and 2.6 suggest that there is a significant relationship between the beef cycle and the slaughter or retention of female animals. Marshall (1964) describes this relationship as follows:

> "When the price of cattle is high relative to other production possibilities the tendency is to hold back cows and heifers for breeding. Inventories are thus augumented, marketings reduced and prices strengthened. As inventory numbers build up and the progeny of increased cow numbers reach market weight marketings increase. Eventually increased marketings reduce prices to a point that discourages further expansion and eventually some liquidation of inventories takes place. The following decline in marketings results in prices increasing and the beginning of a new cycle."

Cattle producers have always had to adjust and respond to the beef cycle as part of the biological and economic environment in which they operate. The remainder of this chapter will be an examination of the economic options and decisions faced by cow-calf producers and previous theoretical attempts to model this behavior.

2.3 ALTERNATIVE PRODUCTION STRATEGIES AVAILABLE TO COW-CALF PRODUCERS

The cow-calf farmer is engaged in the primary activity of reproducing animals and selling the progeny. A secondary activity is the selling of cull cows (and bulls). These activities are distinct from the specialized feeder operator whose primary role is the production of finished beef. The basic decision of the cow-calf farmer is whether to sell a calf now or feed to heavier weights before selling. This decision will depend on the prevailing and expected economic conditions: the price of animals at different weights; the availability of pasture and its quality; the price of associated inputs; and the opportunity cost of the farmer. At any point in time, therefore, it is likely that a cow-calf farmer will have a variety of animals in his herd (eg., bulls, cows, steers, heifers, calves) at different weights and ages.

In managing the herd, the cow-calf farmer is faced with three major decisions (Yver 1971):

a) determining optimal herd size (and associated optimal input levels);

b) determining the optimal numbers of different types of animals in the herd; and

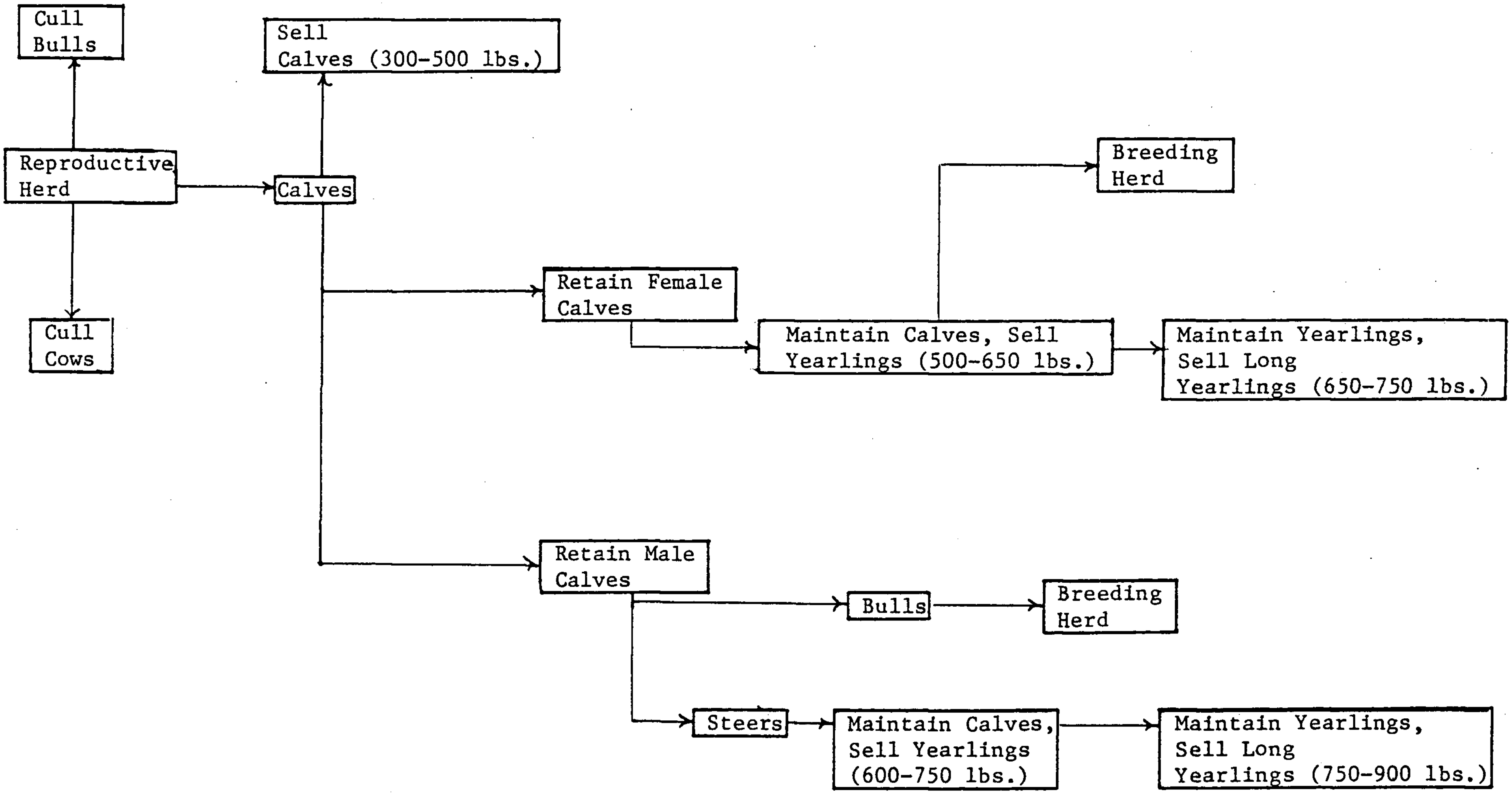
c) determining whether an animal should be sold or retained in the herd for the purpose of producing more animals.

The first and third decisions are typical production decisions (i.e., determining the size of plant and output rate) while the second is basically a portfolio decision.

Figure 2.7 helps to describe the economic options available to the cow-calf producer. The focus of a cow-calf farmer's management decisions is the reproductive herd which includes bulls, cows, and heifers.[6] The number of calves produced in any one year depends on the number of cows and heifers bred nine months earlier. A successful calving rate of 85% is considered average. Generally, because of Canadian weather conditions, calving is timed to take place in the

Figure 2.7

Flow Diagram of Cattle Production Decisions



early spring. The new calves can be sold to feedlots in the fall of the year in which they are born or retained in the herd over the winter. The cow-calf farmer has available a number of production alternatives for the retained calves. Bull calves can be retained for breeding within the reproductive herd or they can become steers. Steers can be sold to feedlots as yearlings at approximately 600-750 pounds or maintained on pasture and sold as long yearlings at approximately 750-900 pounds. (Feedlots sell finished steers at approximately 1000-1100 pounds).

Female calves can be kept as replacement heifers or sold to feedlots. Heifers can be sold as yearlings at approximately 500-650 pounds or maintained on pasture and sold as long yearlings at approximately 650-750 pounds. (Feedlots sell finished heifers at approximately 850-950 pounds). Of course, the decision on whether to use a heifer as a replacement can be made up to the time the animal is sold.

In the case of steers, the decision of the farmer is quite straightforward: he must decide on the optimal weight and time to sell the animal. In the case of bulls, cows, and heifers, the decision is more complicated. He must decide whether to sell the animal, retain it for further fattening (heifers), or incorporate it into the breeding herd for producing calves.

A number of economic studies have attempted to model the economic options available to cow-calf producers. The next section will examine two important contributions in this area.

2.4 EXISTING THEORETICAL MODELS OF THE COW-CALF INDUSTRY

There have been a number of important theoretical attempts to model the characteristics of the cow-calf industry. Jarvis (1968) and Yver (1971) use a basic capital-theoretic approach to model this industry. The emphasis of their models is the possible existence of negative short run supply elasticities. Carvalho (1972) on the other hand, is interested in capturing the dynamic characteristics of the cow-calf industry by using dynamic programming techniques. In addition, Carvalho combines this approach with time series analysis to incorporate price expectations into the model. Because many existing empirical studies of the cattle industry are based either on the Jarvis and Yver models or on the Carvalho model, their main results are summarized below. The Yver model, although similar to the Jarvis model, is less complicated and is discussed in place of the Jarvis model.[7]

Yver defines the problem faced by the cattle producer as one of determining the quantity of feed inputs used and the time of sale of the animal. This problem is equivalent to the maximization of the present net discounted value of the animal at birth. For steers this problem can be represented as follows.

$$(2.1) \qquad Vm(0) = qW(tm)e^{-rtm} - p\int_0^{tm} f(x)e^{-rx}\,dx,$$

where Vm(0) is the discounted value at birth, q and p are respectively the price of beef and feed per unit of weight, W is the weight of the animal, tm is the slaughter age, f(x) is the feed input at any point in time, and r is the interest rate. The first term on the right hand side of (2.1) is the total revenue from the sale of the animal at age tm discounted to the present. The model assumes that the farmer knows the price of beef (q) with certainty. The second term on the right hand side represents the cost of feeding the animal over its lifetime, discounted to the present. The model assumes that the price of feed is constant over the lifetime of the animal.

If one assumes that the animal is fed optimally throughout its lifetime, the first order condition for the maximization of Vm(0) requires that:

(2.2)

$$\frac{\partial Vm(0)}{\partial tm} = e^{-rtm}[qW'(tm)-rqW(tm)-pf(tm)] = 0.$$

Equation (2.2) indicates that a steer will be slaughtered when the percentage increase in its weight equals the rate of interest plus feed costs per dollar's worth of animal, or

(2.3)

$$\frac{\partial W(tm)}{\partial t}\,\frac{1}{W(tm)} = r+\frac{pf(tm)}{qW(tm)}.$$

The second order condition for the maximization of Vm(0) is:

(2.4)

$$\frac{\partial Vm(0)}{\partial tm^2} = e^{-rtm}[qW''(tm) - rqW'(tm) -pf'(tm)] < 0.$$

At slaughter age tm , it is likely that both the weight W(tm) of the steer and feed intake f(tm) will be increasing (W'(tm), f'(tm) > 0). Therefore, in order to satisfy (2.4), it is sufficient that the steer be increasing in weight at a decreasing rate at slaughter age tm (i.e., W''(tm) < 0).

Yver considers the effect of changes in beef and feed prices on the optimal slaughter age of steers. Using Equation (2.2) and the implicit function theorem, he is able to show that

$$(2.5) \qquad dtm = \frac{-pf(tm)\ (dlnq - dlnp)}{[qW''(tm) - rqW'(tm) - pf'(tm)]},$$

where the denominator is negative from the second order condition (2.4).

In Equation (2.5), pf(tm) represents feed costs at slaughter age tm and is positive. Furthermore, the negative sign on the right hand side is cancelled by the negative sign of the denominator. Therefore, this equation indicates that an increase in beef prices or a decline in feed costs will increase the optimal slaughter age of a steer. Consequently, this result demonstrates that a negative supply response is expected in the short run.[8]

This model can be extended to represent female animals by taking into account the female animals' additional output in the form of calves in the discounted value function. After accounting for this additional factor, Yver is again able to show a negative supply response in the short run for female animals.

In addition, Yver reaches a number of conclusions with regard to changes in the capital price of cattle and changes in beef and feed prices. The algebra used in generating these conclusions is tedious and will not be presented here. However, the conclusions can be summarized as follows:

1) The elasticity of capital price with respect to beef

price is:

i) positive and highest at birth, declining monotonically towards unity as the animal approaches the optimum slaughter age;

ii) larger for females than for male animals.

2) The elasticity of capital price with respect to feed price is:

i) negative and largest in absolute value at birth, declining monotonically toward zero as the animal approaches the optimum slaughter age;

ii) larger in absolute value for female than for male animals.

3) An increase in beef price or a decline in feed price will increase the optimum slaughter age of all animals in the herd.

To summarize, the Yver (and Jarvis) results indicate that an increase in the price of beef (expected to persist into the future) increases the marginal value product of the animal, thereby increasing the optimal slaughter age.[9] Under these conditions the cattle producer will find it profitable to retain animals in the herd that otherwise may have been sold. For steers, this implies keeping the animal longer and fattening to heavier weights. For heifers and cows, it implies either fattening to heavier weights (heifers) or breeding the animals to obtain calves. In the aggregate and in the short run, this indicates that there will be a decrease in the slaughter of all animals. In the long run, the supply elasticities of beef will be positive due to the increase in herd size and average weights.

The Yver and Jarvis models were initial attempts to model the cattle industry and to provide some theoretical justification for the negative short run supply elasticities obtained in past empirical work. These models focused primarily on the short run behavior in the industry and did not account for a number of important factors such as the dynamic nature of the industry and the importance of price expectations in decision-making. Carvalho (1972) attempted to include these two factors in an economic model of the cattle industry by allowing a dynamic relationship to be derived from profit maximizing farmer behavior. An econometric system of equations is obtained as a solution to the maximizing problem. In addition, he introduced the notion of quasi-rational expectations to account for farmers' expectations of prices.

The Carvalho[10] model assumes that the farmer is a profit maximizer over all time periods during which he is in operation. The farmer operates his farm for m periods and then retires. At any point in time, the farmer is n periods from retiring.

The farm has three kinds of animals according to age: I_{0j}, animals born in period j which cannot be sold in this period; I_{1j}, animals less than one year of age at the beginning of period j which can be sold at market price c_j; and animals over one year of age in period j. In addition, all animals can be divided into three categories: (1) animals in the breeding herd; (2) feeder cattle to be sold now or in the future; and (3) calves.

Carvalho assumes that the profits generated over the total time the farm is in operation can be approximated, in period n, by a quadratic function as:

$$V(S_n,\&_n,V_n,C_n|K_n,F_n,I_n,n) = q_nV_n+P_nS_n+c_nC_n-.5a(K_n+\&_n-V_n)^2$$
$$-.5b(K_n-V_n)^2-.5d(I_{0n})^2-.5f(F_n+I_{1n}-\&_n-C_n-S_n)^2-.5g(F_n-S_n)^2$$
$$+\alpha E_n[V(S_{n-1},\&_{n-1},V_{n-1},C_{n-1}|K_{n-1},F_{n-1},I_{n-1},n-1)],$$

subject to the following identities:

$$F_n = F_{n+1}+I_{n+1}-\&_{n+1}-C_{n+1}-S_{n+1},$$
$$K_n = K_{n+1}+\&_{n+1}-V_{n+1},$$
$$I_{0n} = \lambda K_n \quad (\lambda = \text{calving rate}),$$
$$I_{1n} = I_{0n+1},$$

where:
- K_n = number of animals in the breeding herd,
- $\&_n$ = new animals added to the herd,
- V_n = animals culled from the herd,
- F_n = animals on feed,
- S_n = number of feeder animals sold,
- C_n = number of calves sold for slaughter,
- F_{n-1} = number of feeder calves next period ($= F_n+I_n-C_n-\&_n-S_n$),
- q_n = price of culls,
- P_n = price of feeders,
- c_n = price of calves.

V(.) is the expected present value of profits when there are n periods left until retirement,

$q_nV_n+P_nS_n+c_nC_n$ = total revenue,

$.5a[K_n+\&_n-V_n]^2$ = maintenance cost of animals kept in stock,

$.5b[K_n-V_n]^2$ = aging cost of animals kept in stock,

$.5d[I_{0n}]^2$ = cost of producing calves,

$.5f(F_n+I_{1n}-\&_n-C_n-S_n)^2$ = feeding cost for animals on feed,

$.5g(F_n-S_n)^2$ = aging cost of animals on feed,

α = one period discount rate,

E_n = expectation operator at period n, and

$[V(\cdot_{n-1}|\cdot_{n-1}]$ = value of next periods profits.

Using a quadratic function ensures a maximum or minimum by the global convexity or concavity of this function. As well, the simplicity of the profit function allows solution by dynamic programming techniques. Carvalho also shows that this function satisfies the conditions for first-period certainty equivalence.

The maximizing solution requires solving the model in the last year before retirement, then, working backwards, solving it in each period until the solutions converge. In this manner the following general solutions are obtained:

$$S_n = (1/g)P_n-(1/g)c_n-(1/g)\alpha^2E_n(P_{n-2})+F_n,$$

$$\&_n = (1/b)g_n-[(1/a+\lambda^2\alpha d)+(1/b)]c_n+(1/a+\lambda^2\alpha d)\alpha E_n(q_{n-1})$$
$$(1/a+\lambda^2\alpha d)\alpha^2E_n(c_{n-2})+[1/a+\lambda^2\alpha d)+1/d)]\alpha^2E_n(P_{n-2}),$$

$$V_n = (1/b)q_n-(1/b)c_n+K_n,$$

$$C_n = [(1/a+\lambda^2\alpha d)+(1/b)+(1/f)+(1/g)]c_n-(1/g)P_n-(1/b)q_n$$
$$-(1/f)\alpha E_n(P_{n-1})-(1/a+\lambda^2\alpha d)\alpha E_n(q_{n-1})$$
$$-(1/a+\lambda^2\alpha d)\alpha^2E_n(c_{n-2})-[(1/a\lambda^2\alpha d)+(1/b)+(1/f)+(1/g)]$$
$$\alpha^2E_n(P_{n-2})+I_{1n}.$$

A number of future prices appear as exogenous variables in the solution equations. These prices are generated as conditional expectations from past prices according to expectations formed by a quasi-rational expectation process (Nerlove 1972). Generally, quasi-rational expectations imply that anticipated values of variables may be replaced by their maximum-mean-square-error predictions.

The solution equations form the basis of the econometric model.

Carvalho provides useful interpretations of the coefficients in these solution equations which are pertinent to the study at hand. 1) Steer sales will increase if the expected change in steer prices increases or if there is a large number of young steers reaching nine months of age. 2) Heifer sales will increase as the actual price of heifers increases, provided this increase overwhelms the expected increase in heifer prices. 3) If price expectations for steers and heifers are high compared to actual prices, heifer and steer sales will decrease. 4) Cow sales will increase as the price of cows increases and therefore fewer heifers need to be sold for a given total revenue.

The contribution of the Carvalho model is twofold. First, one need not be satisfied with static models incorporating some form of distributed lag structure to account for dynamic elements. Instead, the dynamics can be derived from a profit maximizing model. Second, in contrast to the Yver model, Carvalho is able to show that short run supply behavior depends on price expectations of cattle producers.

There are however, two main deficiencies in the Carvalho model. First, it concentrates on generating output supply and inventory equations but ignores the derived demand by producers for associated inputs. This is necessary due to the complexity of the primal model used in the analysis. Second, the importance of the effect of price expectations on the short run supply response is not developed in a rigorous theoretical manner. Rather, it is determined ex post, from the interpretation of the regression coefficients. In the next chapter, an attempt will be made to overcome these problems by using the theory of duality to model the cow-calf industry.

FOOTNOTES TO CHAPTER TWO

1 Statistics Canada , Selected Agriculture Statistics Canada and the Provinces, Ottawa, 1983.

2 Alberta Agriculture, The Beef Cow-Calf Manual, Edmonton, Agdex No. 420/10, 1976, p.4.

3 Canada's major trading partners in beef and animal products are the U.S., Australia, New Zealand, and England.

4 See Martin (1981).

5 Because of this characteristic, one can capture the essential features of the Canadian cow-calf industry by analyzing western Canadian cow-calf production.

6 A heifer becomes a cow after its first calf is born.

7 The Jarvis model allows for the quantity of inputs fed to the animal to be an endogenous variable: otherwise both models are identical.

8 It should be noted that Yver qualifies these results and lists a number of reasons why the estimated signs of short run supply elasticites may not be negative (price expectations of farmers, data problems, and factor input constraints).

9 This is true only under certain reqularity conditions of the production function and if the grading system permits flexible slaughter weights.

10 This is a simplified version of the model estimated by Carvalho but it does capture the main characteritics of his model. See Carvalho (1972) or Nerlove, Grether, and Carvalho (1979).

3. A THEORETICAL MODEL OF THE COW-CALF INDUSTRY

3.1 INTRODUCTION

The purpose of this chapter is to develop a theoretical model which describes the short run supply and derived input demand behavior of a representative cow-calf producer. An attempt is made to extend existing theoretical models by concentrating on three areas: 1) modelling both the output supply and input demand by cow-calf producers within a multi-output, multi-input profit function; 2) determining the theoretical implications of farmers' price expectations for short run supply behavior; and 3) analyzing the model within an intertemporal framework from which a tractable econometric model can be derived.

In the first section (3.2), an initial attempt will be made to model cow-calf farmers' short run behavior using a farm-level variable profit function but assuming only a single output profit function. This will allow the dynamic aspects of cow-calf production to be emphasized and will facilitate the subsequent development of a multi-output, multi-input profit function. In order to assume the existence of an industry profit function (which is obtained by aggregating from the farm level to the industry level) two issues must be addressed: i) aggregation of inputs; and ii) aggregation across farms. Section (3.3) will address input aggregation by examining the importance and inplications of separability as a maintained hypothesis. Restrictions on the underlying farm-level technology which result from consistent aggregation from the farm level to the representative (aggregate) producer level will be determined in Section (3.4).

In Section (3.5), a single output profit function for a representative cow-calf producer will be postulated. The implications for short run behavior of changes in producers' price expectations as well as other comparative statics using this representative profit function will be derived in Section (3.6). In the following section (3.7), the single output representative profit function will be extended to accommodate the multi-output, multi-input technology of the cow-calf industry. This section also includes a description of the restrictions imposed on the model due to the biological nature of production.

A number of elasticity measurements appropriate to the technology of cow-calf production will be reported in Section (3.8). Finally, a number of testable hypotheses, generated from restrictions on the theoretical multi-output, multi-input profit function, will be posited in Section (3.9).

3.2 A SINGLE OUTPUT PROFIT FUNCTION FOR A COW-CALF PRODUCER

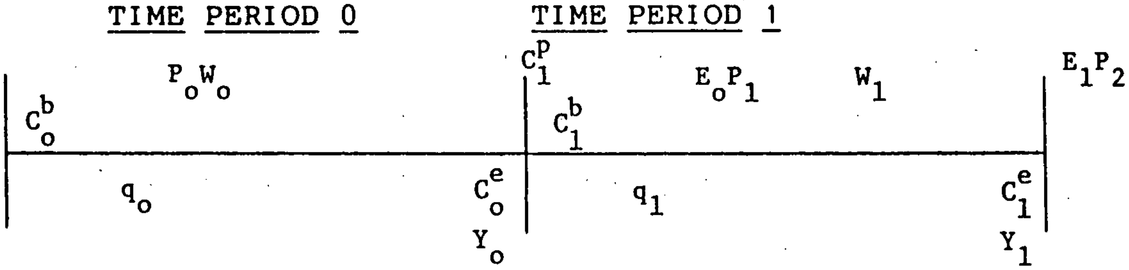
Before describing the theorectical model, it should be emphasized that a number of characteristics of the cow-calf industry will impose dynamic restrictions on the model. The existence of "second hand" markets (auction markets) for all categories of animals, except breeding females, implies that at the farm level the stock of animals can be increased by natural reproduction or by purchasing animals.[1] However, at the industry level the aggregate herd can only be increased by natural reproduction.[2] These conditions impose a dynamic constraint at both the farm level (the number of replacement heifers next period is determined by the number of female animals bred this period) and the industry level (next period's beginning stock of animals is determined by the number of animals left over at the end of the period).

To account for these dynamic constraints in the theorectical model, one assumes that the objective of the cow-calf producer is to maximize expected profits over a two-period planning horizon subject to the constraint that next period's beginning stock of animals is decided this period on the basis of expected price next period. Subsequently, the entire period in which the farmer is in business can be viewed as overlapping two-period planning horizons.

The basic problem facing a cow-calf farmer is to determine whether it is more profitable to sell an animal this period at known (certain) output price or retain the animal for sale in the future at an uncertain price. These simple dynamics are illustrated in Fiqure 3.1.

The farmer is assumed to have a given stock of animals at the beginning of period zero (C_o^b). Moreover, the farmer knows (with certainty) output price in period zero (P_o) and input prices in period zero (W_o). But in period zero, the farmer does not know output price in period one (P_1). Rather, in period zero, he forms some expectation of what output price will be in period one (E_oP_1).

Figure 3.1 Dynamic Behavior of a Cow-Calf producer



The farmer combines the initial stock of animals (C^b_o) with a vector of variable inputs (q_o). Then, responding to an economic environment with output price P_o, input price W_o, and his expectations about price next period, the farmer determines the stock of animals retained at the end of the first period (C^e_o) and the output supply (Y_o) during period zero (which is defined as the residual from the maximization process). It is important to note that end-of-period stocks are valued at the expected output price prevailing next period but that current output supply is valued at output price in period zero. Given the farmer's expectation of output price next period (E_oP_1), he may decide to purchase other animals (C^p_1) to augment end-of-period stocks (C^e_o). This will determine beginning-of-period stocks in period one (C^b_1).

In period one, the farmer combines beginning stock (C^b_1) with a vector of variable inputs (q_1), with input prices (W_1), and, given his expectation of price in the next period (E_1P_2), he determines the end of period stock of animals (C^e_1) and the quantity of animals supplied during period one (Y_1) again as a residual of the maximization process. Note that output supply in period one (Y_1) is again valued at known output price (P_1).

Consequently, the beginning stock of animals in any period is just the previous period's ending stock of animals plus any animals purchased at the beginning of the next period or:

$$C_i^e + C_{i+1}^p = C_{i+1}^b$$

Output supply in any period is just the beginning-of-period stock of animals minus the end-of-period stock of animals or:

$$C_i^b - C_i^e = Y_i$$

The intertemporal problem faced by the farmer can be viewed as the maximization of each period's profits, subject to price expectations and to the dynamic constraint. This simple model of dynamic behavior can be characterized using a discrete, two-period, variable profit function in the framework of Hicks (1946), Malinvaud (1953), Diewert (1972), and Diewert and Lewis (1981).

Assume for this initial analysis that the farm's capital stock consists only of cows and that breeding a cow this period gives rise to two cows next period. The output of the farm will be a flow supply of beef. In addition, the following assumptions are employed in the model.

i) The stock of animals is quasi-fixed in the sense that the stock in any period is chosen before the output price of beef is observed (Hartman 1976). That is, the farmer determines the stock of animals at the beginning of next period given today's expectation of output (beef) prices next period. This assumption is not unrealistic in the cattle industry given that a cow-calf farmer must decide on whether to breed a cow to obtain another animal in the future, based on his expectations of the prevailing price when the progeny is sold.

ii) In any period, variable inputs are chosen given complete knowledge of output price and input prices in that period. This assumption allows the farmer to adjust employment of variable inputs after output prices are known. Consequently, variable input usage can be adjusted to accommodate errors in stock decisions (Hartman 1976).

iii) Variable input prices are known with certainty.

iv) The farmer is a price taker in all output and input markets.

v) There are no costs to adjusting the stock of animals. The dynamics of the model derive from the assumption that the stock of animals is determined with respect to expected future price; they do not arise from convex adjustment costs.

This last assumption requires further comment. As a firm alters its capital stock it may incur additional costs over and above the purchase price of the new capital. These costs of capital stock adjustment are based on the assumption that there are costs associated with reorganization and retraining with the adoption of new equipment (Nickell 1978, p.25). It is generally assumed that these costs increase at an increasing rate as the speed of adjustment increases (Brechling 1975).

In terms of cattle production, the assumption of zero adjustment costs at the farm level appears to be rather innocuous. The farmer can decrease or increase his cattle herd by transporting animals to and from the nearest auction market. Because it is assumed that the cattle producer is a price taker in all markets, he can alter associated input levels without incurring additional costs. At the industry level however, this assumption is less tenable. At the industry level, the herd can expand only as fast as its reproductive potential will allow. But as the industry expands it will increase its demand for inputs. If the industry is not a price taker in all input markets (e.g., land), then as industry demand for inputs increases, some input prices will increase. This must translate into an adjustment cost associated with increasing the size of the aggregate herd (Nickell 1978, p.35).

The intertemporal model developed in this chapter could be modified to handle adjustment costs. However, because such costs are not the primary focus of this research, it will be assumed that adjustment costs are not a significant factor at either the farm or industry levels. Modelling and estimation of adjustment costs will be reserved for another study.

Following Epstein (1977) and Epstein and Denny (1980), the technology of the farm can be described by a concave production function $f(q,C^b,C^e) = Y$, where q is a vector of inputs, C^b is beginning-of-period stock of cows, C^e is end-of-period stock of cows, and Y is the output of beef during that period. The production function f(.) shows the technological possibilities available for combining the vector of inputs with the beginning stock of cows to determine end-of-period stocks and output supply of beef. f is strictly increasing in q and C^b, indicating that the marginal products of inputs and beginning stocks are strictly positive. f is decreasing in C^e, indicating that the more cows available at the end of the period (C^e), the less output supplied (Y) during the period.

At any point in time, current beef prices and factor prices are known but next period's beef prices are uncertain. The farmer is assumed to have a subjective probability distribution concerning these prices and to select a strategy to maximize the expected value of the discounted sum of anticipated profits over a two-period future planning horizon (subject to the initial stock of cows (C_o^b), the animal accumulation equation, and his price expectations). At the farm level, the farmer can purchase cows (C_t^p) to augment end-of-period stocks at price $\overline{P}_t$. However, it will be assumed that farmers only purchase animals at the beginning of each period. No animals are purchased in the first period ($C_o^p=0$). These characteristics can be described as:

$$(3.1) \quad \underset{q_t, C_t^e, C_t^p}{\text{Max}} \; E \sum_{t=o}^{1} \frac{1}{(1+r)^t} \left[P_t f(q_t, C_t^b, C_t^e) - W_t^T q_t - \overline{P}_t C_t^p\right],$$

$$\text{s.t.} \quad C_t^b = (1+\lambda)C_{t-1}^e + (1+\lambda)C_t^p,$$

$$C_o^b > 0,$$

$$C_o^p = 0,$$

where: q_t is a vector of inputs chosen during period t given that the farmer knows with certainty current output and input prices;

W_t is a vector of factor input prices;

C_t^e is the end-of-period stock of animals and is determined with respect to the farmer's expectation of beef prices next period;

C_t^p is the number of cows purchased at the beginning of period t: it is determined according to the farmer's desired future levels of animal stocks subject to expectations of future profits and beef prices;

C_t^b is the beginning-of-period stock of animals and, except for period zero in which stock is given ($C_o^b > 0$), the beginning stock of cows in period t is determined in the previous period (t-1) by the formula $C_t^b = (1+\lambda)C_{t-1}^e + (1+\lambda)C_t^p$ which takes account of the reproductive ability (λ) of cows to produce news cows, $0 \leq \lambda \leq 1$. This formula indicates that the number of cows at the beginning of any period t is equal to the number of cows retained in the last period plus the progeny of those cows plus any cows bought at the beginning of the period and their progeny;

P_t is the price of beef per hundredweight;

$\bar{P}_t$ is the stock price of a cow and is not only a function of beef prices but will also include a component that represents the animal's ability to produce new animals;

E is the mathematical expectation operator; and

r is the discount rate, assumed constant and known with certainty.

After rearranging the animal accumulation constraint as $C_t^p = [C_t^b \;/(1+\lambda)] - C_{t-1}^e$ and substituting into the maximization problem, Equation (3.1) can be rewritten as:

$$\text{(3.2)} \quad \underset{q_t, C_t^e, C_t^b}{\text{Max}} \; \sum_{t=o}^{1} \frac{1}{(1+r)^t} \left[P_t f(q_t, C_t^b, C_t^e) - W_t^T q_t - \frac{\bar{P}_t C_t^b}{(1+\lambda)} + \bar{P}_t C_{t-1}^e\right].$$

The maximization problem in Equation (3.2) can be viewed as a two-stage optimization procedure. In the first stage, the farmer views the number of cows available in any period as being fixed or predetermined. He must decide on the optimal quantity of inputs to combine with the fixed stock of cows from which he determines optimal inventory carryovers (end-of-period stocks) and current period output as the residual. Optimal inventory carryovers are valued by the farmer at the output price he expects to prevail next period discounted to the present or:

$$Z_t = \frac{1}{(1+r)} E_t(\overline{P}_{t+1})$$

In the second stage of the optimization procedure, the farmer determines optimal beginning stocks for the next period. This will involve the purchase of animals to augment existing stocks.

The first stage in maximizing Equation (3.2) can be defined as follows:

$$(3.3) \quad \Pi_t(P_t, W_t, Z_t; C_t^b) = \max_{q_t, C_t^e} \; P_t f(q_t, C_t^b, C_t^e) - W_t^T q_t + Z_t C_t^e$$

$\Pi(.)$ is defined as the variable profit function dual to $f(.)$.[3] Samuelson (1953-54) introduced the concept of a variable profit function while Gorman (1968) and McFadden (1970) determined its properties.

In order for there to exist a dual relationship between the production possibility set and the variable profit function, certain regularity conditions must be satisfied by each function (Lau 1972, and Diewert 1973 and 1974).[4]

For ease in exposition of the regularity conditions and for greater generality, redefine the production possibility set as follows: $f(Y,X;v)$, where $f(.)$ is the production possibility set and $Y = (Y1,..., Ym)$ is an M-dimensional vector denoting variable outputs. X = (X1,..., Xn) is an N-dimensional vector denoting variable inputs, V = (V1,..., Vj) is a J-dimensional vector denoting the fixed inputs, and z = (Y,x;v) is the M+N+J-dimensional vector of all outputs and inputs.

The following assumptions are made on f:[5]

f1) f is a closed non-empty subset of M+N+J-dimensional space,

f2) f is a convex set,

f3) if $z' \varepsilon T, z'' \leqq z'$ then $z'' \varepsilon T$,

f4) if $(Y,x;v) \varepsilon f$ then the components of Y are bounded from above for v fixed.

An economic interpretation of each assumption is provided by Diewert (1973 and 1974). Condition (f1) is a mathematical regularity condition, (f2) indicates that the technology exhibits non-increasing marginal rates of transformation, (f3) implies free disposal, and (f4) indicates that a bounded vector of inputs can produce only a bounded vector of outputs.

Continuing with the above notation, if the farmer faces positive prices for the variable outputs $p = (p_1, \ldots, p_m)$, positive prices for the variable inputs $w = (w_1, \ldots, w_n)$, and the fixed inputs are fixed at v, the variable profit function can be defined as:

$$(3.4)\ \Pi(P,W;V) = \max_{y,x}\ [P^T Y - W^T X: (Y,X;V) \varepsilon f],\ P >> 0m,\ W >> 0n.$$

If f satisfies conditions (f1) to (f4) and the variable profit function satisfies Equation (3.4), then Diewert (1973) has shown that $\Pi(.)$ satisfies the following conditions:

$\Pi 1)$ $\Pi(p,w,;v)$ is a non-negative function for $p >> 0m$, $w >> 0n$, and any v,

$\Pi 2)$ $\Pi(.)$ is nondecreasing in p,

$\Pi 3)$ $\Pi(.)$ is nonincreasing in w,

$\Pi 4)$ $\Pi(.)$ is homogeneous of degree one in p and w,

$\Pi 5)$ $\Pi(.)$ is convex in p and w,

$\Pi 6)$ $\Pi(.)$ is concave in v for every fixed p and w.

Condition $\Pi(1)$ is a regularity condition which is consistent with economic profit maximization, $\Pi(2)$ indicates that if $p' > p''$ then $\Pi(p',w;v) > \Pi(p'',w;v)$, $\Pi(3)$ indicates that if $w' > w''$ then $\Pi(p,w';v) < \Pi(p,w'';v)$, and $\Pi(4)$ indicates that for every $\lambda > 0$, $\Pi(\lambda p, \lambda w; v) = \lambda \Pi(p,w,;v)$. Moreover, f exhibits constant returns to scale if and only if $\Pi(.)$ is homogeneous of degree one in v or $\lambda > 0$, $\Pi(p,w;\lambda v) = \lambda \Pi(p,w;v)$. $(\Pi 5)$ and $(\Pi 6)$ ensure that the profit function is well-behaved for small changes in prices and that there exists a maximum for each given vector of prices and fixed inputs.

Diewert (1973) proves that given any function Π satisfying conditions $(\Pi 1)$ to $(\Pi 6)$, there exists a unique f satisfying conditions (f1) to (f4) that generates Π through Equation (3.4). Thus f and Π are equivalent representations of technology and therefore Π may be used to characterize the technology and test for structure.

Returning to the intertemporal problem of the cattle producer, the dual relationship defined in Equation (3.3) can be used to rewrite Equation (3.2) as:

$$(3.5) \quad \underset{C_t^b}{\text{Max}} \; E \sum_{t=o}^{1} \frac{1}{(1+r)t} \left[\Pi(P_t, W_t, Z_t; C_t^b) - \frac{\bar{P}_t C_t^b}{(1+\lambda)} \right].$$

Generally, the intertemporal problem (3.5) is solved for each period but only the plans for t=0 are carried out because of errors in expectations (Epstein and Denny 1980). Furthermore, if the variable profit function defined by Equation (3.3) satisfies conditions ($\Pi 1$) to ($\Pi 6$) and is, in addition, differentiable with respect to output, input, and expected output prices, then Equation (3.3) can be solved for the optimal quantities of output supply, input demand, and end of period inventories by applying Hotelling's Lemma (Hotelling 1932). These optimal solutions are defined as:

(3.6) $$Y_t^* = \Pi_{P_t}(P_t, W_t, Z_t; C_t^b),$$
$$q_t^* = -\Pi_{W_t}(P_t, W_t, Z_t; C_t^b),$$
$$C_t^{e*} = \Pi_{Z_t}(P_t, W_t, Z_t; C_t^b),$$

where Πi denotes the partial differentation of $\Pi(.)$ with respect to p_t, w_t, and z_t respectively. Y^*_t, q^*_t, and C_t^{e*} represent the profit maximizing quantities of output supply, input demand, and end-of-period stock demand respectively, as functions of the prices (p_t, w_t, and z_t) and the level of the fixed factor C_t^b.

Equation (3.6) explicitly defines the first stage of the optimizing problem facing the farmer. In the second stage of the optimization, the farmer has only to determine next period's optimal beginning stock of cows. Recall that beginning animal stock in period one is chosen in period zero to maximize the expected value of profit in period one or:

(3.7) $$E_o[\Pi(P_1, W_1, Z_1; C_1^b) - P_1 C_1^b/(1+\lambda)].$$

Next period's optimal animal stock C_1^{b*} is determined by differentiating Equation (3.7) with respect to C_1^b and then solving the first order condition for C_1^* or:

(3.8) $$E_o\overline{P}_1 = E\Pi_{C_1^b}(P_1,W_1,Z_1;C_1^{b*}).(1+\lambda).$$

It is interesting to note that the production function is homogeneous of degree one if and only if the variable profit function can be written as $C_t^b\ \Pi(p_t,w_t,z_t)$. Therefore, if there are constant returns to scale in production, it is clear that C_1^b in Equation (3.8) would vanish and consequently C_1^b is not defined. This problem can be avoided by assuming that the variable profit function is strictly concave in the fixed input.

An econometric model can be postulated, using Equations (3.6) and (3.8), by specifying a functional form for $\Pi(.)$, determining price expectations of cattle producers, and specifying the stochastic disturbances for each equation. However, as is often the case, the data available for estimating the econometric equations relate to aggregate variables rather than farm level variables. Rather than estimate a farm level model, one must postulate the existence of an aggregate "representative" farm. However, before specifying an aggregate profit function, the restrictions imposed by aggregation must be examined.

3.3 SEPARABILITY AS A MAINTAINED HYPOTHESIS

In most studies of aggregate technology, separability of the profit and production functions plays a significant role.

Separability is postulated to lessen econometric problems such as multicollinearity and to facilitate estimation. If separability can be assumed, aggregate commodities can be defined, thereby reducing the information necessary to estimate a given system of equations.[6]

Micro inputs can be aggregated if the marginal rate of substitution between any two inputs (i,j) is essentially unaffected by the level of use of a third input (k). The micro pair (i,j) is then separable from k (Leontief 1947).[7]

Formally, let firm Z have a production function;

(3.9) $f^z = f^z(X_1^z, \ldots, X_m^z)$ and $X^z = (X_1^z, \ldots, X_m^z)$,

where f is output and Xi are micro inputs.

Next partition X^z into n subgroups: $({}^1X^z, \ldots, {}^nX^z)$, and partition the price vector correspondingly as:

(3.10) $q = (q1, \ldots, qm) = ({}^1q, \ldots, {}^nq)$.

Equation (3.9) can be rewritten as:

(3.11) $f^z = f^z({}^1x^z, \ldots, {}^nx^z)$.

Now let $\psi^1, \ldots, \psi^n$ be homogeneous quantity aggregators and $Q^1, \ldots, Q^n$ be homogeneous price aggregators defined over $({}^1x^z, \ldots, {}^nx^z)$ and $({}^1q, \ldots, {}^nq)$ respectively. Then, the production function of firm Z can be written as:

(3.12) $f^z = \bar{f}^z(\psi^1({}^1x^z), \ldots, \psi^n({}^nx^z))$.

Since $\bar{f}^z$ is increasing in its arguments and each aggregator function ψ^i is linear homogeneous, $\bar{f}^z$ is homothetically separable (Blackorby, Primont, and Russell 1978, Chapter Three).

The economic implication of assuming homothetically separable production functions is:

$$\frac{\partial}{\partial {}^{k}X_{r}^{z}} \left(\frac{\partial f^{z} / \partial {}^{l}X_{i}^{z}}{\partial f^{z} / \partial {}^{l}X_{j}^{z}} \right) = 0 \quad i,j \varepsilon {}^{l}X^{z},\ r \varepsilon {}^{k}X^{z},$$

That is, the marginal rate of substitution between the ith and jth input in the lth aggregator function is independent of the rth input in the kth aggregator function.

It has been shown (Blackorby, Primont, and Russell 1978 and Blackorby 1982) that this treatment of micro inputs is consistent with profit maximizing behavior at the aggregate level if and only if the aggregate profit and production functions are separable in the same appropriate partition of commodities and prices.[8] Therefore, the profit function with output price (P) and output quantity (Y) can be written as:

(3.13)
$$\Pi^{z}(P,q) = \max \left[PY - q^{T}X^{z} : f^{z}(X^{z}) \geq fo \right]$$
$$= \Pi^{z}(P, Q^{1}({}^{1}q), \ldots, Q^{n}({}^{n}q)).$$

3.4 AGGREGATION OVER FARMS

Aggregate production functions and their dual profit functions are theoretical constructs widely used in applied economic research. However, these aggregate functions are a purely fictitious concept. A micro production function, because it fully describes the technology used by a farm, is significantly different than its aggregate counterpart. At the aggregate level, no one maximizes the profit of the industry or minimizes its cost. The supply of outputs and demand for inputs, at the industry level, are derivd from the decisions of the various individual farms which are assumed to be profit maximizers.

Therefore, in what context is it appropriate to think of an "aggregate production function" as a complete representation of individual farm production functions? Two types of aggregation can be considered: i) exact aggregation and ii) fictitious aggregation.[9]

Exact aggregation (Gorman 1968, Blackorby, Primont and Russell 1978, and Blackorby and Schworm 1982a, 1982b, and 1983) implies that one can postulate the existence of a representative producer whose profit maximizing behavior, with regard to output supply and input demand, is identical to the profit maximizing behavior of all individual farms combined.

Consider an industry that consists of Z farms with technology sets f^z. Each f^z is a function of (X^z, K^z) where X^z is a N-dimensional vector of outputs and inputs (outputs are designated by positive signs, and inputs are designated by negative signs) and K^z is the fixed input vector for each firm $Z = 1...z$. Let $P = (P1,..., Pn)$ be the corresponding price vector parametric to all farms.

At the micro level, each farm has a production possibility set $f^z = f^z(X^z,K^z)$. Given that the regularity conditions are satisfied, the technology can be described completely using a dual profit function:

$$\Pi^z(P,K^z) = \max_x \ [PX/ \ (X,K) \ \varepsilon \ f^z]$$

where the optimal net output vector is defined as:

$$\frac{\partial \Pi^z(P,K^z)}{\partial P_i} = X_i^z \qquad i = 1 \ldots n.$$

The question of exact aggregation is: what are the conditions imposed on individual farm technologies for which the following holds?:

$$(3.14)\quad \Pi(P,K(K^1, \ldots, K^z)) = \sum_z \Pi^z(P,K^z) = \sum_z \max_x [PX^z/(X^z,K^z)\varepsilon f^z] ,$$

$$X_i = \Sigma X_i^{\,z} = \frac{\partial \Pi(P,K(.))}{\partial P_i},$$

$$\Pi(P,K(.)) = \max_x [PX/(X,k)\ \varepsilon F] ,$$

given the vector of prices P, the vector of fixed factors $(K^1, \ldots, K^z)$ and no external economies or diseconomies.

The necessary and sufficient conditions under which (3.14) is satisfied were provided by Gorman (1968) (see Blackorby, Primont, and Russell 1978) where it is demonstrated that (3.14) holds if and only if all farms are identical at the margin. This indicates that each farm must have a quasi-homothetic production function (i.e., Gorman Polar Form (GPF)) with a profit function of the form:

$$(3.15)\quad \Pi^z(P,K^z) = \Pi^z(P)\bar{K}^z(K^z) + \Pi^{zo}(P)$$

Moreover, the aggregate profit function for the industry must be of the form:

$$(3.16)\quad \Pi(P,k(\bar{k})) = \sum_z \Pi^z(P,K^z) = \sum_z \Pi^z(P)k^z(\bar{k}^z) + \sum_z \Pi^{zo}(P).$$

Equations (3.15) and (3.16) indicate that each farm's profit function must be affine in the fixed factor and that all farms value an extra unit of the fixed factor equally (i.e., the shadow price of the fixed factor is the same for all farms). Finally, the assumption that all farms are operating with constant returns to scale implies that the following restrictions are imposed on (3.15) and (3.16) respectively (Gorman 1968):

$$\Pi^{zo}(P) = 0$$

and

$$\sum_z \Pi^{zo}(P) = 0 .$$

The aggregate net output vector can now be written as:

$$(3.17) \quad X_i = \frac{\partial\Pi(P,k(\bar{k}))}{\partial P_i} = \sum_z \bar{k}^z(k^z)\,\frac{\partial\Pi^z(P)}{\partial P_i} + \sum_z \frac{\partial\Pi^{zo}(P)}{\partial P_i}, \quad i = 1 \ldots n.$$

It is worthwhile at this point to emphasize an important restriction of the GPF. Because each farm must use the fixed factor equally efficiently, a redistribution of fixed factors amongst the farms will have a neutral effect on aggregate profit but will change the net output vectors and the profits earned by individual farms. What this implies is that once an aggregate profit function has been defined as:

$$\Pi(P,k) = \Pi(P)k(k) + \Pi^o(P),$$

it is invariant to changes in the distribution of the fixed factors amongst individual farms and thus, is completely determined. Of course, $\Pi(P, K)$ is only an "exact" representation of the aggregate technology as long as the underlying micro profit functions, $\Pi^z(P,K^z)$ remain.

Consequently, assuming that all farms are identical at the margin in their technology and that the parameters of $\Pi(P,K)$ can be identified, knowledge of aggregate data alone is sufficient to obtain an exact characterization of the micro production processes.

It is clear that the conditions under which an exact aggregate can be obtained are quite restrictive.

Consequently, the very existence of such an aggregator is not at all certain (Gorman 1968). In a situation where the conditions of production differ significantly from farm to farm, the abstraction of a representative producer loses its meaning. In this case, only the knowledge of all details pertaining to the production process would permit an exact model of the industry.

Consider an aggregate profit function, $\hat{\Pi}(P,K)$, which is not obtained by the restrictions of exact aggregation (i.e., fictitious aggregation). What are the properties of $\hat{\Pi}(P,K)$?

First, because it is not an exact aggregator, the structural form of $\hat{\Pi}(P,K)$ does not reveal the structural form of the individual farm's profit functions. Because $\hat{\Pi}(P,K)$ is not exact, the underlying micro production functions are not quasi-homothetic and consequently, all farms are not identical at the margin. Therefore, some farms may differ siginificantly in their technology.

Second, $\hat{\Pi}(P,K)$ does not convey any information on specific technologies and its structural form is uninformative.

Third, if an aggregate profit function $\Pi(P,K)$ is exact, it is invariant to a redistribution of the fixed factors amongst individual farms. However, this is not the case for $\hat{\Pi}(P,K)$. There may exist different structural forms of $\hat{\Pi}(P,K)$ for different distributions of K. Therefore, $\hat{\Pi}(P,K)$ is contingent upon K.

Consequently, even if $\hat{\Pi}(P,K)$ is "well-behaved" and shows all the usual properties of a profit function, the aggregate function to which it is dual is also contingent upon K. Moreoever, there are price paths and an initial distribution of fixed factors that would generate aggregate data that cannot be rationalized by a technology satisfying the regularity conditions (Blackorby and Schworm 1982b).

The reason for this is quite simple. The aggregate production function is obtained from $\hat{\Pi}(P,K)$ which, when estimated, picks up aggregate inputs demanded and outputs supplied and the corresponding price vectors (given the initial distribution of fixed factors) and attempts to measure substitution possibilities. But as the fixed factors are redistributed among farms, the aggregate demand and supply for all factors and for all farms changes (although of course, P is unchanged). When $\hat{\Pi}(P,K)$ is not an exact aggregator function, it is really a bogus function. However, virtually all empirical research using aggregate data sets relies on fictitious aggregation. The hope is that such functions are useful in the neighborhood of some initial distribution of fixed factors and therefore will provide an approximation of the behavior of aggregate quantities.

The applied researcher who has available only aggregate data is really faced with two choices beyond abandoning the project: 1) he can impose the restriction that all farms value a marginal unit of a fixed factor equally and therefore rely on exact aggregation; or 2) he can assume the data are generated by a representative producer and impose homothetic separability on the technology set (Blackorby 1982).

If condition (1) holds over all farms, then the appropriate procedure is exact aggregation. However, if it does not hold, then there is, at present, no way to determine which procedure will generate the best results. The researcher's choice will depend generally on the objective of the study and the characteristics of the data (Blackorby and Schworm 1982a). The important point is that empirical results generated using aggregate data must be interpreted as conditional upon the restrictions imposed by the aggregation procedure.

3.5 A SINGLE-OUTPUT PROFIT FUNCTION FOR A REPRESENTATIVE COW-CALF PRODUCER

Assume there exists an aggregate production technology defined for the cow-calf industry. This representative farm can be described by an aggregate production function $Y = F(q,C^b,C^e)$ where Y is an aggregate quantity index of beef supplied and F is the production possibility set defined for a vector of aggregate inputs (q), a quantity index of the beginning stock of cows (C^b), and a quantity index of ending stock of cows (C^e). F is increasing in q and C^b but decreasing in C^e. Assume that F satisfies conditions (f1) to (f4) in Section (3.2).

The problem faced by the representative farm at the industry level is identical to that faced by the individual cattle producer except that the additional restriction on herd expansion must be imposed. These characteristics can be described as:

$$(3.18) \quad \max_{Y_t, q_t, C_t^e} E \sum_{t=0}^{1} \frac{1}{(1+r)^t} [P_t Y_t - W_t q_t : (q_t C_t^b, C_t^e, Y_t) \varepsilon F],$$

$$\text{s.t.} \quad C_t^b = (1+\lambda) C_{t-1}^e,$$

$$C_o^b > 0$$

All variables are as defined in Section (3.2) except that each variable, where applicable, should now be interpreted as the aggregate representation for the industry. Furthermore, the animal accumulation constraint restricts the industry's ability to increase next period's beginning animal stocks to the reproductive capacity of last period's ending female stocks.[10] Additionally, this constraint reduces the maximization problem of the representative farm from a two-stage maximization problem (for the individual farm) to a one-stage maximization problem. That is, the farmer views the number of cows at the beginning of any period as being fixed or predetermined. He must decide on the optimal quantity of inputs to combine with the fixed stock of cows. From this he determines optimal inventory carryovers (end-of-period stocks), leaving current period output as the residual. Again, optimal inventory carryovers are valued at

$$Z_t = \frac{1}{(1+r)} E_t(\bar{P}_{t+1}).$$

As before, the intertemporal problem (3.18), is solved across the two periods but only the plans for t=0 are actually carried out because errors in expectations necessitate revision of plans once the second period arrives. A dual profit function can again be used to represent, in any period t, the maximizing behavior of the representative farm . This is defined as:

$$(3.19)\quad \Pi(P_t,W_t,Z_t;C_t^b) = \max_{q_t C_t^e} \; P_t F(q_t,C_t^b,C_t^e) - W_t q_t + z_t C_t^e.$$

The industry's optimal output supply, input demand, and end-of-period inventory can be determined by applying Hotelling's Lemma to Equation (3.19). These industry equations are defined as:

$$(3.20)\quad Y_t^* = \Pi_{pt}(P_t,W_t,Z_t;C_t^b),$$

$$q_t^* = -\Pi_{wt}(P_t W_t,Z_t;C_t^b),$$

$$C_t^{e*} = \Pi_{zt}(P_t,W_t,Z_t;C_f^b).$$

where $\Pi i(.)$ is the partial differential of $\Pi(.)$ with respect to pt, wt, and zt respectively. $Y*t$, $q*t$, and C_t^{e*} denote the representative farm's profit maximizing quantities of output supply, input demand, and end–of–period inventory demand respectively, as functions of the prices (pt, wt, and zt) and the level of the fixed factor C_t^b.

Duality techniques can be used to generate a formula to predict when the industry will be increasing or reducing the number of animals in the herd. The industry's optimal shadow price of an animal in the herd can be determined (Diewert 1974) by differentiating Equation (3.19) with respect to beginning-of-period animal stocks (C_t^b),

$$(3.21)\quad \Pi_{C_t^b}(P_t,W_t,Z_t;C_t^b) = \text{shadow price of an animal in the herd.}$$

An increase in herd size can be predicted if the industry's shadow price is greater than the (flow) price of an animal or:

$$(3.22)\quad \Pi_{C_t^b}(P_t,W_t,Z_t;C_t^b) > \text{price of an animal.}$$

A decrease in herd size can be predicted if the opposite occurs.[11]

Equation (3.21) has an interesting property. The cow-calf model characterized in Equation (3.20) is defined as a short run model: consequently econometric results must be interpreted subject to the level of the fixed factor. However, it is possible to obtain long run estimates by combining the information contained in Equation (3.21) and Equation (3.20). (See Berndt, Morrison, and Watkins 1982, and Brown and Christensen 1981).

In long run equilibrium (at optimal herd size), the optimal shadow price of an animal must equal the (flow) price ($\hat{P}t$) or:

(3.23) $\Pi_{C_t^b}(P_t, W_t, Z_t; C_t^{b*}) = \hat{P}_t$.

The optimal profit maximizing herd size C_t^{b*} can be derived by solving Equation (3.23) given pt, wt, zt, and $\hat{P}t$ as:

(3.24) $C_t^{b*} = \Pi^*(P_t, W_t, Z_t, \hat{P}_t)$.

Long run characteristics of the industry can be obtained by substituting C_t^{b*} into Equation (3.20) and deriving the desired measurements. Similarly, the response of C_t^{b*} to changes in price can be obtained directly form Equation (3.24).

3.6 SOME COMPARATIVE STATICS

Using Equation (3.20), comparative static results can be obtained for changes in the optimal levels of the endogenous variables caused by a change in the exogenous parameters. In an attempt to sign these results, the restrictions implied by duality theory and neo-classical production theory will be imposed on the single output profit model.

To facilitate exposition, Equation (3.20) will be repeated:

(3.20) $$Y_t^* = \Pi p_t(P_t,W_t,Z_t;C_t^b),$$
$$q_t^* = -\Pi w_t(P_t,W_t,Z_t;C_t^b),$$
$$C_t^{e*} = \Pi z_t(P_t,W_t,Z_t;C_t^b).$$

First, consider a change in current output supply ($Y*_t$) due to a change in current price (p_t). Differentiating $Y*t$ with respect to p_t results in:

(3.25) $$\frac{\partial Y_t^*}{\partial P_t} = \Pi_{P_tP_t}(P_t,W_t,Z_t;C_t^b) + \Pi_{P_tZ_t}(P_t,W_t,Z_t;C_t^b).\frac{\partial Z_t}{\partial P_t},$$

where $\Pi_{P_tP_t}(.)$ represents the change in $Y*t$ from a change in current price (pt) holding all other variables constant (i.e., the second derivative). $\Pi_{P_tP_t}(.)$ is positive by convexity of the profit function, implying current output will increase when current price increases.

$\Pi_{P_tz_t}(.)$ represents the change in $Y*t$ from a change in expected price (zt) holding all other variables constant.

Generally, the sign of $\Pi_{P_tz_t}(.)$ is unknown and will depend on whether current output is a substitute or a complement with end-of-period stock of animals. However, the restrictions imposed by the biological nature of cattle production indicates that in order to supply more current output, fewer animals will be retained in the herd at the end of the period. Consequently, current output supply and end-of-period stock of animals are substitutes and the sign of $\Pi_{P_t Z_t}$ is negative. This indicates that current output supply will decrease when expected future output price increases.

$\frac{\partial Zt}{\partial Pt}$ represents the change in expectations about future price caused by a change in current output price. The sign of $\frac{\partial Zt}{\partial Pt}$ will depend on how the farmer uses current price in revising his expectations of the future and may be positive, negative, or zero.

If $\frac{\partial Zt}{\partial Pt} = 0$, this implies no change in expected price following a change in current price. The sign of $\frac{\partial Yt^*}{\partial Pt}$ will thus be determined by the sign of $\Pi_{P_t P_t}(.)$ which is postive, implying that current output will increase given an increase in current price.

If $\frac{\partial Zt}{\partial Pt} < 0$, the farmer expects future price to decrease given an increase in current price. In this case, current output will again increase because the positive sign of $\Pi_{P_t P_t}(.)$ is reinforced by the positive sign of $\Pi_{P_t Z_t}(.) \frac{\partial Z_t}{\partial P_t}$

Finally, if $\frac{\partial Zt}{\partial Pt} > 0$, the farmer expects the future price of animals to increase given an increase in current price, then the sign of $\frac{\partial Yt^*}{\partial Pt}$ will be as follows:

if $\frac{\partial Zt}{\partial Pt} > 0$ then $\frac{\partial Yt^*}{\partial Pt} \gtrless 0$ iff $\Pi_{P_t P_t} \gtrless \Pi_{P_t Z_t} \frac{\partial Zt}{\partial Pt}$.

That is, if $\frac{\partial Zt}{\partial Pt} > 0$, a negative supply response is expected in the short run if the magnitude of $\Pi_{P_t P_t}$ is smaller than $\Pi_{P_t Z_t} \frac{\partial Zt}{\partial Pt}$.

It is of some interest to transform Equation (3.25) into an elasticity measurement:

(3.26)

$$\underset{\text{Total Elasticity of Supply}}{\left[\frac{\partial Yt}{\partial Pt}\cdot\frac{Pt}{Yt}\right]} = \underset{\text{Direct Elasticity of Supply}}{\left[\frac{\partial \Pi Pt}{\partial Pt}\cdot\frac{Pt}{Yt}\right]} + \underset{\text{Cross Elasticity of Output}}{\left[\frac{\partial \Pi Pt}{\partial Zt}\cdot\frac{Zt}{Yt}\right]} \cdot \underset{\text{Elasticity of Expectation}}{\left[\frac{\partial Zt}{\partial Pt}\cdot\frac{Pt}{Zt}\right]}.$$

Equation (3.26) can be interpreted in the following manner. The total elasticity of supply is not only dependent on the technological structure of the industry, as measured by the direct elasticity of supply, but is also dependent on the substitution possibilities between production today and production tomorrow, as measured by the cross elasticity of output supply with respect to ending stock of animals, and the sensitivity of farmers' price expectations with respect to changes in current price, as measured by the elasticity of expectations. The importance of this discussion is to demonstrate that in this model, the convexity of the profit function does not ensure a positive total elasticity of supply (i.e., an upward sloping supply curve). Rather, the sign of the total elasticity of supply will depend on the sign of the elasticity of expectations. Therefore, a short run negative supply elasticity in the cow-calf industry is not a prediction from economic theory: rather the sign of the elasticity is unknown and will depend on price expectations of producers.

Given this result, how is it possible that the Jarvis (1969) and Yver (1971) models are able to predict a negative supply elasticity in the short run? Recall that their results are obtained by allowing the future price of beef to change holding other variables constant. Or in the context of the model developed in this chapter, they focus on the consequences for current output given a change in expected price:

$$\frac{\partial Y_t^*}{\partial Z_t} = \Pi_{P_t Z_t}(\cdot)$$

This derivative was signed in Equation (3.25) and shown to be negative indicating that an increase in expected future price, holding all other variables constant, will decrease current output supply. Consequently, the Jarvis and Yver models are not incorrect but rather they misinterpret the variables on which current output decisions depend.

Two other comparative statics are of interest: i) a change in current input demand due to a change in current output price;

$$\frac{\partial q^*}{\partial Pt} = \frac{\partial \Pi Wt}{\partial Pt} + \frac{\partial \Pi Wt}{\partial Zt} \cdot \frac{\partial Zt}{\partial Pt},$$

and ii) a change in ending period stock of animals due to a change in current price;

$$\frac{\partial C_t^e}{\partial P_t} = \frac{\partial \Pi z_t}{\partial P_t} + \frac{\partial \Pi z_t}{\partial z_t} \cdot \frac{\partial z_t}{\partial P_t} .$$

(i) The sign of $\frac{\partial \Pi Wt}{\partial Pt}$ is unknown and depends on whether the input is a normal or inferior input. If the input is normal, then the sign of $\frac{\partial \Pi Wt}{\partial Pt}$ is positive and conversely, the sign is negative if it is an inferior input. Therefore, assuming non-inferior inputs implies that the demand for inputs will increase.

The second term on the right hand side is easy to handle. Variable inputs are chosen in the model after output levels are determined. Therefore, the optimal input level is independent of expected future prices and consequently, $\frac{\partial \Pi Wt}{\partial Zt} = 0$. This comparative static indicates that in terms of input demand, the structure of technology alone determines the requirements, independent of changes in price expectations.

(ii) The results of this comparative static are opposite to the results achieved for $\frac{\partial Yt^{*}}{\partial Pt}$. However, it is presented to show consistency in the profit model.

Applying Young's theorem to the first term on the right hand side indicates that

$$\frac{\partial \Pi Zt}{\partial Pt} = \frac{\partial \Pi Pt}{\partial Zt}$$

From the discussion of Equation (3.25), the sign of $\frac{\partial \Pi Pt}{\partial Zt}$ is negative and therefore, $\frac{\partial \Pi Zt}{\partial Pt}$ is also negative. This indicates that there is a decrease in end-of-period stocks of animals when current price increases, ceteris paribus.

$\frac{\partial \Pi Zt}{\partial Zt}$ is the change in end-of-period stock of animals given a change in expected price. This derivative is positive from the convexity of the profit function.

Finally, $\frac{\partial Zt}{\partial Pt}$ represents a change in price expectations given a change in current price. The sign of $\frac{\partial Zt}{\partial Pt}$, which can be positive, negative, or zero, is identical to the discussion presented earlier. Therefore, the sign of $\frac{\partial C_t^e}{\partial Pt}$ does not only depend on the structure of technology but as with Equation (3.25), depends on price expectations of producers.

3.7 A MULTI-OUTPUT, MULTI-INPUT MODEL OF A REPRESENTATIVE COW-CALF PRODUCER

It is now quite straightforward to extend the single output model of the cattle producer to describe a multi-output, multi-input cow-calf producer. This section will maintain all of the assumptions set out in Section (3.2) except that the capital stock of the farmer now consists of five categories of animals (i.e., bulls, cows, heifers, steers, and calves) and correspondingly, output supply will also consist of the five animal categories.

The objective of the multi-output, multi-input cow-calf producer is to maximize the expected net present value of his operation from the sale of animals over two time periods. The multi-output producer is faced with two basic problems: i) determining the type of animal (i.e, out of which category) to be sold; and ii) determining whether it is more profitable to sell the animal this period at a known output price or retain the animal for sale in the future at an uncertain price.

Generalizing Epstein (1977) and Epstein and Denny (1980) to the multi-output, multi-capital stock case, the technology of the farm can be described by a concave transformation function $F(q,A^b,A^e,Y) = 0$, where q is an I-dimensional vector of inputs $q = (q1,\ldots, qI)$, A^b is an N-dimensional vector of beginning-of-period stock of animals, A^e is an N-dimensionsl vector of end-of-period stock of animals, and Y is an N-dimensional vector of output supply during that period. The aggregate transformation function F(.) shows the technological possibilities available for combining the vector of inputs with the vector of beginning stock of animals to determine the vector of end-of-period stock of cows and the vector of output supply as the residual. F(.) is increasing in the individual components of the vectors of q and A^b; it is decreasing in the individual components of the vector of A^e.

At any point in time, the vectors of current output and factor prices are known but the vector of next period's output prices is uncertain. The producer is assumed to have a subjective probability distribution concerning this vector of prices and to select a strategy to maximize the expected value of the discounted sum of anticipated profits over a two-period future planning horizon, subject to the initial vector of animal stocks, the vector of price expectations, and the animal accumulation equations and identities. This strategy can be summarized as:

$$(3.27) \quad \max_{q_t, A_t^e, Y_t} \; E \sum_{t=0}^{1} \frac{1}{(1+r)^t} \left[P_t^T Y_t - W_t^T q_t : (q_t, A_t^b, A_t^e, Y_t) \in F\right]$$

subject to $A^b >> 0$,

and the following identity restrictions:

i) $B_t^b = B_{t-1}^e + \lambda 1 C_a^e t-1$,

ii) $C_t^b = C_{t-1}^e + RH_{t-1}^e$,

iii) $S_t^b = S_{t-1}^e + \lambda 2 Ca_{t-1}^e$

iv) $H_t^b = H_{t-1}^e - RH_{t-1}^e + \lambda 3 Ca_{t-1}^e$

v) $Ca_t^b = \S(C_{t-1}^e + RH_{t-1}^e)$,

where p_t is a current period vector of output prices assumed known in period t,

w_t is a current period vector of input prices assumed known in period t,

λ_i is the percentage of calves that become bulls, steers, and heifers respectively,[12]

§ is the percentage of cows and replacement heifers bred in period t-1 that successfully calved in period t,

b denotes beginning of period,

e denotes end of period,

A is a vector of animals stocks consisting of five categories of animals,

B is the stock of bulls,

C is the stock of cows,

S is the stock of steers,

H is the stock of heifers,

Ca is the stock of calves, and

RH is the stock of replacement heifers.

The animal accumulation constraints are significantly more complicated in the multi-output case and reflect the interrelationships between the different categories of animals.

Constraint i) shows that the number of bulls available in period t is identically equal to the number of bulls left over at the end of the previous period plus the percentage of calves that are retained as bulls at the end of the previous period.

Constraint ii) indicates that the number of cows available in period t is identically equal to the number of cows left over at the end of the previous period plus the number of heifers entering the breeding herd at the end of the previous period.

Constraint iii) shows that the number of steers at the beginning of period t is identically equal to the number of steers at the end of the previous period plus the percentage of calves at the end of the previous period that become steers.

Constraint iv) indicates that the number of heifers at the beginning of period t is identically equal to the number of heifers at the end of period t-1 plus the percentage of calves at the end of the previous period which are female, minus replacement heifers that enter the breeding herd.

Finally, constraint v) shows that the number of calves at the beginning of period t is equal to the percentage of cows and replacement heifers bred in period t-1 that successfully calved at the beginning of period t.

In any period t, the farmer views the number of animals in each category as being fixed or predetermined. He must decide on the optimal quantity of inputs to combine with the fixed stock of animals from which he determines, for each category of animal, the optimal end-of-period stock and current period output as the residual. End-of-period stocks of animals in each category are valued by the farmer at the output price he expects for each animal category next period discounted to the present or:

(3.28)

$$z_{it} = [1 / (1 + r) \cdot E_t(\overline{P}_{it-1})], \quad i = 1, \ldots, n,$$

where $z_{it} = (z_{1t}, \ldots, z_{nt})$ is defined as a vector of expected prices.

A multi-output, multi-input dual profit function can be used to represent, in any period t, the maximizing behavior of the representative producer. This is defined as:

(3.29)
$$\Pi(P_t,W_t,z_t;A_t^b) = \max_{Y_t,q_t,A_t^e}[P'Y_t - W'q_t + z'_tA_t^e: (q_t,A_t^b,A_t^e,Y_t)\epsilon F].$$

The representative farm's vector of output supply, input demand, and end of period inventory can be determined by applying Hotelling's Lemma to Equation (3.29).

These equations are defined as:

(3.30)
$$Y_{it}^* = \Pi_{P_{it}}(P_t,W_t,z_t;A_t^b) \qquad i = 1,\ldots,n,$$
$$q_{jt}^* = -\Pi_{w_{jt}}(P_t,W_t,z_t;A_t^b) \qquad j = 1,\ldots,I,$$
$$A_{it}^{e*} = \Pi_{z_{it}}(P_t,W_t,z_t;A_t^b) \qquad i = 1,\ldots,n,$$

where Y*t, q*t, and A_t^{*e} are the representative producer's profit maximizing quantities of output supply, input demand, and end of period stock demand respectively, as functions of the vector of prices (p_t, w_t, and z_t) and the levels of the fixed stock of animals, A_t^b.

It should be noted that similar to Equation (3.21) in Section (3.5), a shadow price for each category of animal can be obtained by differentiating Equation (3.29) with respect to the appropriate stock. Moreover, long run structural estimates of the technology can again be determined as described in Section (3.5).

The system of equations in (3.30) can be used to postulate an econometric model by specifying a functional form for Π(.), determining the vector of price expectations of cattle producers, and specifying the stochastic disturbances for each equation. However, before attempting to estimate this system of equations, the elasticities and other summary statistics available to describe the structure of the underlying transformation function will be presented.

3.8 CHARACTERIZING THE STRUCTURE OF PRODUCTION

In describing the technology of an industry, researchers are interested in determining how the relationships among inputs and among outputs change given changes in exogenous variables. Generally, these measures determine the structure and curvature properties of isoquants and transformation curves (i.e., the rate at which inputs or outputs may be substituted in production). Additionally, other measures of interest are the price elasticities of input demand and output supply. Of course, such measurements are conditional on the assumptions of production (i.e., fixed factors).

One measure of the ease with which inputs may be substituted in production is the Hicks-Allen elasticity of substitution (σ_{ij}) which measures the normalized change of the input ratios (q_i/q_j) with respect to changes in the marginal rate of substitution (F_i/F_j). The normalization is such that $\sigma_{ij} = \sigma_{ji}$ and that σ_{ij} is invariant to changes in the scale of measurement of the inputs:

$$\sigma_{ij} = \sum_{k=1}^{I} (F_k q_k |\overline{F}_{ij}|) / (q_i q_j |\overline{F}|)$$

where $F_k = \frac{\partial F}{\partial q_k}$, $\overline{F}$ is the bordered hessian of F and $\overline{F}_{ij}$ is the cofactor of $\partial^2 F / \partial q_i \partial q_j$ in $|\overline{F}|$.

Diewert (1974) extended and generalized the notion of elasticity of substitution to the multi-output, multi-input variable profit function by defining the following elasticities:

i) an elasticity of transformation between output and variable input quantities i and h defined for each period t:

$$\alpha_{ih}(P_t,W_t,z_t,;A_t^b) = \frac{\Pi(P_t,W_t,z_t;A_t^b)\ .\ \partial^2\Pi(.)/\partial P_i\partial P_h}{[\partial\Pi(.)/\partial P_i]\ .\ [\partial\Pi(.)/\partial P_h]},\quad ih = 1,\ldots,n.$$

ii) an elasticity of substitution between fixed inputs j and k defined for each period t:

$$\beta_{jk}(P_t,W_t,z_t;A_t^b) = \frac{\Pi(.)\ .\ \partial^2\Pi(.)/\partial A_j^b\partial A_k^b}{[\partial\Pi(.)/\partial A_j^b]\ .\ [\partial\Pi(.)/\partial A_k^b]},\qquad jk = 1,\ldots,n.$$

iii) an elasticity of intensity between variable quantity i and fixed factor j defined for each period t:

$$\gamma_{ij}(P_t,W_t,z_t;A_t^b) = \frac{\Pi(.)\partial^2\Pi(.)/\partial P_i\partial A_j^b}{[\partial\Pi(.)/\partial P_i]\ .\ [\partial\Pi(.)/\partial A_j^b]},\qquad ij = 1,\ldots,n.$$

These elasticities provide measures of the responsiveness of variable outputs, inputs, and shadow prices of fixed factors to changes in prices of variable outputs, inputs, and changes in quantities of fixed factors. With the help of Hotelling's Lemma and the usual symmetry conditions, all three elasticities are normalized to be invariant to the scale of measurement and furthermore the following results are obtain, $\alpha_{ih} = \alpha_{hi}$, $\beta_{jk} = \beta_{kj}$, and $\gamma_{ij} = \gamma_{ji}$.

Diewert (1979) has also shown that: a) the matrix $[\alpha_{ih}]$ of elasticities of transformation is positive semidefinite and of rank at most equal to n-1: consequently, $\alpha_{ii} \geq 0$, $\forall i$; and

b) the matrix $[\beta_{jk}]$ of elasticities of substitution is negative semidefinite of rank at most equal to n-1: consequently, $\beta_{jj} \leq 0, \forall j$.

In addition to the above measures of substitution, a number of non-normalized partial elasticities can be defined to provide alternative measures of the curvature properties:

i) the elasticity of output supply (Yi) with respect to price (Ph) defined for each period t:

$$\varepsilon_{ih} = \frac{\partial Y_i}{\partial P_h} \cdot \frac{P_h}{Y_i}, \quad ih = 1,\ldots,n.$$

Of course, this elasticity can be defined for input demand (q) and end of period stock of animals ($\dot{A}^e$) using the appropriate prices.

ii) the inverse price elasticity of fixed factor j and k defined for each period t:

$$\eta_{jk} = \frac{\partial R_j}{\partial A_k^b} \cdot \frac{A_k^b}{R_j}, \quad jk = 1,\ldots,n.$$

where Rj is the shadow price of the jth fixed factor.

iii) the elasticity of the variable quantity i with respect to the jth fixed factor defined for each period t:

$$\zeta_{ij} = \frac{\partial Y_i}{\partial A_j^b} \cdot \frac{A_j^b}{Y_i}, \quad ij = 1,\ldots,n.$$

iv) the elasticity of fixed factor j's shadow price with respect to the price of the ith variable quantity defined for each period t:

$$\rho_{ji} = \frac{\partial R_j}{\partial P_i} \cdot \frac{P_i}{R_j}$$

Finally, it can be shown that the following relationships hold between the normalized and non-normalized elasticities (see Kohli 1976):

$$\alpha_{ih} = \varepsilon_{ih} / S_h = \varepsilon_{hi} / S_i,$$

$$\beta_{jk} = \eta_{jk} / s_k = \eta_{kj} / s_i,$$

$$\gamma_{ij} = \zeta_{ij} / s_j = \rho_{ji} / Si,$$

where $S_i = P_i Y_i / \Pi$ is variable quantity i's share of revenue and $s_j = R_j A_j^b / \Pi$ is fixed input j's share of revenue.

3.9 TESTING FOR STRUCTURE USING A MULTI-OUTPUT, MULTI-INPUT VARIABLE PROFIT FUNCTION

It has been previously stated that if a profit function satisfies certain regularity conditions, the parameters of the underlying transformation function can be recovered. This result indicates that properties such as homogeneity, homotheticity, separability, and jointness of the technology can be determined by testing for the structure of the dual profit function. In this section, a number of theorems will be presented which describe these properties. This section relies on Lau (1972) where proofs of the theorems may be found.

Before stating the theorems, several definitions must be established:

Definition 1): A function F(Y,q,A) where Y is a vector of outputs, q is a vector of inputs, and A is a vector of fixed factors, is said to be almost homogenous of degrees k1, k2, k3, and k4 iff $F(\lambda^{k1} Y, \lambda^{k2} q, \lambda^{k3} A) = \lambda^{k4} F(Y,q,A)$ for any scalar $\lambda > 0$.

Definition 2): An almost homogenous function satisfies a modified Euler Theorem:

$$k1\Sigma\frac{\partial F}{\partial Y_i}Y_i + k2\Sigma\frac{\partial F_{q_i}}{\partial q_i}q_i + k3\Sigma\frac{\partial F}{\partial A_i}A_i = k4F.$$

Definition 3): A multi-output, multi-input technology is said to be separable in outputs and inputs (variable and fixed) if there exist functions f and q such that:

$$f(Y) - g(g,A) = 0.$$

Definition 4): A function F(Y,q,A) is said to be non-joint in inputs if there exist individual production functions:

$$Y_i = f_i(X_{i1}, \ldots, X_{in}) \quad \forall\ ij,$$

with the properties: i) there are no economies of jointness; and ii) there are no diseconomies of jointness.

Assume that the regularity conditions are satisfied for both F(.) and Π(.). Then the following theorems can be stated.

Theorem 1): A production function is homogenous of degree k in A, k>0, iff the variable profit function is almost homogenous of degree 1 and 1/k in prices and fixed factors respectively.

Theorem 2): A production function is homothetically separable in Y, q, and A or F(G(Y),J(q),H(A)) where G, J, and H are homogenous of degree one, iff the variable profit function is defined as:

$$\Pi^* = \Pi(G(P), J(q), H(A)).$$

Theorem 3): A multi-output, multi-input technology is separable in Definition 3) iff the variable profit function is defined as:

$$\Pi(f(P), g(g,A)),$$

which implies that the output supply equations are independent of q and that the input demand equations are independent of p.

Theorem 4): A production function is non-joint in inputs iff the following differentiation of the variable profit function holds:

$$\frac{\partial^2 \Pi(P,q,A)}{\partial P_i \partial P_j} = 0 \quad i \neq j, \quad \forall\ ij.$$

To make these theorems empirically operational, a functional form for $\Pi(.)$ must be postulated (i.e., a functional form that does not impose the properties to be tested) and then the restrictions on the parameters of the functional form corresponding to these properties must be determined. Appropriate statistical tests can be performed to test each property. Such a procedure will be carried out in Chapter Four, which also includes a discussion of the data and transformations of the data necessary to undertake the empirical analysis.

FOOTNOTES TO CHAPTER THREE

1 Cow-calf farmers prefer to reproduce female animals from existing stock in order to maintain the genetic base of the herd.

2 Very few animals are imported for the purposes of breeding. In 1982 there where only 1830 animals imported for this purpose (Agriculture Canada 1982).

3 The variable profit function is also defined by some authors as a gross or restricted profit function.

4 This section relies entirely on Diewert (1973) and (1974).

5 For alternative assumptions on f(.) see Lau (1974).

6 Separabilty is consistent with decentralized decision-making-- see Blackorby, Primont, and Russell (1978) Chapter Three.

7 See Blackorby, Primont, and Russell (1978) for an alternative definition.

8 There have been a number of attempts to test for consistent separablity in cost and profit functions-- see Berndt and Christensen (1973), Denny and Fuss (1977), and Woodland (1978).

9 A number of authors have used the term "fictitious" when describing aggregation problems (Gorman (1968) and Blackorby, Primont, and Russell (1978)).

10 Following a change in an exogeneous variable the restriction on herd expansion will limit the industry to increase its stock of animals, over a number of time periods, to reach a new equilibrium level. It should be

noted however, that the industry can rapidly decrease the herd by slaughtering animals.

11 Equation (3.22) indicates that if the farmer places a greater value on the animal in the herd than the value he could obtain by selling it, the farmer will retain the animal.

12 Assume that the probability that a cow will give birth to a male (or female) animal is 0.5. This assumption is consistent with typical biological reproduction of male and female animals.

4. VARIABLE SPECIFICATION AND FUNCTIONAL FORMS

4.1 INTRODUCTION

The purpose of this chapter is to discuss the methodology employed in postulating an econometric model and to describe the data used in generating the econometric results. The first stage in estimating the system of equations in (3.30) requires specifying some expectation process to be used in predicting next period's cattle prices. In Section (4.2), a "quasi-rational" expectation process is posited to predict exactly the price expectations of cow-calf producers. This expectation procedure is based on a Box and Jenkins (1976) time series method whereby an autoregressive integrated moving average (ARIMA) model is hypothesized to represent the expectation process.

In Section (4.3), two alternative data sets, cross-sectional and time-series, are identified and reported. As well, the transformations necessary to facilitate econometric estimation are discussed. Specifically, to estimate the system of equations in (3.30), the following information is required: i) the quantity of different outputs produced by cow-calf farms and associated output prices; ii) the quantity of different inputs used on farms and associated input prices; iii) the end-of-period stocks of cattle and associated expected prices; and iv) the beginning stocks of cattle.

Finally, in Section (4.4), functional forms are specified for different versions of the model and the stochastic specification of the econometric equations is examined.

Furthermore, null hypotheses are presented for testing statistically the variable profit function for symmetry, linear homogeneity in prices, non-joint production in outputs, "almost homothetic" in outputs, and "almost homogeneous" in outputs.

Before examining expectations formation, it would be appropriate to summarize the procedure that was followed in generating the final statistical results. The complexity of the theoretical model necessitated (as an initial procedure) the specification of a simple functional form to represent the multi-output, multi-input variable profit function. A Cobb-Douglas form was chosen. This was combined with the assumption that expectations of prices next period are exactly represented by the predictions of a polynomial distributed lag model (Almon 1965) of past annual own-prices.[1]

It is well known that the Cobb-Douglas functional form imposes restrictive curvature properties on the production technology set (i.e., complementarity amongst inputs and an elasticity of substitution equal to one). However, it is not as well known, that for the multi-output Cobb-Douglas profit function to satisfy convexity in output prices, the restriction that the ratio of total revenue of the ith output to overall profit be greater than one for all i, is required. In other words, the revenue generated from each output must be greater than the overall profit generated by the firm. It is clear that this condition is always satisfied in the single output case[2] but is unlikely to be satisfied in the multi-output case. Casual observation of the data sample used in this study revealed that these convexity conditions would not be satisfied.

To circumvent this problem, it was decided to generate an aggregate output price index using a translog functional form[3] but maintaining a Cobb-Douglas structure on the input side. The translog functional form is a member of the group of flexible functions and, as such, does not require restrictions on revenue shares to satisfy convexity. This aggregate index was estimated for the three-output case and after checking second order conditions (i.e., checking the signs of the characteristic roots of the Hessian matrix), it was determined that in fact, the estimated aggregate price index was convex in prices. This aggregate price index was then employed in estimating a normalized Cobb-Douglas variable profit function.

Within the restrictive nature of the Cobb-Douglas, the results of the estimation were very satisfactory. These results, as well as the estimated aggregate translog price index and the estimated polynomial distributed lag price expectation model, are reported in Appendix D.

With the initial success of the Cobb-Douglas specification, it was decided to allow greater flexibility of structure in input prices while maintaining both a flexible structure in output prices and a polynomial distributed lag expectation process. This greater flexibility is achieved by specifying a multi-output, multi-input variable translog profit function (Christensen, Jorgenson, and Lau 1971 and Diewert 1974). This functional form can provide a second-order local approximation to an arbitrary function. In addition, it has a sufficient number of parameters to allow estimation of the first and second order derivatives of an arbitrary function at the point of approximation (Hanoch 1975). This implies that restrictions are not imposed a priori on elasticities of choice.

Using a combined cross-sectional, time-series data base, a translog profit function was estimated for the three-output, three-input, one fixed factor case. An examination of the empirical results generated using this flexible functional form, combined with an Almon lag expectation process, verified that the model performed well. These results, including estimates of elasticities of choice, are also reported in Appendix D.

The use of an Almon lag model to generate price expectations assumes a rather naive process for predicting prices. It was decided that a more "rational" price expectation process would more accurately represent actual price expectations of cow-calf producers and consequently provide more efficient econometric results. This was achieved by adopting Nerlove's "quasi-rational" expectations approach (Nerlove, et al. 1979). It is assumed that price expectations are represented exactly by the predictions of a time series (ARIMA) model. This expectation process, combined with a multi-output, multi-input variable translog profit function, provides the main empirical specification of the theoretical model. Econometric results are generated using a cross-sectional, time-series data base and are reported in Chapter Five.

In addition to the cross-sectional data, a time-series data set is also utilized in the estimation. Because of the cyclical nature of beef production, this data set will allow elasticity measurements over the beef cycle which can be compared to the cross-sectional results during a single period of the cycle.

However, a number of variables required to estimate the profit function are not available on a time-series basis. Specifically, this data set does not include information on total profits, crop production, or the quantities of inputs used on cow-calf farms. It does include information on current cattle prices, expected cattle prices, crop prices, input prices for labour, capital, and materials and services, and inventories of cattle on cow-calf farms.

From the available time-series data, net output supply equations will be specified for total cattle output supply and total end-of-period inventory demand. It is unfortunate that because the profit variable is absent from the data, a translog functional form could not be specified for the variable profit function. Instead, a normalized quadratic functional form will be used. To complete the empirical research, these equations are estimated with the time-series data sample maintaining a "quasi-rational" expectation procedure. These results are reported and compared to the cross-sectional results in Chapter Five.

4.2 PRICE EXPECTATIONS

In specifying the variables used in the econometric model, it would be preferable to define a market-determined representation of expected prices. The market does provide futures prices for beef animals. However, two problems precluded their use in this study: a) futures prices are available for only one category of feeder animal (steers) whereas this study requires price predictions for all categories of animals on farms; and b) futures prices are quoted in U.S. funds and this implies that their use in Canadian studies must include a prediction for expected exchange rates. Consequently, it is necessary in this research to define some process for predicting these unobservable prices.

It will be assumed that cow-calf farmers' expectation of future cattle prices can be represented exactly by the predictions of a time series model generated using a combination of weighted averages of past prices going back p periods and of random disturbances going back q periods, as described by Box and Jenkins (1976). Interestingly, Nerlove, et al. (1979) shows that such an autoregressive intergrated moving average (ARIMA) model exhibits many of the properties of Muth's (1961) rational expectations model. Moreover, a time series approach does not require solving the complete model to determine expectation formation (i.e., expected price as a function of the exogeneous parameters). This is an important advantage because it allows one to apply more easily the time series approach to empirical research yet maintain the basic properties of a fully rational expectation approach. Nerlove refers to time series expectation formation as "quasi-rational".

For this study, the procedure will be to estimate an ARIMA(p,q) function for each expected price variable in the model. The general specification of an ARIMA(p,q) model can be written as:

$$(1 - \phi_1 - \phi_2\beta^2 - \ldots - \phi_p\beta^p)\Delta^d Y_t = \delta_t(1 - \Theta_1\beta - \Theta_2\beta^2 - \ldots - \Theta_q\beta^q)\varepsilon t,$$

where B is the back shift operator,

$\Delta^d Yt$ is the observed variable differenced d times,

εt is a random disturbance term,

δ_t is an intercept term, and

ϕ_i and Θ_j are the coefficients to be estimated.

This model can be conveniently rewritten as:

$$\Delta^d Y_t = \frac{\delta + \Theta(\beta)}{\phi(\beta)} \varepsilon_t.$$

Average annual prices, for the period 1946 to 1983, for five major auction markets in western Canada (Calgary, Edmonton, Regina, Saskatoon, and Winnipeg) were provided by Agriculture Canada. An ARIMA(p,q) model was estimated for each category of animal in each market location.[4]

The estimated results were not significantly different in each market location. Therefore, only the results for the Calgary market will be presented here. The estimated equations for the other market locations are reported in Appendix E.

In Figure 4.1, a graph of the autocorrelation and partial autocorrelation functions for the steer price series is presented. An examination of the structure of these functions

FIGURE 4.1

Plot of Autocorrelation and Partial Autocorrelation Function, Steer Price Series, Calgary

```
PLOT OF PARTIAL AUTOCORRELATIONS

         -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG  CORR. +----+----+----+----+----+----+----+----+----+----+
                                    I
  1  0.859                  +       IXXXXXXX+XXXXXXXXXXXXX
  2 -0.265                  +XXXXXXXI       +
  3  0.040                  +       IX      +
  4 -0.116                  +    XXXI       +
  5  0.237                  +       IXXXXXX +
  6  0.058                  +       IX      +
  7 -0.113                  +    XXXI       +
  8 -0.030                  +      XI       +
  9 -0.088                  +     XXI       +
 10 -0.017                  +       I       +
 11  0.067                  +       IXX     +
 12 -0.129                  +    XXXI       +
 13 -0.069                  +     XXI       +
 14 -0.083                  +     XXI       +
 15  0.104                  +       IXXX    +
 16 -0.061                  +     XXI       +
 17 -0.088                  +     XXI       +
 18 -0.036                  +      XI       +
 19  0.036                  +       IX      +
 20 -0.025                  +      XI       +
 21 -0.087                  +     XXI       +
 22 -0.018                  +       I       +
 23 -0.093                  +     XXI       +
 24 -0.067                  +     XXI       +
 25  0.022                  +       IX      +
 26  0.109                  +       IXXX    +
 27 -0.012                  +       I       +
 28 -0.084                  +     XXI       +
 29 -0.117                  +    XXXI       +
 30  0.068                  +       IXX     +
 31  0.115                  +       IXXX    +
 32 -0.033                  +      XI       +
```

```
PLOT OF AUTOCORRELATIONS

         -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG  CORR. +----+----+----+----+----+----+----+----+----+----+
                                    I
  1  0.859                  +       IXXXXXXX+XXXXXXXXXXXXX
  2  0.669             +            IXXXXXXXXXXXX+XXXX
  3  0.510           +              IXXXXXXXXXXXXX +
  4  0.360          +               IXXXXXXXXX      +
  5  0.290         +                IXXXXXXX         +
  6  0.281         +                IXXXXXXX         +
  7  0.251        +                 IXXXXXX           +
  8  0.210        +                 IXXXXX            +
  9  0.147        +                 IXXXX             +
 10  0.065        +                 IXX               +
 11  0.017        +                 I                 +
 12 -0.026        +                XI                 +
 13 -0.078        +               XXI                 +
 14 -0.123        +              XXXI                 +
 15 -0.146        +             XXXXI                 +
 16 -0.167        +             XXXXI                 +
 17 -0.192        +            XXXXXI                 +
 18 -0.209        +            XXXXXI                 +
 19 -0.214       +             XXXXXI                  +
 20 -0.221       +            XXXXXXI                  +
 21 -0.239       +            XXXXXXI                  +
 22 -0.247       +            XXXXXXI                  +
 23 -0.264       +           XXXXXXXI                  +
 24 -0.294      +            XXXXXXXI                   +
 25 -0.306      +           XXXXXXXXI                   +
 26 -0.275      +            XXXXXXXI                   +
 27 -0.223      +             XXXXXXI                   +
 28 -0.178     +                XXXXI                    +
 29 -0.169     +                XXXXI                    +
 30 -0.171     +                XXXXI                    +
 31 -0.150     +                XXXXI                    +
 32 -0.127     +                 XXXI                    +
```

suggests that the series is non-stationary. In an attempt to correct this problem, the series is transformed by first differences.[5] A graph of the autocorrelation and partial autocorrelation functions representing the transformed series is reproduced in Figure 4.2. It appears that this problem has been corrected. Therefore, it is assumed that the first differenced price series is stationary.

The plot of the partial autocorrelation function presented in Figure 4.2 can be used to provide an initial specification of the ARIMA model. The large standard errors in the first and second lags may indicate an autoregressive process of (2,1,0). Subsequently, a variety of autoregressive specifications were fitted to the data. In addition, a moving average component was eventually included in an attempt to find the best specification.[6]

After diagnostic checks were completed, the most appropriate ARIMA specification remained (2,1,0). Furthermore, the ARIMA(2,1,0) model provided the best fit for each animal price series. This is not unexpected given the integrated nature of these markets.

The ARIMA(2,1,0) specification can be written as follows:

$$\Delta P_{it} = \phi_1 \Delta P_{it-1} + \phi_2 \Delta P_{it-2} + \varepsilon_{it},$$

where Δ indicates first differences,

P_i is the price series for the ith animal category, and

$\hat{\phi}_1 + \hat{\phi}_2 < 1$ is a necessary condition for stationarity.

The estimated coefficients for each ARIMA(2,1,0) model, for each animal category, are reported in Table 4.1. All

FIGURE 4.2

Plot of Autocorrelation and Partial Autocorrelation Functions, First Differenced Steer Price Series, Calgary

PLOT OF PARTIAL AUTOCORRELATIONS

```
          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG  CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   0.266                  +       IXXXXXXX+
  2  -0.417                XX+XXXXXXXI       +
  3  -0.060                  +     XXI       +
  4  -0.252                  + XXXXXXI       +
  5   0.043                  +       IX      +
  6   0.022                  +       IX      +
  7  -0.080                  +     XXI       +
  8   0.095                  +       IXX     +
  9  -0.070                  +     XXI       +
 10   0.141                  +       IXXXX   +
 11  -0.030                  +      XI       +
 12   0.081                  +       IXX     +
 13  -0.056                  +      XI       +
 14   0.007                  +       I       +
 15  -0.027                  +      XI       +
 16  -0.034                  +      XI       +
 17  -0.049                  +      XI       +
 18  -0.128                  +    XXXI       +
 19  -0.022                  +      XI       +
 20  -0.043                  +      XI       +
 21  -0.029                  +      XI       +
 22   0.059                  +       IX      +
 23  -0.049                  +      XI       +
 24   0.010                  +       I       +
 25  -0.116                  +    XXXI       +
 26  -0.222                  + XXXXXXI       +
 27   0.024                  +       IX      +
 28   0.031                  +       IX      +
 29  -0.122                  +    XXXI       +
 30   0.013                  +       I       +
```

PLOT OF AUTOCORRELATIONS

```
          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG  CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   0.266                  +       IXXXXXXX+
  2  -0.317                 +XXXXXXXXI        +
  3  -0.277                +  XXXXXXXI         +
  4  -0.181                +    XXXXXI         +
  5   0.031                +         IX        +
  6   0.198               +          IXXXXX     +
  7   0.053               +          IX         +
  8  -0.000               +          I          +
  9  -0.041               +         XI          +
 10   0.006               +          I          +
 11   0.041               +          IX         +
 12   0.032               +          IX         +
 13  -0.043               +         XI          +
 14  -0.057               +         XI          +
 15  -0.036               +         XI          +
 16   0.005               +          I          +
 17  -0.006               +          I          +
 18  -0.060               +        XXI          +
 19  -0.051               +         XI          +
 20   0.028               +          IX         +
 21   0.029               +          IX         +
 22   0.068               +          IXX        +
 23   0.008               +          I          +
 24  -0.083               +        XXI          +
 25  -0.124               +       XXXI          +
 26  -0.202               +     XXXXXI          +
 27  -0.029               +         XI          +
 28   0.237               +          IXXXXXX    +
 29   0.079              +           IXX         +
 30  -0.049              +          XI           +
```

TABLE 4.1

Estimated Coefficients ARIMA(2,1,0) Model, Steers, Calves, Cows, and Heifers; Calgary

Equation		Estimated Coefficients	Standard Error
Steers	Φ_1	.4199	.164*
	Φ_2	-.3962	.163*
Calves	Φ_1	.5262	.153*
	Φ_2	-.5853	.160*
Cows	Φ_1	.3343	.168**
	Φ_2	-.3589	.166**
Heifers	Φ_1	.3022	.171**
	Φ_2	-.3017	.169**

* significant at 10 percent level
** significant at 5 percent level

estimated coefficients are significant at either the 10 percent or 5 percent level. Moreover, the necessary condition for stationarity $\hat{\phi}_1 + \hat{\phi}_2 < 1$ is satisfied in each estimated equation.

From these estimated equations, a prediction is generated for each animal category, for each year, to correspond with the data base used in the econometric estimation. Price predictions for all cases are reported in Appendix F.

For steers and calves, the predicted ARIMA price is discounted back one period and defined as the expected price for each animal. For cows and heifers, however, it is assumed that farmers value a female animal next period at its own expected price plus the price expected from the sale of its newborn calf. This expected value is discounted back one period and defined as the expected price for each female animal.

These expected price series will be combined with the main data base to complete the data requirements necessary for econometric estimation.

4.3 DATA

The main data base used in estimating the econometric models was assembled from a variety of sources. Two surveys conducted by Statistics Canada (Farm Expenditure Survey (FES) and National Livestock Survey (NLS)[7]) were the primary sources for inventory and expenditure data on cow-calf farms. Generally, prices of farm inputs were obtained from the main Cansim files of Statistics Canada and cattle output prices were obtained from market quotations reported in the Livestock Market Review.

The FES is a probability survey conducted annually in the three prairie provinces and the Peace River region of British Columbia. It is designed to provide information on total agriculture receipts, farm input expenditures, inventories of livestock on farms, and land use in western Canada. This survey is defined as an area frame survey. This implies that a sample of farms from a specific agricultural census region is selected in a random fashion for participation in the survey. Some large farms are targeted to be included in the survey regardless of whether they are selected in the random sample. Data are collected by personal interviews from each participating farm. From these data, an estimate for each variable is generated for each specific agricultural census region.

The accuracy of the FES is measured against the Census of Agriculture survey which is taken every five years. The estimates generated by the FES are within approximately 10 percent of the census bench marks.[8] An example of the questionnaire for the 1981 FES and a map of the soil zones in western Canada appears in Appendix A.

For purposes of extracting information on beef-cattle production from the FES, a cow-calf farm was defined to have thirty or more beef breeding cows in inventory. According to this definition, Statistics Canada provided data on forty-seven variables for fourteen soil zone locations for the period 1978 to 1981. This resulted in a total cross-sectional, time-series sample of fifty-six observations. Table 4.2 provides summary information on each variable collected.

Attempts to estimate output supply equations for each animal category were unsuccessful due to serious multicollinearity problems. It was decided therefore, to specify three aggregate output groups: 1) total cattle supply sold off farms; 2) total end-of-period inventory demand; and 3) total crop supply.[9]

The FES does not provide direct information on cattle sold off farms.[10] However, using a combination of inventory data, calving rates, and growth rates of animals in different categories, values for this variable can be generated. Figure 4.3 provides a diagrammatic illustration of how this variable is determined. Specifically, the supply of animals is determined as follows:

Female Supply: Cows in period t are either sold in period t or are maintained on farms and become part of the cow inventory in t+1. Heifers in period t are either sold in period t or become cows in period t and maintained on farms to become part of cow inventory in t+1. Consequently, female supply is equal to the number of cows and heifers in period t minus the number of cows in period t+1.

Steer Supply: Steers are normally sold off farms for finishing at approximately nine hundred pounds. Consequently, steers reported on farms in period t will be sold during the period and therefore not reported as inventory in t+1.

Calf Supply: Calves reported on farm in period t will

TABLE 4.2

Summary of FES Data: Cross-Sectional

Variable	Mean	Minimum	Maximum
Cash receipts from Custom Work $	1,869,000	19,548	25,377,000
Miscellaneous Farm Expenses $	1,133,500	116,310	5,232,300
Cash Wage, Hired Labour $	6,155,200	341,110	24,513,000
Cash Wage, Family Labour $	1,650,800	25,571	6,180,800
Cash Value, Hired Labour Room and Board $	413,360	30,686	2,372,100
Pesticide Expenditure $	3,864,700	49,032	15,202,000
Custom Work Expenses $	3,570,700	222,840	15,158,000
Feed and Supplements Expenses $	12,817,000	267,290	73,786,000
Veterinary medicine and Artificial Insemination Expenses $	1,491,900	74,612	5,105,900
Expenditure on Loans$	1,3831,000	470,260	63,170,000
Telephone Expenses $	700,480	31,288	1,702,900
Electricity Expenses $	1,802,500	53,395	4,628,800
Fuel Expenses $	1,147,900	55,020	4,188,200
Insurance Premiums $	3,379,500	68,834	10,846,000
Property Taxes $	3,649,100	116,780	9,890,500
Capital Cost Allowance $	31,451,000	1,294,600	82,233,000
Total Acres Seven Grains	1,032,400	27,970	2,599,300
Acres Tame Hay	294,600	28,481	902,700
Acres Land Rental	1,534,400	67,474	4,076,000
Repairs to Farm Buildings $	2,121,900	66,505	7,906,600
Repair to Fences $	1,309,800	27,204	3,758,900
Expenditure Twine and Wire $	783,390	38,084	1,856,400
Expenditure Hardware $	1,484,900	59,141	3,995,100

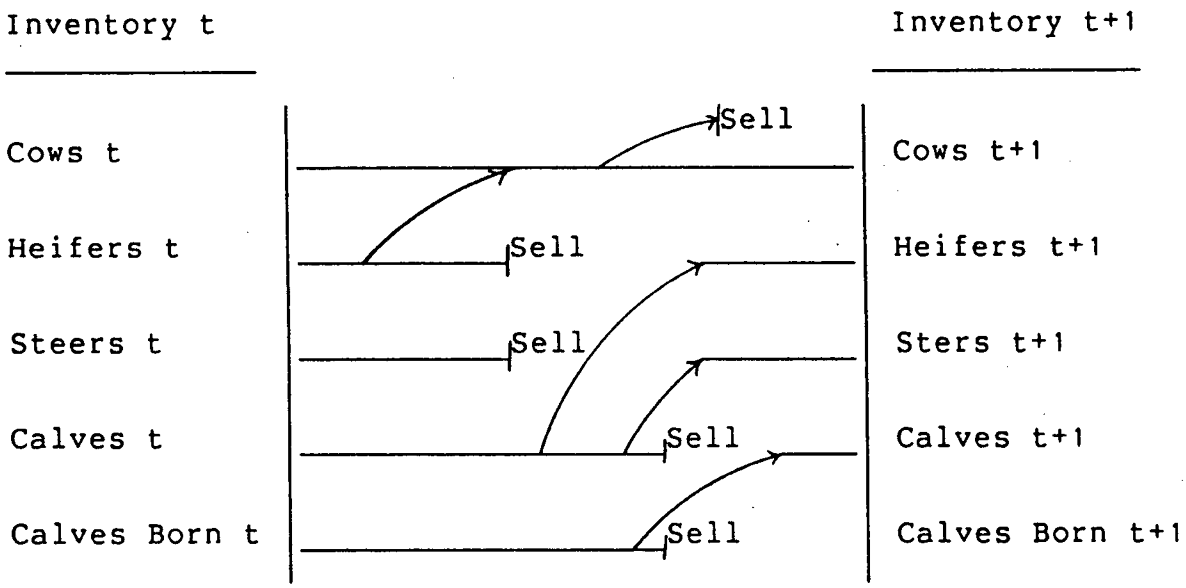
Table 4.2 (cont.)

Summary of FES Data: Cross-Sectional

Variable	Mean	Minimum	Maximum
Acres of Other Crops	25,177	898	87,378
Acres of Summer Fallow	508,120	6,693	1,637,000
Acres All Crops	1,864,000	71,841	3,927,800
Acres Improved Pasture	203,090	26,874	809,560
Total Other Land	1,928,300	119,470	4,792,600
Rental Expenses $	7,546,700	339,300	26,578,000
Machinery Expenses $	22,922,000	1,480,200	69,540,000
Seed Expenses $	2,331,600	171,020	6,675,600
Fertilizer Expenses $	9,938,500	458,540	46,615,000
Irrigation Expenses $	175,000	0	1,894,700
Other Operating Expenses $	301,870	9,496	1,844,200
Total Agriculture Receipts $	195,230,000	10,758,000	618,420,000
Portion of Receipts from the Sale of Grains $	74,194,000	1,716,800	243,950,000
Total Acres All Land	3,990,200	230,320	8,931,600
Oats Fed bu.	3,788,900	131,520	11,085,000
Barley Fed bu.	4,723,000	106,200	31,828,000
Wheat Fed bu.	203,130	0	786,410
Calves #	154,120	7,650	333,920
Total Cattle and Calves #	147,030	24,569	974,960
Calves Born Alive Last Six Months #	159,120	7,835	331,550
Cows and Heifers Expected to Calve Next Six Months #	7,611	0	36,672
Beef Cows #	182,550	9,269	517,090
Bulls #	8,629	853	24,512
Steers #	41,051	2,634	146,540

FIGURE 4.3

Cattle Supply off Farms



either be sold during the period or enter heifer or steer inventories in t+1. Calves born during period t will either be sold or enter calf inventories in t+1. Consequently, calf supply is equal to the number of calves in period t plus the number of calves born in period t less the number of heifers, steers, and calves in inventory in t+1.

Total cattle supply is defined as the sum of animals sold in each category.

Annual average cattle prices from five major western Canadian auction markets[11] (Calgary, Edmonton, Regina, Saskatoon, and Winnipeg) are available for each animal category. These prices were used to generate a weighted average price for all cattle. The weights represented the number of animals in each category multiplied by the average weight (in pounds) of an animal in each category. Total revenue obtained from the sale of cattle is determined by the number of animals (multiplied by the average weight of an animal) multiplied by the weighted average price of all cattle.

The total number of animals in inventory at the end of the period is taken directly from the FES and is equal to the sum of animals in each category.

For econometric specification, it was decided that rather than using the expected price of cattle next period, it would be preferable to generate a variable representing the expected gain from maintaining the animal on the farm and selling it next period. This expected gain variable was defined by first subtracting the revenue received from the sale of animals from the value of the beginning stock of animals. Next, the discounted value of the end-of-period stock of animals was generated using (ARIMA) expected prices from which the reduced value of the beginning herd was subtracted. Using this procedure, the total discounted expected gain was generated. Finally, the discounted expected gain per head was generated by dividing total discounted expected gains by the number of animals at the end of the period, multiplied by the average weight of an animal in each category.

A quantity index of crop output is generated by dividing the total receipts from the sale of crops, as reported in the FES, by an aggregate crop price index. The aggregate crop price index was provided by Agriculture Canada and is defined to equal 100 in 1971.

The FES reports expenditure data for twenty-four input variables. Farm input price indexes were therefore required to correspond to these twenty-four expenditure variables. These price indexes were obtained from Statistics Canada's Cansim data file on a provincial basis for each year 1978 to 1981. All price indexes are set to 100 in the base year of 1971.

It was decided to aggregate expenditures into three groups: labour, capital, and materials and services.

Labour expenses included expenditures on hired labour, family labour, and room and board. The hired labour wage rate was used as the labour price index and it was assumed that this wage was paid to both hired and family labour.

Capital expenses included expenditures on repairs to buildings, repairs to fences, capital depreciation, machinery expenses, taxes, custom work, financial loan expenses, land rental, and a flow variable representing the services from a given stock of land.[12] The capital price index is generated using a Cobb-Douglas aggregator function[13] and represents for each variable in this category, the rental price of annual per unit flows of services.

Materials and services expenses included expenditures on feed and supplements, veterinary medicines, artificial insemination, telephone, electricity, fuel, irrigation, hardware, miscellaneous farm expenses, and other operating expenses. The materials and services price index was also generated using a Cobb-Douglas aggregator function for the defined variables.

It was decided, for a tractable specification, to specify only one overall fixed stock variable rather than separate ones for each animal category. This variable was defined as the number of beginning animals in all categories and is obtained directly from the FES.

Finally, an estimate of profit is generated by taking total revenue (the sum of revenue from cattle sales, crop sales, and total discounted expected gains) and subtracting total expenditures on variable inputs. All variables are defined in real terms by dividing by the consumer price index (1971=100).

The definitions of each expenditure and price variable are summarized in Table 4.3. In addition, a complete listing of all data used in the transformations is reported in

TABLE 4.3

Definition of Variables (Translog)

Variable		Definition
$\bar{P}_1$	Cattle Output Price Index	Weighted Average Price Index All Cattle
$\bar{P}_2^e$	Expected Cattle Price Index	Weighted Average Expected Gain All Cattle
$\bar{P}_3$	Crop Output Price Index	Index of the Price of all Crops Produced
$\bar{P}_4$	Labour Input Price Index	Index of the Hourly wage Rate
$\bar{P}_5$	Capital Input Price Index	Index of the Rental Price of Capital
$\bar{P}_6$	Materials and Services Input Price Index	Index of the Price of All Materials and Services
A^b	Beginning Cattle Inventories	Total Number of Animals Beginning of Each Period
S_1	Cattle Revenue Share	Total Revenue from the Sale of All Cattle Divided by Total Profit
S_2	Expected Cattle Revenue Share	Total Expected Gain Revenue from the Sale of Cattle Next Period Divided by Total Profit
S_3	Crop Revenue Share	Total Revenue from the Sale of All Crops Divided by Total Profit
S_4	Labour Expenditure Share	Total Expenditure for Hired and Family Labour Plus Room and Board Divided by Total Profit
S_5	Capital Expenditure Share	Estimated Expenditure of the Flow of Capital Services Divided by Total Profit
S_6	Materials and Services Expenditure Share	Total Expenditure on All Materials and Services Divided by Total Profit

Appendix B.

The NLS provides an alternative source from which to obtain estimates of cattle inventories.

This publication reports the total number of animals on farms in each category for each province on a time-series basis. For the purposes of this study, cattle inventories were collected for western Canada, for the period 1956 to 1982. Included in the inventory data were estimates of calving rates. The NLS does not provide information on farm input expenditures or total crop output supply for cow-calf farms. The consequence of this limited data base is that econometric equations can only be specified for two output equations: 1) total cattle output supply; and 2) total end-of-period inventory demand. Both variables were generated according to the procedures outlined for the corresponding variables in the FES case. In addition, the output price for each variable is determined on a time-series basis following the procedures previously outlined.

Agriculture Canada provided aggregate price indexes corresponding to the three input groups defined in the FES case. These price indexes represent price changes, for the three input groups, for western Canada over the period 1956 to 1982. Each index has a base of 100 in 1971.

Finally, beginning-of-period stocks of cattle for each year, for western Canada, were obtained directly from the NLS. Definitions of the output and price variables are summarized in Table 4.4. In addition, a complete listing of the time-series data is reported in Appendix C.

TABLE 4.4

Definition of Variables (Time-Series Data)

Variable		Definition
$\bar{P}_1$	Cattle Output Price Index	Weighted Average Time-Series Price Index All Cattle
$\bar{P}_2^e$	Expected Cattle Price Index	Weighted Average Time-Series Expected Gain All Cattle
$\bar{P}_3$	Crop Output Price Index	Time-Series Index of the Price of all Crops Produced
$\bar{P}_4$	Labour Input Price Index	Time-Series Index of the Hourly Wage Rate
$\bar{P}_5$	Capital Input Price Index	Time Series Index of the Rental price of Capital
$\bar{P}_6$	Materials and Services Input Price Index	Time-Series Index of the Price of all Materials and Services
A^b	Beginning Cattle Inventories	Total Number of Animals Beginning of Each Period, Time-Series
Qc	Quantity of Cattle Produced	Output of all Cattle, Time-Series
A^e	End-of-Period Inventories	Total Number of all Animal at the End of the Period, Time-Series

Before proceeding with the econometric specification of the model, it is interesting to consider the consequences of using a cross-sectional (FES) versus time-series (NLS) data base in the estimation.

In the cross-sectional data, beginning stocks of cattle are declining over the four year period. One would expect that because producers are not restricted in reducing herd size, beginning stocks of cattle can be considered to be at some optimal level given the level of the exogeneous variables. Consequently, elasticities of choice should be interpreted under the assumption of a fully adjusted beginning stock of animals.

In the time-series data, beginning stocks of cattle have generally increased over the time period considered. However, the rate at which herd size can increase is restricted by the breeding capability of the female herd. Consequently, elasticities of choice should be interpreted under the assumption that beginning stocks of cattle may not have adjusted completely to changes in the exogeneous variables.

Given the Le Châtelier Principle (Silberberg 1978), one can conclude that own elasticities of supply estimated using cross-sectional data (FES) will be greater than (or at least equal to) corresponding estimates using time-series data (NLS).[14] This a priori prediction on the magnitude of elasticities of choice will be challenged empirically in Chapter Five.

4.4 STOCHASTIC SPECIFICATION AND ESTIMATION TECHNIQUES

The transcendental logarithmic functional form is postulated for the multi-output, multi-input variable profit function. The restricted translog profit function is defined as a second order logarithmic Taylor series expansion. For the three-output, three-input, one fixed factor case, it can be written as:

(4.1)
$$\ln\Pi(\overline{P},A^b) = \alpha_0 + \sum_{i=1}^{6} \alpha_i \ln\overline{P}_i + \tfrac{1}{2}\sum_{i=1}^{6}\sum_{h=1}^{6} \gamma_{ih}\ln\overline{P}_i\ln\overline{P}_h$$
$$\sum_{i=1}^{6} \delta_i \ln\overline{P}_i \ln A^b + \beta_k \ln A^b + \tfrac{1}{2}\beta_{kk}\ln A^b \ln A^b,$$

where $\Pi(\overline{P},A^b)$ is restricted profit (total revenues minus total costs of variable inputs), $\overline{P}$ is a six-dimensional vector representing output prices of cattle, expected price of cattle and crops, and input prices of labour, capital, and materials. A^b is the beginning stock of cattle on farms. Symmetry of the Hessian matrix requires $\gamma_{ih} = \gamma_{hi}$, for all i and h and homogeneity of degree one in prices requires the following restrictions on the parameters:

(4.2)
$$\sum_{i=1}^{6} \alpha_i = 1, \quad \sum_{i=1}^{6} \gamma_{ih} = 0, \; h = 1,\ldots 6, \quad \sum_{i=1}^{6} \delta_i = 0.$$

Multicollinearity problems generally preclude direct econometric estimation of the parameters in Equation (4.1). However, if one assumes that the translog variable profit function satisfies (at least locally) conditions (Π_1) to (Π_6) of Chapter Three, the revenue share equations for each output and expenditure share equations for each input can be obtained by applying Hotelling's Lemma to (4.1):

(4.3)
$$\frac{\partial \ln\Pi(\overline{P},A^b)}{\partial \ln\overline{P}_i} = S_i = \frac{\overline{P}_i q_i}{\Pi},$$

where $\overline{P}i$ is the price of the ith output or input, qi is the quantity of the ith output or input, and expenditure shares are affixed with negative signs.

For econometric estimation, the translog variable profit function will be considered an exact representation of the true profit function. If the translog function is assumed to approximate the true profit function in the econometric analysis, then the error terms appended to each equation must account for errors in approximation as well as random errors in profit maximizing behavior.

In specifying stochastic disturbances for the equations in (4.3), it is assumed that any deviation of actual revenue or expenditure shares from profit maximizing levels is due to random errors in optimization. These random disturbances are modeled by appending additive disturbance terms (εi) to each share equation in (4.3). Furthermore, it is assumed that εi's are normally distributed with zero means and a positive semidefinite variance-covariance matrix, Ω . The variance-covariance matrix must be positive semidefinite because the adding-up constraint on the share equations implies that it will be singular. The singularity of Ω is avoided in the econometric procedure by dropping one share equation in the estimation. Finally, the vector of errors is assumed to be contemporaneously correlated across equations but temporally independent. These conditions can be written as:

$$\varepsilon_i \sim N(0,\sigma_i^2),$$
$$E(\varepsilon_{it}\varepsilon_{jt}) = \sigma_{ij}^2 \text{ , and}$$
$$E(\varepsilon_{it}\varepsilon_{js}) = 0 \quad \forall\, t \neq s.$$

The cross-sectional, time-series nature of the sample utilized in the econometric estimation of Equation (4.3) necessitates the use of covariance estimators[15] to take account of yearly differences in the data. To save degrees of freedom, the covariance estimators take the form of yearly dummy variables and are attached to the constant term in each share equation.

The share equations for cattle, end-of-period inventories, crops, labour, capital, and materials can now be rewritten incorporating error terms and yearly dummy variables as:

(4.4)
$$S_i = \alpha_i + \sum_{h=1}^{6} \gamma_{ih} \ln\overline{P}_h + \delta_i \ln A^b + \sum_{k=1}^{3} \beta_{ki} D_k + \varepsilon_i \qquad i = 1,\ldots,6,$$

where Dk is a dummy variable for year k (i.e., Dk takes the value 1 in year k and zero otherwise) and all other variables are as previously defined.

The cross equation constraints imposed by the symmetric Hessian matrix and other restrictions to be discussed below, necessitate the use of a multivariate generalized least squares procedure to estimate (4.4). To ensure efficient estimation of the parameters, Zellner's seemingly unrelated regression (SUR) technique is employed. The materials' share equation is dropped in the estimation to ensure non-singularity of Ω. Zellner's SUR estimates of the parameters are invariant to which equation is dropped and are asymptotically equivalent to maximum likelihood estimates if the coefficients are iterated until convergence (Barten 1969).

In order for there to exist a dual relationship between the variable profit function and the underlying transformation function, Equation 4.1 must satisfy the properties of symmetry, homogeneity of degree one in prices, monotonicity, and convexity in prices. These properties must also hold in the estimated system of share equations (4.4). However, for the translog function, these properties do not hold generally but may hold over an arbitrary set of data.

A necessary and sufficient condition for the translog variable profit function to satisfy symmetry is that the Hessian matrix of (4.4) with respect to prices be symmetric. This implies that the estimated share equations should satisfy the property that $\gamma ih = \gamma hi$, for all i and h.

The property of homogeneity of degree one in prices for the variable profit function implies that the share equations are homogeneous of degree zero in prices. This condition imposes the following restrictions on the estimated parameters:

$$\sum_{h=1}^{6} \gamma_{ih} = 0 \qquad i = 1,\ldots,6,$$

$$\sum_{i=1}^{6} \gamma_{ih} = 0 \qquad h = 1,\ldots 6, \text{ and}$$

$$\sum_{i=1}^{6} \delta_{i} = 0 \qquad i = 1,\ldots,6.$$

In addition, the following adding up restrictions are imposed on the dummy variables:

$$\sum_{k=1}^{3} \beta_{ki} = 0 \qquad i = 1,\ldots,6 \text{ and}$$

$$\sum_{i=1}^{6} \beta_{ki} = 0 \qquad k = 1,2,3.$$

The properties of monotonicity and convexity are not properties which are easily summarized as linear restrictions on the share equations. Rather, the consistency of these properties with the share equations will be evaluated after estimation. To satisfy monotonicity, the predicted shares must be positive for revenues and negative for expenditures. A necessary condition for convexity in prices is that own supply elasticities are positive and own derived demand elasticities are negative. A necessary and sufficient condition for convexity is that the Hessian of the variable profit function with respect to prices is positive semidefinite.

This Hessian matrix [H] can be conveniently characterized in terms of the estimated coefficients in (4.4) and the predicted revenue and expenditure shares. [H] is written as:

$$[H] = \begin{bmatrix} \gamma_{11} + S_1(S_1 - 1) & \gamma_{12} + S_1S_2 & \cdots & \gamma_{16} + S_1S_6 \\ \gamma_{21} + S_2S_1 & \gamma_{22} + S_2(S_2 - 1) & \cdots & \gamma_{26} + S_2S_6 \\ \vdots & \vdots & & \vdots \\ \gamma_{61} + S_6S_1 & \gamma_{62} + S_6S_2 & \cdots & \gamma_{66} + S_6(S_6 - 1) \end{bmatrix}$$

where [H] must be positive semidefinite.

Rather than maintaining the hypotheses of symmetry and homogeneity of degree zero in prices, it is preferable to test statistically for these properties. Table 4.5 summarizes the linear restrictions on the share equations as null hypotheses. A likelihood ratio test will be used for hypothesis testing. The likelihood ratio test compares the value of the likelihood function under the null hypothesis (Lo) (i.e., with restrictions imposed on the model) to the value of the unrestricted likelihood function (La). It is well known that

-2(lnLa-lnLo) is asymptotically distributed as Chi-squared. The null hypothesis is rejected or not rejected depending on whether the value of -2(lnLa-lnLo) is greater or less than a critical value of χ^2 with k degrees of freedom, where k is the number of independent restrictions.

After testing for these properties, symmetry and homogeneity of degree zero in prices will be imposed on the estimated model and further statistical testing will be done under these maintained hypotheses.

Once the conditions for profit maximization have been satisfied, the estimated share equations can be used to describe certain properties of the underlying transformation function. Of particular interest in this study is whether the underlying transformation function can be described as: i) "almost homothetic" in outputs; ii) "almost homogeneous" in outputs; and iii) exhibiting joint production between crops and cattle supply, as defined in Section (3.9) of Chapter Three. These characteristics of the transformation function are tested by imposing linear restrictions on the parameters of the estimated share equations. Table 4.5 summarizes the linear restrictions on Equation (4.4) which are sufficient conditions for the translog variable profit function to be consistent with these three properties. A likelihood ratio test will again be used to test each property.

The estimated parameters of the revenue share equations can also be used to provide a measure of short run returns to scale (RTS) in the cow-calf industry. Generally, estimates of returns to scale are determined under the maintained

TABLE 4.5

Testing for Structure with Linear Restrictions on the Share Equations

Property		Linear Restrictions on Share Equations(4.4): Null Hypotheses	
Symmetry	Ho:	$\gamma_{ih} - \gamma_{hi} = 0$	$\forall i,h, = 1,\ldots,6$
Homogeneity of Degree Zero in Prices	Ho:	$\sum_{h=1}^{6} \gamma_{ih} = 0$	$\forall i = 1,\ldots,6$
Almost Homotheticity in Output Prices	Ho:	$\sum_{i=1}^{3} \gamma_{ih} = 0$	$h = 1,2,3$
Almost Homogeneity in Output Prices	Ho:	$\sum_{i=1}^{3} \gamma_{ih} = 0$	$h = 1,2,3$
	Ho:	$\sum_{i=4}^{6} \gamma_{ih} = 0$	$h = 4,5,6$
	Ho:	$\sum_{i=1}^{6} \delta_i = 0$	$\forall i = 1,\ldots,6$
Joint Production Technology in Crops and Beef	HO:	$\alpha_{i3} = 0$	$i = 1,2$
	Ho:	$\alpha_{3h} = 0$	$h = 1,2$

hypothesis of homogeneity in technology. However, Weaver (1982) has derived a formula to measure returns to scale in non-homothetic multi-output technologies. Furthermore, restrictions are imposed on the formula to ensure that the measurement is taken along the expansion path.

For the multi-output variable translog profit function, a measure of returns to scale can be estimated using the following formula:

$$RTS = 1 - 1/\sum_{k=1}^{3} S_k,$$

where Sk is defined over revenue shares only. A measure of returns to scale for each soil zone will be calculated.

Finally, other characteristics of the technology set can be described by elasticities of choice. For the translog variable profit function, these elasticities will be functions of the estimated parameters and the predicted revenue and expenditure shares. The elasticity of net output i with respect to price $\overline{P}h$ can be written as:

$$\varepsilon_{ih}(\overline{P},A^b) = \hat{S}_h - \hat{\gamma}_{ih}/\hat{S}_i \qquad i = 1,\ldots 6,\ h = 1,\ldots 6,\ i \neq h.$$

Own elasticity of net output supply can be written as:

$$\varepsilon_{ii}(\overline{P},A^b) = \hat{S}_i + \hat{\gamma}_{ii}/\hat{S}_i - 1 \qquad i = 1,\ldots,6.$$

The own elasticity of cattle supply (εii) is generated under the assumption that price expectations are not adjusted. If changes in price expectations are allowed, an estimate of the total own elasticity of cattle supply (ηii) can be determined. For the translog variable profit function, this formula can be written as:

Total Elasticity		Direct Elasticity		Cross Elasticity		Elasticity of Expectations
η_{11}	=	$[\varepsilon_{11}]$	+	$[\varepsilon_{12}]$	$\cdot$	$[\xi_{21}]$
	=	$[\hat{S}_1 + \hat{\gamma}_{11}/\hat{S}_1 - 1]$	+	$[\hat{S}_2 - \hat{\gamma}_{12}/\hat{S}_1]$	$\cdot$	$\dfrac{[\partial\, P_2^e\, \overline{P}_1]}{[\partial\, \overline{P}_1\, \overline{P}_2^e]}$,

where $\frac{\partial \overline{P}_2^e}{\partial \overline{P}_1} \cdot \frac{\overline{P}_1}{\overline{P}_2^e}$ represents the percentage change in the expected price of cattle caused by a percentage change in the current price of cattle.

Alternative estimates of the elasticities of choice can be generated using the time-series data sample. However, because some variables are not available on a time-series basis, it was necessary to specify an alternative functional form for the variable profit function in this case. It was decided that a normalized quadratic functional form (as developed by Lau (1974)) would be appropriate for this purpose.

The normalized quadratic function is a member of the group of flexible functional forms and will provide a second order approximation to an arbitrary function. The variable normalized quadratic profit function for the three-output, three-input one fixed factor case can be written as:

(4.5)

$$\Pi'(\overline{P}, A^b) = bo + \sum_{i=1}^{5} b_i \overline{P}_i' + aoA^b + \tfrac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} b_{ij}\overline{P}_i'\overline{P}_j' + \tfrac{1}{2}aooA^{b2} + \sum_{i=1}^{5} \overline{P}_i' A^b ,$$

where Π' is $\Pi/\overline{P}_6$ and $\overline{P}_i'$ is $\overline{P}_i/\overline{P}_6$ and all variables are as previously defined. The normalized quadratic functional form maintains linear homogeneity of the profit function in prices but symmetry of the Hessian matrix requires the restriction $b_{ij}=b_{ji}$, for all i and j. In addition, if the quadratic variable profit function satisfies at least locally the conditions (Π_1) to (Π_6) in Chapter Three, the net output supply equations can be obtained by applying Hotelling's Lemma to (4.5):

(4.6) $$\frac{\partial \Pi'(\overline{P},A^b)}{\partial \overline{P}'} = Y_i,$$

where Yi is the ith net output quantity.

Assuming a stochastic specification for (4.6) similar to that previously discussed for the translog variable profit function and, in addition, appending a time trend variable to each equation in (4.6) to account, in a rudimentary way, for technological change in the cow-calf industry, the net output equations can now be rewritten as:

(4.7) $$Y_i = b_i + \sum_{i=1}^{5} b_{ij}\overline{P}_j' + ao_i A^b + \alpha_i t + \varepsilon_i \qquad i = 1,2,$$

where t is a time trend variable and ε_i is a random error term.

Econometric estimation of (4.7) can proceed as described in the translog case but symmetry and homogeneity of degree zero in prices will be imposed as maintained hypotheses.

Because the Hessian of the quadratic variable profit function is the same at all observations, the elasticities of choice can easily be derived directly from the estimated net output equations. The own price elasticity of supply is defined as:

$$\varepsilon_{ii}^q = \hat{b}_{ii}\overline{P}_i'/Y_i \qquad i = 1,2.$$

The elasticity of net output Yi with respect to price Pj is defined as:

$$\varepsilon^q_{ij} = \hat{b}_{ij}\overline{P}'_j/Y_i \qquad \forall\ i,j\ i \neq j.$$

The elasticity of net output Yi with respect to the fixed factor (A^b) is defined as :

$$\varepsilon^q_{ia} = \hat{a}o_i A^b/Y_i.$$

Finally, allowing for adjustments in expectations, an estimate of total elasticity of supply can again be generated as:

Total Elasticity		Direct Elasticity		Cross Elasticity		Elasticity of Expectations
η^q_{11}	=	$[\varepsilon^q_{11}]$	+	$[\varepsilon^q_{12}]$	X	$[\xi_{21}]$
	=	$[\hat{b}_{11}\overline{P}'_1/Y_1]$	+	$[\hat{b}_{12}\overline{P}'_2/Y_1]$	X	$\dfrac{[\partial\overline{P}^e_2}{[\partial\overline{P}_1} \cdot \dfrac{\overline{P}_1]}{\overline{P}^e_2]}$,

where all variables are as previously defined.

This completes the discussion of stochastic and functional form specification and data transformation. We can now turn to a discussion of the econometric results.

FOOTNOTES TO CHAPTER FOUR

1 The Almon lag expectation model was chosen for two reasons: first, this model is commonly used in agricultural economics for generating price predictions (Ospina and Shumway, n.d.); and second, specification and estimation of the model is straightforward.

2 For an example of the one output Cobb-Douglas variable profit function see Yotopoulos, Lau, and Lin (1976).

3 Fuss (1977) employs a similar technique to generate an aggregate input price index for a vector of energy inputs.

4 It was decided to estimate price expectations for each market location because it was observed that prices varied systematically between market locations.

5 The series was differenced a number of times: however, these transformations added no new information.

6 The addition of higher order autoregressive and moving average components either reduced the significance of or changed the signs of the estimated coefficients. Futhermore, in some cases the necessary condition for stationarity was violated.

7 See Statistics Canada, Methodology Paper Number 3, Data Collection and Estimating Procedures of the Livestock Estimation Unit, Agriculture Statistics Division, Ottawa, 1982.

8 Statistics Canada, Methodology Paper Number 3, p.117.

9 It was necessary to include a total crop supply variable because on examination, the data revealed that the cow-calf

farm as defined generated approximately 30 to 40 percent of total revenue from the sale of crops.

10 The number of bulls in the aggregate Canadian herd has remained stable at approximately 5 percent. Given this fact and the specialized nature of the bull market, it was decided to eliminate bulls from the analysis.

11 These prices are reported in Livestock Market Review, Agriculture Canada, Ottawa, various issues.

12 The rental price of land is defined as:

$$p_t = (r - \rho_t)/(1 + r)\overline{P}_t,$$

where p_t = rental price of land,

$\overline{P}_t$ = asset price of land,

ρ_t = rate of growth of land prices , set equal to 3% (Barichello 1979),

r = interest rate.

13 The Cobb-Douglas price aggregator function is defined as:

$$P(p_i) = \Pi p_i^{\alpha i},$$

where P(.) is the aggregate price index,

p_i is the price of the ith input, and

$\alpha_i = P_i x_i / \Sigma P_j x_j$; (x_i is the ith input quantity).

14 It should be noted that two additional factors may affect the magnitude of these elasticities. First, the cross-sectional sample is defined to include only cow-calf farms with thirty or more beef cows whereas the time-series data includes all farms with beef cattle in western Canada. Consequently, there is greater potential for output variations in the cross-sectional data caused by farms outside the sample moving into the cross-sectional

classification. Therefore, output elasticities calculated using this data set should be larger in magnitude than those using the time-series sample. Second, for each data set, it is necessary to specify a different functional form for the variable profit function; the effect of the alternative functional form specification on the magnitudes of the calculated elasticities is not certain.

15 Two techniques have been proposed to ensure efficient estimation when using a combined cross-sectional, time-series sample: 1) covariance estimation; and 2) error components. The primary difference between the two methods is that the covariance model assumes that the cross-sectional parameters are fixed whereas the error components model assumes that such parameters are stochastic (Judge, et al. 1980). Covariance estimators are used in this study simply because they are more expedient.

Table 5.1

Regression Coefficients-Translog Profit Function

Share	Prices								Dummy Variables		
	Cattle	Inventories	Crops	Labour	Capital	Materials	Stock	Constant	1981	1980	1979
Cattle	.86 (8.4)*	-.241 (8.2)	-.33 (5.1)	-.078 (4.6)	.077 (4.9)	-.288 (6.1)	.037 (5.2)	.787 (6.3)	.156 (6.9)	-.004 (.42)	-.151 (7.1)
Inventories	-.241 (8.2)	.289 (7.5)	-.107 (2.6)	.014 (2.9)	-.01 (2.1)	.054 (4.9)	-.036 (3.4)	1.09 (8.2)	-.053 (3.5)	.02 (1.1)	.033 (1.7)
Crops	-.33 (5.1)	-.107 (2.6)	.315 (4.8)	.015 (1.4)	-.039 (4.0)	.147 (6.3)	.011 (.90)	-.585 (3.8)	-.048 (2.4)	-.008 (4.3)	.056 (2.2)
Labour	-.078 (4.6)	.014 (2.9)	.015 (1.4)	.02 (2.3)	-.007 (1.4)	.037 (2.2)	-.002 (1.7)	-.095 (3.8)	-.019 (4.6)	-.002 (1.1)	.02 (5.9)
Capital	.077 (4.9)	-.01 (2.1)	-.039 (4.0)	-.007 (1.4)	-.02 (3.3)	-.001 (.05)	.002 (1.5)	.055 (2.5)	.019 (5.1)	-.006 (3.5)	-.013 (4.0)
Materials	-.288	.054	.147	.037	-.001	.051	-.012	-.252	-.055	0	.055

*** t-statistics in parentheses**

5. PARAMETER ESTIMATES AND SUMMARY STATISTICS

5.1 INTRODUCTION

In this chapter, empirical results are reported and discussed for each model specified in Section (4.4) of Chapter Four. In Section (5.2), the estimated parameters of the share equations for the multi-output, multi-input variable translog profit function are presented. Statistical testing to determine the technical structure of the cow-calf industry is carried out and includes estimates of elasticities of choice and returns to scale. These results constitute the main empirical findings of this dissertation.

In the last Section (5.3), the time-series based econometric results estimated using net output supply equations which are derived from a multi-output, multi-input variable normalized quadratic profit function are reported. Measurements of elasticities of choice are again generated and compared to earlier results.

5.2 EMPIRICAL RESULTS USING A TRANSLOG VARIABLE PROFIT FUNCTION

Estimates of the parameters of the five revenue and expenditure share equations derived using Zellner's (SUR) procedure for estimating systems of equations are given in Table 5.1. Seven iterations were required for convergence. These coefficients represent the maintained hypotheses of symmetry and homogeneity of degree zero in prices. The parameter estimates for the materials and services expenditure equation are derived using symmetry, homogeneity, and the adding up constraints. Asymptotic t-statistics are given in parentheses.[1]

All own output price coefficients are positive and statistically significant at the 5 percent level. This is a necessary condition for positive own output supply elasticities. The asymptotic t-statistics for own input price coefficients also indicate statistical significance at the 5 percent level. Moreover, of the remaining price coefficients, 84 percent are statistically significant at the 10 percent level of significance. The estimated coefficients for the beginning stock of cattle are highly significant in both total cattle output supply and total end of period inventory demand equations. But this coefficient is not statistically different from zero in the total crop revenue share equation. For the labour and capital expenditure share equations, the estimated beginning cattle stock coefficients are marginally significant with asymptotic t-statistics of 1.7 and 1.5 respectively.

Generally, the statistical significance of the price and beginning cattle stock coefficients provide support for the econometric specification of the variable and fixed inputs as defined.

It is interesting to examine the estimated coefficients for the covariance estimators in Table 5.1. These coefficients are statistically significant at the 10 percent level for all input share equations for the years 1981 and 1979. But they are statistically insignificant, except for the capital share equation, for the year 1980. These results provide strong evidence that the intercept coefficients have varied between the base year (1978) and 1979, and again varied between the base year and 1981. This indicates that the data are not drawn from a homogeneous sample and consequently, to generate efficient parameter estimates, it is necessary to maintain the dummy variable specification in the estimation.

Goodness-of-fit summary statistics are provided in Table 5.2. This table indicates that the estimated equations account for 72.2, 64.6, 44.9, 61.6, and 56.9 percent of the variation in the shares for cattle, end-of-period inventory, crop, labour, and capital share equations respectively. Given the cross-sectional data utilized in the estimation, these R^2 measurements can be considered quite adequate. In addition, Table 5.2 reports the result from testing the null hypothesis that all estimated coefficients are equal to zero. The null hypothesis is soundly rejected.

These statistical results provide preliminary validation of the model. However, it is necessary to test the estimated equations to ensure that the conditions for duality are satisfied. Symmetry of the Hessian matrix and linear homogeneity in prices are tested using the null hypotheses defined in Table 4.5 of Chapter Four. The results of these tests are reported in the first half of Table 5.3 for two critical values of the Chi-squared statistic and indicate the general consistency of these properties in the estimated share equations. The only exception is that homogeneity of prices is rejected at a 5 percent level of significance.

TABLE 5.2

Goodness of Fit Statistics

Share Equation	R^2	SEE
Cattle	.7220	.0358
End-Of-Period Inventories	.6463	.0615
Crops	.4493	.0672
Labour	.6156	.0054
Capital	.5690	.0049

Ho: All Coefficients Equal to Zero	χ^2	d.f.	$\chi^2(.01)$	Decision
	198.01	30	50.98	Reject

TABLE 5.3

Testing for Structure

Test Ho:	λ*	d.f.	$\chi^2(.05)$	Decision	$\chi^2(.01)$	Decision
Homogeneous of Degree One in Prices	12.46	5	11.07	Reject	15.09	Accept
Symmetry	15.26	10	18.31	Accept	23.21	Accept
"Almost Homothetic"	31.82	3	7.82	Reject	11.35	Reject
"Almost Homogeneous"	35.70	4	9.49	Reject	13.28	Reject
Non-Joint Production	31.02	4	9.49	Reject	13.28	Reject

* $\lambda = -2(\ln La - \ln Lo)$

Since the properties of symmetry and homogeneity are not statistically rejected at the 10 percent level in the unrestricted model, it is not unreasonable to impose these properties in the estimation in order to perform additional tests.

Checking regularity conditions, the predicted revenue shares are positive and expenditure shares are negative for all observations which indicates that the translog variable profit function satisfies the monotonicity property. Convexity of this variable profit function in prices is checked by computing the eigenvalues of the Hessian matrix of the profit function with respect to prices. The Hessian matrix is convex if all eigenvalues are non-negative. Table 5.4 reports the elements of the Hessian matrix (using predicted shares determined at the means of the exogeneous variables) and estimates of the eigenvalues. Unfortunatly, these results indicate that the full variable profit function is not convex in prices.[2] It is worth noting however, that the 3x3 Hessian of output prices and the 3x3 Hessian of input prices are convex. The eigenvalues for these sub-matrices are also reported in Table 5.4.

Given that at the means of the exogeneous variables the Hessian matrix is non-convex, this property should be checked at each sample point. In Table 5.5 the eigenvalues for the Hessian matrix are reported for each observation. These results illustrate that at each sample point five eigenvalues are positive but one value is negative; again indicating a non-convex Hessian matrix. However, it is interesting to note

TABLE 5.4

Hessian Coefficients and Eigenvalues

Hessian coefficients

	Cattle	Inven.	Crops	Labour	Capital	Materials
Cattle	.615	-.013	-.261	-.095	.068	-.330
Inven.	-.013	.04	-.022	-.007	-.021	.002
Crops	-.261	-.022	.181	.009	-.042	.131
Labour	-.095	-.007	.009	.062	-.006	.041
Capital	.068	-.021	-.042	-.006	.002	.001
Materials	-.33	.002	.131	.041	.001	.16

Eigenvalues

Hessian Matrix :	.9228	.0932	.0569	.0363	-.0439	-.0069
Output Price Sub-Matrix :	.737	.076	.022			
Input Price Sub-Matrix :	.162	.060	.0008			

TABLE 5.5
Eigenvalues for Hessian Matrix at each Observation

0.92746	-0.08158	0.05807	0.03151	0.01281	0.00014
0.92659	0.09111	-0.05993	0.05898	0.01832	0.00016
0.88902	-0.06818	0.06693	0.04109	0.01797	0.00014
0.88348	0.07085	-0.06380	0.04558	0.01915	0.00016
0.90472	-0.08110	0.05937	0.02968	0.01409	0.00015
0.92363	-0.07411	0.06114	0.04038	0.01375	0.00015
0.91942	-0.07741	0.06032	0.03462	0.01417	0.00015
0.90425	-0.07169	0.06324	0.03729	0.01323	0.00014
0.91351	-0.07677	0.05916	0.03153	0.01285	0.00014
0.89467	-0.06949	0.06387	0.03791	0.01581	0.00015
0.91187	-0.08022	0.06010	0.03134	0.01437	0.00014
0.92406	-0.07805	0.05682	0.03563	0.01288	0.00015
0.91199	-0.07336	0.05734	0.03411	0.01135	0.00015
0.93385	-0.07944	0.05283	0.02903	0.00871	0.00014
0.91502	-0.07719	0.06467	0.04570	0.02020	0.00016
0.93252	0.10822	0.06044	-0.05765	0.02838	0.00017
0.88055	0.07087	-0.06607	0.04672	0.02427	0.00015
0.88311	0.07378	-0.06131	0.04828	0.02415	0.00016
0.90214	-0.07358	0.06249	0.03636	0.01706	0.00015
0.89024	0.06892	-0.06876	0.04446	0.02114	0.00016
0.89305	-0.07254	0.06473	0.03879	0.01907	0.00015
0.91269	-0.07046	0.06365	0.04391	0.01760	0.00015
0.90104	-0.07300	0.06258	0.03689	0.01734	0.00015
0.88165	0.06997	-0.06582	0.04589	0.02331	0.00015
0.90167	-0.07536	0.06419	0.03856	0.01890	0.00015
0.90456	-0.07520	0.06004	0.03964	0.01758	0.00015
0.89725	-0.06991	0.06343	0.04348	0.01971	0.00015
0.90214	-0.07429	0.06166	0.04158	0.01875	0.00015
0.94763	0.10956	-0.06680	0.04847	0.01502	0.00015
0.98123	0.17964	-0.05663	0.04408	0.01071	0.00015
0.92820	0.08791	-0.05879	0.04592	0.01553	0.00016
0.92364	0.08288	-0.05722	0.04372	0.01504	0.00015
0.95250	-0.07229	0.07137	0.04176	0.01108	0.00015
0.95157	0.10290	-0.06138	0.04421	0.01016	0.00016
0.96264	0.07903	-0.07356	0.04135	0.01076	0.00016
0.93718	0.09400	-0.06031	0.04507	0.01202	0.00016
0.95429	-0.07258	0.07031	0.04060	0.01008	0.00015
0.93047	0.08425	-0.05891	0.04436	0.01358	0.00016
0.95249	-0.07543	0.07383	0.04341	0.01278	0.00015
0.97379	0.11181	-0.07297	0.03945	0.01026	0.00015
0.95767	0.09423	-0.06689	0.03902	0.00944	0.00015
0.98458	0.11562	-0.07034	0.03683	0.00758	0.00015
0.96825	0.10511	-0.06893	0.05123	0.01238	0.00015
0.99325	0.16478	-0.06278	0.04801	0.00932	0.00015
0.93761	0.07718	-0.06007	0.05093	0.01323	0.00015
0.93860	0.09178	-0.05609	0.05304	0.01469	0.00015
0.97837	0.09870	-0.06683	0.04772	0.01011	0.00015
0.96089	0.11081	-0.06043	0.05228	0.01057	0.00015
0.98904	0.09913	-0.07140	0.04639	0.01067	0.00015
0.95162	0.11010	-0.05788	0.05420	0.01241	0.00015
0.99734	0.09857	-0.07213	0.04458	0.00936	0.00015
0.94313	0.07667	-0.06034	0.04978	0.01124	0.00016
0.98830	0.10929	-0.07047	0.04764	0.01119	0.00015
0.95834	0.07945	-0.07010	0.04357	0.00971	0.00015
0.93973	0.06911	-0.06474	0.04352	0.00995	0.00014
0.94574	0.07320	-0.06608	0.04370	0.00940	0.00015

that for each observation one eigenvalue is significantly larger then the other values and close to one in magnitude, whereas the remaining values are relatively close to zero.

These point estimates do not prove that the true underlying profit function is non-convex in prices. Wales (1977) has shown that a non-convex result may not indicate an absence of optimizing behavior, rather it may indicate that the FFF does not provide a good approximation to the true function. Neverless, Wales concludes that this result does not preclude obtaining good elasticity estimates.

In sum, the estimated coefficients of the revenue and expenditure share equations are generally statistically significant with the share equations providing a good fit to the data. Furthermore, statistical testing indicates that the estimated variable profit function satisfies the required duality properties of symmetry, linear homogeneity in prices, and monotonicity. Finally, it will be assumed that the true profit function is convex in prices. Consequently, one can conclude that the estimated share equations have performed well and that they adequately represent the profit maximizing behavior of cow-calf producers.

Using the estimated coefficients of the revenue and expenditure share equations, one can test for certain characteristics of the underlying transformation function as defined in Table 4.5 of Chapter Four. These statistical tests are reported in the bottom half of Table 5.3. "Almost-homothetic" in outputs is rejected at both the 5 and the 10 percent level of significance. Subsequently, it must follow that "almost-homogeneous" in outputs is also rejected. This is due to the fact that almost-homogeneous is nested within the almost-homothetic hypothesis. These results are consistent with the findings of other economic studies (Lopez (1980), Kunimoto (1983)) on Canadian agriculture.

These tests support the contention that cow-calf production technologies are not characterized by constant returns to scale. However, following the definition of returns to scale in Section (4.4) of Chapter Four, an estimate of a returns-to-scale measure can be determined. In Table 5.6, estimates of the returns to scale in 1981 are provided for each of the fourteen soil zone locations. These estimates are generated using the predicted revenue shares for each observation. The results clearly indicate decreasing returns to scale for all soil zone locations. What this means is that a given increase in outputs requires inputs to be increased in a significantly greater proportion.

The author is unaware of past Canadian studies which provide similar measures of returns to scale in agriculture. However, these estimates, although small in magnitude, are consistent with U.S. agricultural studies which also report decreasing returns to scale (Ray 1982 and Weaver 1983).

The last structural test assesses joint production possibilities between crops and cattle on cow-calf farms. Results from the statistical testing of the non-joint production hypothesis are also reported in Table 5.3 and indicate that non-joint production of crops and cattle can be rejected at both the 5 and the 10 percent levels of

TABLE 5.6

Returns to Scale

Soil Zone	Returns to Scale
1	.065
2	.094
3	.093
4	.102
5	.071
6	.072
7	.071
8	.079
9	.072
10	.088
11	.071
12	.065
13	.072
14	.058

significance. This indicates that there is a significant benefit to jointly producing crops and cattle on cow-calf farms. A crop cow-calf production system allows the farmer the option of marketing grain directly or through cattle in the form of beef.

The author is again not aware of published results testing for joint production possibilities in Canadian agriculture. However, in a working paper, Lopez (1981) does test for this characteristic and rejects joint production between crops and cattle. His result must be interpreted carefully because it is based on highly aggregated data and does not reflect the technology of a specifically defined farm as do the results for this study.

Summarizing, the technological structure of cow-calf production in western Canada is defined by a non-homothetic, non-homogeneous transformation function subject to decreasing returns to scale and joint production between crops and cattle.

The statistical tests presented above provide information which is necessary to characterize cow-calf production. Of equal interest are measures of input substitution and responsiveness of cow-calf farmers to changes in prices. These partial elasticities of choice (computed at the means of the exogeneous variables) are given in Table 5.7. Approximate standard errors for each estimate are in parentheses.[3] These estimates are generated using the fitted translog variable profit function and consequently should be interpreted as short run elasticities.

TABLE 5.7

Elasticities of Choice (Translog)

	Cattle	Invent.	Crop	Labour	Capital	Materials
		A			B	
Cattle	1.43 (.237)*	-.03 (.067)	-.602 (.149)	-.021 (.019)	.158 (.036)	-.769 (.021)
Invent.	-.025 (.055)	.075 (.072)	-.042 (.078)	-.014 (.009)	-.04 (.008)	.003 (.02)
Crops	-1.63 (.402)	-.139 (.261)	1.13 (.408)	.054 (.063)	-.265 (.061)	.820 (.144)
Labour	2.48 (.42)	.28 (.12)	-.215 (.25)	-.154 (.216)	.154 (.13)	-1.024 (.416)
Capital	-3.24 (.74)	1.01 (.223)	2.02 (.466)	.293 (.248)	-.116 (.288)	-.05 (.575)
Materials	3.34 (.47)	-.015 (.109)	-1.32 (.233)	-.414 (.168)	-.011 (.122)	-1.61 (.523)
		C			D	

*standard error in parentheses

Before proceeding with a discussion of this table, recall that the theoretical model developed in Chapter Three provided a number of a priori predictions about the signs of these elasticities. Specifically, output supply functions must have non-negative slopes, derived input demand functions must have non-positive slopes, and there is a negative or substitute relationship between cattle supply and end-of-period inventory demand. An examination of Table 5.6 indicates that all a priori expectations are confirmed.

In describing the elasticities in Table 5.7, it is convenient to divide the table into four sub-matrices (A, B, C, and D) as defined.

In sub-matrix A, the own elasticities of supply and cross price elasticities for cattle, end-of-period inventory, and crop supply are given. Own elasticities of supply for cattle (1.43) and crops (1.13) are statistically significant at the 5 percent level and are positive and greater than one indicating an elastic response to changes in own prices. This implies that output quantities of cattle and crops are significantly altered in response to changes in current prices. The own elasticity of end-of-period inventories however, is positive but less than one (.075), (with a confidence level of 85 percent) indicating an inelastic response to changes in expected cattle prices. This implies that end-of-period inventories of cattle are not substantially altered in response to changes in expected cattle prices.

From the magnitude of these own elasticities, one can argue that cow-calf farmers' output response to changes in expected cattle price is relatively minor (i.e., there is no significant output adjustment in an attempt to counter the cattle cycle). Rather, output supply responds primarily to changes in current cattle price (i.e., changes in cattle output are positively correlated with price fluctuations over the cattle cycle). In other words, these results support the existence of a cattle cycle.

In determining output substitution possibilities, recall that negative cross price elasticities between two quantities imply that they are substitutes and positive cross price elasticities imply complementarity. Using this definition, the estimated cross price elasticities indicate a substitute relationship amongst all output categories. For example, a one percent increase in crop prices results in a decrease in end-of-period inventories and cattle output of -.042% and -.602% respectively. A one percent increase in cattle prices causes a small reduction in inventories (-.025%) but a major shift away from crop production (-1.63%). Finally, a one percent increase in expected cattle prices results in a small decrease in cattle and crop supply of -0.03% and -.139% respectively. However, the magnitude of the standard errors implies that only cattle and crop outputs are statistically significant subsitutes at the 5 percent level.

One can conclude from these cross price elasticities that there is significant scope for changing the output composition between crops and cattle on cow-calf farms in western Canada. In Table 5.8, a summary of the cross price and own price effects are presented.

TABLE 5.8

Summary of Cross Price and Own Price Elasticity

	Cattle	Inventories	Crop
Cattle	Elastic	Substitute	Substitute
Inventories	Substitute	Inelastic	Substitute
Crop	Substitute	Substitute	Elastic

Estimates of cross price and own price input demand elasticities are shown in sub-matrix D in Table 5.7. The own price input demand elasticities for labour and materials are significally negative and greater than one in absolute value at a 5 percent level of significance, indicating an elastic derived demand for both inputs. This implies that in response to an increase in input prices, cow-calf farmers decrease the quantity of labour and material inputs utilized substantially. On the other hand, own derived demand elasticity for capital inputs is negative but less than one in absolute value indicating an inelastic demand for this input. However, this estimate is not statistically significantly different from zero. In other words, the quantity of capital inputs used is not sensitive to changes in own price. The magnitude of these coefficients indicates that employment of capital inputs is more stable relative to employment of labour and material inputs.

The signs of the cross price elasticities in sub-matrix D defines inputs as substitutes or complements. On the input side, a negative cross price elasticity implies complementarity and a positive cross price elasticity implies substitutibility. A one percent increase in the price of capital increases the quantity of labour demanded by .154% (with a standard error of .13). Conversely, a one percent increase in the price of labour increases the quantity of capital demanded by .293% (with a standard error of .248). These two measures define, at the 85 percent confidence level, a substitute relationship between labour and capital. For a given set of relative prices, the strength of the substitution effect between labour and capital implies, mutatis mutandis, that cow-calf farms are substituting away from labour and towards greater capitalization.

On the other hand, a one percent increase in the price of materials reduces the quantity demanded of both labour and capital by -1.024% and -.051% respectively. The magnitude of these elasticities combined with the small standard errors for the labour estimate implies a stronger complementarity between materials and labour than between materials and capital. Further evidence of the degree of complementarity between materials and the other inputs is provided by the fact that a one percent increase in the price of labour or capital reduces the quantity of materials employed by -.414% and -.011% respectively. Again, the complementarity between labour and materials is statistically significant at the 5 percent level whereas the estimated complementarity between capital and materials is not statistically significant.

Table 5.9 summarizes the relationships between inputs for cow-calf farms.

Turning now to examine sub-matrix B, which provides values of the elasticities of output supply with respect to input prices, consider a one percent increase in the price of labour. This results in a reduction in the level of end-of-period inventories and cattle supply of -.014% (statistically significant at the 5 percent level) and -.021% (statistically significant at the 15 percent level) respectively, but it results in an increase in crop production of .054% (although

TABLE 5.9

Summary Classification of Farm Inputs

	Labour	Capital	Materials
Labour	Elastic	Substitute	Complement
Capital	Substitute	Inelastic	Complement
Materials	Complement	Complement	Elastic

this result is not significantly different from zero). This implies that cattle production, and to a lesser extent, end-of-period inventories, are labour intensive operations.

On the other hand, a one percent increase in the flow price of capital results in a large decrease in quantity of crops supplied (-.265%) and a minor decrease in end-of-period inventories (-.04%) but now cattle supply increases by .158%. These estimates are all statistically significant at the 5 percent level and imply that crop production and again, to a lesser extent, end of period inventories, are capital intensive operations.

Finally, a one percent increase in the price of materials has the effect of significantly increasing total crop supply by .820%, but results in a significantly large decrease in cattle supply of -.769%. (End-of-period inventories would increase by .003% but this estimate is not significantly different from zero.) This result would imply that cattle production is also material intensive. Furthermore, this result supports the argument (by cattlemen's groups) that changes in the price of intermediate inputs significantly affects the cost of cattle production and subsequently, the supply of cattle.

Generally, policies that distort downwards the relative price of an input have the effect of increasing the supply of that output which uses the input more intensively. For example, the Canadian government's policy of subsidizing the interest rate on farm loans would tend to decrease the price of farm capital resulting in an increase in the production of crops and a decrease (although smaller in magnitude) in the production of cattle. Classification of outputs according to input intensities is summarized in Table 5.10.

The final sub-matrix (C), provides estimates of the elasticities of input demand with respect to output prices. These elasticities will be used to classify inputs as superior ($\varepsilon ij > 1$), normal ($0 \leq \varepsilon ij \leq 1$), or inferior ($\varepsilon ij < 0$).

Consider a one percent increase in expected inventory prices. This will result in an increase in the quantity of labour and capital demanded by .18% and 1.01% respectively but in a decrease in the quantity of material inputs demanded by -.015%. However, statistical tests indicate that all three inputs can be defined as normal inputs in the production of end-of-period inventories.

Increases in the prices of cattle and crops have considerably larger effects on the demand for inputs. In the production of cattle, labour and materials can be classified as superior inputs: however, capital appears to be an inferior input. Statistical tests on each variable supports this classification. This classification is reversed in the production of crops where capital is now defined as superior and materials calculated to be inferior. Additionally, the large standard errors for the labour estimate results in the classification of labour as a normal input. These input demand elasticities with respect to output supply are conveniently summarized in Table 5.11.

The classification of labour as a superior input in the production of cattle is consistent with the major emphasis

TABLE 5.10

Classification of Outputs
With Respect to Input Use

	Labour	Capital	Materials
Cattle	Intensive	-	Intensive
Inventories	Less Intensive	Less Intensive	-
Crops	-	Intensive	-

TABLE 5.11

Classification of Inputs
With Respect to Output Use

	Cattle	Inventories	Crop
Labour	Superior	Normal	Normal
Capital	Inferior	Normal	Superior
Material	Superior	Normal	Inferior

still placed on the cowboy in the production of cattle in western Canada whereas in the production of crops, labour's inferior classification combined with capital's superior classification is consistent with a net migration of labour off the farm and an emphasis on increasing capitalization.

Policies designed to increase farm prices of either cattle or crops will have quite different effects on rural development. Increasing crop prices will give rise to substitution away from labour which will encourage increased migration off farms and increasing capitalization. Increased cattle prices, on the other hand, will result in increased farm employment.

It would be helpful to compare the elasticity estimates presented in this section with other studies on Canadian agriculture. However, the author is unaware of any past research which reports estimates of elasticities of choice for such disaggregated outputs and inputs combined with specific farm data.

Completing the reporting of empirical results for the multi-output, multi-input translog variable profit function requires a calculation of the total elasticity of cattle supply as defined in Section (4.4) of Chapter Four. Recall that this elasticity measure takes account not only of the effect of cattle price fluctuations, but also the effect of changing expectations of cattle prices on cattle supply.

For convenience, the formula for estimating the total elasticity of cattle supply is reproduced here:

Total Elasticity		Direct Elasticity	Cross Elasticity		Elasticity of Expectations
η_{11}	$=$	$[\varepsilon_{11}]$	$+ [\varepsilon_{12}]$	$\cdot$	$[\xi_{21}]$
	$=$	$[\hat{S}_1 + \hat{\gamma}_{11}/\hat{S}_1 - 1]$	$+ [\hat{S}_2 - \hat{\gamma}_{12}/\hat{S}_1]$	$\cdot$	$\dfrac{[\partial P_2^e}{[\partial \bar{P}_1} \cdot \dfrac{\bar{P}_1]}{\bar{P}_2^e]}$,

The direct elasticity of supply $[\varepsilon_{11}]$ and cross elasticity of supply $[\varepsilon_{12}]$ are calculated, at the means of the exogenous variables, to be 1.43 and -.03 respectively (Table 5.6). Thus, all that is required to generate an estimate of this total elasticity is a measure of the elasticity of expectations. This is determined by first taking a weighted average of the first derivatives of each ARIMA model estimated in Section (4.2) of Chapter Four. This defines an estimate for $\partial\overline{P_2^e}/\partial\overline{P}^1$ which is then transformed using the mean of each price series $\overline{P}_1$ and $\overline{P_2^e}$ to provide a point estimate of the elasticity of expectations. This value is calculated to be .4186.

Given that the cross elasticity of supply is negative and that the elasticity of expectations is positive, this indicates that accounting for adjustments in expectations of cattle prices caused by changes in current cattle price will always decrease the elasticity of cattle supply. However, this effect is not strong enough to reduce the total elasticity of cattle supply to zero or less. The total elasticity is calculated to be 1.41.

Therefore, the results of the estimation do not support a perverse short run supply response. Rather, the evidence clearly indicates a positive short run supply function for cattle in western Canada. Some speculative reasons for this result will be offered after the time-series based results have been examined.

5.3 EMPIRICAL RESULTS USING TIME-SERIES DATA

Before discussing the results generated using a normalized quadratic variable profit function, it is important to emphasize the reasons for estimating these additional time-series parameters.

The cross-sectional results may not fully capture the influence of two characteristics in the cow-calf industry. The first is the cyclical nature of cattle production resulting in well defined price fluctuations. The second is that cattle inventories have increased significantly over the last thirty years. The total number of cattle on farms in 1956 was approximately 11 million head: this number increased to 13 million head by 1982.[4]

Given that price predictions are generated using time series procedures, the first characteristic may not go undetected in the cross-sectional results. However, the time-series sample will certainly allow for greater variability in cattle price data used in the econometric estimation. The second characteristic is more important. Using a time-series data sample, elasticities of choice can be calculated under the condition of increasing cattle inventories. Or in other words, under the constraint that beginning inventories have not adjusted fully to changes in exogenous parameters, these values can then be compared to elasticities generated given the assumption of an optimal beginning inventory (i.e., cross-sectional results).

Initial estimates of the parameters of the two net output supply equations, total cattle supply and total end-of-period inventory demand, were derived using Zellner's SUR technique. However, the Durbin-Watson test indicated first-order autocorrelation in each equation. To correct this problem, all variables used in the estimation were transformed [5] using $\hat{\rho} = 1$ [6] and the model re-estimated. Using the first-differenced transformation indicates that the estimated intercept term can be interpreted as a trend variable (Kmenta 1971, p.290). Consequently, the time trend variable can be droped in the estimation. The estimated parameters are presented in Table 5.12. Three iterations were required for convergence. These equations are estimated under the maintained hypotheses of symmetry of the Hessian matrix and homogeneity of degree zero in prices. Asymptotic t-statistics are given in parentheses.

The signs of the estimated price coefficients are consistent with a priori expectations. That is, own price coefficients are positive: the cattle price coefficient is statistically significant at the 5 percent level and the end-of-period inventory coefficient is statistically significant at the 10 percent level of significance. The crop price coefficient is statistically significant at the 5 percent level in both equations. However, the input price coefficients are not statistically significant in either equation. Contrary to the translog case, positive own output price coefficients are not only a necessary but a sufficient

TABLE 5.12

Regression Coefficients,
Quadratic Profit Function

Coefficients	Equation Cattle	Equation Inventory
Cattle Price'	9989.8 (3.4)*	-14677.0 (2.6)
Expected Gain'	-14677.0 (-2.6)	18339.0 (1.6)
Crop Price'	-2983.5 (-5.1)	4912.9 (4.3)
Labour Price'	0495.21 (-.14)	3014.1 (.42)
Capital Price'	3542.2 (.26)	-7174.7 (-.26)
Beginning Stock	4.4 (9.4)	3.1 (3.4)
Constant	-304.93 (-1.7)	361.76 (1.02)
R^2	.8384	.6941
d.w.	1.4	1.5
SEE	696.92	1370.6

*t-statistic in parentheses

	χ^2	d.f.	$\chi^2(.05)$	Decision
Ho: all coefficients equal to zero	136.38	11	19.68	Reject

condition for generating positive output supply elasticities.

Finally, the estimated coefficients for the beginning stock of cattle variable are statistically significant at the 5 percent level in both output equations.

The intercept term for the cattle equation is significantly negative at the 95 percent confidence level, whereas for the end-of-period inventory equation the intercept term is significantly positive at only the 80 percent confidence level. This indicates that technical change has been biased against cattle production but in favor of end-of-period inventories.

The technical bias against cattle production has been reported in other studies (McKay, Laurence, and Vlasterin 1982). Additionally, these studies have been able to demonstrate a bias in favor of crop production. However, data limitations prohibit estimating the crop equation and therefore this result could not be tested. The technical bias in favor of end-of-period inventories indicates that technical change has enabled farmers to maintain larger cattle inventories. This has been achieved primarily by technical advancements that enable farmers to efficiently feed large numbers of animals. Moreso, this result is consistent with observed increases in the aggregate herd over the period of this study.

Summary measures of goodness of fit estimates are also reported in Table 5.12. The equations have R^2 measures of .8384 and .6941 for total cattle supply and total end of period inventory demand respectively. These statistics indicate that the estimated equations explain the variation in output quantities well. The Durbin-Watson statistic (for the transformed variables) implies that autocorrelation is not a serious problem. Finally, a Chi-squared test statistic for the null hypothesis that all estimated coefficients are equal to zero shows an easy rejection.

Because only two net output equations can be estimated, many of the parameters of the normalized quadratic variable profit function are unknown. Consequently, it is not possible to determine whether the properties of duality are fully satisfied. However, the two estimated equations can be evaluated to determine the consistency of their estimated coefficients with the desired properties.

Both equations satisfy the monotonicity requirement at each observation. That is, both equations predict positive output response. Furthermore, both equations satisfy the necessary condition for obtaining a positive semidefinite Hessian matrix (i.e., own price coefficients are positive). From these results, it is assumed that the estimated net output equations probably satisfy the duality properties and therefore represent the profit maximizing behavior of cow-calf producers.

Using the formulas presented in Section (4.4) of Chapter Four, estimates of the partial elasticities of choice are given in Table 5.13. These estimates are computed at the means of the exogenous variables. In describing these elasticities, it will be convenient to once again divide the table into sub-matrices (here A, B, and C).

TABLE 5.13

Elasticities of Choice (Quadratic)

	Prices						
	Cattle	Invent.	Crop	Labour	Cap.	Materials	Beginning Stock
Cattle	.19	-.083	-.269	-.031	.043	.295	1.8
Invent.	-.099	.037	.16	.067	-.03	-.10	.47

In sub-matrix A, the own elasticities of supply as well as cross price elasticities for total cattle supply and end-of-period inventories are displayed. Own elasticities of supply are consistent with a priori expectations and are positive: however, both cattle supply (.19) and inventory (.037) elasticity estimates are less than one indicating an inelastic response to price variations.

The inelastic response for end-of-period inventories is consistent (although smaller in magnitude) with the estimate obtained using the cross-sectional translog model. However, the inelastic cattle supply response is significantly lower than the one obtained using the cross-sectional translog model. The alternative own-elasticity estimates are compared in Table 5.14.

What these results indicate is that under the general restriction of increasing herd size (i.e., constrained adjustment to optimal herd levels), the own elasticity of supply for both cattle supply and end of period inventories is reduced. These results provide empirical evidence to support the Le Châtelier principle discussed in Section (4.3) of Chapter Four.[7]

It is worth noting that the magnitude of the time-series estimated elasticities support results presented earlier that cow-calf farmers respond relatively less to changes in expected cattle prices than to changes in current cattle prices.

The estimated cross price elasticities given in sub-matrix A of Table 5.13 are consistent with a priori

TABLE 5.14

Summary of Own Elasticity of Supply

	Translog (Cross-Sectional)	Quadratic (Time-Series)
Cattle	1.43	.19
Inventory	.075	.037

expectations and indicate a substitute relationship between crops and cattle supply (-.269), between cattle supply and end-of-period inventory (-.083), and between end-of-period inventory and cattle supply (-.099). However, the cross price elasticity between crops and end-of-period inventories is .16 which suggests a complementary relationship between these two inputs. This result is opposite to that generated in the cross-sectional translog model. However, these results again demonstrate considerable scope for changes in the exogeneous variables to influence the output composition on cow-calf farms.

These empirical findings indicate that during periods when inventories of animals are increasing, an increase in crop prices results in a reduction in cattle supply but causes an increase in the number of animals held in inventory. On the other hand, if cattle inventories are at an optimal level, an increase in crop prices results in a reduction in both cattle supply and end-of-period inventories.

Sub-matrix B defines the elasticity of output supply with respect to input prices. The elasticity estimates for the materials and services variable are derived from the estimated equation using the symmetry and homogenity restrictions. A one percent increase in the price of labour will decrease total cattle supply by -.031% (which is consistent with results obtained for the translog variable profit function) but increases end-of-period inventories by .067%. A one percent increase in the price of capital or materials and services will increase total cattle supply by .043% and .295%

respectively but decrease end-of-period inventories by -.03% and -.10% respectively.

Finally, sub-matrix C shows the elasticity of output supply with respect to beginning inventories. Both estimates are positive, indicating that a one percent increase in the beginning number of animals will increase both cattle supply by 1.8% and animals held in inventory by .47%. The magnitude of these results again indicate cow-calf farmers' preferences for current cattle production over future cattle production.

Following procedures previously outlined, the total elasticity of cattle supply can be calculated for the time-series estimates. Table 5.15 reports the value of this elasticity, estimated at the means of the exogenous variables, and for each observation.

These estimates indicate that if expectations are allowed to adjust to changes in cattle prices output supply will always decrease. That is, cow-calf farmers will alter end-of-period inventories and cattle supply in response to changing cattle prices and expected prices. However, there is no evidence to indicate that this tendency is sufficiently strong enough to decrease short run elasticities of supply to zero or less. These results support evidence presented earlier and therefore, one can conclude quite strongly that short run cattle supply functions are positively sloped throughout. However, it is worth noting that the total elasticity of cattle supply is inelastic for non-optimal levels of cattle inventories but as cattle inventories approach an optimal level, the elasticity of

TABLE 5.15

Total Elasticity of Cattle Supply

	Total Elasticity of Supply
Means of Exogeneous Variables	.16
1956	.095
1957	.073
1958	.102
1959	.121
1960	.083
1961	.104
1962	.084
1963	.103
1964	.080
1965	.067
1966	.071
1967	.078
1968	.071
1969	.105
1970	.134
1971	.101
1972	.102
1973	.128
1974	.071
1975	.037
1976	.036
1977	.046
1978	.103
1979	.151
1980	.082
1981	.057
1982	.058

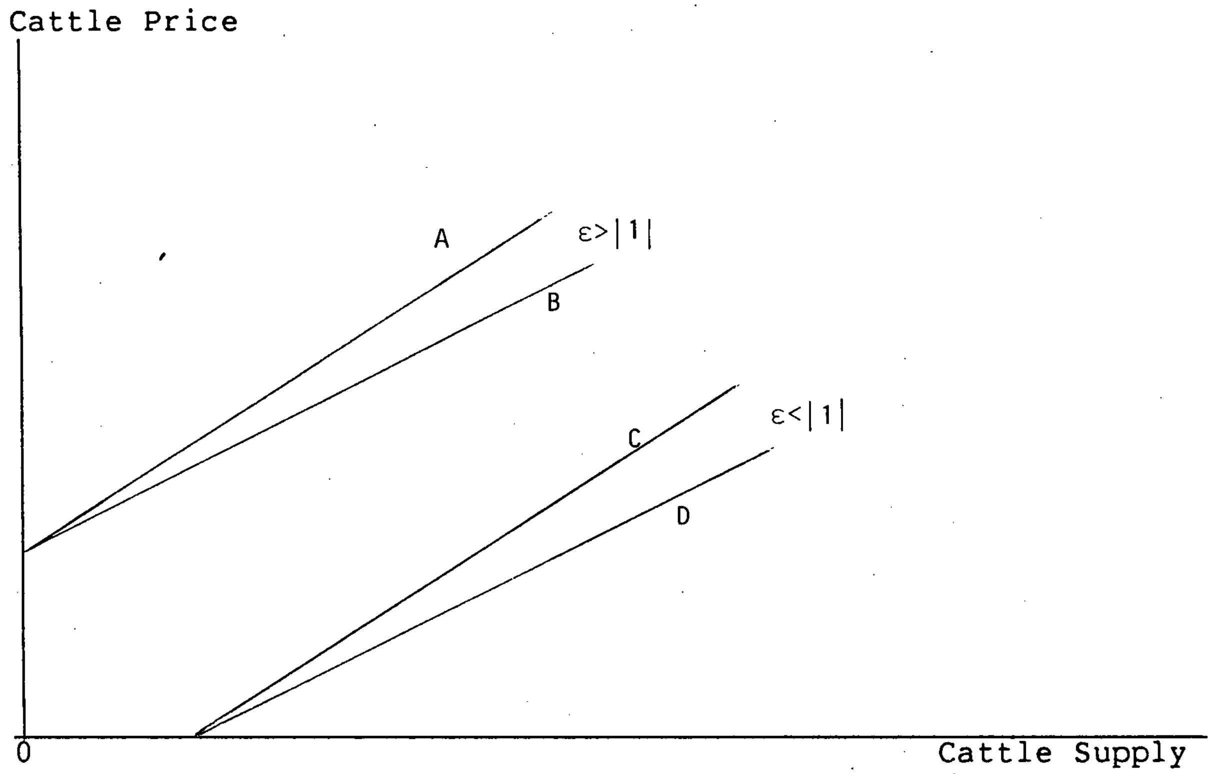
cattle supply increases and in fact, becomes elastic. Figure 5.1 provides a visual accounting (for illustration only) of the effect of changing price expectations on the slope of the cattle supply function for both the cross-sectional and time-series results. Curves A and B represent the cross-sectional results whereas C and D represent the time-series results. Allowing price expectations to adjust to changes in current price increases the slope of the supply functions (from B to A and from D to C) which decreases the elasticity of cattle supply in both cases.

To complete the empirical presentation, Table 5.16 provides a summary of the total elasticity of supply estimates generated in this study and other estimates of these short run elasticities as reported in past research.

Before concluding this chapter, it is appropriate to offer some explanation of why there is no evidence of perverse short run behaviour in the Canadian cow-calf industry. Three factors can be identified which may influence this behaviour. First, in terms of North American cattle supply, Canada is a small open economy with cattle prices determined in the U.S. market. Factors external to the Canadian market cause fluctuations in cattle prices. The cow-calf farmer may or may not be aware of these factors but eitherway, this increases the uncertainty of predicting future cattle prices. The consequences of this may be that the cow-calf farmer responds relatively more to changes in current cattle prices than to expected price changes. Second, defining fluctuations in prices and cattle marketings as a cattle cycle tends to imply

FIGURE 5.1

Supply Functions,
Cross-Sectional versus Time-Series



A - Cross-sectional : Price expectation adjustment
B - Cross-sectional : No adjustment
C - Time-series : Price expectation adjustment
D - Time-series : No adjustment

TABLE 5.16

Summary of Cattle Supply Elasticities

Elasticity with respect to the Price of:

	Feeder Cattle	Non Feeder Cattle	All Cattle
This Study All Cattle (Canada) Translog (cross-sectional)	-	-	1.41
Quadratic (time-series)	-	-	.16
Other Studies Ospina & Shumway (U.S)	-	-	-.45
Langemier & Thompson (U.S.) feeder cattle	-.98	.30	
non feeder cattle	1.42	-1.24	
all cattle			-1.06
George & King (U.S.) all cattle	-	-	-.42
Tryfos (Canada)	-	-	-.009
Yver (Argentina) all cattle (short run)			-1.61
all cattle (long run)			1.15

some regularity to these variations. This is not the case. It is not surprising then that cow-calf farmers do not respond to price changes as if they were clearly defined cyclical fluctuations. This factor would imply a preference for current production over future production. Third, empirical evidence indicates considerable scope for output substitution on cow-calf farms. This will allow cow-calf farmers to alter their output composition in response to changes in prices and expected prices.

To conclude this dissertation, a summary of findings and conclusions is presented in Chapter Six.

FOOTNOTES TO CHAPTER FIVE

1 Asymptotic t-ratios are defined as the ratio of the parameter estimates to their asymptotic standard errors.

2 Using rather complicated non-linear transformations one can impose convexity on the model (Lau 1978). However, this procedure imposes convexity at only one point (i.e., the point of expansion) and is rather costly computationally to perform.

3 I would like to thank Dr. Ken White for his assistance in deriving the standard errors for the elasticity estimates.

4 Canadian cattle numbers reached a high of 15.6 million head in 1975. Statistics Canada, Livestock and Animal Products Statistics 23-203, Ottawa, various issues.

5 Each variable is transformed according to the following formula:

$$X_t - \hat{\rho}X_{t-1} = \tilde{X}_t.$$

6 The variables were transformed using alternative estimates for $\hat{\rho}$, however, except for $\hat{\rho} = 1$ the Durbin-Watson test indicated that first-order autocorrelation remained.

7 In addition, the Le Châtelier Principle implies restrictions on the cross-price elasticities. However, because only two output equations are estimated this restriction can not be tested, see Diewert (1974).

6. SUMMARY AND CONCLUSIONS

The purpose of this chapter is to present a brief summary of the dissertation and to report the principal findings and conclusions.

The cow-calf farmer is engaged in the primary activity of reproducing animals and selling the progeny. The basic decisions facing the farmer are whether to sell an animal now, feed to heavier weights before selling, or retain the animal in the breeding herd for the purpose of producing new animals. The decision to sell an animal or to keep it in the breeding herd depends on prevailing and expected economic conditions.

These basic production decisions can give rise to an interesting economic characteristic whereby the elasticity of supply in the short run is negative and gradually becomes positive over a long adjustment period. Given an increase in the price of beef expected to persist into the future, the cattle producer will find it profitable to retain animals in the herd that otherwise may have been sold. For steers, this implies keeping the animal longer and fattening to heavier weights. For heifers and cows, it implies either fattening to heavier weights (heifers) or breeding the animals to obtain calves. In the aggregate and in the short run, this indicates that there will be a decrease in the slaughter of all animals. In the long run, the supply elasticities of beef will be positive due to the increase in herd size and average weights.

The aim of this study was to develop a theoretical profit maximizing model of a cow-calf farm that explains this behavior in the short run and to empirically estimate short run supply response and investment behavior of cattle producers.

In developing the theoretical model, the cow-calf farmer was assumed to have a predetermined stock of animals at the beginning of each period. Moreover, at any point in time, current beef and factor prices were known but next period's beef prices were uncertain.

The farmer combines the initial stock of animals with a vector of variable inputs and, responding to an economic environment given output prices, input prices, and his expectations about price next period, the farmer determines the stock of animals retained at the end of the period and the output supply during the period. End-of-period stocks are valued at expected output price next period and current output supply is valued at output price this period.

This simple dynamic behavior can be characterized using a dual variable profit function where profits are a function of output prices, expected output prices, input prices, and predetermined stocks of animals. By applying Hotelling's Lemma to the variable profit function, the optimal quantities of output supply, input demand, and end-of-period inventories can be determined. These equations can be used to postulate an econometric model.

Using the theoretical model, a comparative static analysis was carried out to determine short run supply response of cow-calf farmers. In this model, the sign of the short run elasticity of cattle supply depends on three factors: i) the technological structure of the industry; ii) the substitution possibilities between production today and production tomorrow; and iii) the sensitivity of farmers' price expectations with respect to changes in current price. One can conclude from this result that a short run negative supply elasticity in the cow-calf industry is not a prediction from economic theory: rather the sign of the elasticity is unknown and will depend on price expectations of producers.

The first stage in estimating the system of output, input, and end-of-period inventory equations required specifying some expectation process to be used in predicting next period's cattle prices. A "quasi-rational" expectation process was posited to predict exactly the price expectations of cow-calf producers. This expectation procedure was based on a time series method whereby an autoregressive integrated moving average model was hypothesized to represent the expectation process. An ARIMA model was estimated for each expected price variable in the model. The predictions generated by these estimated models were combined with the main data base to complete the data requirements necessary for econometric estimation.

To estimate the full variable profit function, the following information was required: i) the quantity of different outputs produced by cow-calf farms and associated output prices; ii) the quantity of different inputs used on farms and associated input prices; ii) the end-of-period stocks of cattle and associated expected prices; and iv) the beginning stocks of cattle. Two surveys conducted by

Statistics Canada (FES and NLS) were the primary sources for inventory and expenditure data on cow-calf farms. The FES is a cross-sectional data series whereas the NLS is a time-series data sample. Because of the cyclical nature of beef production, the time-series data set allowed for elasticity measurements over the beef cycle which could be compared to the cross-sectional results during a single period of the cycle. Generally, prices of farm inputs were obtained from the main Cansim files of Statistics Canada and cattle output prices were obtained from market quotations reported in the Livestock Market Review.

It was decided, for a tractable econometric specification, to specify three aggregate output variables (total cattle supply sold off farms, end-of-period inventory demand, and total crop supply), three aggregate input variables (labour, capital, and materials and services), and one fixed factor representing the beginning stock of cattle.

The transcendental logarithmic functional form was postulated for the multi-output, multi-input variable profit function. For econometric estimation, Hotelling's Lemma was used to obtain the revenue share equations for each output and expenditure share equations for each input. Zellner's SUR technique was employed (combined with the cross-sectional data sample) to estimate this system of equations. The estimated coefficients were used to test for structure and to calculate elasticities of choice for the cow-calf industry.

Alternative estimates of the elasticities of choice could then be generated using the time-series data sample. However, a number of variables required to estimate the full profit function were not available on a time-series basis. Specifically, this data set did not include information on total profits, crop production, or the quantities of inputs used on cow-calf farms. It did include information on current cattle prices, expected cattle prices, crop prices, input prices for labour, capital, and materials and services, and inventories of cattle on cow-calf farms.

From the available time-series data, net output supply equations were specified for total cattle output supply and total end-of-period inventory demand. It is unfortunate that because the profit variable was absent from the data, a translog functional form could not be specified for the variable profit function. Instead, a normalized quadratic functional form was used.

For the translog variable profit function case, the estimated coefficients of the revenue and expenditure share equations were generally statistically significant with the share equations providing a good fit to the data. Furthermore, statistical testing indicated that the estimated variable profit function satisfied the required duality properties of symmetry, linear homogeneity in prices, and monotonicity. Convexity of the Hessian matrix was determined at each observation by calculating the associated eigenvalues. Unfortunately, convexity failed because one eigenvalue was negative at each observation. However, it is assumed that the true profit function is convex in prices. Consequently, one can conclude that the estimated share equations have performed well and that they adequately represent the profit maximizing behavior of cow-calf producers.

The estimated coefficients of the revenue and expenditure share equations were used to test for certain characteristics of the underlying transformation function. It was determined that the technological structure of cow-calf production in western Canada is defined by a non-homothetic, non-homogeneous transformation function subject to decreasing returns to scale and joint production between crops and cattle.

Other characteristics of the cow-calf industry were determined by calculating elasticities of choice. These elasticities conformed to all a priori expectations with output supply functions having non-negative slopes, derived input demand functions having non-positive slopes, and a substitute relationship predicted between cattle supply and end-of-period inventory demand.

Own elasticities of supply for cattle and crops indicated an elastic response to changes in own prices whereas the own elasticity of end-of-period inventories indicated an inelastic response to changes in expected cattle prices.

These results imply that there is no significant output adjustment in an attempt to counter the cattle cycle. Rather changes in cattle output are positively correlated with price fluctuations over the cattle cycle. In other words, these results support the existence of a cattle cycle.

In addition, cross-price elasticities defined a substitute relationship amongst all output categories. This indicates significant scope for changing the output composition between crops and cattle on cow-calf farms in western Canada.

The own elasticities of input demand for labour and materials implied an elastic demand for both inputs whereas the own elasticity of input demand for capital indicated an inelastic demand for this input. This implies that the employment of capital inputs on farms is more stable relative to the employment of labour and materials inputs.

The cross price elasticity between labour and capital defined these inputs as substitutes. Moreover, for a given set of relative prices, the strength of this substitution effect implied that cow-calf farms are substituting away from labour and towards greater capitalization.

Other elasticity results suggested that in the production of cattle, both labour and materials are used more intensively than capital inputs. Conversely, in the production of crops, the capital input is used more intensively than other inputs.

In the production of each output, inputs were classified as being superior, normal, or inferior. From this classification, it was concluded that policies designed to increase farm prices of either cattle or crops will have quite different effects on rural development. Increasing crop prices will give rise to substitution away from labour which will encourage increased migration off farms and increasing capitalization. Increased cattle prices, on the other hand, will result in increased farm employment.

To complete the empirical results for the translog variable profit function, the total elasticity of cattle supply was calculated. This elasticity measure takes account not only of the effect of cattle price fluctuations, but also the effect of changing expectations of cattle prices on cattle supply. It was determined that accounting for adjustments in expectations of cattle prices caused by changes in current cattle prices will always decrease the elasticity of cattle supply. However, this effect was not strong enough to reduce the total elasticity of cattle supply to zero or less.

The elasticities estimated using the normalized quadratic variable profit function combined with the time-series data provided alternative measures (although generally similar) to compare with the cross-sectional results.

Own supply elasticities were consistent with a priori expectations and were positive. However, both cattle supply and inventory estimates were inelastic and smaller in magnitude than the corresponding cross-sectional elasticities.

The cross price elasticities on the output side defined (as expected) a substitute relationship between crops and cattle which again implied that considerable scope exists for changing the output composition between crops and cattle on cow-calf farms.

Finally, the total elasticity of cattle supply was calculated for the time-series estimates. In calculating this elasticity, it was again determined that if expectations are allowed to adjust to changes in cattle prices, output supply will always decrease. However, there is no evidence to indicate that this tendency was significantly strong enough to decrease short run elasticities of cattle supply to zero or less. Therefore, one may conclude that although negative short run supply elasticities are a theoretical possibility in the cow-calf industry, empirical evidence indicates that the short run cattle supply function in western Canada is positively sloped throughout.

It is appropriate to complete a dissertation by offering some suggestions for future research. There are three areas which may offer some potential for increasing our understanding of the technological structure of cattle production and provide additional information for policy determination: 1) the empirical implications of using alternative price expectation processes in modelling the cow-calf industry-- specifically, the empirical consequences of using continuous and discrete processes for predicting cattle prices; 2) modelling the input side of cow-calf technology with greater precision and testing for separability-- the Farm Expenditure Survey can provide the data necessary for this examination; 3) specifying a Gorman Polar Form to represent the variable profit function-- this will impose exact aggregation on the model and presumably provide more accurate empirical results.

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APPENDIX

A. Farm Expenditure Survey Questionnaire, 1981

SECTION A. OPERATING ARRANGEMENTS

Section R | 110 | | 9

1. At July 1, 1981, was this farm being operated as:

(a) an individual or family holding (excluding partnerships and corporations)?	111		1	(Go to Question 3)
(b) a partnership? (i) with a written agreement	111		2	(Go to Question 2)
(ii) with no written agreement (a verbal partnership)	111		3	(Go to Question 2)
(c) a corporation or company?	111		4	(Go to Question 3)
(d) a community pasture or co-operative grazing association?	111		5	(Go to Question 3)
(e) a Hutterite colony?	111		6	(Go to Question 3)
(f) other? Please specify. ______	111		7	(Go to Question 3)

2. If a partnership, record name(s) and address(es) of partner(s).
If one or more of the partners operate another farm entirely separate from this farm, DO NOT INCLUDE this other farm when completing this questionnaire for the partnership farm.

What are the names and addresses of the partners?

Name	Address
	(Go to Question 3)
Name	Address
	(Go to Question 3)
Name	Address
	(Go to Question 3)

3. Is the operator a hired manager? .... Yes [ ]   No [113 | | 2] (Go to Section B)

What is the name and address of the OWNER?

Name	Address

4-3104-414.1

SECTION B. AREA AND LOCATION OF FARM LAND OWNED, RENTED OR MANAGED

Section R	120		9

This section deals with all the land you OPERATE at the present time including cropland, woodland, waste land, pasture land and summerfallow.

- Include land you MANAGE FOR OTHERS and land you RENT FROM OTHERS as well as land you OWN.
- Exclude land you RENT TO OTHERS.

1. Is the headquarters of the holding situated within the boundaries of the segment? . . . . . Yes | 121 | | 1 |
   No | 121 | | 2 |

(X) one box

2. Will the land area figures in this questionnaire be reported in acres? . . . . . ☐

   OR

   hectares? . . . . . | 128 | | 2 |

	Total land operated at July 1, 1981 (1)	Land operated inside segment at July 1, 1981 (2)
3. Of the total land area you operated July 1, 1981, how much did you: (a) Rent or lease from others?	126 None ☐	123 None ☐
(b) Own and operate? • Exclude land rented to others	125 None ☐	122 None ☐
4. Total land operated July 1, 1981 *(Sum 3a and 3b)*	127	124
5. Of the total land reported above, what is the area of woodland? • Include woodlots, cut-over land, etc.	129 None ☐	130 None ☐

	Total Land Operated at July 1, 1980
6. At July 1, 1980 how much land did you operate? Include land rented or leased FROM others. Exclude land rented or leased TO others	131 None ☐

EDIT:
Are the figures in Column (1) greater than or equal to the corresponding figures in Column (2)?
Yes ☐ *(Go to Section C)* No ☐ ——▸ *Make corrections with respondent. Continue*

4-3104-414.1

SECTION C. LAND USE

Section R	200		9

This section deals with land use for this year and last year.

1. Did you grow any wheat, oats, barley, rye, flaxseed, rapeseed or mustard seed last year OR are you growing any of these crops this year?

Yes ☐ No | 201 | | 2 | *(Go to Part B)*

PART A: THE SEVEN GRAINS

	Total Land Operated at July 1, 1980 *to the nearest acre (hectare)* Seeded 1980 (last year) (1)		Total Land Operated at July 1, 1981 *to the nearest acre (hectare)* Seeded 1981 (this year) (2)	
2. Wheat:				
(a) Durum	None ☐	202	None ☐	252
(b) Utility	None ☐	203	None ☐	253
(c) Spring (red or white)	None ☐	204	None ☐	254
(d) Winter	None ☐	205 Harvested 1980	None ☐	255 Remaining for harvest in 1981
3. Oats	None ☐	206	None ☐	256
4. Barley	None ☐	207	None ☐	257
5. Rye (a) Fall	None ☐	208 Harvested 1980	None ☐	258 Remaining for harvest in 1981
(b) Spring	None ☐	209	None ☐	259
6. Flaxseed	None ☐	210	None ☐	260
7. Rapeseed (canola)	None ☐	211	None ☐	261
8. Mustard seed	None ☐	212	None ☐	262
9. Total seven grains *(Sum 2 to 8)*	None ☐	213	None ☐	263

COMMENTS:

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SECTION C. LAND USE (concluded)

Transfer the totals reported in question 9, Box 213 and Box 263 to their respective boxes in question 10 below.

PART B. – OTHER LAND USE	Total Land Operated at July 1, 1980 *to the nearest acre (hectare)* — Seeded 1980 (last year) (1)		Total Land Operated at July 1, 1981 *to the nearest acre (hectare)* — Seeded 1981 (this year) (2)	
10. Total seven grains *(from Boxes 213 and 263)*	None ☐		None ☐	
11. Cqrn (a) for grain	None ☐	214	None ☐	264
(b) for fodder and ensilage	None ☐	215	None ☐	265
12. Other crops (include mixed grains, sunflower seed, vegetables, pulses, etc.)	None ☐	216	None ☐	266
13. Tame hay (area cut or to be cut for hay, ensilage or seed). • Exclude wild hay	None ☐	217	None ☐	267
14. Summerfallow	None ☐	218	None ☐	268
15. Improved land for pasture or grazing (improved by seeding, draining, irrigating, fertilizing, or brush or weed control)	None ☐	220	None ☐	270
16. Other improved land (barnyards, lanes, home gardens, improved idle land, etc.)	None ☐	223	None ☐	273
17. Woodland • Include woodlots, cut-over land, etc.	None ☐	224	None ☐	274
18. Other unimproved land (unimproved hayland, native pasture, sloughs, marshes, etc.) Exclude woodland	None ☐	225	None ☐	275
19. Total all land *(Sum 10 to 18)*..................	None ☐	222	None ☐	272

EDIT:

1. Does the figure in Box 272 equal the figure in Box 127 (Page 3)?
   Yes ☐ No ☐→ Make corrections with respondent. *Continue.*
2. Does the figure in Box 274 equal the figure in Box 129 (Page 3)?
   Yes ☐ No ☐→ Make corrections with respondent. *Continue.*
3. Does the figure in Box 222 equal the figure in Box 272?
   Yes ☐ *(Go to Section D)* No ☐→ Ask respondent for reason and write it below?

____

____

SECTION D. GRAINS FED (NON-COMMERCIAL)

Section R	280		9

1. Did you feed any oats, barley or feed wheat to livestock during the 11-month period August 1, 1980 to July 1, 1981?
   - Include whole, chopped, rolled and crushed grain both with and without commercial supplements added.
   - Exclude – brand name commercially prepared feeds.
     – grains grown together

Report SEPARATELY all grains mixed together AFTER harvest

Yes ☐ No | 281 | | 2 | *(Go to Section E)*

2. How will your grains fed figures be reported? .... Bushels .... ☐

Tons of 2,000 lbs.	282		2
Metric tonnes	282		3

3. For the last eleven months, that is, between August 1, 1980 and July 1, 1981, please estimate the total amount of the following grains fed to livestock:

	Amount fed between August 1, 1980 and July 1, 1981 on total land operated
(a) Oats fed	283 None ☐
(b) Barley fed	284 None ☐
(c) Wheat fed (feed, utility or other)	285 None ☐

COMMENTS:

SECTION E. CATTLE AND CALVES

Section R 400 | | 9

1. Since January 1, 1981, have you had, or do you have, cattle or calves on the land you operate?
   - Include – all animals on this holding, regardless of ownership.
   - Include – all animals OWNED BY YOU but pastured on a community pasture or public land.
   - Exclude – animals OWNED BY YOU but kept on a farm, ranch or feedlot operated by someone else.

Yes ☐ No 401 | | 2 *(Go to Section F)*

PART A. INVENTORY AT JULY 1, 1981

	Total Number at July 1, 1981
2. Bulls, 1 year and over	403 None ☐
3. Cows (all cows and heifers which have calved at least once) (a) mainly for DAIRY purposes	404 None ☐
(b) mainly for BEEF purposes	405 None ☐
4. Heifers, 1 year and over (which have never calved) (a) raised for DAIRY herd replacement	406 None ☐
(b) raised for BEEF herd replacement	407 None ☐
(c) raised for SLAUGHTER	402 None ☐
5. Steers, 1 year and over	408 None ☐
6. Calves, under 1 year old	409 None ☐
7. Total cattle and calves *(Sum 2 to 6)*	410 None ☐

8. Does this figure *(Enter Box 410)* ________ account for all of the cattle and calves on the land operated, plus all those kept on community pasture and on public land?

Yes ☐ → *(Go to Question 9)*

No ☐ → *Make corrections, then go to Question 9.*

9. Did you milk any cows YESTERDAY?

Yes ☐ No 431 | | 2 *(Go to Part B)*

(a) How many cows were milked YESTERDAY?	Total Number 419
(b) How much milk did these cows produce YESTERDAY? (1 pound = 0.44 litre, 1 kilogram = 1 litre approx., 1 gallon = 4.5 litres)	Litres (1 day's production) 420

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SECTION E. CATTLE AND CALVES (concluded)

PART B. CHANGE IN CATTLE AND CALF INVENTORIES FROM JUNE 3, 1981 CENSUS TO JULY 1, 1981.

10. Since the June 3, 1981 Census of Agriculture, please report the number of:

	Total Number
(a) Births, purchases, and transfers to the land you operate (between June 3, 1981 and July 1, 1981)	428 None ☐
(b) Deaths, sales, slaughterings and transfers from the land you operate (between June 3, 1981 and July 1, 1981)	429 None ☐

PART C. CALVINGS AND DEATHS

All questions below refer to 6 month periods

	Total Number
11. How many calves were born alive since January 1, 1981, that is, during the past 6 months, on the land you operate?	421 None ☐
12. How many cows and heifers are expected to calve before January 1, 1982, that is, during the next 6 months?	424 None ☐
13. How many cattle (1 year and over) have died, or have been destroyed, as a result of accident, injury or disease since January 1, 1981?	426 None ☐
14. How many calves (under 1 year) have died, or have been destroyed, as a result of accident, injury or disease since January 1, 1981?	427 None ☐

COMMENTS:

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SECTION F. PIGS (concluded)

PART B. CHANGE IN PIG INVENTORY FROM JUNE 3, 1981 CENSUS TO JULY 1, 1981

7. Since the June 3, 1981 Census of Agriculture, please report the number of:

	Total Number
a) Births, purchases and transfers to the land you operate (between June 3, 1981 and July 1, 1981)	640 None ☐
b) Deaths, sales, slaughterings and transfers from the land you operate (between June 3, 1981 and July 1, 1981)	641 None ☐

PART C. FARROWINGS, BIRTHS AND DEATHS

All questions below refer to 3 month periods

	Total Number
8. How many sows and gilts farrowed during April, May and June 1981 on the land you operate?	634 None ☐
9. How many pigs were born alive during April, May and June 1981 on the land you operate?	635 None ☐
10. How many pigs have died, or have been destroyed, as a result of accident, injury or disease BEFORE weaning during April, May and June 1981?	636 None ☐
11. How many pigs have died, or have been destroyed, as a result of accident, injury or disease AFTER weaning during April, May and June 1981?	637 None ☐
12. How many sows and gilts are expected to farrow during July, August and September 1981?	638 None ☐
13. How many sows and gilts are expected to farrow during October, November and December 1981?	639 None ☐

SECTION F. PIGS

Section R	600		9

1. Since April 1, 1981, have you had, or do you have, pigs on the land you operate?
   - Include all pigs on this holding regardless of ownership.
   - Exclude pigs owned by you but kept on a farm operated by someone else.

Yes ☐ No | 601 | | 2 | *(Go to Section G)*

PART A. INVENTORY AT JULY 1, 1981

		Total Number at July 1, 1981
2. Boars 6 months and over for breeding		605 None ☐
3. Sows for breeding and bred gilts		606 None ☐
4. All other pigs	(i) Under 45 pounds (20 kg)	607 None ☐
	(ii) 45 to 130 pounds (20 to 60 kg)	608 None ☐
	(iii) over 130 pounds (60 kg)	609 None ☐
5. Total pigs *(Sum 2 to 4)*		610 None ☐

6. Does this figure *(Enter Box 610)* ______ account for all of the pigs on the land operated?

Yes ☐ → *(Go to Part B)*

No ☐ → *Make corrections, then go to Part B*

COMMENTS:

1104-414.1

SECTION G. OTHER LIVESTOCK OR POULTRY

Section R	300		9

1. At July 1, 1981, do you have SHEEP and LAMBS, POULTRY or OTHER LIVESTOCK on the land you operate?
   - Include all livestock and poultry on this holding regardless of ownership.
   - Include all livestock OWNED BY YOU but pastured on a community pasture or public land.
   - Exclude livestock and poultry OWNED BY YOU but kept on a farm operated by someone else.

Yes ☐ No | 301 | | 2 | *(Go to Section H)*

PART A. SHEEP AND LAMBS

	Total Number at July 1, 1981
2. Sheep and Lambs	304 None ☐

PART B. POULTRY

	Total Number at July 1, 1981
3. HENS and PULLETS, 20 weeks of age and over, kept for laying	503 None ☐

4. OTHER POULTRY (for example, broilers, turkeys, ducks, etc.)

PLEASE SPECIFY	Total Number at July 1, 1981

OFFICE USE ONLY

504 None ☐

PART C. OTHER LIVESTOCK

5. Please list any OTHER LIVESTOCK (for example horses, goats, rabbits, etc.)
   - Exclude family pets.

PLEASE SPECIFY	Total Number at July 1, 1981

OFFICE USE ONLY

505 None ☐

SECTION H. FARM BUSINESS EXPENSES (H1 TO H17)

Enter figure reported in Box 131, question 6, page 3 .... None ☐

Is the amount reported above greater than zero? Yes ☐(Below) ...... No ☐ *(Go to Section K)*

The following sections deal with farm operating expenses that you had during the calendar year 1980. In cases where records are not kept on a calendar year basis, expenses should be reported for the most current fiscal year end.

Calendar Year refers to the period January 1 to December 31. Fiscal Year refers to any twelve month period which a business uses as its income tax year (for example, April 1 to March 31.)

SECTION H1. RENTAL AND LEASING EXPENSES FOR AGRICULTURAL LAND OR BUILDINGS

Section R | 700 | | 9

1. Did you have any cash rent, share rent or leasing expenses in 1980 for agricultural land or buildings rented or leased from others?
   - Include – taxes paid by you on property rented from others.
     – community pasture or other grazing fees.

Yes ☐ No | 701 | | 2 | *(Go to Section H2)*

	Total expense in 1980 $
2. In 1980, what was the amount of your:	
(a) Cash rent or leasing expenses?	702 None ☐ .00
(b) Share rent or rent-in-kind (estimated dollar value)?	703 None ☐ .00
3. Total rental and leasing expenses *(Sum 2a and 2b)*	704 .00

EDIT:
1. Is box 126, page 3 equal to zero? If yes, please specify reason for rent or leasing expenses ______________________

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SECTION H2. OPERATING EXPENSES FOR MOTOR VEHICLES AND FARM MACHINERY

Section R | 710 | | 9

1. Did you have any operating expenses for motor vehicles and farm machinery during 1980?
   - Include farm business share of car.

Yes ☐ No 711 | | 2 *(Go to Section H3)*

	Total Farm Business Expense in 1980 $
2. During 1980, what were your farm expenses for:	
(a) Fuel, oil and lubricants: report amount paid before any rebates are received from claims made to the federal or provincial governments	720 None ☐ .00
(b) Repairs, maintenance, license, registration and insurance costs, (include parts, labour, tires, batteries, antifreeze, etc.)	721 None ☐ .00
3. Total expense *(Sum 2a and 2b)*	722 .00

COMMENTS:

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SECTION H3. SEED

Section R | 730 | | 9

1. Did you have any expenses during 1980 for the purchase of seed and seedlings?

Yes ☐ No 731 | | 2 *(Go to Section H4)*

If seed treatment or cleaning costs were included in the purchase price, report total expense.

	Total expense in 1980 $
2. During 1980, what were your expenses for:	
(a) Wheat, oats, barley, rye, flaxseed, rapeseed and mustard seed?	732 None ☐ .00
(b) Other seed? Please specify ________	733 None ☐ .00
3. Total seed expenses *(Sum 2a and 2b)*	734 .00
4. What portion of the total cost for all seed was for seed bought from elevators, seed houses and seed dealers? • Exclude seed bought from other farmers	None ☐ 735 .00 OR 022 %

COMMENTS:

SECTION H4. FERTILIZER

Section R	740		9

1. Did you have any expenses during 1980 for the purchase of fertilizer?

Yes ☐ No 741 | | 2 *(Go to Section H5)*

If custom fertilizer spreading costs were included in the purchase price, report total expense.

	Total expense in 1980 $
2. Fertilizer expenses	742 .00
3. What portion of the total expense figure for fertilizer was used or will be used in the production of wheat, oats, barley, rye, flaxseed, rapeseed and mustard seed?	None ☐ 743 .00 OR 023 %

SECTION H5. CHEMICALS (PESTICIDES)

Section R	750		9

1. Did you have any expenses during 1980 for chemicals to control all types of weeds, plants, insects, rodents, etc.?

Yes ☐ No 751 | | 2 *(Go to Section H6)*

If custom chemical application costs were included in the purchase price, report total expense.

	Total expense in 1980 $
2. Chemical expenses (include herbicides, insecticides, fungicides and other pesticides)	752 .00
3. What portion of the total expense figure for chemicals was used or will be used in the production of wheat, oats, barley, rye, flaxseed, rapeseed and mustard seed?	None ☐ 753 .00 OR 024 %

SECTION H6. FEED AND SUPPLEMENTS

Section R 770 | 9

1. In 1980, did you have any expenses for feed and supplements?
   - Include cost of hay and straw used for feed.

Yes ☐ No 771 | 2 *(Go to Section H7)*

	Total expense in 1980 $
2. In 1980, what were your total expenses for feed and supplements purchased from other farmers and from commercial channels?	772 .00
3. What portion of the total cost of feed was for feed purchased through commercial channels? • Exclude feed bought from other farmers	None ☐ 025 / 773 .00 OR %

SECTION H7. VETERINARY AND A.I.

Section R 780 | 9

1. In 1980, did you have any expenses for veterinary services, medicines or A.I. fees?

Yes ☐ No 781 | 2 *(Go to Section H8)*

	Total expense in 1980 $
2. Total expenses for veterinary services, medicines and A.I. fees?	782 .00

SECTION H8. BUILDING AND FENCE REPAIRS

Section R 790 | 9

1. Did you have any expenses during 1980 for repairs and maintenance of farm buildings and fences?
   - Include farm business share of expenses for repairs to the farm or any off-farm dwelling.
   - Exclude capital expenditures, that is, new construction, renovations and additions.

Yes ☐ No 791 | 2 *(Go to Section H9)*

	Total expense in 1980 $
2. What were your total expenses in 1980 for:	
(a) Repairs and maintenance to farm buildings?	792 None ☐ .00
(b) Fencing?	793 None ☐ .00
3. Total expenses for repairs to farm buildings and fencing *(Sum 2a and 2b)*	794 .00

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SECTION H9. CONTAINERS, TWINE AND WIRE

Section R 800 | 9

1. In 1980, did you have any expenses for small containers, baler twine, binder twine and baling wire?

Yes ☐ No 801 | 2 *(Go to Section H10)*

	Total expense in 1980 $
2. Total expenses for small containers, baler twine, binder twine and baling wire	802 .00

SECTION H10. SMALL TOOLS AND MISCELLANEOUS HARDWARE

Section R 810 | 9

1. In 1980, did you have expenses for small tools and miscellaneous hardware?
   - Include hand sprayers, dusters, fire extinguishers, grease guns, shovels, carpentry and other like tools, and all other equipment costing less than $200 per item.
   - Exclude materials accounted for in Section H8 (BUILDING AND FENCE REPAIRS)

Yes ☐ No 811 | 2 *(Go to Section H11)*

	Total expense in 1980 $
2. Total expenses for small tools and miscellaneous hardware required for the farm business	812 .00

SECTION H11. INTEREST ON FARM LOANS, CREDIT AND MORTGAGES

Section R 820 | 9

1. In 1980, did you have any farm business loans or mortgages?

Yes ☐ No 821 | 2 *(Go to Section H12)*

	Total expense in 1980 $	
2. What were your total interest expenses for these loans?	822 .00	
3. What portion of your interest expenses was for the purchase of real estate, farm vehicles, machinery, livestock, poultry, loans for building construction or renovation, or land improvement?	None ☐	824 .00 — OR — 026 %

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SECTION H12. ELECTRICITY, TELEPHONE AND HEATING FUEL

Section R 830 9

1. Did you have any electricity, telephone or heating fuel expenses during 1980?
   - Include farm business share of house expenses.
   - Exclude installation costs.

Yes ☐ No 831 2 *(Go to Section H13)*

	Farm business share of expenses in 1980 $
2. What was the farm business share for:	
(a) Telephone expenses?	832 None ☐ .00
(b) Electricity expenses?	833 None ☐ .00
(c) Fuel expenses for heating, irrigation and grain drying? • Include natural gas, propane, heating oil, coal, wood • Exclude fuel expenses for motor vehicles and farm machinery already reported	834 None ☐ .00
3. Total telephone, electricity and heating fuel expenses *(Sum 2a to 2c)*	835 .00

SECTION H13. INSURANCE PREMIUMS

Section R 860 9

1. Did you have any property or crop insurance expenses during 1980?
   - Exclude – insurance on property rented to others.
     – insurance on motor vehicles and machinery reported earlier.
     – personal life insurance premiums.
     – unemployment insurance and liability insurance paid on behalf of employees.
     – Western Grain Stabilization Act (WGSA) levies.

Yes ☐ No 861 2 *(Go to Section H14)*

	Total expense in 1980 $
2. During 1980, what were your total expenses for:	
(a) Crop and hail insurance? • Include insurance from government and non-government agencies	863 None ☐ .00
(b) Farm business insurance? Include – fire, wind and other property insurance on all farm buildings, machinery and equipment – farm business share of insurance on the farm or on off-farm dwellings and contents – insurance on livestock and grain in storage	866 None ☐ .00
3. Total insurance premiums *(Sum 2a and 2b)*	865 .00

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SECTION H14. WAGES, SERVICES AND SUPPLIES FOR HIRED LABOUR

Section R 850 | 9

1. Did you have any expenses for hired farm labour during 1980?
   - Exclude – paid labour for housework, custom work and contract work.
     – utilities, fuel and other items already claimed.

Yes ☐ No 851 | 2 *(Go to Section H15)*

		Total expense in 1980 $
2. What were your total cash wages for hired farm labour in 1980? • Include any contributions for Unemployment Insurance, Canada Pension Plan, Workmen's Compensation, etc. made on behalf of your employees		852 None ☐ .00
3. Of the above cash wage expense, how much was for your spouse and your children under the age of 18?	$ 853 None ☐ .00	
4. What is the estimated cash value of housing or lodging, food, fuel, transportation, utilities, etc. provided to hired farm labour during 1980? • Exclude benefits to family labour		854 None ☐ .00
5. Total expenses for wages, services and supplies for hired labour *(Sum 2 and 4)*		855 .00

COMMENTS:

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SECTION H15. CUSTOM WORK AND MACHINE HIRE

Section R	760	9

The following section concentrates on operating expenses which are of a recurring nature such as stone picking, seed treatment and custom spreading of fertilizers.

- **Exclude** – expenses where the benefits will be spread over many years, for example, dugouts, barns, clearing land, grain bins, etc.
  – seed, fertilizer and chemical materials, as well as custom work included in SECTIONS H3, H4 and H5.

	Total expense in 1980 $
1. Did you have any expenses in 1980 for:	
(a) Tilling, seeding, swathing, combining and grain drying	None ☐ .00
(b) Seed treatment and cleaning	None ☐ .00
(c) Custom spreading of chemical fertilizer, spraying and dusting	None ☐ .00
(d) Grain, livestock and feed trucking	None ☐ .00
(e) Baling, chopping and feedlot cleaning	None ☐ .00
(f) Renting or leasing of any machinery or equipment for farm purposes	None ☐ .00
(g) Other, please specify ______	None ☐ .00
2. Total custom work and machine hire expenses *(Sum 1a to 1g)*	762 .00

Did the farm operator report any custom work and machine hire expenses for 1980?

Yes ☐ No | 761 | | 2 |

Go to Section H16

SECTION H16. MISCELLANEOUS FARM BUSINESS EXPENSES

Section R	840		9

1. In 1980, did you have any expenses for accounting and consulting services, bank services, legal services, memberships (farm organizations, unions, etc.), promotion, farm magazines, bulletins and technical journals?
   - Exclude interest charges on bank loans.

Yes ☐ No | 841 | | 2 | *(Go to Section H17)*

	Total expense in 1980 $
2. Total miscellaneous farm business expenses	842 .00

SECTION H17. OTHER FARM OPERATING EXPENSES AND DEPRECIATION

Section R	870		9

1. During 1980, what were your expenses for:

	Total expense in 1980 $
(a) Livestock and poultry purchases?	871 None ☐ .00
(b) Property taxes?	872 None ☐ .00
(c) Depreciation or capital cost allowances?	873 None ☐ .00
(d) Irrigation levies and taxes?	874 None ☐ .00
(e) Other? Please specify ______	875 None ☐ .00

COMMENTS:

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SECTION I. RECEIPTS FROM CUSTOM WORK AND MACHINE RENTAL

Section R 910 9

1. In 1980, did you have any cash receipts from custom work or from rental or leasing of your farm machinery to others?
   - Include custom feeding of cattle.
   - Exclude custom work done on an exchange basis, that is, where no money changes hands.

Yes ☐ No 911 2 *(Go to Section J)*

2. Total receipts from custom work and machine rental .... $ 912 .00

SECTION J. TOTAL AGRICULTURAL RECEIPTS

Section R 900 9

1. What were your total agricultural receipts in 1980?
   - **Include** – sales of all agricultural products.
     - Box 703: landlord's share of products sold.
     - Box 912: custom work and machine hire receipts.
     - stabilization and deficiency payments.
     - CWB payments received in 1980.
     - cash advances for stored grain, patronage dividends and crop insurance .... $ 901 None ☐ .00

2. What portion of the above total was for the sale of wheat, oats, barley, rye, flaxseed, rapeseed and mustard seed?
   - Include Canadian Wheat Board payments received in 1980 .... None ☐ 902 .00 OR 027 %

SECTION K. SASKATCHEWAN AND BRITISH COLUMBIA ONLY: FEDERAL/PROVINCIAL AGREEMENT TO SHARE INFORMATION

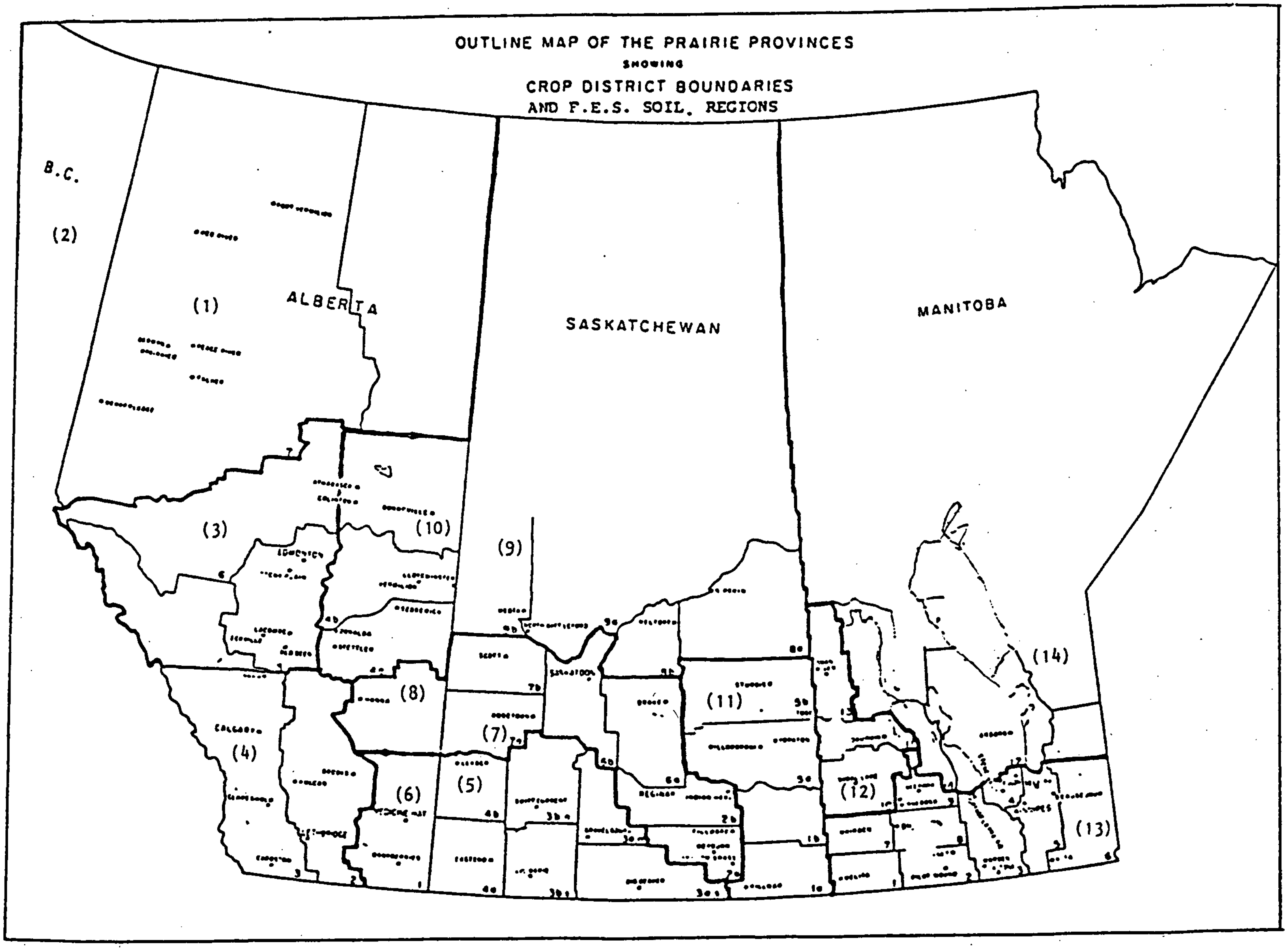
To avoid duplication of inquiries and to reduce the costs of data collection, this survey is conducted under a joint agreement to collect and share information, as provided by Section 11 of the Statistics Act, with the Saskatchewan Department of Agriculture and the British Columbia Ministry of Agriculture.

Are you willing to share this information with the agency/agencies in your province?

(please check)

Yes (O.K. to share information) 032 2

No (not O.K. to share information) 032 1


OUTLINE MAP OF THE PRAIRIE PROVINCES
SHOWING
CROP DISTRICT BOUNDARIES
AND F.E.S. SOIL. REGIONS
B.C.
(2)
(1)
ALBERTA
SASKATCHEWAN
MANITOBA
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)

B. Cross-sectional Data By Soil Zone

Year	Soil Zone	Prices; cwt. Cows	Steers	Steer Calves	Heifers	Heifer Calves
1981	1	46.59	74.66	75.13	68.39	65.80
	2	46.59	74.66	75.13	68.39	65.80
	3	46.59	74.66	75.13	68.39	65.80
	4	48.52	76.58	75.64	72.36	66.53
	5	45.84	75.82	72.92	69.91	60.05
	6	48.52	76.58	75.64	72.36	66.53
	7	48.58	75.81	74.56	70.30	63.46
	8	48.52	76.58	75.64	72.36	66.53
	9	48.58	75.81	74.56	70.30	63.46
	10	46.59	74.66	75.13	68.39	65.80
	11	45.84	75.82	72.92	69.91	60.05
	12	48.10	73.98	73.88	67.55	65.16
	13	48.10	73.98	73.88	67.55	65.16
	14	48.10	73.98	73.88	67.55	65.16
1980	1	51.27	79.10	91.90	72.93	80.14
	2	51.27	79.10	91.90	72.93	80.14
	3	51.27	79.10	91.90	72.93	80.14
	4	51.77	82.01	94.01	75.86	84.64
	5	49.34	78.55	93.66	71.48	79.26
	6	51.77	82.01	94.01	75.86	84.64
	7	52.06	79.18	92.26	73.08	81.23
	8	51.77	82.01	94.01	75.86	84.64
	9	52.06	79.18	92.26	73.08	81.23
	10	51.27	79.10	91.90	72.93	80.14
	11	49.34	78.55	93.66	71.48	79.26
	12	52.05	78.60	88.53	71.14	79.40
	13	52.05	78.60	88.53	71.14	79.40
	14	52.05	78.60	88.53	71.14	79.40
1979	1	55.80	91.08	108.65	88.17	94.29
	2	55.80	91.08	108.65	88.17	94.29
	3	55.80	91.08	108.65	88.17	94.29
	4	58.27	92.46	108.07	88.99	96.75
	5	54.62	93.42	107.84	87.98	91.44
	6	58.27	92.46	108.07	88.99	96.75
	7	56.39	90.91	108.88	85.90	99.57
	8	58.27	92.46	108.07	88.99	96.75
	9	56.39	90.91	108.88	85.90	99.57
	10	55.80	91.08	108.65	88.17	94.29
	11	54.62	93.42	107.84	87.98	91.44
	12	56.88	87.28	104.36	81.26	92.80
	13	56.88	87.28	104.36	81.26	92.80
	14	56.88	87.28	104.36	81.26	92.80
1978	1	38.73	65.35	75.07	56.86	65.30
	2	38.73	65.35	75.07	56.86	65.30
	3	38.73	65.35	75.07	56.86	65.30
	4	40.27	66.53	82.06	58.86	72.35
	5	38.19	64.24	84.89	56.96	75.38
	6	40.27	66.53	82.06	58.86	72.35
	7	40.06	63.38	79.31	57.17	70.48
	8	40.27	66.53	82.06	58.86	72.35
	9	40.06	63.38	79.31	57.17	70.48
	10	38.73	65.35	75.07	56.86	65.30
	11	38.19	64.24	84.89	56.96	75.38
	12	39.93	60.48	74.05	53.72	64.68
	13	39.93	60.48	74.05	53.72	64.68
	14	39.93	60.48	74.05	53.72	64.68

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Prices: Indexes Building Repairs	Fencing	Machinery Operation	Seed
1981	1	253.50	223.00	257.20	345.00
	2	250.20	286.40	289.40	345.00
	3	253.50	223.00	257.20	345.00
	4	253.50	223.00	257.20	345.00
	5	254.10	247.60	271.20	345.00
	6	253.50	223.00	257.20	345.00
	7	254.10	247.60	271.20	345.00
	8	253.50	223.00	257.20	345.00
	9	254.10	247.60	271.20	345.00
	10	253.50	223.00	257.20	345.00
	11	254.10	247.60	271.20	345.00
	12	243.70	276.70	273.90	345.00
	13	243.70	276.70	273.90	345.00
	14	243.70	276.70	273.90	345.00
1980	1	236.60	217.00	213.80	300.10
	2	210.50	266.80	232.70	300.10
	3	236.60	217.00	213.80	300.10
	4	236.60	217.00	213.80	300.10
	5	238.20	226.00	222.30	300.10
	6	236.60	217.00	213.80	300.10
	7	238.20	226.00	222.30	300.10
	8	236.60	217.00	213.80	300.10
	9	238.20	226.00	222.30	300.10
	10	236.60	217.00	213.80	300.10
	11	238.20	226.00	222.30	300.10
	12	228.30	246.90	223.30	300.10
	13	228.30	246.90	223.30	300.10
	14	228.30	246.90	223.30	300.10
1979	1	231.00	199.40	182.60	223.00
	2	204.70	252.50	200.20	223.00
	3	231.00	199.40	182.60	223.00
	4	231.00	199.40	182.60	223.00
	5	226.00	207.90	193.30	223.00
	6	231.00	199.40	182.60	223.00
	7	226.00	207.90	193.30	223.00
	8	231.00	199.40	182.60	223.00
	9	226.00	207.90	193.30	223.00
	10	231.00	199.40	182.60	223.00
	11	226.00	207.90	193.30	223.00
	12	213.80	221.60	193.00	223.00
	13	213.80	221.60	193.00	223.00
	14	213.80	221.60	193.00	223.00
1978	1	205.30	180.10	170.60	215.20
	2	183.00	230.60	181.80	215.20
	3	205.30	180.10	170.60	215.20
	4	205.30	180.10	170.60	215.20
	5	197.40	191.20	181.60	215.20
	6	205.30	180.10	170.60	215.20
	7	197.40	191.20	181.60	215.20
	8	205.30	180.10	170.60	215.20
	9	197.40	191.20	181.60	215.20
	10	205.30	180.10	170.60	215.20
	11	197.40	191.20	181.60	215.20
	12	188.60	199.60	179.70	215.20
	13	188.60	199.60	179.70	215.20
	14	188.60	199.60	179.70	215.20

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Prices: Indexes Fertilizer	Pesticide	Twine	Feed + Supplements
1981	1	366.60	359.90	398.00	349.90
	2	366.60	359.90	398.00	349.90
	3	366.60	359.90	398.00	349.90
	4	366.60	359.90	398.00	349.90
	5	366.60	359.90	398.00	349.90
	6	366.60	359.90	398.00	349.90
	7	366.60	359.90	398.00	349.90
	8	366.60	359.90	398.00	349.90
	9	366.60	359.90	398.00	349.90
	10	366.60	359.90	398.00	349.90
	11	366.60	359.90	398.00	349.90
	12	366.60	359.90	398.00	349.90
	13	366.60	359.90	398.00	349.90
	14	366.60	359.90	398.00	349.90
1980	1	317.70	327.40	403.80	270.50
	2	317.70	327.40	403.80	270.50
	3	317.70	327.40	403.80	270.50
	4	317.70	327.40	403.80	270.50
	5	317.70	327.40	403.80	270.50
	6	317.70	327.40	403.80	270.50
	7	317.70	327.40	403.80	270.50
	8	317.70	327.40	403.80	270.50
	9	317.70	327.40	403.80	270.50
	10	317.70	327.40	403.80	270.50
	11	317.70	327.40	403.80	270.50
	12	317.70	327.40	403.80	270.50
	13	317.70	327.40	403.80	270.50
	14	317.70	327.40	403.80	270.50
1979	1	266.00	281.60	283.70	233.10
	2	266.00	281.60	283.70	233.10
	3	266.00	281.60	283.70	233.10
	4	266.00	281.60	283.70	233.10
	5	266.00	281.60	283.70	233.10
	6	266.00	281.60	283.70	233.10
	7	266.00	281.60	283.70	233.10
	8	266.00	281.60	283.70	233.10
	9	266.00	281.60	283.70	233.10
	10	266.00	281.60	283.70	233.10
	11	266.00	281.60	283.70	233.10
	12	266.00	281.60	283.70	233.10
	13	266.00	281.60	283.70	233.10
	14	266.00	281.60	283.70	233.10
1978	1	229.90	253.50	217.40	216.10
	2	229.90	253.50	217.40	216.10
	3	229.90	253.50	217.40	216.10
	4	229.90	253.50	217.40	216.10
	5	229.90	253.50	217.40	216.10
	6	229.90	253.50	217.40	216.10
	7	229.90	253.50	217.40	216.10
	8	229.90	253.50	217.40	216.10
	9	229.90	253.50	217.40	216.10
	10	229.90	253.50	217.40	216.10
	11	229.90	253.50	217.40	216.10
	12	229.90	253.50	217.40	216.10
	13	229.90	253.50	217.40	216.10
	14	229.90	253.50	217.40	216.10

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Prices: Indexes Grain Feed	Oats	Barley	Wheat
1981	1	359.90	314.50	387.20	408.70
	2	356.10	331.20	362.00	367.80
	3	359.90	314.50	387.20	408.70
	4	359.90	314.50	387.20	408.70
	5	495.50	469.80	574.50	483.20
	6	359.90	314.50	387.20	408.70
	7	495.50	469.80	574.50	483.20
	8	359.90	314.50	387.20	408.70
	9	495.50	469.80	574.50	483.20
	10	359.90	314.50	387.20	408.70
	11	495.50	469.80	574.50	483.20
	12	427.90	426.30	424.50	439.50
	13	427.90	426.30	424.50	439.50
	14	427.90	426.30	424.50	439.50
1980	1	263.80	225.90	282.90	305.90
	2	273.10	243.30	272.20	286.10
	3	263.80	225.90	282.90	305.90
	4	263.80	225.90	282.90	305.90
	5	358.40	328.80	435.30	350.60
	6	263.80	225.90	282.90	305.90
	7	358.40	328.80	435.30	350.60
	8	263.80	225.90	282.90	305.90
	9	358.40	328.80	435.30	350.60
	10	263.80	225.90	282.90	305.90
	11	358.40	328.80	435.30	350.60
	12	324.00	322.40	322.40	332.50
	13	324.00	322.40	322.40	332.50
	14	324.00	322.40	322.40	332.50
1979	1	221.00	209.60	202.50	250.50
	2	234.80	214.50	194.10	244.60
	3	221.00	209.60	202.50	250.50
	4	221.00	209.60	202.50	250.50
	5	278.30	254.50	311.90	290.60
	6	221.00	209.60	202.50	250.50
	7	278.30	254.50	311.90	290.60
	8	221.00	209.60	202.50	250.50
	9	278.30	254.50	311.90	290.60
	10	221.00	209.60	202.50	250.50
	11	278.30	254.50	311.90	290.60
	12	248.90	247.20	226.60	269.60
	13	248.90	247.20	226.60	269.60
	14	248.90	247.20	226.60	269.60
1978	1	202.70	190.10	201.90	221.20
	2	214.60	195.80	194.20	225.30
	3	202.70	190.10	201.90	221.20
	4	202.70	190.10	201.90	221.20
	5	265.60	256.90	290.50	262.40
	6	202.70	190.10	201.90	221.20
	7	265.60	256.90	290.50	262.40
	8	202.70	190.10	201.90	221.20
	9	265.60	256.90	290.50	262.40
	10	202.70	190.10	201.90	221.20
	11	265.60	256.90	290.50	262.40
	12	226.90	240.20	209.80	223.00
	13	226.90	240.20	209.80	223.00
	14	226.90	240.20	209.80	223.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Prices: Indexes Artificial Insemination	Small Tools	Electricity	Telephone
1981	1	187.40	232.40	211.50	147.90
	2	187.40	204.10	242.90	147.90
	3	187.40	232.40	211.50	147.90
	4	187.40	232.40	211.50	147.90
	5	187.40	225.50	188.80	147.90
	6	187.40	232.40	211.50	147.90
	7	187.40	225.50	188.80	147.90
	8	187.40	232.40	211.50	147.90
	9	187.40	225.50	188.80	147.90
	10	187.40	232.40	211.50	147.90
	11	187.40	225.50	188.80	147.90
	12	187.40	213.90	267.90	147.90
	13	187.40	213.90	267.90	147.90
	14	187.40	213.90	267.90	147.90
1980	1	220.10	219.20	175.00	141.70
	2	220.10	176.90	204.30	141.70
	3	220.10	219.20	175.00	141.70
	4	220.10	219.20	175.00	141.70
	5	220.10	206.50	188.80	141.70
	6	220.10	219.20	175.00	141.70
	7	220.10	206.50	188.80	141.70
	8	220.10	219.20	175.00	141.70
	9	220.10	206.50	188.80	141.70
	10	220.10	219.20	175.00	141.70
	11	220.10	206.50	188.80	141.70
	12	220.10	195.60	267.90	141.70
	13	220.10	195.60	267.90	141.70
	14	220.10	195.60	267.90	141.70
1979	1	212.00	194.60	180.00	141.20
	2	212.00	160.90	186.70	141.20
	3	212.00	194.60	180.00	141.20
	4	212.00	194.60	180.00	141.20
	5	212.00	186.00	188.80	141.20
	6	212.00	194.60	180.00	141.20
	7	212.00	186.00	188.80	141.20
	8	212.00	194.60	180.00	141.20
	9	212.00	186.00	188.80	141.20
	10	212.00	194.60	180.00	141.20
	11	212.00	186.00	188.80	141.20
	12	212.00	181.30	267.90	141.20
	13	212.00	181.30	267.90	141.20
	14	212.00	181.30	267.90	141.20
1978	1	210.20	170.90	175.90	135.30
	2	210.20	151.50	186.70	135.30
	3	210.20	170.90	175.90	135.30
	4	210.20	170.90	175.90	135.30
	5	210.20	160.60	175.80	135.30
	6	210.20	170.90	175.90	135.30
	7	210.20	160.60	175.80	135.30
	8	210.20	170.90	175.90	135.30
	9	210.20	160.60	175.80	135.30
	10	210.20	170.90	175.90	135.30
	11	210.20	160.60	175.80	135.30
	12	210.20	155.90	232.80	135.30
	13	210.20	155.90	232.80	135.30
	14	210.20	155.90	232.80	135.30

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Prices: Indexes Custom Work	Daily Hired Labour	Property Taxes	Interest
1981	1	257.50	306.90	195.80	668.60
	2	254.90	271.00	202.40	668.60
	3	257.50	306.90	195.80	668.60
	4	257.50	306.90	195.80	668.60
	5	246.60	318.20	202.00	668.60
	6	257.50	306.90	195.80	668.60
	7	246.60	318.20	202.00	668.60
	8	257.50	306.90	195.80	668.60
	9	246.60	318.20	202.00	668.60
	10	257.50	306.90	195.80	668.60
	11	246.60	318.20	202.00	668.60
	12	236.10	343.00	204.10	668.60
	13	236.10	343.00	204.10	668.60
	14	236.10	343.00	204.10	668.60
1980	1	230.40	289.50	172.20	471.40
	2	229.30	248.00	171.50	471.40
	3	230.40	289.50	172.20	471.40
	4	230.40	289.50	172.20	471.40
	5	225.00	294.10	177.90	471.40
	6	230.40	289.50	172.20	471.40
	7	225.00	294.10	177.90	471.40
	8	230.40	289.50	172.20	471.40
	9	225.00	294.10	177.90	471.40
	10	230.40	289.50	172.20	471.40
	11	225.00	294.10	177.90	471.40
	12	221.40	326.20	202.70	471.40
	13	221.40	326.20	202.70	471.40
	14	221.40	326.20	202.70	471.40
1979	1	203.40	253.10	152.50	398.30
	2	198.50	236.70	147.60	398.30
	3	203.40	253.10	152.50	398.30
	4	203.40	253.10	152.50	398.30
	5	197.60	269.90	156.20	398.30
	6	203.40	253.10	152.50	398.30
	7	197.60	269.90	156.20	398.30
	8	203.40	253.10	152.50	398.30
	9	197.60	269.90	156.20	398.30
	10	203.40	253.10	152.50	398.30
	11	197.60	269.90	156.20	398.30
	12	200.00	299.40	184.80	398.30
	13	200.00	299.40	184.80	398.30
	14	200.00	299.40	184.80	398.30
1978	1	181.60	238.60	152.50	278.60
	2	177.70	223.30	226.90	278.60
	3	181.60	238.60	152.50	278.60
	4	181.60	238.60	152.50	278.60
	5	182.80	246.10	143.50	278.60
	6	181.60	238.60	152.50	278.60
	7	182.80	246.10	143.50	278.60
	8	181.60	238.60	152.50	278.60
	9	182.80	246.10	143.50	278.60
	10	181.60	238.60	152.50	278.60
	11	182.80	246.10	143.50	278.60
	12	181.20	287.50	170.40	278.60
	13	181.20	287.50	170.40	278.60
	14	181.20	287.50	170.40	278.60

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Prices; Indexes Farm Rent	CPI (1971=100)	Fencing Repairs
1981	1	359.10	236.90	258.20
	2	359.10	236.90	258.20
	3	359.10	236.90	258.20
	4	359.10	236.90	258.20
	5	359.10	236.90	258.20
	6	359.10	236.90	258.20
	7	359.10	236.90	258.20
	8	359.10	236.90	258.20
	9	359.10	236.90	258.20
	10	359.10	236.90	258.20
	11	359.10	236.90	258.20
	12	359.10	236.90	258.20
	13	359.10	236.90	258.20
	14	359.10	236.90	258.20
1980	1	279.30	210.60	237.20
	2	279.30	210.60	237.20
	3	279.30	210.60	237.20
	4	279.30	210.60	237.20
	5	279.30	210.60	237.20
	6	279.30	210.60	237.20
	7	279.30	210.60	237.20
	8	279.30	210.60	237.20
	9	279.30	210.60	237.20
	10	279.30	210.60	237.20
	11	279.30	210.60	237.20
	12	279.30	210.60	237.20
	13	279.30	210.60	237.20
	14	279.30	210.60	237.20
1979	1	242.60	191.20	226.80
	2	242.60	191.20	226.80
	3	242.60	191.20	226.80
	4	242.60	191.20	226.80
	5	242.60	191.20	226.80
	6	242.60	191.20	226.80
	7	242.60	191.20	226.80
	8	242.60	191.20	226.80
	9	242.60	191.20	226.80
	10	242.60	191.20	226.80
	11	242.60	191.20	226.80
	12	242.60	191.20	226.80
	13	242.60	191.20	226.80
	14	242.60	191.20	226.80
1978	1	236.10	175.20	202.30
	2	236.10	175.20	202.30
	3	236.10	175.20	202.30
	4	236.10	175.20	202.30
	5	236.10	175.20	202.30
	6	236.10	175.20	202.30
	7	236.10	175.20	202.30
	8	236.10	175.20	202.30
	9	236.10	175.20	202.30
	10	236.10	175.20	202.30
	11	236.10	175.20	202.30
	12	236.10	175.20	202.30
	13	236.10	175.20	202.30
	14	236.10	175.20	202.30

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Receipts: $ Custom Work	Total Agriculture	Grains
1981	1	861196.00	69004432.00	30060768.00
	2	156959.00	20046976.00	4699093.00
	3	6714407.00	377858992.00	87652526.00
	4	15996818.00	618422546.00	243946834.00
	5	5988133.00	370194156.00	210853708.00
	6	858625.00	100938891.00	42479732.00
	7	2679761.00	246416596.00	134755782.00
	8	565223.00	123855889.00	40391130.00
	9	1929471.00	267709378.00	115052900.00
	10	5196232.00	554136776.00	232451039.00
	11	3306930.00	209836642.00	114442414.00
	12	556710.00	106690231.00	56176697.00
	13	3412218.00	227176263.00	101855787.00
	14	940607.00	53887773.00	12984888.00
1980	1	228392.00	49181057.00	19341093.00
	2	478165.00	20020827.00	5491368.00
	3	4464154.00	363462541.00	68505901.00
	4	21873769.00	568327306.00	190862782.00
	5	2249517.00	307794834.00	174460432.00
	6	311003.00	93308016.00	28482517.00
	7	1708522.00	272034984.00	139815823.00
	8	363791.00	109769488.00	42324153.00
	9	1449689.00	218840603.00	99173629.00
	10	3532707.00	442647642.00	155266500.00
	11	1300937.00	225512181.00	102887047.00
	12	1869534.00	83623172.00	36094375.00
	13	2210467.00	164794614.00	68398128.00
	14	1987664.00	61819410.00	12631950.00
1979	1	478165.00	44434246.00	10886191.00
	2	19548.00	11060588.00	1716811.00
	3	1521372.00	281807485.00	63100491.00
	4	25377328.00	558740318.00	151528553.00
	5	2273599.00	251528614.00	122992011.00
	6	30048.00	75285114.00	16992149.00
	7	2004649.00	257857869.00	129746041.00
	8	641867.00	87258228.00	30593476.00
	9	2787492.00	209446613.00	82432722.00
	10	2839443.00	368325851.00	120817725.00
	11	560720.00	197905775.00	83106868.00
	12	226554.00	60404321.00	26600643.00
	13	979395.00	172185857.00	60624769.00
	14	1201968.00	45282841.00	7133268.00
1978	1	360417.00	21928690.00	4902209.00
	2	385405.00	10757768.00	3465771.00
	3	1770757.00	208307390.00	37808449.00
	4	14701805.00	452241930.00	106880854.00
	5	1099474.00	204888786.00	94347162.00
	6	281170.00	67254294.00	15084603.00
	7	1305357.00	191627091.00	106703979.00
	8	201647.00	54131506.00	20223020.00
	9	1695629.00	156057169.00	74038060.00
	10	1136646.00	242170413.00	67389682.00
	11	1982675.00	146831925.00	70633576.00
	12	180598.00	46003016.00	21600361.00
	13	1038577.00	144626306.00	46153713.00
	14	389870.00	37081924.00	5797794.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Misc.	Hired Labour	Family Labour	Room + Board
1981	1	443380.00	1305831.00	433217.00	78796.0
	2	162186.00	1059284.00	74260.00	121724.0
	3	2783140.00	14650994.00	6180814.00	396782.0
	4	5232301.00	24513426.00	4663250.00	1200306.0
	5	1477928.00	9667286.00	3688391.00	270833.0
	6	550612.00	4244354.00	1382691.00	297663.0
	7	1276516.00	7077235.00	2645176.00	179605.0
	8	626606.00	3773600.00	1018535.00	189090.0
	9	1185886.00	10684261.00	3677490.00	549199.0
	10	2834278.00	15325973.00	5595321.00	602252.0
	11	1001729.00	8065039.00	3489641.00	153660.0
	12	425424.00	2873786.00	1194850.00	159910.0
	13	1547507.00	7099405.00	1209994.00	259483.0
	14	338467.00	1986004.00	605722.00	146298.0
1980	1	380509.00	1378821.00	475594.00	98078.0
	2	139441.00	1170645.00	53251.00	168381.0
	3	1962931.00	10646402.00	3153166.00	1103847.0
	4	3995068.00	23128158.00	4766726.00	2372132.0
	5	1213808.00	7614097.00	2932959.00	326117.0
	6	426660.00	3860852.00	1162350.00	197353.0
	7	1526532.00	8738538.00	2831016.00	548928.0
	8	428408.00	4692383.00	1069858.00	188367.0
	9	1005174.00	8390793.00	2530416.00	738971.0
	10	2296741.00	14494241.00	3945450.00	1021537.0
	11	1333715.00	5879082.00	2586376.00	280033.0
	12	306476.00	2495535.00	1049612.00	81679.0
	13	701209.00	3475056.00	845294.00	231434.0
	14	262277.00	2278024.00	486690.00	184062.0
1979	1	255234.00	837368.00	157407.00	74513.0
	2	116313.00	383482.00	25571.00	102302.0
	3	1674324.00	5618449.00	1053110.00	730880.0
	4	4096067.00	21261629.00	1794692.00	1373417.0
	5	1227374.00	5517396.00	1298789.00	492000.0
	6	400987.00	2631056.00	279202.00	156357.0
	7	1084552.00	6298019.00	1917723.00	270953.0
	8	509684.00	2723029.00	440703.00	93433.0
	9	1031090.00	6536701.00	1360652.00	663814.0
	10	1863664.00	8569875.00	1630880.00	795766.0
	11	883827.00	4308817.00	1045586.00	229977.0
	12	264430.00	1379469.00	228843.00	90650.0
	13	1060863.00	3317466.00	544669.00	247397.0
	14	183838.00	1531350.00	195146.00	126103.0
1978	1	343815.00	713653.00	229915.00	38214.0
	2	156665.00	341106.00	149202.00	30686.0
	3	1515355.00	6908217.00	1703936.00	879991.0
	4	3099600.00	20169432.00	3174516.00	1587088.0
	5	923183.00	5094319.00	1756781.00	403371.0
	6	365973.00	2704260.00	652417.00	170084.0
	7	1297230.00	5474556.00	2300708.00	345847.0
	8	418651.00	1330699.00	473282.00	282552.0
	9	775004.00	4997709.00	1424016.00	522997.0
	10	1660075.00	5005076.00	2188289.00	425415.0
	11	861795.00	3596033.00	1683269.00	257239.0
	12	352203.00	883811.00	165597.00	129616.0
	13	979486.00	4477823.00	534229.00	339054.0
	14	208114.00	1513999.00	286586.00	141714.0

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Pesticide	Custom Work	Feed + Supplements
1981	1	1075849.00	1607579.00	3463687.00
	2	120230.00	697567.00	994182.00
	3	5974791.00	8115454.00	19767462.00
	4	11313184.00	15145941.00	73785600.00
	5	7197874.00	6890977.00	22769111.00
	6	1292502.00	2664105.00	9473521.00
	7	5882897.00	4255609.00	16296504.00
	8	1700626.00	2194402.00	8155861.00
	9	7443529.00	4261261.00	9516930.00
	10	15202173.00	15158327.00	27397437.00
	11	5908766.00	3934396.00	9925806.00
	12	3486102.00	1646101.00	3156532.00
	13	8894202.00	6063169.00	12279585.00
	14	944390.00	1108648.00	3851327.00
1980	1	524546.00	838755.00	1994248.00
	2	49032.00	521656.00	790665.00
	3	4672776.00	5268751.00	24762689.00
	4	9262628.00	11701593.00	58438651.00
	5	4189690.00	3798441.00	16931331.00
	6	725477.00	1527836.00	7897040.00
	7	4341050.00	4925397.00	20380444.00
	8	1169084.00	994502.00	6207869.00
	9	5567305.00	5179575.00	7911963.00
	10	10704360.00	7734537.00	19078980.00
	11	5127500.00	3969964.00	16994164.00
	12	2386046.00	1649727.00	5075033.00
	13	4434958.00	3450473.00	17954261.00
	14	712992.00	1346659.00	6463063.00
1979	1	399616.00	865891.00	1129487.00
	2	71712.00	234374.00	363548.00
	3	4227998.00	5081446.00	22106413.00
	4	7023863.00	10759995.00	64857405.00
	5	3850644.00	2853852.00	10771106.00
	6	640434.00	1365692.00	5526133.00
	7	5390250.00	3267434.00	11570493.00
	8	726998.00	1438961.00	5395533.00
	9	4946248.00	2447162.00	6709134.00
	10	8007411.00	5808227.00	18114441.00
	11	4800323.00	2639491.00	7086903.00
	12	2287752.00	904997.00	1651887.00
	13	5067768.00	3384916.00	9661447.00
	14	548233.00	613733.00	2663373.00
1978	1	277737.00	785863.00	826140.00
	2	240641.00	222841.00	267285.00
	3	3272177.00	2955327.00	15879192.00
	4	5117971.00	8299652.00	43821748.00
	5	2870402.00	3231379.00	8258080.00
	6	438371.00	1277547.00	5474762.00
	7	4419814.00	2486168.00	7135760.00
	8	456437.00	565259.00	2708170.00
	9	5065210.00	2531154.00	5128369.00
	10	5679775.00	3081527.00	12614860.00
	11	3904248.00	2175529.00	3967830.00
	12	1683073.00	598945.00	1535164.00
	13	4184923.00	2840056.00	8811965.00
	14	518297.00	590355.00	2002284.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Vet + Artificial Insemination	Interest on Loans	Telephone
1981	1	580809.00	8012127.00	288825.00
	2	280534.00	3340005.00	133574.00
	3	4090674.00	34442391.00	1355824.00
	4	5105883.00	63170463.00	1679451.00
	5	2218745.00	35787448.00	1334304.00
	6	579177.00	7868979.00	254452.00
	7	2010782.00	20875797.00	861661.00
	8	923140.00	10159465.00	407450.00
	9	1759961.00	24292598.00	792599.00
	10	4013219.00	57522760.00	1525427.00
	11	1647088.00	20080649.00	686671.00
	12	623658.00	8061884.00	248059.00
	13	1643325.00	1692670.00	633540.00
	14	498070.00	470255.00	324887.00
1980	1	341531.00	6344059.00	296253.00
	2	178746.00	2973055.00	120198.00
	3	3073768.00	30047549.00	1379298.00
	4	3876794.00	57600252.00	1702931.00
	5	1594320.00	24978997.00	1154092.00
	6	621675.00	4742134.00	312984.00
	7	2191901.00	23133223.00	1210221.00
	8	790850.00	6229689.00	446190.00
	9	1629934.00	16578166.00	865935.00
	10	3246921.00	42382317.00	1502702.00
	11	1855515.00	17420689.00	859665.00
	12	709174.00	5904521.00	298169.00
	13	1315864.00	16385148.00	607349.00
	14	539308.00	4445575.00	320357.00
1979	1	548274.00	5262112.00	242954.00
	2	74612.00	1098254.00	31288.00
	3	2975098.00	17393725.00	1215356.00
	4	4545861.00	40612507.00	1609256.00
	5	1515004.00	16934334.00	1040745.00
	6	366184.00	2920298.00	196297.00
	7	2014192.00	16190059.00	915927.00
	8	541599.00	5689553.00	444247.00
	9	1710681.00	14789414.00	880408.00
	10	2821272.00	24223384.00	1323024.00
	11	2196796.00	14099012.00	773031.00
	12	332549.00	3852454.00	204452.00
	13	1324132.00	12149390.00	558738.00
	14	347718.00	2567016.00	195711.00
1978	1	211422.00	613811.00	228306.00
	2	109720.00	491116.00	89081.00
	3	1886474.00	4410485.00	935546.00
	4	3315453.00	11526299.00	1410204.00
	5	1084573.00	3359640.00	819645.00
	6	398136.00	912735.00	216784.00
	7	1261172.00	2822993.00	738610.00
	8	325233.00	1674767.00	320720.00
	9	1108873.00	2677789.00	588091.00
	10	1900751.00	6693003.00	1005271.00
	11	1266626.00	1582533.00	689164.00
	12	280704.00	997370.00	172167.00
	13	986510.00	3033420.00	553704.00
	14	325623.00	1001047.00	225225.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Electricity	Fuel	Insurance
1981	1	708371.00	401072.00	1103706.00
	2	227792.00	160525.00	159692.00
	3	3883668.00	2292300.00	6102282.00
	4	4165063.00	3218239.00	10846184.00
	5	2746130.00	1517827.00	7747274.00
	6	576393.00	599205.00	1998436.00
	7	2077997.00	902674.00	6106082.00
	8	958584.00	548098.00	2831962.00
	9	1923441.00	877424.00	4193868.00
	10	3711765.00	2705718.00	9505185.00
	11	1717002.00	669830.00	5784475.00
	12	859146.00	324567.00	1735575.00
	13	1984133.00	694852.00	4078125.00
	14	856537.00	202950.00	859805.00
1980	1	605697.00	485177.00	756468.00
	2	179429.00	180451.00	233717.00
	3	3863978.00	3005743.00	4372277.00
	4	4628779.00	4188200.00	8532114.00
	5	2628199.00	1857003.00	5773325.00
	6	613870.00	573119.00	1542297.00
	7	2554128.00	1875679.00	5982657.00
	8	997624.00	584666.00	2264338.00
	9	1882771.00	1703860.00	3539361.00
	10	3278702.00	2709449.00	6909279.00
	11	2229450.00	1340910.00	5342597.00
	12	1009122.00	390726.00	1388918.00
	13	1877526.00	520608.00	2613256.00
	14	1012448.00	284627.00	845690.00
1979	1	512764.00	292450.00	627102.00
	2	53395.00	55020.00	68834.00
	3	3382126.00	2457590.00	3476782.00
	4	3757057.00	3273086.00	6633640.00
	5	2396389.00	1770687.00	5084049.00
	6	405046.00	437729.00	987233.00
	7	2476526.00	1463551.00	6004582.00
	8	868739.00	535918.00	1280702.00
	9	2178373.00	1329108.00	3584736.00
	10	3070968.00	2233483.00	4853653.00
	11	2133703.00	1433053.00	3817821.00
	12	831314.00	350459.00	1118121.00
	13	2079444.00	735224.00	2818127.00
	14	742208.00	206997.00	394035.00
1978	1	546391.00	341981.00	448709.00
	2	140637.00	95511.00	170459.00
	3	2433042.00	1678674.00	2627636.00
	4	3880673.00	2722565.00	4945778.00
	5	2046965.00	1374054.00	4720179.00
	6	532088.00	381960.00	1068055.00
	7	2090850.00	1189058.00	5129566.00
	8	643927.00	321161.00	1067497.00
	9	1729119.00	782592.00	2838098.00
	10	2658040.00	1759703.00	3828526.00
	11	1834995.00	1055985.00	4017323.00
	12	794976.00	279257.00	1072921.00
	13	2193042.00	604783.00	2956014.00
	14	770571.00	307702.00	460082.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Property Tax	Depreciation	Building Repairs
1981	1	844611.00	9404018.00	891819.00
	2	176571.00	2100143.00	164059.00
	3	5482938.00	63807431.00	5280290.00
	4	7833695.00	80115253.00	7906551.00
	5	9890461.00	62240864.00	2824674.00
	6	1210469.00	14325780.00	774101.00
	7	5312501.00	50329652.00	2315565.00
	8	1878389.00	19965125.00	1389963.00
	9	4762849.00	36493448.00	2453299.00
	10	8046915.00	82233441.00	5455804.00
	11	5659376.00	36614591.00	1979636.00
	12	2469792.00	14772700.00	952967.00
	13	5136627.00	29195733.00	2264886.00
	14	1395154.00	8701976.00	497675.00
1980	1	681380.00	9461013.00	619209.00
	2	187802.00	2386745.00	196324.00
	3	4441520.00	65470742.00	4531329.00
	4	6655388.00	73875804.00	6469924.00
	5	8516039.00	54720894.00	2864026.00
	6	1952538.00	14100925.00	748786.00
	7	6234212.00	48503163.00	2360119.00
	8	1856521.00	18871472.00	883780.00
	9	4392774.00	37236810.00	2068957.00
	10	6656018.00	71267927.00	3732038.00
	11	5618518.00	40722480.00	2328207.00
	12	2171314.00	13919459.00	1005960.00
	13	4141422.00	26690584.00	1876444.00
	14	1112679.00	10958829.00	781732.00
1979	1	545796.00	10853578.00	465070.00
	2	116780.00	1294554.00	66505.00
	3	3698704.00	52476355.00	3965410.00
	4	7091463.00	59189042.00	6013242.00
	5	7126074.00	49940628.00	2573873.00
	6	1097438.00	8928490.00	522093.00
	7	5669892.00	50116086.00	2451967.00
	8	1110563.00	17428486.00	768030.00
	9	4098901.00	37652794.00	2227948.00
	10	5138630.00	58289337.00	4466204.00
	11	4546930.00	36160541.00	2168989.00
	12	1666974.00	9197278.00	725770.00
	13	3782190.00	25848705.00	1776189.00
	14	857879.00	6465004.00	564120.00
1978	1	340326.00	4150089.00	457737.00
	2	197961.00	1849368.00	250118.00
	3	3219789.00	38761244.00	2825116.00
	4	5664297.00	57744467.00	3987440.00
	5	6183670.00	43680584.00	2284152.00
	6	1437642.00	12968795.00	862852.00
	7	6286317.00	41906773.00	2461868.00
	8	1043297.00	11910413.00	564507.00
	9	3733705.00	26632151.00	1656865.00
	10	4303791.00	35984272.00	4030321.00
	11	4550774.00	28805626.00	1767566.00
	12	1477306.00	7945392.00	712647.00
	13	3606715.00	20768491.00	1914019.00
	14	1039502.00	5809655.00	676916.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Rental	Machinery	Seed
1981	1	2347930.00	11629733.00	1148700.00
	2	465432.00	3960682.00	514625.00
	3	11713816.00	54469821.00	5440749.00
	4	22732692.00	55066901.00	4523363.00
	5	13839929.00	44677252.00	2284540.00
	6	2719929.00	9609172.00	633015.00
	7	11639316.00	36295873.00	2383136.00
	8	4350344.00	14530497.00	597873.00
	9	9387737.00	33353259.00	4566410.00
	10	23799645.00	69539964.00	6675581.00
	11	8569584.00	32513981.00	3670806.00
	12	3640208.00	14626929.00	1706099.00
	13	7290640.00	31692508.00	4912247.00
	14	2032495.00	12217437.00	1157480.00
1980	1	1336184.00	7679156.00	618540.00
	2	362542.00	2901372.00	192249.00
	3	12690743.00	40678179.00	4206984.00
	4	26577998.00	50318434.00	5228461.00
	5	16600326.00	36666662.00	2167987.00
	6	2001858.00	7728612.00	717305.00
	7	15309897.00	35442041.00	3563111.00
	8	4263367.00	13379886.00	546233.00
	9	9667148.00	29027273.00	3692527.00
	10	16025937.00	51907738.00	5088342.00
	11	9368233.00	30130893.00	3533218.00
	12	3541224.00	12784197.00	1660840.00
	13	6785140.00	20831451.00	4431883.00
	14	1521068.00	10700942.00	917594.00
1979	1	479605.00	7445386.00	722602.00
	2	339303.00	1480204.00	171023.00
	3	8865101.00	31877822.00	4039767.00
	4	19772871.00	40033928.00	3954920.00
	5	9513101.00	28530972.00	1393377.00
	6	1635130.00	5754439.00	505943.00
	7	12453306.00	28735014.00	2167864.00
	8	3101739.00	8260422.00	536389.00
	9	8740839.00	27279265.00	3263364.00
	10	12742865.00	36548830.00	3842261.00
	11	5231367.00	22294831.00	2978549.00
	12	1753542.00	7841970.00	1304156.00
	13	8679488.00	17656406.00	3242914.00
	14	1563871.00	7089774.00	633643.00
1978	1	373922.00	5117505.00	453639.00
	2	491837.00	2236662.00	177927.00
	3	6997168.00	23809977.00	3124300.00
	4	15023742.00	34701066.00	3566643.00
	5	8960997.00	25436049.00	1094443.00
	6	1927452.00	6497354.00	591631.00
	7	8762352.00	24775190.00	1977139.00
	8	1704573.00	6838602.00	377817.00
	9	6427456.00	22574849.00	2607439.00
	10	10256784.00	30629209.00	3528819.00
	11	5992353.00	22591510.00	2708063.00
	12	1942862.00	7015729.00	1105228.00
	13	7041289.00	18552040.00	2975987.00
	14	1258924.00	7664000.00	745151.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Fencing Repairs	Twine + Wire	Hardware
1981	1	527412.00	396087.00	634740.00
	2	196614.00	99933.00	151301.00
	3	3728656.00	1842548.00	3762318.00
	4	2444183.00	1351417.00	3750614.00
	5	2330619.00	997619.00	2921449.00
	6	458409.00	189291.00	595253.00
	7	1377066.00	823146.00	2009052.00
	8	907886.00	255660.00	954933.00
	9	1821189.00	1021408.00	1655078.00
	10	3705807.00	1422058.00	3746062.00
	11	1765525.00	900222.00	1514295.00
	12	485036.00	357162.00	668013.00
	13	1197332.00	931080.00	1692670.00
	14	486797.00	403534.00	470255.00
1980	1	378899.00	346845.00	701435.00
	2	125401.00	125158.00	267023.00
	3	2968528.00	1856414.00	3019576.00
	4	2388589.00	1668076.00	3995113.00
	5	2063117.00	1345151.00	2338613.00
	6	660644.00	255066.00	690515.00
	7	1586456.00	1235600.00	2491761.00
	8	889599.00	325001.00	954035.00
	9	1207505.00	1064476.00	1556174.00
	10	3758887.00	1478389.00	3137159.00
	11	1212891.00	1146714.00	1729529.00
	12	562376.00	458419.00	624482.00
	13	1025385.00	808605.00	1104541.00
	14	587705.00	382968.00	493317.00
1979	1	253964.00	247992.00	368886.00
	2	27204.00	38084.00	59141.00
	3	2604099.00	1628234.00	2777170.00
	4	2298418.00	1479584.00	3509112.00
	5	1610484.00	1136218.00	2159882.00
	6	467513.00	219785.00	471100.00
	7	1322442.00	1045935.00	2131926.00
	8	990720.00	264666.00	781110.00
	9	1390158.00	1205464.00	1835759.00
	10	2973527.00	1650951.00	2552728.00
	11	1347174.00	1096802.00	1301576.00
	12	399192.00	247922.00	445777.00
	13	748957.00	831049.00	930861.00
	14	513465.00	279647.00	433496.00
1978	1	290455.00	187252.00	344976.00
	2	104656.00	73497.00	114444.00
	3	2067523.00	1094196.00	2158975.00
	4	2211783.00	1330471.00	2322071.00
	5	1709433.00	931264.00	1727931.00
	6	517867.00	292859.00	489983.00
	7	1424005.00	692418.00	1707562.00
	8	540709.00	205766.00	608737.00
	9	1113805.00	905951.00	1293068.00
	10	2505078.00	1184119.00	2131257.00
	11	1218230.00	870863.00	1153705.00
	12	436692.00	253422.00	340333.00
	13	870294.00	766312.00	959935.00
	14	540510.00	220822.00	411809.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Expenditure: $ Fertilizer	Irrigation	Other
1981	1	4552104.00	0.0	144072.00
	2	823422.00	0.0	11376.00
	3	23615482.00	27782.00	210692.00
	4	33679644.00	1894672.00	407911.00
	5	6068933.00	164295.00	177847.00
	6	2571543.00	253963.00	93979.00
	7	7728924.00	120329.00	219181.00
	8	1400715.00	10528.00	44801.00
	9	17264488.00	13202.00	69135.00
	10	46615041.00	0.0	155284.00
	11	8700811.00	166.00	282052.00
	12	8488230.00	0.0	27848.00
	13	17697486.00	0.0	275676.00
	14	3384426.00	0.0	9946.00
1980	1	2670252.00	17976.00	51595.00
	2	650134.00	302.00	30427.00
	3	19908746.00	15312.00	261059.00
	4	28489907.00	1825600.00	378766.00
	5	4861713.00	478884.00	191131.00
	6	1403622.00	261382.00	78881.00
	7	9484002.00	111256.00	511022.00
	8	1545929.00	19000.00	117086.00
	9	14996368.00	0.0	44235.00
	10	29293798.00	1000.00	166338.00
	11	9063718.00	37394.00	288839.00
	12	6333442.00	0.0	93980.00
	13	13222369.00	0.0	262306.00
	14	2546440.00	0.0	35378.00
1979	1	2847228.00	0.0	82809.00
	2	458543.00	0.0	99864.00
	3	17600494.00	87724.00	886962.00
	4	27527427.00	1709615.00	671589.00
	5	3791746.00	405621.00	119792.00
	6	1221637.00	288143.00	11648.00
	7	10639665.00	21849.00	189591.00
	8	1685671.00	10505.00	142827.00
	9	13853248.00	0.0	312403.00
	10	22436217.00	1164.00	302792.00
	11	8387632.00	54586.00	349827.00
	12	5074812.00	11026.00	214407.00
	13	13125254.00	5077.00	336670.00
	14	1726562.00	5304.00	11513.00
1978	1	1222735.00	0.0	9496.00
	2	1201406.00	248.00	232449.00
	3	12956492.00	0.0	1844156.00
	4	22321693.00	1504437.00	1169044.00
	5	2252895.00	90627.00	289189.00
	6	1057444.00	222387.00	378963.00
	7	7041243.00	46082.00	1268367.00
	8	834009.00	0.0	260854.00
	9	10403566.00	10.00	864482.00
	10	15906005.00	0.0	760206.00
	11	6506594.00	60902.00	641835.00
	12	3368362.00	0.0	143366.00
	13	12252735.00	7282.00	600265.00
	14	1795427.00	14095.00	68453.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Acres: Total of 7 Grains	Tame Hay	Rented Land
1981	1	366516.00	246379.00	428117.00
	2	61813.00	86079.00	138157.00
	3	1128662.00	890095.00	1356160.00
	4	2036666.00	361252.00	1922621.00
	5	1939235.00	281699.00	4075988.00
	6	371369.00	49199.00	1290770.00
	7	1534546.00	192683.00	1257266.00
	8	721953.00	113725.00	3247162.00
	9	1361581.00	392292.00	1997421.00
	10	2599305.00	609789.00	1848443.00
	11	1310021.00	180547.00	763202.00
	12	541365.00	127898.00	377094.00
	13	1050914.00	287454.00	784954.00
	14	205689.00	214659.00	1208652.00
1980	1	303664.00	178011.00	415210.00
	2	58561.00	74973.00	67474.00
	3	1148531.00	902697.00	1355732.00
	4	2276044.00	378104.00	2788536.00
	5	1954909.00	306079.00	3822595.00
	6	373166.00	76022.00	2106745.00
	7	1876436.00	391560.00	1693780.00
	8	696805.00	141356.00	2310534.00
	9	1299791.00	302216.00	2261031.00
	10	2155027.00	516909.00	2421534.00
	11	1615616.00	235453.00	897107.00
	12	516540.00	158073.00	443380.00
	13	839094.00	311528.00	697142.00
	14	160447.00	184584.00	1216744.00
1979	1	205029.00	193343.00	250868.00
	2	27970.00	29575.00	94351.00
	3	986992.00	883254.00	1474954.00
	4	1960517.00	483148.00	2836234.00
	5	1781996.00	334786.00	3503472.00
	6	247220.00	53166.00	1508371.00
	7	1916560.00	297157.00	1472811.00
	8	639581.00	130085.00	3377117.00
	9	1354552.00	437657.00	2403749.00
	10	1813940.00	598017.00	2849089.00
	11	1340634.00	234042.00	811406.00
	12	389251.00	104549.00	249966.00
	13	913779.00	259084.00	813751.00
	14	154242.00	157903.00	1051217.00
1978	1	198269.00	199467.00	298725.00
	2	37802.00	28481.00	84833.00
	3	940820.00	846848.00	1585269.00
	4	1998755.00	495001.00	1936623.00
	5	1821287.00	331717.00	3200173.00
	6	247210.00	56893.00	2124811.00
	7	1842131.00	284896.00	1458498.00
	8	635609.00	129418.00	2507702.00
	9	1285825.00	435042.00	1663632.00
	10	1809310.00	544089.00	2015509.00
	11	1306365.00	234027.00	783637.00
	12	399543.00	98638.00	269535.00
	13	919077.00	272869.00	748389.00
	14	133307.00	153249.00	1356211.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Acres: Other Crops	Summer Fallow	All Crops
1981	1	5013.00	73738.00	691648.00
	2	3396.00	10059.00	161348.00
	3	12228.00	102417.00	2133404.00
	4	18834.00	705764.00	3122516.00
	5	35107.00	1597981.00	3854023.00
	6	11774.00	316856.00	749199.00
	7	26859.00	1071744.00	2825833.00
	8	31690.00	529902.00	1397272.00
	9	42523.00	433763.00	2230160.00
	10	67140.00	611109.00	3887344.00
	11	23141.00	703899.00	2217609.00
	12	10287.00	178490.00	858041.00
	13	87378.00	156996.00	1582744.00
	14	15569.00	74862.00	510781.00
1980	1	10807.00	57206.00	549690.00
	2	4480.00	6693.00	144708.00
	3	19744.00	108511.00	2180308.00
	4	33773.00	809748.00	3524075.00
	5	26704.00	1637048.00	3927799.00
	6	4444.00	306214.00	768878.00
	7	32401.00	1384961.00	3694295.00
	8	29586.00	564682.00	1432681.00
	9	62777.00	451951.00	2128709.00
	10	44689.00	560383.00	3283519.00
	11	22435.00	932225.00	2819239.00
	12	10093.00	171383.00	858191.00
	13	61879.00	142059.00	1391321.00
	14	24282.00	71792.00	441106.00
1979	1	1646.00	77324.00	477364.00
	2	1092.00	13203.00	71841.00
	3	32718.00	135548.00	2041902.00
	4	48425.00	931985.00	3431954.00
	5	6050.00	1588606.00	3711799.00
	6	12141.00	211905.00	527150.00
	7	11403.00	1463123.00	3692061.00
	8	10027.00	478093.00	1260198.00
	9	37250.00	590999.00	2428242.00
	10	60088.00	577315.00	3052205.00
	11	13856.00	813314.00	2408464.00
	12	15190.00	161591.00	672909.00
	13	56267.00	248425.00	1488020.00
	14	24590.00	63880.00	400617.00
1978	1	4350.00	66600.00	468687.00
	2	898.00	13912.00	81095.00
	3	36816.00	162901.00	1991682.00
	4	30185.00	877233.00	3410528.00
	5	2846.00	1571502.00	3728125.00
	6	10605.00	210597.00	528165.00
	7	5469.00	1439288.00	3575820.00
	8	13026.00	496514.00	1278349.00
	9	38500.00	617265.00	2376654.00
	10	65682.00	554771.00	2976714.00
	11	11997.00	803564.00	2359698.00
	12	7670.00	162834.00	670665.00
	13	50951.00	259652.00	1510064.00
	14	21157.00	90484.00	398449.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Acres: Improved Pasture	Other Land	Total Land
1981	1	130850.00	639899.00	1462398.00
	2	39415.00	244037.00	444801.00
	3	809562.00	1561368.00	4504304.00
	4	355059.00	3116650.00	6594267.00
	5	284947.00	4792648.00	8931642.00
	6	73825.00	1861749.00	2684774.00
	7	213637.00	1214000.00	4253470.00
	8	33478.00	3399936.00	4830689.00
	9	217595.00	2232206.00	4679921.00
	10	432334.00	2643988.00	6963617.00
	11	84240.00	988919.00	3300744.00
	12	66232.00	504479.00	1428718.00
	13	149335.00	938787.00	2670833.00
	14	75305.00	1603743.00	2189820.00
1980	1	91123.00	610722.00	1251588.00
	2	46212.00	198575.00	389496.00
	3	731709.00	1769527.00	4681626.00
	4	433338.00	3604241.00	7560743.00
	5	311828.00	4561596.00	8801403.00
	6	119270.00	2883523.00	3771679.00
	7	195680.00	1779249.00	5669660.00
	8	326177.00	2301072.00	4059973.00
	9	210325.00	2563920.00	4903681.00
	10	444834.00	3141105.00	6869108.00
	11	105031.00	1232324.00	4156976.00
	12	61731.00	497132.00	1417260.00
	13	134598.00	966269.00	2492291.00
	14	67838.00	1652187.00	2161155.00
1979	1	83050.00	521621.00	1081716.00
	2	39009.00	119467.00	230318.00
	3	622863.00	1899734.00	4564475.00
	4	355487.00	3784770.00	7570275.00
	5	239726.00	4598845.00	8550185.00
	6	135544.00	2112140.00	2774774.00
	7	212188.00	1451628.00	5356756.00
	8	39652.00	3171785.00	4475693.00
	9	209796.00	2698639.00	5335943.00
	10	359956.00	3703648.00	7115632.00
	11	105692.00	1229224.00	3743257.00
	12	45803.00	382080.00	1099941.00
	13	99677.00	1046660.00	2634248.00
	14	39098.00	1426311.00	1866027.00
1978	1	82292.00	542512.00	1009498.00
	2	26874.00	164355.00	338061.00
	3	616785.00	1790317.00	4183813.00
	4	361377.00	3299509.00	6667722.00
	5	242169.00	4414048.00	8463786.00
	6	135945.00	3017786.00	3774398.00
	7	212262.00	1554200.00	5305498.00
	8	37169.00	2508684.00	3698592.00
	9	197966.00	1960810.00	4670373.00
	10	341905.00	2730624.00	6021560.00
	11	101281.00	1178466.00	3795182.00
	12	44705.00	417513.00	1088939.00
	13	98629.00	1100462.00	2736500.00
	14	40765.00	1656460.00	2173945.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Quantity: bu. Wheat Fed	Oats Fed	Barley Fed
1981	1	16698.00	1245911.00	763209.00
	2	5000.00	356161.00	187486.00
	3	354360.00	7081003.00	10439811.00
	4	369325.00	4038434.00	17138253.00
	5	147205.00	3780700.00	3659549.00
	6	11504.00	539549.00	1310703.00
	7	194578.00	4561345.00	4033252.00
	8	90015.00	2143672.00	1523881.00
	9	124443.00	5038804.00	5138179.00
	10	126954.00	9581151.00	14392678.00
	11	176393.00	5566290.00	3182063.00
	12	31495.00	2267197.00	1712565.00
	13	212508.00	4236258.00	3693021.00
	14	62147.00	1143004.00	843604.00
1980	1	7800.00	712737.00	926485.00
	2	8245.00	315310.00	170202.00
	3	305441.00	7148308.00	11976537.00
	4	523811.00	4156520.00	18833405.00
	5	322138.00	3613506.00	2660482.00
	6	99409.00	947405.00	1491555.00
	7	643057.00	6312505.00	5174275.00
	8	143943.00	2138215.00	1095456.00
	9	165261.00	5761057.00	5079747.00
	10	547709.00	11085495.00	10468848.00
	11	375332.00	6072486.00	3593482.00
	12	20638.00	2313272.00	2171996.00
	13	195463.00	3235551.00	3890880.00
	14	166311.00	712793.00	902912.00
1979	1	12207.00	777578.00	1141256.00
	2	1102.00	131516.00	106196.00
	3	786406.00	6717466.00	12548101.00
	4	729531.00	8663249.00	31827757.00
	5	363665.00	3493138.00	2505093.00
	6	45596.00	766051.00	1025086.00
	7	653177.00	5039493.00	5589703.00
	8	445190.00	2224130.00	1060958.00
	9	212397.00	7081495.00	4675395.00
	10	297135.00	10903683.00	8600299.00
	11	448233.00	7399882.00	4101385.00
	12	55678.00	1709414.00	1402629.00
	13	316866.00	4790867.00	3536518.00
	14	198754.00	1433088.00	1070440.00
1978	1	0.0	816190.00	557845.00
	2	5000.00	191159.00	633485.00
	3	109177.00	4919108.00	8254304.00
	4	326823.00	3660538.00	16112848.00
	5	200954.00	3172032.00	1590180.00
	6	16613.00	837497.00	1512718.00
	7	123874.00	4508700.00	3468570.00
	8	54703.00	1143515.00	977384.00
	9	70219.00	3842927.00	3636065.00
	10	174275.00	8309804.00	6111956.00
	11	43697.00	6021379.00	1632991.00
	12	35161.00	1435637.00	873601.00
	13	101555.00	4930447.00	2891279.00
	14	100280.00	1151222.00	592231.00

B. Cross-sectional Data By Soil Zone (continued)

Year	Soil Zone	Quantity: Head Calves Born	Beef Cows	Replacement Heifers
1981	1	68906.00	78740.00	11886.00
	2	20916.00	24848.00	4797.00
	3	330090.00	375585.00	67594.00
	4	325742.00	357753.00	59345.00
	5	272700.00	299056.00	36520.00
	6	65276.00	69926.00	13221.00
	7	132479.00	153619.00	25360.00
	8	114822.00	122615.00	15164.00
	9	165736.00	185753.00	25293.00
	10	309558.00	352425.00	47438.00
	11	137818.00	154327.00	20856.00
	12	63729.00	69864.00	10208.00
	13	135035.00	151788.00	26980.00
	14	91473.00	101810.00	24405.00
1980	1	51923.00	57246.00	14172.00
	2	19902.00	22382.00	5386.00
	3	331554.00	369101.00	65633.00
	4	306492.00	343525.00	57300.00
	5	261451.00	286365.00	41692.00
	6	101077.00	108394.00	20445.00
	7	188946.00	517091.00	39245.00
	8	90296.00	105411.00	15967.00
	9	192338.00	212577.00	34668.00
	10	307069.00	328066.00	56623.00
	11	169293.00	188051.00	33356.00
	12	62726.00	70162.00	12114.00
	13	128730.00	145105.00	23237.00
	14	86969.00	99762.00	15164.00
1979	1	56211.00	64789.00	10268.00
	2	7835.00	9269.00	3413.00
	3	331456.00	369122.00	60687.00
	4	331345.00	356713.00	66066.00
	5	241312.00	268980.00	42587.00
	6	72132.00	80021.00	12719.00
	7	168493.00	185766.00	33887.00
	8	116324.00	126472.00	23647.00
	9	190642.00	221094.00	41228.00
	10	297564.00	322718.00	51644.00
	11	155874.00	178381.00	31475.00
	12	48475.00	54240.00	6820.00
	13	126565.00	139657.00	27489.00
	14	62018.00	73590.00	13775.00
1978	1	45133.00	50768.00	13809.00
	2	14505.00	15188.00	3448.00
	3	306890.00	345208.00	93897.00
	4	320727.00	360773.00	98130.00
	5	278438.00	307327.00	53782.00
	6	78052.00	87797.00	23881.00
	7	185045.00	204244.00	35743.00
	8	85822.00	96538.00	26258.00
	9	164573.00	181648.00	31788.00
	10	259152.00	291510.00	79291.00
	11	163552.00	180521.00	31591.00
	12	47173.00	52356.00	14921.00
	13	134147.00	148887.00	42433.00
	14	88071.00	97748.00	27858.00

B. Cross-sectional Data By Soil Zone (continued)

Quantity: Head

Year	Soil Zone	Steers	Slaughter Heifers	Calves	Cattle + Calves
1981	1	7970.00	1766.00	66453.00	170794.00
	2	4507.00	1996.00	21066.00	58684.00
	3	82631.00	47001.00	327469.00	926546.00
	4	146540.00	64988.00	313328.00	974962.00
	5	43681.00	17373.00	257065.00	669184.00
	6	26883.00	12134.00	61504.00	188117.00
	7	39960.00	17275.00	130261.00	376887.00
	8	15502.00	14176.00	112251.00	287581.00
	9	39149.00	28621.00	162323.00	452647.00
	10	62887.00	62089.00	297943.00	848417.00
	11	42420.00	17313.00	135411.00	380474.00
	12	17456.00	9784.00	62603.00	174486.00
	13	39569.00	22749.00	132534.00	383289.00
	14	16961.00	7967.00	90039.00	247362.00
1980	1	7069.00	2434.00	48521.00	132022.00
	2	2634.00	476.00	19467.00	57472.00
	3	106139.00	51727.00	328773.00	944256.00
	4	134313.00	68023.00	309296.00	943673.00
	5	30401.00	7064.00	263558.00	643089.00
	6	16007.00	5470.00	99609.00	256145.00
	7	29230.00	13256.00	190526.00	507055.00
	8	16709.00	7370.00	96358.00	247163.00
	9	32804.00	12905.00	191096.00	497860.00
	10	75804.00	62554.00	301540.00	851344.00
	11	38143.00	11578.00	165045.00	445873.00
	12	16503.00	5648.00	64112.00	175631.00
	13	34360.00	20203.00	132066.00	366046.00
	14	11820.00	3877.00	89588.00	229587.00
1979	1	13327.00	2408.00	52475.00	146606.00
	2	2899.00	332.00	7650.00	24569.00
	3	76989.00	36968.00	333924.00	908259.00
	4	142411.00	52711.00	318259.00	969452.00
	5	33320.00	18584.00	243440.00	620321.00
	6	14602.00	3719.00	72324.00	189115.00
	7	28859.00	12785.00	163342.00	439299.00
	8	13685.00	4749.00	108509.00	284137.00
	9	39765.00	10160.00	192540.00	518671.00
	10	74820.00	39234.00	298272.00	807909.00
	11	34894.00	9156.00	157048.00	422165.00
	12	9729.00	3683.00	49797.00	128243.00
	13	37767.00	15419.00	125474.00	357652.00
	14	14424.00	4061.00	62659.00	172409.00
1978	1	17016.00	0.0	45640.00	91431.00
	2	3007.00	0.0	13426.00	30552.00
	3	115645.00	0.0	310342.00	727402.00
	4	120859.00	0.0	324335.00	973918.00
	5	40874.00	0.0	209904.00	443235.00
	6	29412.00	0.0	78930.00	171271.00
	7	27165.00	0.0	138886.00	398189.00
	8	32340.00	1978	86788.00	151077.00
	9	24159.00	Included in	124066.00	385017.00
	10	97656.00	Replacement	262067.00	598284.00
	11	24009.00	Heifers	123296.00	347438.00
	12	15969.00		45079.00	106413.00
	13	45411.00		128192.00	331732.00
	14	29813.00		84161.00	172030.00

C. Time-Series Data

Year	Steer*	Expected Steer	Heifer	Expected Heifer	Cow	Expected Cow
1956	16.10	15.77	12.10	11.91	10.40	9.99
1957	16.85	17.34	12.87	13.36	11.40	12.06
1958	21.90	23.72	18.93	20.53	15.84	16.97
1959	23.08	21.57	19.32	17.61	16.55	15.19
1960	19.90	18.10	16.71	15.80	14.87	14.05
1961	20.50	22.01	16.68	17.46	15.05	15.71
1962	24.20	25.52	20.25	21.34	16.60	17.05
1963	23.25	21.38	20.47	19.46	16.55	15.98
1964	20.70	20.01	17.83	16.97	14.75	14.17
1965	21.95	23.49	18.33	19.28	13.90	14.26
1966	24.90	25.64	20.30	20.74	17.95	19.61
1967	26.40	25.86	22.00	21.92	18.50	17.23
1968	26.40	25.81	22.50	22.14	18.45	18.24
1969	31.25	33.27	26.45	27.49	21.70	22.80
1970	32.40	30.96	27.05	26.04	22.20	21.20
1971	33.80	33.93	27.80	27.85	22.20	22.02
1972	37.84	38.98	32.32	33.46	25.85	27.07
1973	49.89	53.35	43.15	45.06	33.91	35.29
1974	42.64	34.82	35.78	30.29	26.06	20.54
1975	36.84	37.28	30.77	31.48	21.30	22.53
1976	36.62	38.83	31.97	33.84	22.91	25.16
1977	40.54	42.27	34.52	34.93	24.99	25.11
1978	66.53	75.89	58.86	65.45	40.27	44.63
1979	92.46	93.05	88.99	90.75	58.27	58.80
1980	82.01	67.35	75.86	62.80	51.77	43.14
1981	76.58	78.44	72.36	75.26	48.52	49.77
1982	74.64	81.37	69.14	77.20	46.39	51.35

Prices and Expected Prices

* Cattle prices in units cwt.

C. Time-Series Data (cont.)

Year Prices and Expected Prices

Year	Calf	Expected Calf	Grain Index	C.P.I.	Interest Rate	Labour Index
1956	10.40	9.99	98.80	68.50	5.04	48.90
1957	11.40	12.06	92.40	70.70	5.58	51.90
1958	15.84	16.97	94.90	72.60	5.27	54.10
1959	16.55	15.19	97.70	73.40	5.62	56.50
1960	14.87	14.05	102.80	74.30	5.75	58.30
1961	15.05	15.71	118.50	75.30	5.60	59.60
1962	16.60	17.05	124.90	75.90	5.71	60.90
1963	16.55	15.98	121.40	77.20	5.75	62.40
1964	14.75	14.17	122.30	78.60	5.75	65.30
1965	13.90	14.26	120.90	80.50	5.77	69.70
1966	17.95	19.61	125.80	83.50	6.00	76.80
1967	18.50	17.23	123.30	86.50	5.92	83.50
1968	18.45	18.24	110.50	90.00	6.92	88.30
1969	21.70	22.80	98.90	94.10	7.96	92.70
1970	22.20	21.20	99.80	97.20	8.17	94.90
1971	22.20	22.02	100.00	100.00	6.48	100.00
1972	25.85	27.07	117.10	104.80	6.00	108.50
1973	33.91	35.29	223.00	112.70	7.65	124.10
1974	26.06	20.54	311.40	125.00	10.75	148.10
1975	21.30	22.53	298.40	138.50	9.42	176.30
1976	22.91	25.16	245.30	148.90	10.04	203.40
1977	24.99	25.11	213.00	160.80	8.50	225.80
1978	40.27	44.63	229.90	175.20	9.58	239.90
1979	58.27	58.80	285.60	191.20	12.90	254.10
1980	51.77	43.14	357.60	210.60	14.25	272.30
1981	48.52	49.77	377.00	236.90	19.29	291.10
1982	46.39	51.35	325.30	262.50	15.81	309.90

C. Time-Series Data (cont.)

Year	Prices		Cattle Inventories (,000)			
	Capital Index	Materials Index	End-of-Period Steer	Heifer	Cow	Calf
1956	63.40	74.30	749.8	1615.8	1530.3	537.7
1957	67.50	75.50	838.4	1667.0	1602.0	569.5
1958	71.30	76.80	659.8	1773.0	1633.0	520.7
1959	74.60	78.80	614.0	1852.0	1720.0	520.5
1960	76.40	80.50	668.2	1911.0	1776.3	538.8
1961	78.50	81.80	791.6	2016.8	1921.4	586.4
1962	79.70	88.50	737.0	2037.0	1989.0	581.0
1963	81.80	87.80	795.0	2152.0	2105.0	665.0
1964	83.50	87.40	945.0	2292.0	2333.0	778.0
1965	84.50	87.40	943.0	2399.0	2528.0	806.0
1966	86.80	91.00	995.1	2377.9	2517.4	735.8
1967	89.60	94.90	950.0	2305.0	2514.0	771.0
1968	93.20	96.20	939.0	2236.0	2444.0	721.0
1969	95.10	98.70	921.0	2197.0	2428.0	708.0
1970	97.30	97.60	984.0	2363.0	2597.0	836.0
1971	100.00	100.00	980.0	2555.9	2866.4	901.4
1972	103.60	103.10	1039.0	2706.0	3047.0	1024.0
1973	107.90	109.60	1038.0	2883.0	3341.0	1023.0
1974	121.10	121.10	1277.0	3073.0	3658.0	1122.0
1975	140.30	136.50	1428.0	3135.0	3747.0	1164.0
1976	153.10	150.10	1410.0	3027.0	3362.0	1261.0
1977	164.80	161.10	1199.0	2862.0	3265.0	1119.0
1978	176.50	172.70	1119.0	2677.5	3017.0	1060.0
1979	193.90	190.10	1096.0	2626.0	2964.0	1043.0
1980	221.90	207.50	998.0	2733.5	3013.0	1025.0
1981	260.70	244.60	988.0	2796.0	2937.0	1024.0
1982	287.60	268.40	998.0	2683.0	2845.0	1009.0

C. Time-Series Data (cont.)

Year	Cattle Inventories (,000)					Quantity
	Beginning-of-Period				Calves	Grain
	Steer	Heifer	Cow	Calf	Born	Index
1956	669.0	1490.0	1345.0	494.0	2148.6	86.3
1957	749.8	1615.8	1530.3	537.7	2351.0	47.8
1958	838.4	1667.0	1602.0	569.5	2375.9	51.3
1959	659.8	1773.0	1633.0	520.7	2322.0	55.0
1960	614.0	1852.0	1720.0	520.5	2401.4	67.3
1961	668.2	1911.0	1776.3	538.8	2500.5	22.9
1962	791.6	2016.8	1921.4	586.4	2509.0	87.4
1963	737.0	2037.0	1989.0	581.0	2616.0	109.3
1964	795.0	2152.0	2105.0	665.0	2775.0	80.5
1965	945.0	2292.0	2333.0	778.0	3001.0	95.1
1966	943.0	2399.0	2528.0	806.0	2921.0	124.9
1967	995.1	2377.9	2517.4	735.8	2830.0	80.2
1968	950.0	2305.0	2514.0	771.0	2725.0	102.2
1969	939.0	2236.0	2444.0	721.0	2714.0	105.9
1970	921.0	2197.0	2428.0	708.0	2851.0	55.7
1971	984.0	2363.0	2597.0	836.0	3149.0	100.0
1972	980.0	2555.9	2866.4	901.4	3462.0	84.1
1973	1039.0	2706.0	3047.0	1024.0	3626.0	94.6
1974	1038.0	2883.0	3341.0	1023.0	3837.0	74.6
1975	1277.0	3073.0	3658.0	1122.0	3889.0	111.1
1976	1428.0	3135.0	3747.0	1164.0	3518.0	151.2
1977	1410.0	3027.0	3362.0	1261.0	3553.0	134.3
1978	1199.0	2862.0	3265.0	1119.0	3357.0	131.4
1979	1119.0	2677.5	3017.0	1060.0	3213.0	97.0
1980	1096.0	2626.0	2964.0	1043.0	3239.0	123.0
1981	998.0	2733.5	3013.0	1025.0	3239.0	172.8
1982	988.0	2796.0	2937.0	1024.0	3170.0	183.8

D. Regression Results using Cobb-Douglas and Translog Functional Forms: Almon Lag Price Predictions

The results obtained from econometric estimation of the multi-output, multi-input variable profit function assuming that farmers' expectations of cattle prices can be represented exactly by the predictions of an Almon lag (Almon 1965) expectation process are reported in this appendix.

This expectation process defines expected price as the prediction of a polynomial distributed lag model of annual own prices prior to the current year. This prediction model can be written as:

(D.1)
$$P^e_{t+1} = a + \sum_{i=0}^{n} W_i P_{t-i}$$

The relationship between expected prices (P^e_{t+1}) and past prices (P_{t-i}) can be described by a finite lag of n periods with lagged weights (W_i) constrained to lie on a polynomial of degree q:

$$W_i = \sum_{k=0}^{q} B_k i^k \text{ , } n \geq q.$$

Equation (D.1) is used to generate an expected price for each animal category. Data used to estimate the polynomial are based on annual observations of prices from 1946 to 1983, for five auction markets in western Canada as described in Chapter Four.

In order to generate the best fit to the data, alternative specifications of the model were attempted. The degree of the polynomial was varied from one to four and the length of the lag was varied from two to five years. The final model was selected on the basis of R^2-values and t-statistics for the estimated coefficients.

A polynomial of degree three with a lag length of five provided the best fit to the data. In Table D.1, the estimated coefficients for each animal category for the Calgary market are reported. The econometric results for the other market areas are similar.

An example of expected prices generated by the steer equation is reported in Table D.2. This table illustrates that predicted prices follow actual prices and are dampened within one period. This is implied by the large estimated coefficients in the first year as compared to other coefficients.

The prices predicted for each animal category were transformed into expected gain variables as described in Chapter Four. These expected gain variables were combined with the main data base to allow econometric estimation of the model.

The Cobb-Douglas functional form was postulated as an initial specification of the multi-output, multi-input variable profit function model. This functional form for the three-output, three-input, one-fixed-factor case can be written as:

(D.2)

$$\Pi = a\ \bar{P}_1^{\alpha 1}\ \bar{P}_2^{e\alpha 2}\ \bar{P}_3^{\alpha 3}\ \bar{P}_4^{\alpha 4}\ \bar{P}_5^{\alpha 5}\ \bar{P}_6^{\alpha 6}\ A^{b\xi}\ D_1^{\delta 1}\ D_2^{\delta 2}\ D_3^{\delta 3},$$

where all variables are as previously defined (Table 4.3) except that $\bar{P}_2^e$ is generated using an Almon lag expectation process.

It is interesting to note that for input prices, the

TABLE D.1

Estimated Price Prediction Equations using a Polynomial Distributed Lag

Time Period	Steer	Calves	Cows	Heifers
t	.988 (.164)*	1.09 (.173)	1.05 (.163)	.941 (.167)
t-1	-.174 (.181)	-.327 (.206)	-.173 (.180)	-.124 (.184)
t-2	-.207 (.081)	-.192 (.084)	-.196 (.091)	-.192 (.091)
t-3	.242 (.191)	.386 (.228)	.229 (.190)	.224 (.200)
t-4	.530 (.250)	.298 (.256)	.346 (.240)	.610 (.280)
Sum Of Lagged Coefficients	1.38	1.26	1.26	1.46
R^2	.9108	.8766	.8656	.8926
Degree of Polynomial	3	3	3	3
Durbin-Watson	1.98	1.86	2.04	2.09

* standard error in parentheses

TABLE D.2

Example of Predicted Prices,
Steer Equation

Year	Observed Value	Predicted Value	Calculated Error
1960	22.62	18.50	4.110
1961	20.16	20.82	-0.662
1962	20.75	17.11	3.638
1963	23.45	19.62	3.833
1964	22.65	25.74	-.3090
1965	20.40	24.49	-4.098
1966	21.40	20.69	0.707
1967	24.70	23.21	1.494
1968	26.40	27.99	-1.598
1969	26.75	27.93	-1.177
1970	31.50	26.34	5.156
1971	33.20	31.96	1.242
1972	33.55	34.90	-1.354
1973	38.60	34.96	3.642
1974	48.98	40.88	8.104
1975	42.03	53.12	-11.088
1976	34.25	44.39	-10.137
1977	35.44	37.17	-1.728
1978	38.77	46.33	-7.564
1979	65.35	54.85	10.503
1980	91.08	74.72	16.360
1981	79.10	91.01	-11.910
1982	74.66	70.63	4.029
1983	73.26	71.22	2.039

convexity conditions are satisfied in Equation (D.2) if the monotonicity conditions are satisfied. Monotonicity requires that $\hat{\alpha}_j < 0$, j=4,5,6, and this restriction also ensures that convexity is satisfied. This can be demonstrated by examining the second order derivatives of Equation (D.2) with respect to input prices:

$$\Pi_{\bar{p}_j \bar{p}_j} = -\alpha_j(\alpha_j - 1)\bar{P}_j \Pi \quad j = 4,5,6.$$

Convexity requires $\Pi_{\bar{p}_j \bar{p}_j} > 0$ for all j. This condition is satisfied if $\hat{\alpha}_j < 0$ for all j.

For output prices however, the satisfaction of the monotonicity conditions (i.e., $\hat{\alpha}_i > 0$, i=1,2,3) is not sufficient to ensure that convexity is satisfied. This can be demonstrated by examining the second order derivative of Equation (D.2) with respect to output prices:

$$\Pi_{\bar{p}_i \bar{p}_i} = \alpha_i(\alpha_i - 1)\bar{P}_i \Pi \quad i = 1,2,3.$$

Again, convexity requires that $\Pi_{\bar{p}_i \bar{p}_i} > 0$ but this condition is satisfied only if $\hat{\alpha}_i > 1$, for all i. Consequently, the satisfaction of the monotonicity conditions are necessary but not sufficient to ensure convexity in output prices.

Keeping in mind that the α_i 's are defined as the share of revenue from output i in total profit, this restriction indicates that in order to satisfy convexity in output prices, the revenue received for each output i must be greater than the total profit received by the farm.

Casual observation of the sample data used in this study reveals that the convexity conditions would not be satisfied for the multi-output Cobb-Douglas profit function. Furthermore, regression results for Equation (D.2) supported this conclusion.

To circumvent this problem, it was decided to maintain a Cobb-Douglas specification on the input side but to generate an aggregate output price index using a translog functional form (Fuss 1977). The translog function does not require restrictions on the revenue shares in order to satisfy convexity.

The translog price index can be written as:

(D.3)

$$\ln P_I = \ln B_o + \sum_{i=1}^{3} B_i \ln \bar{P}_i + \tfrac{1}{2}\sum_{i=1}^{3}\sum_{k=1}^{3} B_{ij} \ln \bar{P}_i \ln \bar{P}_j,$$

where P_I is the aggregate price index and all other variables are as previously defined. Applying Hotelling's Lemma to Equation (D.3), the revenue share equations can be defined as:

(D.4)

$$S_i = B_i + \sum_{k=1}^{3} B_{ik} \ln \bar{P}_k + \varepsilon_i \qquad i = 1,2,3,$$

where S_i is output i's revenue share in total revenue and ε_i is a random error term.

Econometric estimation of Equation (D.4) will generate estimates of all coefficients in Equation (D.3) except the intercept term, lnBo. Consequently, the aggregate price index ($\ln P_I$) is defined only up to a constant scaling factor.

Dummy variables are added to the intercept term in Equation (D.4) to account for the cross-sectional, time-series data used in estimating the share equations. Furthermore, prior to estimation, symmetry and the adding-up constraints are imposed on the model.

Estimates of the parameters of the three revenue share equations derived using Zellner's (SUR) regression procedure are reported in Table D.3. Five iterations were required for convergence.

Own output price coefficients are positive and statistically significant at the 5 percent level which is a necessary condition for convexity. Furthermore, all remaining price coefficients are statistically significant at the 5 percent level.

Convexity conditions are checked by computing the eigenvalues of the Hessian matrix of the price index function. These values were determined at the means of the endogeneous variables and equalled .332, .102, and .001. Therefore, the Hessian matrix of the price index function is convex.

Measures of output substitution, holding total output constant, can be generated using the estimated coefficients in Table D.3. In Table D.4 the output supply and cross price elasticities are presented. This table indicates that own output supply elasticities are positive and inelastic. In addition, the estimated cross price elasticities suggest a substitute relationship between output pairs.

Using the estimated coefficients in Table D.3, an aggregate price index can now be generated through Equation (D.3). This index can be used to rewrite Equation (D.2) as a single output normalized Cobb-Douglas profit function:

(D.5)

$$\Pi = a\ \bar{P}_4^{\alpha 4}\ \bar{P}_5^{\alpha 5}\ \bar{P}_6^{\alpha 6}\ A^{b\xi}\ D_1^{\delta 1}\ D_2^{\delta 2}\ D_3^{\delta 3},$$

where price and profit variables are normalized by $\hat{P}_I$.

Applying Hotelling's lemma to Equation (D.5), the derived input demand equations can be defined as:

TABLE D.3

Regression Results: Translog Price Index

Share	Prices				Dummy Variables			
	Cattle	Inven.*	Crops	Const.	1981	1980	1979	R^2
Cattle	.421 (5.4)**	-.230 (6.5)	-.191 (3.3)	.595 (6.4)	.056 (3.6)	.0001 (.006)	-.056 (3.3)	.513
Inven.	-.23 (6.5)	.325 (6.6)	-.095 (2.2)	.652 (10.)	-.037 (1.9)	.014 (.81)	.023 (1.0)	.556
Crops	-.191	-.095	.286	-.247	-.019	-.014	.033	

* Inventories
** t-statistics in parentheses

TABLE D.4

Output Supply and Cross Price Elasticities Holding Total Output Constant , Mean of the Exogeneous Variables, 1981

Quantity	Prices		
	Cattle	Inventories	Crops
Cattle	.623	-.200	-.424
Inventories	-.127	.147	-.020
Crops	-.827	-.062	.889

(D.6) $X_j = -\alpha_j \Pi / \bar{P}_j \qquad j = 4,5,6,$

where X_j is the jth input quantity.

Efficient parameter estimates of Equation (D.5) can be generated by simultaneously estimating Equation (D.5) and (D.6) with symmetry restrictions imposed. These estimated parameters are derived using Zellner's (SUR) regression procedure and are exhibited in Table D.5. Own input price coefficients are negative and statistically significant at the 5 percent level, indicating that monotonicity and convexity are satisfied.

These estimated coefficients can be used to compute measures of own price elasticities, cross price elasticities, and elasticities with respect to the fixed factor. These values are reported in Table D.6.

With respect to own prices, aggregate output supply elasticity is positive and inelastic whereas input demand elasticities are negative and elastic. The cross elasticity measurements indicate a complementary relationship between all input pairs. This result is imposed by the Cobb-Douglas functional form.

To complete the presentation of the Cobb-Douglas results, own price and cross price elasticities for the output component are reported in Table D.7. These elasticities now account for the additional effect of changes in aggregate output on the supply of individual outputs.

These results indicate that output supply elasticities are positive but larger in magnitude than the corresponding "output-constant" elasticities reported in Table D.4. In

TABLE D.5

Joint Estimation: Normalized Cobb-Douglas Profit Function and Net Input Demand Equations

Variable	Parameter	Estimated Coefficients
Profit Function		
Constant	lna	2.46 (7.4)
Labour	α_1	-.059 (16.8)
Capital	α_2	-.055 (16.8)
Materials	α_3	-.114 (12.6)
Begining Inventories	A^b	1.06 (39.28)
1981 = 1		.237 (3.9)
1980 = 1		.151 (2.6)
1979 = 1		-.041 (.686)
Net Input Equations		
Labour	α_1	-.059 (13.3)
Capital	α_2	-.055 (16.8)
Materials	α_3	-.114 (12.6)

TABLE D.6

Own Price Elastiticies, Cross Price Elastitices, and Elastiticies With Respect To the Fixed Factor: Cobb-Douglas Profit Function

Quantity	Price				
	Aggregate Output	Labour	Capital	Materials	Beginning Inventories
Aggregate Output	.228	-.059	-.055	-.114	1.02
Labour	1.228	-1.059	-.055	-.114	1.02
Capital	1.228	-.059	-1.055	-.114	1.02
Materials	1.228	-.059	-.055	-1.114	1.02

TABLE D.7

Total Supply Elasticities: Output Component

Output	Prices		
	Cattle	Inventories	Crops
Cattle	.697	-.084	-.386
Inventories	-.049	.263	.018
Crops	-.753	.054	.927

addition, accounting for changes in aggregate output has altered the apparent relationship between inventories and crops from substitutes to complements.

The results obtained using a Cobb-Douglas specification were satisfactory. However, because of the restrictions imposed a priori by this functional form, it is inferior to models which allow greater flexibility of structure. To acheive this flexibility, a translog functional form is specified to represent the multi-output, multi-input variable profit function model. The procedure followed in estimating this model is identical to that described in Chapter Four. The estimated parameters are reported in Table D.8. These coefficients are quite similar to those reported in Chapter Five which are based on the assumption of ARIMA price expectations. It is worth noting however, that the coefficients reported in Table D.8 generally have lower t-statistics than the corresponding estimates in Chapter Five.

Finally, own price and cross price elasticities for cow-calf production, which are computed subject to the Almon lag expectation process, are presented in Table D.9. Again, these estimates are generally quite similar to those reported in Table 5.6 in Chapter Five.

Table D.8

Estimated Parameters, Translog Profit Function;

Almon Lag Price Expectations

Share	Prices								Dummy Variables			
	Cattle	Inventories	Crops	Labour	Capital	Materials	Stock	Constant	1981	1980	1979	R^2
Cattle	.849	-.246	-.328	-.074	.077	-.279	.037	.761	.144	.002	-.145	.6947
	(8.2)*	(7.7)	(5.2)	(4.3)	(4.9)	(5.9)	(5.3)	(6.1)	(6.9)	(.19)	(6.9)	
Inventories	-.246	.299	-.105	.012	-.011	.051	-.036	1.09	-.046	.016	.031	.6395
	(7.7)	(7.0)	(2.3)	(2.3)	(2.1)	(4.3)	(3.4)	(8.1)	(2.7)	(1.0)	(1.4)	
Crops	-.328	-.105	.320	.013	-.038	.139	.01	-.578	-.046	-.009	.055	.4554
	(5.2)	(2.3)	(4.8)	(1.3)	(3.8)	(5.9)	(.88)	(3.7)	(2.1)	(.56)	(2.1)	
Labour	-.074	.012	.013	.021	-.007	.035	-.002	-.092	-.018	.002	.02	.6081
	(4.3)	(2.3)	(1.3)	(2.6)	(1.4)	(2.1)	(1.7)	(3.7)	(4.7)	(1.4)	(5.8)	
Capital	.077	-.011	-.038	-.007	-.017	-.003	.002	.054	.016	-.003	-.012	.5174
	(4.9)	(2.1)	(3.8)	(1.4)	(2.9)	(.29)	(1.5)	(2.5)	(4.5)	(2.4)	(3.8)	
Materials	-.279	.051	.139	.035	-.003	.057	-.011	-.235	-.05	-.004	.051	

* t-statistics in parentheses

TABLE D.9

Price Elastitices, Cross Price Elastitices Translog Profit Function, Mean of Exogeneous Variables 1981, Almon Price Expectations

Quantity	Prices					
	Cattle	Inventories	Crops	Labour	Capital	Materials
Cattle	1.380	-.028	-.604	-.211	.154	-.710
Inventories	-.023	.094	-.046	-.022	-.041	.015
Crops	-1.760	-.167	1.290	.044	-.274	.851
Labour	2.160	.280	-.152	-1.530	.143	-.893
Capital	-3.220	1.080	1.960	.291	-.211	.068
Materials	4.110	-.111	-1.680	-.509	.019	-1.830

E. Estimated Parameters: ARIMA Models

The estimated coefficients for the ARIMA(2,1,0) model for each animal category in each market location (i.e., Edmonton, Regina, Saskatoon, and Winnipeg) are reported in this appendix.

The ARIMA(2,1,0) specification can be written as:

$$\Delta P_{ijt} = \phi_{1j}\Delta P_{ijt-1} + \phi_{2j}\Delta P_{ijt-2} + \varepsilon_{ijt} \qquad j = 1,\ldots,4,$$

where Δ indicates first differences,

P_{ij} = is the price series of the ith animal category in the jth market location,

$\hat{\phi}_{1j} + \hat{\phi}_{2j} < 1$,j = 1...4, is a necessary condition for stationarity, and

ε_{ij} is a random error term.

The estimated coefficients for each ARIMA(2,1,0) model are reported in Table E.1.

Except for the parameters in the heifer equation for Regina, all estimated coefficients are statistically significant at either the 10 percent or 5 percent level of significance. Moreso, at the 95 percent confidence level the necessary condition for stationarity $\hat{\phi}_1 + \hat{\phi}_2 < 1$ is satisfied in each estimated equation.

If the ARIMA models are correctly specified, the residuals should have independent and identical normal distributions. This condition can be evaluated by examining the plots of the autocorrelation function of the residuals for each equation and checking the statistical significance of each observation. Table E.2 reproduces the autocorrelation function for each equation along with 95 percent confidence intervals for each observation, which are denoted by the "+" symbol on both sides of the vertical axis. The large confidence intervals indicate that each observation is statistically insignificantly different from zero.

TABLE E.1

Estimated Parameters: ARIMA(2,1,0)

Market Location	Animal Category	Estimated Coefficients $\hat{\Phi}_1$	$\hat{\Phi}_2$	$\hat{\Phi}_1 + \hat{\Phi}_2$
Edmonton	Steers	.4027**	-.3856**	.0171
	S.E.	(.165)	(.1632)	(.232)
	Calves	.4333**	-.5040**	-.0707
	S.E.	(.1602)	(.1631)	(.228)
	Cows	.3747**	-.3814**	-.0066
	S.E.	(.1661)	(.1659)	(.235)
	Heifers	.2731*	-.2856*	-.0125
	S.E.	(.1734)	(.1727)	(.245)
Regina	Steers	.2508*	-.2865*	-.0357
	S.E.	(.172)	(.170)	(.242)
	Calves	.4972**	-.5361**	-.0389
	S.E.	(.1615)	(.1698)	(.234)
	Cows	.2955**	-.3272**	-.0317
	S.E.	(.1702)	(.1689)	(.239)
	Heifers	.1565	-.2181	-.0616
	S.E.	(.177)	(.175)	(.249)
Saskatoon	Steers	.3313**	-.3289**	.0024
	S.E.	(.1691)	(.1668)	(.238)
	Calves	.4757**	-.5400**	-.0643
	S.E.	(.1579)	(.1628)	(.227)
	Cows	.3146**	-.3450**	-.0304
	S.E.	(.170)	(.1693)	(.239)
	Heifers	.2823*	-.2753*	.007
	S.E.	(.1744)	(.1730)	(.224)
Winnipeg	Steers	.3680**	-.3553**	.0127
	S.E.	(.1677)	(.1665)	(.236)
	Calves	.2402*	-.3787**	-.1385
	S.E.	(.170)	(.1738)	(.243)
	Cows	.3282**	-.3608**	-.0326
	S.E.	(.1684)	(.1681)	(.238)
	Heifers	.3508**	-.3206**	.0302
	S.E.	(.1714)	(.1706)	(.242)

* significant at the 10 percent level of significance

** significant at the 5 percent level of significance

TABLE E.2

Plots of the Autocorrelation Function of the Residuals

Edmonton Market

Steers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.072	XXI
2	-0.126	XXXI
3	0.053	IX
4	-0.225	XXXXXXI
5	-0.005	I
6	0.180	IXXXX
7	-0.036	XI
8	0.052	IX
9	0.007	I
10	0.020	I
11	0.009	I
12	0.051	IX
13	-0.048	XI
14	-0.020	XI
15	-0.038	XI
16	-0.019	I
17	-0.034	XI
18	-0.005	I
19	-0.074	XXI
20	0.065	IXX
21	0.011	I
22	0.001	I
23	0.035	IX
24	-0.104	XXXI
25	-0.133	XXXI
26	-0.047	XI
27	-0.126	XXXI
28	0.215	IXXXXX
29	-0.026	XI
30	-0.063	XXI

Calves

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.052	XI
2	-0.153	XXXXI
3	0.044	IX
4	-0.157	XXXXI
5	-0.114	XXXI
6	0.136	IXXX
7	0.060	IX
8	-0.029	XI
9	0.028	IX
10	0.114	IXXX
11	-0.053	XI
12	0.055	IX
13	0.001	I
14	-0.073	XXI
15	-0.016	I
16	-0.006	I
17	-0.108	XXXI
18	0.085	IXX
19	-0.089	XXI
20	0.019	I
21	0.073	IXX
22	0.047	IX
23	-0.099	XXI
24	-0.091	XXI
25	0.032	IX
26	-0.137	XXXI
27	-0.099	XXI
28	0.192	IXXXXX
29	-0.105	XXXI
30	-0.026	XI

Cows

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.040	XI
2	-0.144	XXXXI
3	0.059	IX
4	-0.201	XXXXXI
5	-0.141	XXXXI
6	0.202	IXXXXX
7	0.038	IX
8	-0.011	I
9	-0.008	I
10	0.092	IXX
11	-0.058	XI
12	0.097	IXX
13	-0.008	I
14	-0.129	XXXI
15	0.058	IX
16	-0.051	XI
17	-0.094	XXI
18	0.081	IXX
19	-0.054	XI
20	0.032	IX
21	-0.003	I
22	0.147	IXXXX
23	-0.103	XXXI
24	-0.130	XXXI
25	-0.035	XI
26	-0.148	XXXXI
27	-0.086	XXI
28	0.222	IXXXXXX
29	-0.029	XI
30	-0.028	XI

Heifers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.069	XXI
2	-0.086	XXI
3	-0.056	XI
4	-0.179	XXXXI
5	-0.071	XXI
6	0.182	IXXXXX
7	-0.023	XI
8	0.030	IX
9	0.021	IX
10	0.029	IX
11	-0.002	I
12	0.054	IX
13	-0.023	XI
14	-0.077	XXI
15	-0.021	XI
16	-0.013	I
17	-0.012	I
18	-0.030	XI
19	-0.036	XI
20	0.054	IX
21	0.012	I
22	0.035	IX
23	-0.035	XI
24	-0.091	XXI
25	-0.078	XXI
26	-0.079	XXI
27	-0.086	XXI
28	0.226	IXXXXXX
29	-0.031	XI
30	-0.021	XI

TABLE E.2 (cont.)

Plots of the Autocorrelation Function of the Residuals

Saskatoon Market

Steers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.055	XI
2	-0.140	XXXXI
3	0.083	IXX
4	-0.268	XXXXXXXI
5	0.021	IX
6	0.176	IXXXX
7	-0.034	XI
8	0.073	IXX
9	-0.015	I
10	0.016	I
11	0.005	I
12	0.043	IX
13	-0.035	XI
14	-0.034	XI
15	-0.021	XI
16	-0.031	XI
17	-0.007	I
18	-0.043	XI
19	-0.035	XI
20	0.050	IX
21	-0.021	XI
22	0.026	IX
23	0.026	IX
24	-0.142	XXXXI
25	-0.038	XI
26	-0.119	XXXI
27	-0.094	XXI
28	0.183	IXXXXX
29	0.002	I
30	-0.068	XXI

Calves

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.035	XI
2	-0.190	XXXXXI
3	0.123	IXXX
4	-0.206	XXXXXI
5	-0.063	XXI
6	0.116	IXXX
7	0.076	IXX
8	-0.073	XXI
9	0.063	IXX
10	0.063	IXX
11	-0.032	XI
12	0.035	IX
13	0.011	I
14	-0.068	XXI
15	-0.027	XI
16	0.006	I
17	-0.092	XXI
18	0.053	IX
19	-0.051	XI
20	0.023	IX
21	0.044	IX
22	0.022	IX
23	-0.069	XXI
24	-0.151	XXXXI
25	0.092	IXX
26	-0.173	XXXXI
27	-0.086	XXI
28	0.148	IXXXX
29	-0.043	XI
30	-0.027	XI

Cows

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.050	XI
2	-0.131	XXXI
3	0.027	IX
4	-0.240	XXXXXXI
5	-0.091	XXI
6	0.191	IXXXXX
7	0.033	IX
8	0.002	I
9	0.001	I
10	0.034	IX
11	0.006	I
12	0.054	IX
13	-0.003	I
14	-0.105	XXXI
15	0.055	IX
16	-0.059	XI
17	-0.065	XXI
18	0.017	I
19	-0.022	XI
20	0.037	IX
21	-0.038	XI
22	0.180	IXXXXX
23	-0.078	XXI
24	-0.133	XXXI
25	-0.038	XI
26	-0.160	XXXXI
27	-0.065	XXI
28	0.188	IXXXXX
29	-0.024	XI
30	0.008	I

Heifers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.042	XI
2	-0.116	XXXI
3	0.046	IX
4	-0.263	XXXXXXXI
5	-0.049	XI
6	0.161	IXXXX
7	-0.021	XI
8	0.058	IX
9	-0.016	I
10	0.040	IX
11	-0.009	I
12	0.047	IX
13	-0.011	I
14	-0.075	XXI
15	-0.025	XI
16	0.022	IX
17	-0.063	XXI
18	0.008	I
19	0.012	I
20	-0.014	I
21	0.028	IX
22	0.052	IX
23	-0.080	XXI
24	-0.089	XXI
25	-0.035	XI
26	-0.147	XXXXI
27	-0.057	XI
28	0.193	IXXXXX
29	-0.022	XI
30	-0.013	I

TABLE E.2 (cont.)

Plots of the Autocorrelation Function of the Residuals

Regina Market

Steers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.057	XI
2	-0.113	XXXI
3	0.031	IX
4	-0.276	XXXXXXXI
5	0.072	IXX
6	0.124	IXXX
7	0.007	I
8	0.055	IX
9	-0.009	I
10	0.008	I
11	-0.020	XI
12	0.054	IX
13	-0.036	XI
14	-0.026	XI
15	-0.023	XI
16	-0.013	I
17	-0.030	XI
18	-0.032	XI
19	-0.035	XI
20	0.044	IX
21	-0.005	I
22	0.013	I
23	0.051	IX
24	-0.138	XXXI
25	-0.063	XXI
26	-0.101	XXXI
27	-0.115	XXXI
28	0.205	IXXXXX
29	-0.013	I
30	-0.054	XI

Calves

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.083	XXI
2	-0.066	XXI
3	-0.021	XI
4	-0.117	XXXI
5	-0.001	I
6	0.053	IX
7	0.108	IXXX
8	-0.088	XXI
9	0.062	IXX
10	0.035	IX
11	0.018	I
12	0.000	I
13	0.010	I
14	-0.061	XXI
15	-0.021	XI
16	-0.015	I
17	-0.065	XXI
18	0.047	IX
19	-0.068	XXI
20	0.049	IX
21	0.012	I
22	0.022	IX
23	-0.042	XI
24	-0.170	XXXXI
25	0.101	IXXX
26	-0.227	XXXXXXI
27	-0.025	XI
28	0.071	IXX
29	0.017	I
30	-0.043	XI

Cows

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.056	XI
2	-0.098	XXI
3	-0.020	XI
4	-0.219	XXXXXI
5	-0.055	XI
6	0.108	IXXX
7	0.061	IXX
8	0.010	I
9	-0.022	XI
10	0.058	IX
11	0.007	I
12	0.050	IX
13	0.013	I
14	-0.129	XXXI
15	0.036	IX
16	-0.027	XI
17	-0.076	XXI
18	0.040	IX
19	-0.039	XI
20	0.056	IX
21	-0.024	XI
22	0.118	IXXX
23	-0.005	I
24	-0.184	XXXXXI
25	-0.031	XI
26	-0.128	XXXI
27	-0.133	XXXI
28	0.255	IXXXXXXX
29	-0.034	XI
30	0.005	I

Heifers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.044	XI
2	-0.103	XXXI
3	0.000	I
4	-0.294	XXXXXXXI
5	-0.011	I
6	0.141	IXXXX
7	0.004	I
8	0.047	IX
9	-0.036	XI
10	0.062	IXX
11	-0.010	I
12	0.036	IX
13	-0.014	I
14	-0.051	XI
15	-0.022	XI
16	-0.027	XI
17	-0.029	XI
18	-0.018	I
19	-0.028	XI
20	0.069	IXX
21	0.014	I
22	0.042	IX
23	0.002	I
24	-0.137	XXXI
25	-0.044	XI
26	-0.086	XXI
27	-0.092	XXI
28	0.187	IXXXXX
29	-0.009	I
30	-0.044	XI

TABLE E.2 (cont.)

Plots of the Autocorrelation Function of the Residuals

Winnipeg Market

Steers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.050	XI
2	-0.151	XXXXI
3	0.082	IXX
4	-0.220	XXXXXXI
5	-0.070	XXI
6	0.216	IXXXXX
7	-0.013	I
8	0.045	IX
9	-0.019	I
10	0.044	IX
11	0.017	I
12	0.030	IX
13	-0.022	XI
14	-0.032	XI
15	-0.025	XI
16	-0.035	XI
17	-0.022	XI
18	-0.025	XI
19	-0.031	XI
20	0.034	IX
21	-0.032	XI
22	0.085	IXX
23	-0.002	I
24	-0.140	XXXI
25	-0.023	XI
26	-0.108	XXXI
27	-0.136	XXXI
28	0.183	IXXXXX
29	-0.019	I
30	-0.061	XXI

Calves

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.054	XI
2	-0.114	XXXI
3	-0.047	XI
4	-0.171	XXXXI
5	-0.144	XXXXI
6	0.137	IXXX
7	0.031	IX
8	0.029	IX
9	-0.032	XI
10	0.110	IXXX
11	0.005	I
12	0.021	IX
13	0.013	I
14	-0.058	XI
15	-0.032	XI
16	-0.040	XI
17	-0.033	XI
18	0.019	I
19	-0.053	XI
20	0.011	I
21	0.099	IXX
22	0.033	IX
23	-0.019	I
24	-0.079	XXI
25	-0.046	XI
26	-0.059	XI
27	-0.170	XXXXI
28	0.170	IXXXX
29	-0.002	I
30	-0.035	XI

Cows

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.056	XI
2	-0.113	XXXI
3	-0.009	I
4	-0.165	XXXXI
5	-0.115	XXXI
6	0.165	IXXXX
7	0.056	IX
8	-0.016	I
9	-0.011	I
10	0.068	IXX
11	0.005	I
12	0.054	IX
13	0.004	I
14	-0.109	XXXI
15	0.037	IX
16	-0.033	XI
17	-0.095	XXI
18	0.054	IX
19	-0.059	XI
20	0.043	IX
21	-0.008	I
22	0.148	IXXXX
23	-0.062	XXI
24	-0.126	XXXI
25	-0.053	XI
26	-0.139	XXXI
27	-0.107	XXXI
28	0.222	IXXXXXX
29	-0.039	XI
30	-0.009	I

Heifers

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
1	-0.058	XI
2	-0.110	XXXI
3	0.007	I
4	-0.197	XXXXXI
5	-0.095	XXI
6	0.193	IXXXXX
7	-0.021	XI
8	0.066	IXX
9	-0.033	XI
10	0.040	IX
11	0.015	I
12	0.034	IX
13	-0.025	XI
14	-0.022	XI
15	-0.036	XI
16	-0.028	XI
17	-0.031	XI
18	-0.011	I
19	-0.041	XI
20	0.061	IXX
21	0.021	IX
22	0.046	IX
23	-0.033	XI
24	-0.103	XXXI
25	-0.051	XI
26	-0.109	XXXI
27	-0.096	XXI
28	0.213	IXXXXX
29	-0.056	XI
30	-0.020	XI

F. Price Predictions: ARIMA Models

Year	Soil Zone	Steer	Calf	Heifer	Cow
1981	1	77.49	76.31	71.50	46.56
	2	77.49	76.31	71.50	46.56
	3	77.49	76.31	71.50	46.56
	4	78.44	74.20	75.26	49.77
	5	79.40	70.21	73.26	46.53
	6	78.44	74.20	75.26	49.77
	7	78.55	75.12	73.04	48.98
	8	78.44	74.20	75.26	49.77
	9	78.55	75.12	73.04	48.98
	10	77.49	76.31	71.50	46.56
	11	79.40	70.21	73.26	46.53
	12	75.36	76.36	69.53	48.55
	13	75.36	76.36	69.53	48.55
	14	75.36	76.36	69.53	48.55
1980	1	64.35	67.72	59.83	43.06
	2	64.35	67.72	59.83	43.06
	3	64.35	67.72	59.83	43.06
	4	67.35	71.39	62.80	43.14
	5	66.46	74.31	62.13	42.40
	6	67.35	71.39	62.80	43.14
	7	66.24	68.34	61.55	45.06
	8	67.35	71.39	62.80	43.14
	9	66.24	68.34	61.55	45.06
	10	64.35	67.72	59.83	43.06
	11	66.46	74.31	62.13	42.40
	12	65.88	68.11	58.76	44.35
	13	65.88	68.11	58.76	44.35
	14	65.88	68.11	58.76	44.35
1979	1	91.19	106.31	90.17	56.19
	2	91.19	106.31	90.17	56.19
	3	91.19	106.31	90.17	56.19
	4	93.05	99.81	90.75	58.80
	5	93.39	96.97	87.62	54.62
	6	93.05	99.81	90.75	58.80
	7	91.82	102.29	87.23	55.84
	8	93.05	99.81	90.75	58.80
	9	91.82	102.29	87.23	55.84
	10	91.19	106.31	90.17	56.19
	11	93.39	96.97	87.62	54.62
	12	89.21	106.44	83.74	57.09
	13	89.21	106.44	83.74	57.09
	14	89.21	106.44	83.74	57.09
1978	1	74.77	86.82	62.15	43.82
	2	74.77	86.82	62.15	43.82
	3	74.77	86.82	62.15	43.82
	4	75.89	98.32	65.44	44.63
	5	70.04	101.80	60.36	41.88
	6	75.89	98.32	65.44	44.63
	7	70.91	94.86	63.50	44.58
	8	75.89	98.32	65.44	44.63
	9	70.91	94.86	63.50	44.58
	10	74.77	86.82	62.15	43.82
	11	70.04	101.80	60.36	41.88
	12	67.73	64.70	60.57	44.01
	13	67.73	64.70	60.57	44.01
	14	67.73	64.70	60.57	44.01