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An Economic Analysis of the Alberta Sheep Industry

by

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ABSTRACT

The objectives of this research are to contribute to an understanding of the Alberta sheep industry in particular, supply response of producers and to provide empirical estimates of short-run transfer and allocative efficiency losses of a supply management marketing program. The research objectives are addressed by means of three empirical models. The main features of the empirical work include (1) the derivation of normative medium term supply elasticities for the commercial sheep industry; (2) the derivation of positive short-run and long-run supply elasticities for the sheep industry; (3) the analysis of structural change within the industry; and (4) the estimation of short term costs of a supply management program.

The linear programming approach was utilized to estimate the supply elasticities for the commercial sheep industry. For lamb, the supply elasticity estimates ranged from 1.11 to 1.47 while the estimates for wool and cull sheep supply were inelastic. The supply estimates derived from the econometric procedure indicate short-run and long-run elasticities as 0.36 and 1.22, respectively. There is evidence that structural change has occurred in the industry over the last 35 years, resulting in a decline in the number of small sheep producers and an increase in medium and large sheep producers.

The welfare economics framework was utilized to assess the potential effects of introducing a supply management marketing program into the industry. The effects of price simulations were analyzed with respect to changes in producer surplus, consumer surplus and allocative efficiency losses of the program. In the short-run the general directions of change resulting from a supply management program are: an increase in producer welfare, a decrease in consumer welfare and an increase in allocative efficiency losses.

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Chapter 1: Introduction

1.1 Nature and Scope of the Study

This study undertakes an economic analysis of the Alberta sheep industry, focusing in particular on producers' supply response. The analysis involves the application of both mathematical programming and econometric approaches to assess the industry's supply response. Furthermore, this study also examines the social costs and income transfers of a supply management marketing program for the industry.

Developing and analyzing a structural model of lamb supply is an important step in understanding the root causes of the decline in the industry over the last thirty years. The basic premise of this study is that the estimation of statistically reliable relationships for sheep supply will provide an understanding of the economic forces which help to determine the structure of the industry. An understanding of the industry's responsiveness to different economic conditions is important to producers, consumers, regional and national policy planners. For policy planners the extent of supply response is crucial in designing appropriate marketing policies for the industry.

The sheep industry has been selected as the focus of the study for a number of reasons. First, there has been little emphasis on research into the structural problems of the industry as the sheep sector makes a relatively minor contribution to the province's agricultural industry relative to other livestock. An indication of the size of the sheep industry in Alberta can be obtained from the proportion of government payments to sheep producers under the provincial Beef and Sheep Support Program. In 1983, the total payments to sheep producers through this program was approximately 1.25 million dollars or 0.9 percent of total payments under this program (Knapp, 1983). Second, with increasing surpluses of some agricultural commodities and consequently declining prices and returns to producers, there is some emphasis on enterprise diversification at the farm level. Sheep production provides a feasible alternative to cattle production in many areas of the province. Third, the future of Canada's largest specialized sheep slaughtering plant (Lambco) depends to a large extent on having a strong domestic industry to provide a consistent supply of animals for processing. The decline in the national and provincial sheep flocks has resulted in a decline in domestic lamb slaughter. This in turn has resulted in consolidation of the industry's infrastructure culminating in higher marketing costs because of lower volume. Reduced output from the sheep industry has encouraged the location of slaughter plants in feeding areas and in addition has accelerated the trend toward a few large slaughtering plants for the lamb industry. Increased concentration in the industry may encourage higher marketing costs as processing plants operate above optimum cost levels due to a lack of competition and/or an increase in the area of procurement and distribution.

Fourth, the Alberta sheep industry has experienced difficulties in the marketing of lamb. These difficulties arise from a number of sources, in particular, static or declining domestic demand for lamb and increased imports of fresh chilled lamb[1]. Increased competition from lamb imports from Australia and New Zealand has focused attention on the marketing performance of the domestic industry and on programs to improving this performance. Finally, examining the supply response of the Alberta sheep industry and the influence of input and output prices on this response may shed light on the fluctuating lamb supply from the industry. This study provides information on the

1 Fresh chilled lamb is essentially fresh lamb which has been subject to cold treatment (cryovac) in order to increase the shelf life.

short-term, medium-term and long-term supply response of the industry, in addition to assessing the impacts of a supply management program on the welfare of producers and consumers.

The remainder of this chapter is divided into three sections. In the first section the historical background of the industry is described. The objectives and hypotheses of the study are outlined in the second section. Lastly, the third section provides a summary of the methodology of the study and the organization of the remaining chapters of the thesis.

1.2 Historical Background of the Study.

The sheep industry occupies a special niche in Canadian agriculture. Although sheep are found in all provinces, the industry is concentrated within three provinces, Alberta, Ontario and Quebec, which account for almost three quarters of the national flock (Appendix A, Table A:1). The national flock has declined from a peak of 3.5 million head in 1931 to a trough of 0.6 million head in 1977. During the 1980s the downward trend ceased and sheep numbers have exhibited a steady increase to reach 0.7 million head in 1989. From the 1986 Census of Agriculture it can be seen that there were approximately 11,000 farms in Canada reporting sheep, a decline of fifteen percent from the 1981 Census. Although the absolute number of sheep farms declined during the 1980s, the provincial shares of the national flock have remained fairly stable with a small decline in the eastern provinces and a slight increase in Alberta and British Columbia. The average number of sheep per farm in 1986 ranged from a low of 37 head in British Columbia to a high of 92 head per farm in Quebec. In eastern Canada the average flock size increased from 60 to 67 head from 1981 to 1986 while in western Canada the average number of sheep declined from 68 to 61 head per farm. However, a more accurate indicator of the number of sheep producers relates to the number of farmers reporting fifty percent or more of their gross farm sales from the sale of sheep, lamb or wool products. In 1986 approximately 2,793 farms reported more than fifty percent of their sales from sheep products.

The Alberta sheep flock reached a peak of 497,000 head, in 1961, and then declined to a low of 143,000 head in 1978. Over the last decade the Alberta flock has shown steady growth to reach 212,000 head in 1989 or approximately 29 percent of the national flock. The distribution of the Alberta sheep flock within the province is shown in Figure 1.1.

Figure 1.1. Distribution of the Alberta Sheep Flock by Census Division 1986, ('000 head).

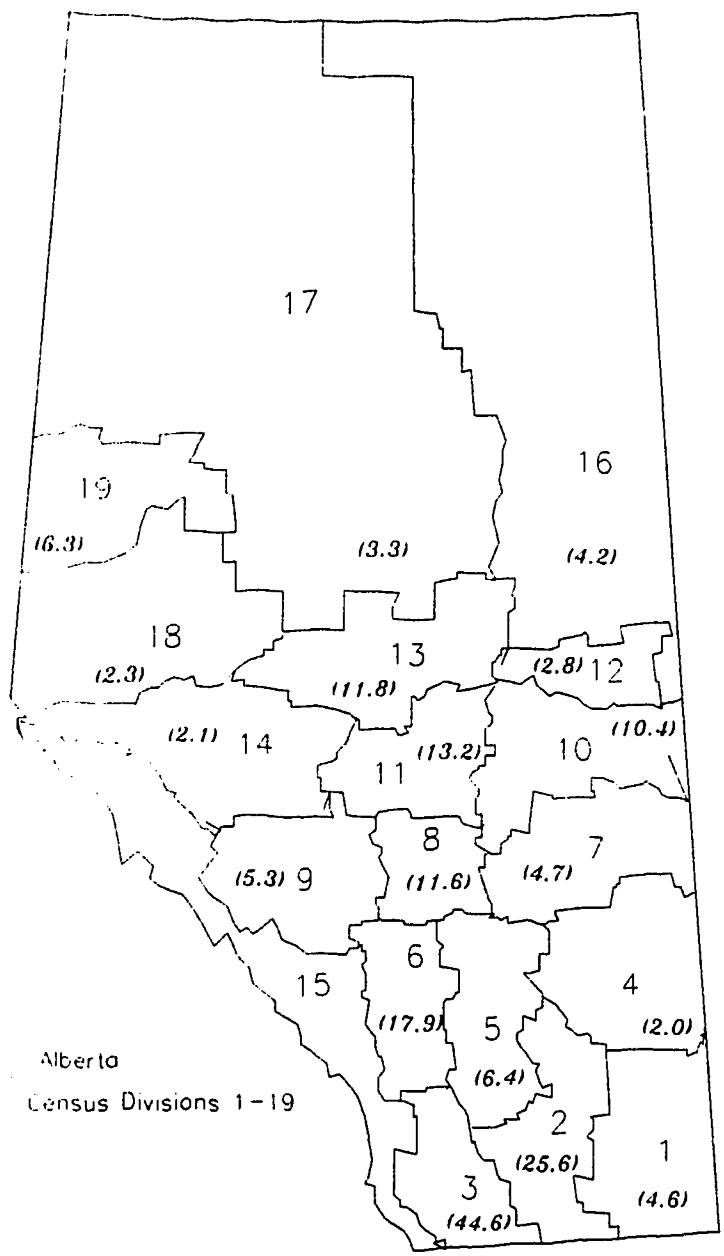
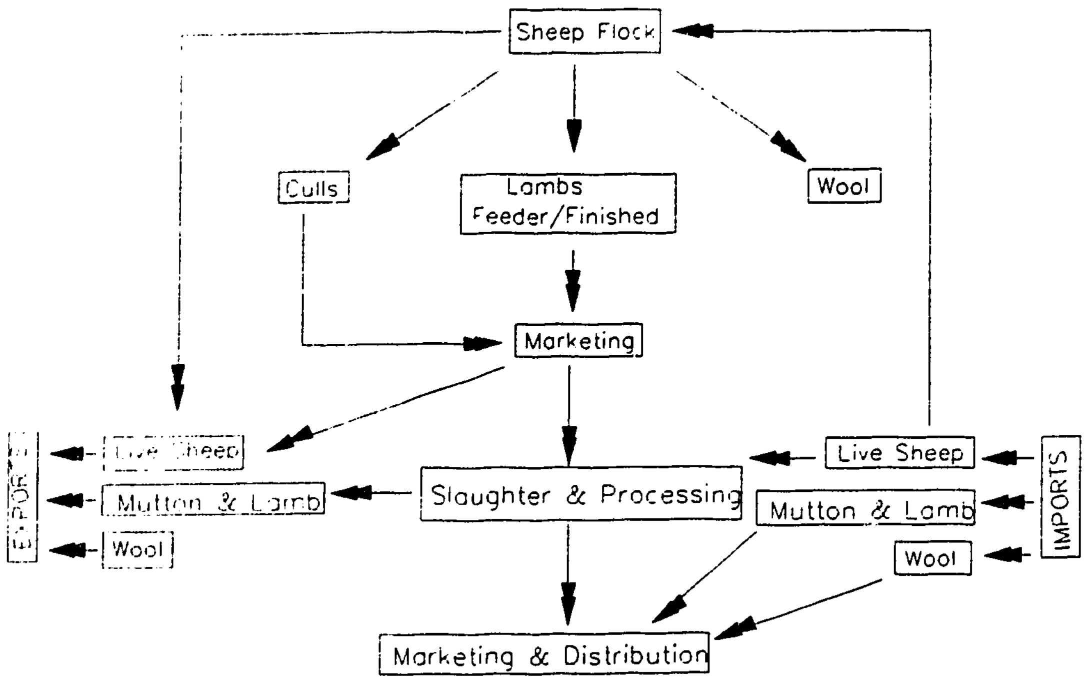


Figure 1.1 shows that sheep can be found in all Census Divisions of Alberta (with the exception of Census Division 15). However, the provincial flock is concentrated in the southern, more arid parts of the province. With respect to sheep production, producers can be broadly divided by production method into two groups; stock sheep producers and lamb feedlot operators. Stock sheep producers manage grazing flocks on pasture or range forage and sell lambs directly for slaughter or for further feeding. Many of the stock sheep producers also have a lamb feedlot. grain or cattle enterprise. Sheep producers compete primarily with beef cattle producers for resources such as grazing land, labor, marketing and transportation facilities[2]. In general, feeder lambs are raised on forage until they reach 27 to 33 kilograms and are then placed in feedlots for finishing on grain. A flow chart of the Canadian sheep and lamb system is illustrated in Figure 1.2.

2 Competition for resources between sheep and cattle can be compared via feed consuming animal units. An animal unit is defined as one cow or five sheep.

Figure 1.2. The Canadian Sheep and Lamb System.



Source: Adapted from Agriculture Canada, *The Canadian Sheep and Lamb System*, 1977.

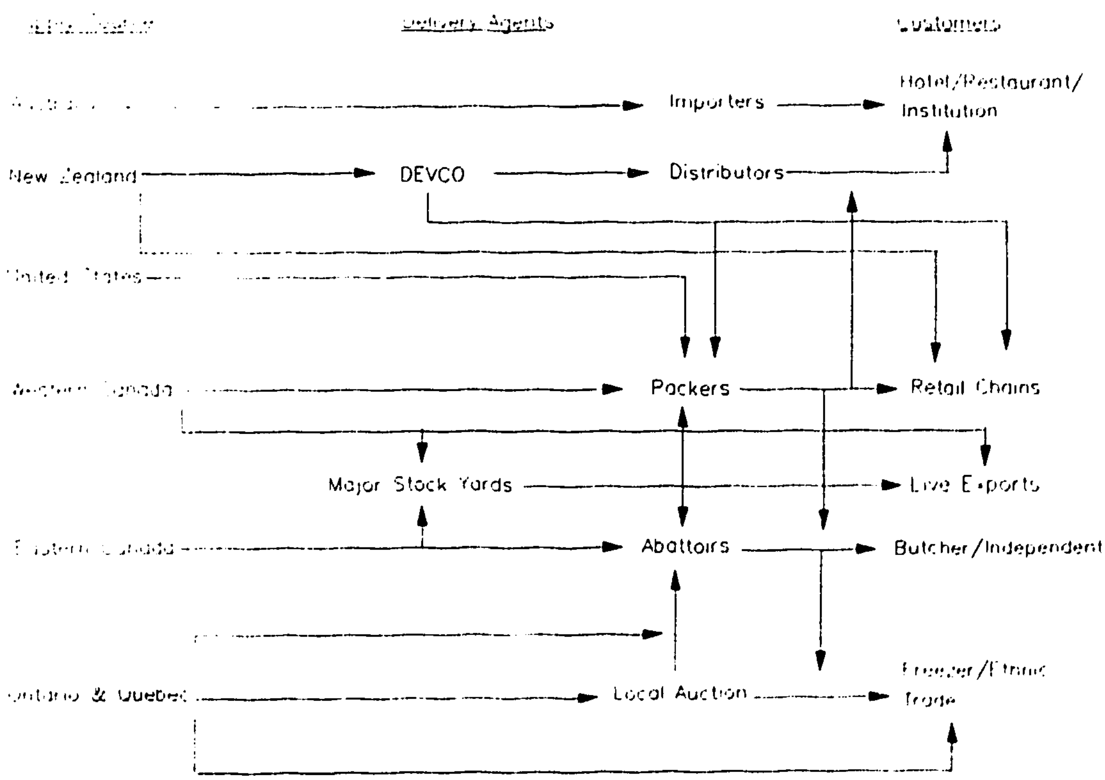
The sheep industry is small and susceptible to competition due to a number of factors including high production costs, low volume of output and the inability of many producers, processors and distributors to expand and adapt to changing economic conditions (McClelland, 1987). In many cases, producers have sheep as a secondary livestock enterprise and often do not have the finances or experience necessary to make changes to their facilities or production system.

The sheep industry is represented by a plethora of provincial and national producer organizations and associations which often differ with respect to the appropriate policies necessary to maintain a viable industry. Provincial and national sheep producer organizations support the industry via product promotion, producer education, marketing advice and lobbying efforts. These organizations attempt to bring greater coordination and stability to the industry. The provincial and federal governments also support the sheep and wool industry via monetary and consultancy incentive programs, sheep production specialists, marketing information and representations with other countries regarding trade issues.

1.2.1 Marketing Channels

Lamb marketing in Canada is complex and involves a range of marketing channels including direct farm gate sales, sales via stockyards, direct sales to packing plants and live exports. The marketing channels for sheep and lambs are illustrated in Figure 1.3.

Figure 1.3. Marketing Channels for Sheep, Lambs and Sheepmeat in Canada.



Source: Derived from Agriculture Canada, *The Sheep Industry -- A Profile*, 1986.

Farm gate sales or the freezer/ethnic trade play a major role in the sheep industry which distinguishes it from other livestock sectors. Direct farm sales including sheep and lamb consumed on the farm account for over forty percent of domestic sheep and lamb marketings in eastern Canada with the remainder sold through public stockyards. Direct sales to the Lambco packing plant is the major marketing channel for sheep and lambs in western Canada. The Lambco plant is the only specialized lamb processing facility in Canada and in 1987, approximately 70,000 sheep were slaughtered at the plant. Since the provincial market for lamb is small due to the small population base, historically, approximately fifty percent of Lambco's output has been shipped to markets in eastern Canada, primarily Toronto and Montreal.

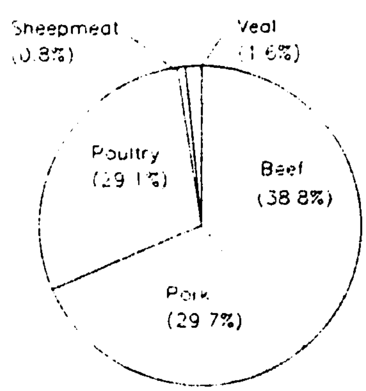
Lamb production in Canada is characterized by having a seasonal pattern of production with most of the lambs born between January and May, while lambs are slaughtered between six and twelve months of age. This results in lamb marketings reaching a peak in the third and fourth quarters with scarcities often occurring in the first and second quarters of the year. Seasonality of production and marketing tends to adversely affect the provision of a consistent supply of Canadian fresh lamb throughout the year. During the January-April period when domestic lambs are in short supply, live lambs are imported from the United States to supplement the domestic product.

In eastern Canada the seasonality pattern is somewhat different with shortages of lamb occurring in the first quarter followed by high supplies in the second, a decline in the third quarter and an increase in the fourth quarter (Birchfield, 1988). This seasonality pattern is determined to a large extent by periods of peak demand. Demand for new crop lambs is greatest during the Christmas and Easter seasons, especially in the urban areas of Montreal and Toronto[3]. Closely associated with seasonality in supply is seasonality of prices with highest prices inversely related to supply levels. The lamb market, because of its small size and seasonality characteristics is more volatile than the pork, beef or poultry markets. The industry exhibits large fluctuations in market returns which may tend to undermine producers' confidence and act as a deterrent to expansion.

1.2.2 Consumption

The consumption of meat in Canada has shown a steady increase over most of the last twenty years. However, over this period a considerable amount of substitution has taken place between the various meat types. In particular, there has been a shift in demand in favor of white meats at the expense of red meats. The relative shares of the major meats consumed in 1988 are shown in Figure 1.4.

Figure 1.4. Relative Shares of Meat Consumption, Canada, 1988.



Source: Derived from Statistics Canada, *Cat. No. 23-202 and Cat. No. 23-203.*

3 New crop lambs are usually less than three months of age and are marketed at live weights of less than thirty kilograms, primarily to the ethnic market.

With respect to overall meat consumption, sheepmeat (lamb and mutton) accounts for less than one percent of total meat consumed in Canada[4]. Consumption of lamb can be divided into two segments, fresh and frozen. Frozen lamb is supplied almost exclusively by imports while fresh lamb is predominantly of domestic origin. Fresh lamb can be regarded as a specialty meat due to the low volume of consumption and high retail price. Lamb consumption is highest among consumers with above average education and income levels (Contemporary Research Centre, 1985).

The consumption of lamb in Canada is unevenly distributed compared to the consumption of other red meats and is characterized by having a strong ethnic influence with consumption largely confined to ethnic groups of European and Middle East origin. Traditionally, persons from the United Kingdom and Mediterranean origin have been the largest consumers of lamb. Highest lamb consumption occurs among people living in the more densely populated areas of Toronto, Montreal and Vancouver.

Canadian consumption of sheepmeat has shown wide fluctuations over the years declining from a high of 2.7 kilograms per capita in 1935 to less than one kilogram per capita in 1950. During the 1950s, 1960s and 1970s lamb consumption continued to be volatile. The downward trend in consumption continued during the late 1970s to reach a low of 0.7 kg. in 1981. During the 1980s, lamb consumption gradually increased to reach 0.8 kg. per capita in 1988. Figure 1.5 illustrates the secular trend in Canadian sheepmeat consumption from 1935 to 1988.

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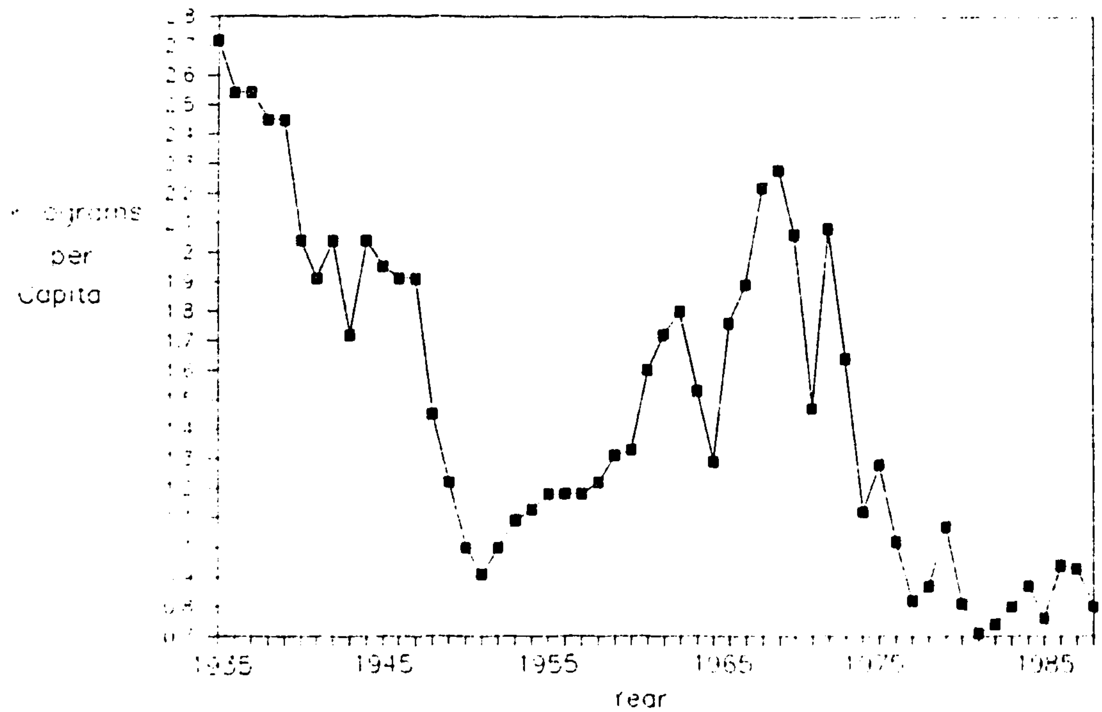
4 Mutton accounts for less than 5 percent of total sheepmeat consumption and is used mainly in processed foods.

Figure 1.5. Sheepmeat Consumption (kg. per capita), 1935-1988.



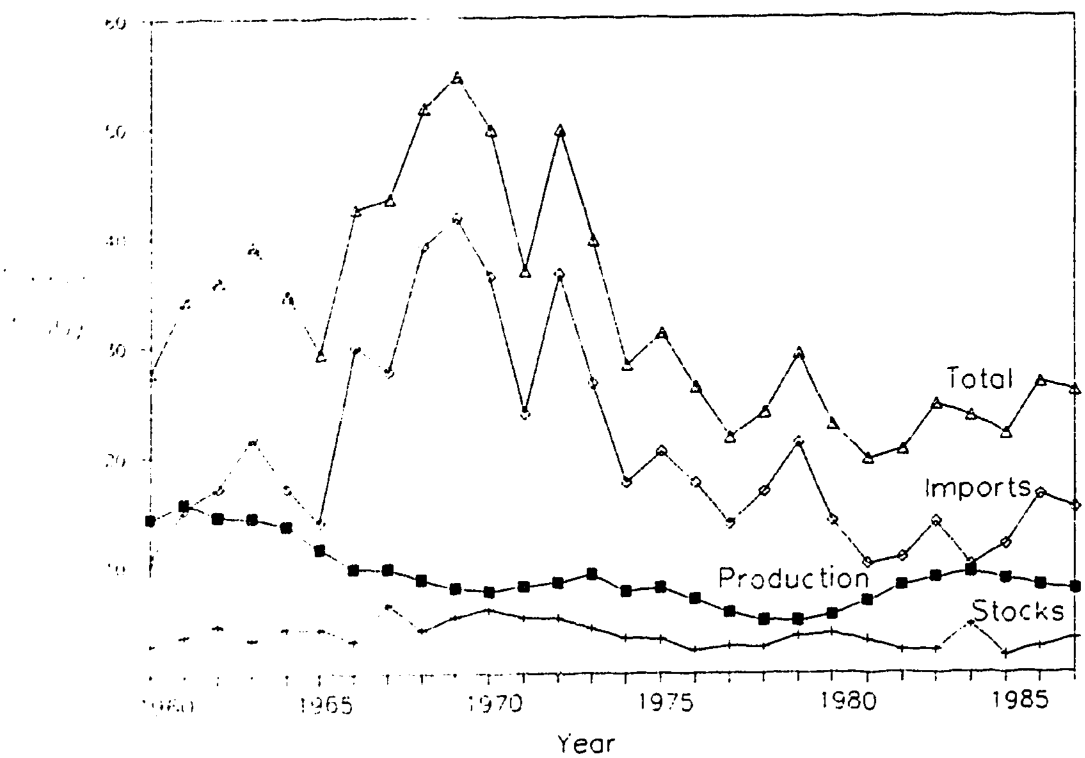
Source: Derived from Statistics Canada, *Cat. No. 23-203* (various issues).

Canada is approximately 35-40 percent self sufficient in sheepmeat with demand exceeding supply in all regions, except the Prairies. The sheepmeat deficit is filled by imports from a number of countries including the United States, N.Z. and Australia.

1.2.3 Supply

Imports of sheepmeat began in the early 1950s with Australia, N.Z. and the U.S. supplying the market requirements in excess of domestic supply. The supply of sheepmeat has declined from a peak of 54,610 tonnes in 1969 to 19,630 tonnes in 1981. The import share of total sheepmeat supply increased from 38 percent in 1960 to almost 58 percent in 1987. Figure 1.6 illustrates the contribution of imports, production and stocks to total sheepmeat supply from 1960 to 1987.

Figure 1.6. Supply of Mutton and Lamb, 1960-1987.



Source: Derived from Agriculture Canada, *Handbook of Food Expenditures, Prices and Consumption*, 1988.

Historically, Australia has been the major supplier of mutton to the Canadian market, while N.Z. has been the major supplier of frozen lamb. Although frozen lamb imports have displayed wide fluctuations during the 1980s, there has been little change in the overall volume of imports. However, fresh chilled lamb imports almost doubled to 3,500 tonnes during the 1980s. Furthermore, an important feature of chilled lamb imports during the 1980s has been the dramatic shift in the source of such imports. Specifically, chilled lamb imports from the U.S. have declined while chilled imports from Australia and N.Z. have increased.

The live trade in commercial sheep has been confined to the U.S., due to proximity and the relative ease with which sheep can be shipped between the U.S. and Canada. With the exception of the mid 1940s and early 1950s, imports of live sheep have always exceeded exports. In certain years when domestic prices are low, the U.S. provides an attractive alternative market for Canadian sheep producers, especially those located in the southern part of the provinces.

Canada like other wool producing countries, has suffered a decline in all sectors of the wool industry due to the advent of synthetic fibres. In 1989, Canadian shorn wool production was approximately 1,170 tonnes (greasy basis), a seven percent increase over the 1988 level. This increase is attributed to an increase in the number of sheep shorn. A mature sheep produces a yearly clip of between 4 to 6 kilograms of wool depending on the breed. The returns for lambs have gradually increased relative to those for wool, to the point that there is little emphasis placed on wool production. The low volume of production has made it difficult to collect, process and merchandise wool. Most of Canada's wool production is exported to the United States, Europe and Japan since Canada does not have facilities available for refining the wool (Birchfield, 1988).

1.3 Objectives and Hypotheses of the Study

The primary objectives of this study are twofold: to develop and analyze a structural model of lamb supply and to analyze the economic effects on producers and consumers of a supply management marketing option for the sheep industry. More specifically, the objectives of this study are as follows:

(i) To derive direct and cross price elasticities of supply for lamb, wool and cull sheep from microeconomic data for the Alberta sheep industry.

(ii) To compare and analyze the supply elasticity estimates from the linear programming approach with estimates derived from the econometric technique based on aggregate or market level data.

(iii) To examine the stability of farms within the industry and the movement of farms between different size groups in addition to entry and exit from the industry.

(iv) To assess the economic effects on producers and consumers of a marketing option based on the supply management principle for the industry.

The general hypotheses postulated are associated with examining the economic efficiency of the sheep industry. The first hypothesis is that the supply response of the Alberta sheep industry is low. The second general hypothesis is that, associated with the low supply response of the industry is a loss of market share for domestic lamb. The specific hypotheses are as follows:

1. That the direct and cross price elasticities of supply for lamb are low and inelastic in the short-run but elastic in the medium and long-run.

2. That the Alberta sheep industry is becoming more concentrated resulting from a decline in the number of small producers and an increase in the number of medium and large size producers.

3. That a supply management marketing program for the industry though yielding some short term benefits to producers would have adverse long term implications for the development of the industry.

1.4 Methodology and Organization of the Study

This section briefly outlines the methodological framework and organization of the following chapters of the study. Chapter 2 outlines the theoretical framework for deriving supply elasticity estimates from microeconomic foundations using the representative farm concept. The structure of the industry is outlined and sheep producers are categorized into three categories based on flock size. Typical or representative sheep farms are defined for each group based on primary survey data supplemented with secondary data. The representative farms are then used to construct normative supply models for lamb, wool and cull sheep.

To estimate supply response using the linear programming technique requires data on the complete farm operation. Estimates of supply response for individual representative farms are derived and aggregated to estimate industry level response. Direct and cross price elasticities of supply for lamb, wool and cull sheep output are estimated using the parametric programming procedure. The linear programming approach to estimating supply response is characterized by a discontinuous step function, i.e., output is perfectly inelastic over relatively large price ranges. The elasticity estimates are incorporated into the welfare framework of Chapter 5 to assess the economic effects of a supply management marketing program for the Alberta sheep industry. Lastly, a Markov chain model which accounts for structural change is estimated and combined with the programming model to estimate the output response of the sheep industry.

In Chapter 3, the theoretical framework for estimating supply elasticities from market level data is outlined, in addition to some discussion of the restrictions and assumptions required for the empirical analysis. The simultaneous equation model that is used to estimate the short-run and long-run elasticities is specified and discussed. This model combines a stock formation equation with a supply equation to give the simultaneous model from which supply elasticities are estimated. Finally, the own and cross price elasticity estimates for lamb are presented and discussed, together with some econometric studies of supply response for the sheep industry.

A critique of the normative programming and positive econometric estimation procedures is presented in Chapter 4. This is followed by a discussion of the theoretical reasons for the divergent elasticity estimates from the two procedures.

The welfare economics framework of economic surplus is presented in Chapter 5. This framework is used to assess the potential economic effects of a supply management marketing program for the sheep industry. A range of supply and demand elasticity estimates is used in the welfare framework to assess the welfare changes of a supply management marketing program for sheep. Some estimates of the income transfers and social costs of the program are presented and discussed. Lastly, Chapter 6 provides a summary of the major findings of the study and outlines some areas for further research.

Chapter 2: A Normative Approach To Supply Analysis

2.1 Introduction

The purpose of this chapter is to present estimates of supply response for the Alberta sheep industry. A brief review of supply theory is given together with a discussion of some relevant normative agricultural supply studies. An understanding of producers' supply response to price changes is important not only for projecting future output of the industry but also for assessing the effects of new policies on the industry. More specifically, supply elasticity estimates are important in evaluating the implications of government policies such as supply control or free market policies on industry structure. Traditionally, both regression analysis and mathematical programming techniques have been used to estimate supply elasticities for agricultural commodities.

Linear programming has been criticized on the grounds that it involves a normative approach to supply estimation where farmers are assumed to be rational in their decision making process to permit approximation by a maximizing model. This often results in overestimation of supply response (Wipf and Bawden, 1969; Quance and Tweeten, 1971). However, where limited data are available, the standard approach to supply estimation has been to adopt the linear programming technique.

Derivation of a normative supply function involves assumptions about the price of a particular product relative to factor prices and other product prices (McKee and Loftsgard, 1961)[5]. The profit function implicitly assumes that all input and product prices hold over the production period. The derived supply function describes the

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5 Several terms are used in the literature to describe supply relations derived from the programming approach. These include normative, conditionally normative and conditionally predictive models of supply.

optimum adjustment in resource allocation to price relationships at a particular point in time, under the assumption that profits are to be maximized. Several assumptions are adopted in constructing a normative supply model regarding specification of the production activities, determination of the relevant constraints with respect to each activity, exogenously determined input prices in addition to the standard linear programming assumptions of linearity, additivity, divisibility, finiteness, non-negativity and proportionality (Best and Ritter, 1985).

The optimum allocation of resources on any individual reference farm depends on the components of the optimum allocation on competing farms in the area. Summation of reference farms' normative supply functions yield an aggregate supply function for the industry. The results obtained by this normative approach are optimum only within the context of the assumed set of norms used in the analysis. Thus, normative results provide a useful point of reference against which divergent use of resources and goals can be compared.

The supply elasticity estimates for aggregate farm output indicate the magnitude of output adjustments in response to changes in commodity market prices. Estimating supply elasticities is difficult because of the influence on supply of exogenous factors such as weather, and because of problems involved in quantifying factors such as changes in technology.

In this chapter, individual farm supply functions are constructed and used to estimate the aggregate normative supply function for the Alberta sheep industry. Direct and cross price supply elasticities for the industry are also reported and discussed. In addition, the sensitivity of the elasticity estimates is tested with respect to changes in market prices and the results reported. The normative supply elasticities are validated by comparing the results from this study with supply elasticity estimates derived from other programming studies of the sheep industry. Finally, a Markov (transitional probabilities) model is outlined and used to project the transition of farms between different size categories.

2.2 Theoretical Framework

The theory of supply involves economic principles of production, trade flows and inventory changes. Traditionally, profit maximization has been assumed as the primary motivational hypothesis whereby producers vary input and output levels to ensure that profits are maximized. Colman (1983) classified methods of analyzing supply response into two broad categories, namely, programming and econometric procedures[6]. The remainder of this chapter will focus on the theoretical framework of supply estimation as it relates to the programming approach, broadly following the procedure outlined by McKee and Loftsgard (1961).

2.2.1 The Linear Programming Procedure

Linear programming is a mathematical concept defined as the optimization of a linear function in several variables subject to a set of linear inequality constraints (Chiang, 1984). Basically, linear programming involves constructing a mathematical model of selected reference farms. The objective function, production activities, resource and institutional constraints for the reference farm are specified. The objective function is usually specified as a profit function but can also incorporate other objectives, for example, risk aversion (Pomareda and Samayoa, 1979). The optimization problem

6 Chapter 3 discusses the econometric approaches to supply estimation.

is then solved using variable price programming which enables supply price relationships to be established for each commodity and reference farm. By attaching appropriate weights to each of the individual reference farm supply functions, an estimate of the aggregate or market level response relationship can be established. The weights attached to each individual supply function reflect the relative importance of the individual reference farm in the population of farms to which the aggregate supply function is to apply.

A number of conceptual problems arise in constructing a mathematical model of a reference farm. The first problem relates to the range of alternative activities to be included in the model. Theoretically, the model should include all possible agricultural activities assuming that profit maximization is the principal behavioral criterion. However, incorporating all possible alternative activities into a linear programming model is not feasible due to:

(a) a lack of detailed reliable data necessary to distinguish between alternative activities; and

(b) the unmanageable size of the programming model.

Therefore, the list of activities to be included in the model is derived by arbitrary decisions based on the researcher's judgement and knowledge of the industry (McKee and Loftsgard, 1961, p. 155).

Model Restrictions

The restrictions to be incorporated into a programming model depend on the primary objectives in analyzing the organization of the farm. To estimate supply response the relevant restrictions can be classified into three broad groups: resource, institutional and technical restrictions. Resource restrictions refer to the physical resources of the farm, for example, land, equipment, buildings, machinery and capital. The relevant resources are incorporated into the programming model by designating separate equations which relate to the use of each distinct resource in the production process. The initial level of each resource restriction is taken as the current stock of each resource. The programming model is constructed in such a way as to allow for the purchase and/or sale of any resource by incorporating a purchase or sale activity for each resource. For resources such as farm buildings which have no value other than in direct use on the farm, the selling activity becomes the slack activity of the programming model when the initial restriction is stated as an inequality.

Capital equations express the amount of capital required per unit of each activity. The opportunity cost of capital in nonfarm uses is incorporated into the model by use of a capital sale activity. Purchase of capital involves the use of available sources of credit expressed in the model as capital borrowing activities. Because different sources of credit are available at different interest rates and/or involving different repayment schedules, separate activities are defined to take this into account. Thus, the capital equations deal with the allocation of both the liquid assets of the farm and any additional capital that the farm may find profitable to acquire from outside credit sources. The coefficients of the capital equations express the total capital requirements per unit of an activity for both single and multiple period inputs. Therefore, the capital coefficients reflect the full cost of introducing an activity into the farm organization and operating this activity over one production period.

The availability of capital and credit constitute the principal resource limitations to the organization of the farm. Credit availability is based largely upon the producer's equity in his assets. The institutional environment within which the farm operates is reflected in the form of institutional constraints on the model. These constraints are often reflected in the type and terms of credit available to the farmer from different sources.

Technical constraints or limitations include factors such as soil characteristics, topography and disease problems of the particular area. The number and nature of such constraints required in any particular programming model depends upon the technical conditions pertaining to the particular programmed farm. A series of technical constraints are required to express the nature of the relationship between activities when activities are combined as sequential components in the production process. This occurs when the output of one activity becomes an input for one or more other activities. For example, feed crops produced on the farm (production activity) may be sold (a sales activity) or used as inputs for livestock activities (a using activity). A complete process combines at least two activities, e.g., a production activity with a using activity. Separate equations are required for each distinct feed category. The output from the crop and/or livestock activities is expressed as a negative input in the appropriate crop and livestock equations. The use of home grown feed by livestock activities on the farm is expressed in the same manner as other input requirements, i.e., as a positive input in the relevant livestock equations.

Constructing the profit equation for the programming model presents a number of difficulties as the model accounts for changes in the quantity of both single and multiple period resources used on the farm. The cost of multiple period resources is pro-rated over the production periods in which their services are available. Any additional costs incurred as a result of resource ownership are also included in the coefficients of the profit equation. These costs are added to the purchase and/or sale price of the resource. Thus, the profit equation includes expenditures on all single period resources used during the production period and all revenue from the sale of products during the same production period in addition to the costs and profits from multiple period resources on an annualized basis.

Because production processes involve considerable time lags, profit maximization must relate to some specific time period. Traditionally, the calendar year has been used as the standard accounting period. Normative supply analysis is concerned specifically with the choice of the most profitable set of alternatives as of a specific point in time (usually the present) given the technological and institutional circumstances. Under these conditions, the most common approach is to seek to maximize profits of the immediate production period as the results that can be achieved in subsequent production periods depend upon how the farm is organized in the preceding production periods.

A movement along a given supply curve (a change in the quantity supplied) can be distinguished from conditions which lead to a shift of the supply curve (Buse and Bromley, 1975). Essentially, a shift in supply implies that more or less of the commodity will be placed on the market at the same price. A supply schedule describes the relationship between the price of a product and the quantity of that product producers place on the market at that price, ceteris paribus. For any given supply curve, the factors that are assumed to remain fixed are the prices of all inputs used to produce the product and the physical production process used to transform the inputs into outputs.

From the preceding discussion, the derivation of a normative supply function involves different assumptions as to the price of a particular product over a specific time period.

The normative supply function describes the optimum adjustment to alternative product price levels at a particular point in time. However, adjustments over time are not considered. The nature of the normative supply function of the farm changes over time due primarily to changes in the farm organization and technological developments.

With this approach to the estimation of an aggregate normative supply function, the selection of reference farms is of crucial importance as they form the base from which any change in organization is made[7]. To a large extent the reference farms determine the nature of the normative supply function. In deriving the aggregate supply function for a commodity, structural changes that have occurred or are expected to occur in the industry should be taken into account.

Since aggregate commodity supply response is derived from the horizontal summation of the individual producer's supply, structural change within the industry is of crucial importance. Learn and Cochrane (1961) define structural change as resulting from a change in one or more of the factors included in the 'ceteris paribus' condition. More specifically, structural change relates to a change in the slope or position of the supply function which may result from a change in one or more of the following:

(1) the nature of the production function;

(2) managerial abilities;

(3) the institutional environment of producers; and

(4) changes in the number and distribution of producers.

7 In the literature, reference farms are also referred to as benchmark, representative or typical farms. These terms are used interchangeably in this study.

Other factors which have structural implications for an industry include the size and degree of specialization among firms, government programs, and the extent of market integration within the industry. Many variables which impinge upon supply cannot be uniquely classified as giving rise to supply shifts or to structural change. For example, changes in some variables such as a new production function for a competing product may give rise to supply shifts of greater significance than structural effects.

Advantages of the Linear Programming Approach

One of the major theoretical advantages of the programming approach to supply response estimation is that the procedure closely follows the steps prescribed by neoclassical supply theory for deriving the output and input levels which maximize the profit of a firm with a given production technology (both involve starting with a known technology at the farm level and aggregating to the market level). Mighell and Black (1951) were the first to combine the typical firm concept with linear programming models to estimate supply response. Day (1963) demonstrated, via the duality theorem, that a single linear programming model for the aggregate is equivalent to a direct aggregation of the solutions to a set of individual firm models. The conditions which are sufficient for this equivalence to hold are: proportional variation of resources and behavioral 'bonds', proportional variation of net return expectations among all firms in the aggregate, and finally, common technical coefficients which appear in the constraints on the firm's decisions (Day, pp. 797-813).

A further advantage of the programming approach stems from the model's capacity to handle the complex of inter-relationships arising from the multiple product nature of the farm. The programming procedure solves for the optimum level of output and inputs in a way which takes full account of the competition between products for limited resources. In principle, the procedure is capable of taking account at the farm level of the effects upon supply of all product prices, all input prices and all relevant institutional, technological and physical restrictions. Full dynamic aspects of supply can be incorporated into the representative farm approach as a result of the development of recursive programming models (Heady, 1961) and dynamic linear programming models (Throsby, 1964 and Johnston, 1965). Multi-period optimization techniques permitted by recursive and dynamic linear programming make it possible for investment activities to be incorporated into the activity set. Both real (financial, physical) and psychological (attitudes/habit) constraints can also be incorporated into the model. These constraints limit producers' ability to adjust to changing supply conditions by restricting the level of activities in any period to a function of their level in the previous period. Colman (1983, p. 213) points out that the majority of programming applications continue to be static and linear in nature.

Limitations of the Linear Programming Approach

There are however, some problems and limitations in adopting the linear programming methodology. Considerable resources have been devoted to finding solutions to the problems associated with aggregation and specification issues[8]. Buckwell and Hazell (1972) in their study suggest that unbiased aggregate supply estimates are attainable only if stringent homogeneity criteria are applied in the classification of farms. They conclude that in practice it is not possible to devise stratification procedures which completely eliminate aggregation bias. Day (1963)

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8 The aggregation problem (across commodities, across space and through time) also creates difficulties with econometric techniques.

suggests the application of three conditions: technological homogeneity, pecunious proportionality and institutional proportionality which would overcome the aggregation bias and guarantee unbiased supply estimates.

Less rigorous conditions have been suggested by Sheehy and McAlexander (1965), which involve classifying farms on the basis of the most limiting resource for each product. They conclude that adopting the homogeneous restriction method leads to less aggregation bias than the conventional procedures based on size and type of farm. Hartley (1962) suggests construction of 'benchmark' farms by averaging the characteristics of groups of farms. However, this approach leads to serious aggregation bias, especially near the extreme end of the price range. Restrictive resources on individual farms are not reflected when resources are averaged, but restrictions existing on individual farms tend to be averaged out.

Fisher (1969), recognizing that complete elimination of aggregation bias is not feasible, proposed an alternative approach to aggregation bias in farm supply analysis. He suggests adopting a systematic cluster analysis technique to identify the groupings which minimize the bias. A major limitation with this approach is that full prior knowledge of the technology matrices of individual farms is required. Frick and Andrews (1965) tested four methods of grouping farms in order to minimize the aggregation bias inherent in conventional linear programming supply functions. The methods include averaging, grouping farms depending on the most limiting resource, grouping farms by size and grouping farms by potential size. Grouping of farms according to the most limiting resource resulted in the least bias. However, a major limitation of this approach is that it ignores size.

Kennedy (1975) suggested yet another method for reducing bias, using regression analysis of available farm resources as a function of size. These results are then incorporated into a linear programming model. This procedure reduces the effects of different resource mixes on the aggregation bias while management uniformity is not affected.

One simplifying assumption which cannot be fully adjusted for is that farmers are assumed to be profit maximizers. Wipf and Bawden (1969) and Zepp and McAlexander (1969) have critized the profit maximization assumption and suggest that this assumption leads to overestimation of supply response under the representative farm approach. Zepp and McAlexander (1969) compare the supply prediction performance of alternative models and conclude that both recursive and linear programming models generate larger predictive errors than a time series regression model.

Conventional linear programming models assume that the farmer's decision making process can be simulated using profit maximization as the primary decision criterion. The profit maximizing behavioral assumption of producers is a simplification of reality, but is useful for many purposes including deriving estimates of supply elasticities. Relaxing the assumption that the objective function, resource constraint and input output coefficients are known with certainty greatly increases the complexity of determining an optimal solution.

At the farm level, there are two major areas of uncertainty. First, there is uncertainty of gross margins due to variability of prices and yields. Second, there is uncertainty of factor requirements and/or factor productivity which can be reflected by stochastic input output coefficients (Wicks et al., 1978).

Several techniques have been used to incorporate risk into the objective function of a conventional linear programming model. These include the focus loss approach (Boussard and Petit, 1967), flexibility constraints (Day, 1963), MOTAD (Hazell 1971, Hazell and Scandizzo, 1974) and the marginal risk constraint approach (Chen and Baker, 1974). Sengupta and Tintner (1971) have suggested that problems with risky resource constraint coefficients can be solved via the dual formulation of the problem. Wicks and Guise (1978) developed a method, namely, mean absolute deviations (MAD) to incorporate risk into the input output coefficients of a conventional linear programming framework. Other approaches include discrete stochastic programming (Rae, 1971) and simulation (Trebeck and Hardaker, 1972). The choice of a particular method depends on the prevailing type of uncertainty, performance of the method and available data.

Other simplifying assumptions of the representative farm approach which are not amenable to modification are those which arise because certain activities which are assumed to be fixed at the farm level are also assumed to be fixed at the aggregate level or conversely, that activities variable at the farm level are also variable at the aggregate level. For example, it is reasonable to assume that the price of inputs and output are unaffected by the decisions of individual reference farms, but at the market level an increase in supply will tend to cause a decrease in the price of the product while the price of inputs may increase.

In this study, the linear programming approach will be used to estimate the industry or aggregate supply function for the Alberta sheep industry. The basic procedure adopted involves constructing a complete linear programming model to describe the production system of a number of reference farm types. Essentially, this amounts to specifying a set of linear, additive production functions for each possible output the farm might produce, in addition to specifying upper and lower bounds on resource availabilities[9]. The design of the reference farm is crucial to the estimation of an aggregate or industry supply function. A number of approaches to the selection of reference farms for the programming technique are discussed following an outline of the general model.

2.2.2 Model Formulation

Mathematical programming is an optimization technique that seeks to solve problems in which the optimizer faces inequality constraints (Chiang, 1984, p. 651). In this study, the linear programming version of mathematical programming is used in which the objective function as well as the inequality constraints are all linear. The essential components of a linear program are, an objective function, a set of constraints and a set of non-negativity restrictions. Problems involving more than two choice variables are usually solved by the simplex method (Dantzig, 1951). The general linear program for estimating supply response can be stated as follows:

(1) **Maximize** $c\,x$

(2) **Subject to** $Ax \leq b$

(3) $x \geq 0$

where

c is the row vector of gross margin for farm activities;

9 The linearity assumption can be relaxed by adopting non linear estimating techniques such as separable programming or quadratic programming.

x is the column vector of activity levels for the farm;

b is the column vector of resource constraints; and

A is the technology matrix.

The technology matrix (A) is composed of elements, a_{ij} which can be interpreted as the amount of input i, required per unit of activity level in activity j. Thus, farm gross margin is maximized subject to the resource constraints on the production of the output mix.

The structure of the equations in the linear programming model for describing production activities can follow one of two approaches, an enterprise approach or a process approach. The enterprise approach requires that the activities in the linear programming model are independent of each other. Thus, each activity contributes to a single objective function in proportion to the activity level.

In this study, however, the process approach is used. The process approach involves treating activities in the linear programming model as interdependent. That is, the farmer selects activities not only on the basis of an activity's direct contribution to the objective function but also on the production of commodities that can be used within the farming operation. Thus, the process approach includes material balance equations which allow for the transfer of resources between activities within the farm operation.

The optimization model outlined above is based on the linear programming formulation of the producer's decision making process subject to production, finance and resource constraints. Linear programming yields the optimum output response to price changes for a given set of input data and a given objective function. To the extent that the specification of the linear programming matrix and the form of the objective function are representative of the 'actual' situation, the output response specified by this optimum combination of activities is a realistic representation of the 'actual' output.

The following simplifying assumptions are made in the development of the programming model. First of all, prices of all farm products and of resources are assumed to be similar for the reference farms. A further assumption relates to the markets for lambs, wool and cull sheep in Alberta; these markets are assumed to be highly coordinated and therefore market prices are assumed to be similar for all farms in the province. Also transportation costs from the reference farms to buying or selling centers and alternative marketing strategies for lambs, wool and cull sheep are not included in the programming model. Information was collected from two sample farms on relevant production activities and stocks of physical and financial resources. This information together with the annual provincial production survey data were used in developing the matrices of the linear program. The programming matrix for each reference farm is basically composed of three interdependent segments namely production, finance and resource. Table B:1 (Appendix B) provides a breakdown of the structural components of the linear programming matrices for the reference farms. The programming matrix for the medium reference farm consists of 72 rows and 59 columns while the large reference farm matrix is of the order of 71 rows and 55 columns.

2.2.3 Selection of Reference Farms

The concept of a representative firm approach (RFA) for studying firm and/or aggregate supply response dates back to the work of Marshall (1948). Several researchers including Barker and Stanton (1965) have adapted and applied this concept to the problem of deriving agricultural output response. Barker and Stanton (1965) outline a five stage procedure to estimate aggregate agricultural supply for a commodity using the representative farm approach. The five stages are as follows:

(1) stratification of all farms in a region into uniform groups;

(2) defining a representative farm for each group;

(3) deriving supply functions for each farm;

(4) aggregation of the individual farm supply functions; and

(5) testing the sensitivity of the model's results in order to make predictions or prescriptions.

The representative farm approach provides an important link between the farm level and the industry level. Specifically, the impact of a change in a variable at the farm level where production decisions are made can be traced to the industry level where policy decisions are made. The farms which are included in the analysis relate not only to those that currently produce the product for which the supply function is to be derived but also to other farms operating in the region. When the price of a product rises, some farmers who are not currently producing the product may find it profitable to enter into the industry. The concept of structural change as it relates to the entry and exit of producers and movement between different size categories will be examined using the Markov chain framework in a later section of this chapter.

Sheehy and McAlexander (1965) outline a theoretical framework for selecting reference farms which can then be used to estimate the aggregate output of a commodity. This framework relates to two basic selection approaches, a traditional approach and an alternative approach. The traditional approach involves classification of farms in a region based on the absolute level of resources. An absolute constraint is defined as one that completely restricts the output of a particular commodity as the price of that commodity is raised indefinitely. That is, when the constraint is operative all of the resource supply will be allocated to the particular commodity. When the resources of such farms are averaged, the disproportionalities existing on individual farms tend to be averaged out. Thus, the reference farm does not reflect the restrictive resources of the individual farms but tends to overestimate aggregate output. Furthermore, with this approach the commodity is assumed to be produced by linear processes that are equally efficient in utilizing resources.

The alternative approach takes account of the level of resources on sample farms and the productivity of these resources. Specifically, this approach involves classification of farms on the basis of the most limiting resource used in the production of the particular commodity. Sorting of farms into groups with the same limiting resource yields reference farms based on the average of resource levels within each group. In such a grouping of farms, differences in output of a commodity from a farm in one group to a farm in another group is proportional to differences in the restricting resource(s). Multiplying by the number of farms in the group allows for the average resource level to be expanded to give an unbiased estimate of the group resources (Sheehy and McAlexander, 1965, p. 686). Similarly, the output associated with the average resource level can be expanded to an unbiased estimate of group output.

Sheehy and McAlexander (p. 687) also point out that the effects of differences in technology on output depend on whether or not the resulting differences in input-output relationships are associated with restrictive or nonrestrictive resources. If differences in the output of a commodity from farm to farm at a given price for that commodity are proportional to differences in at least one resource, then an unbiased group estimate of commodity output can be made. Historically, researchers have adopted average technology when working with large numbers of farms.

2.3 Inputs to the Model

The static partial equilibrium reference farm approach is adopted in this study to derive the aggregate supply function for the Alberta sheep industry. A reference farm is defined as a synthetic construct which is assumed to react to price changes in a manner similar to actual holdings (Monypenny, 1975). The holdings as represented by the reference farms are assumed to be similar in terms of the characteristics that affect their production decision making. Before proceeding with a description of the components of the model, an outline of the structure of the Alberta sheep industry is presented.

The Alberta sheep industry consists of approximately 2,148 producers of which slightly less than half have flocks of 17 head or less. A detailed outline of the structure of the Alberta sheep industry is shown in Table 2.1.

Table 2.1. Classification of Farms Reporting Sheep by Number Reported, Alberta, 1986.

Sheep (No.)	Category	Farms (No.)	Total Sheep (No.)	Share of Provincial Flock (%)
1-17		1,009	6,447	3.6
18-47	small	474	14,153	7.9
48-122		330	26,150	14.6
123-527	medium	263	63,863	35.7
528-1,127		55	40,855	22.8
1,128 +	large	17	27,655	15.4
Total		2,148	179,123	100.0

Source: Derived from Statistics Canada, *Census of Agriculture,* (Alberta), Catalogue No. 96-111.

Sheep producers can be divided into three broad groups, small, medium and large based on flock size[10]. The 'small' category of sheep farmer, that is, with less than 47 head of sheep, accounted for approximately 11.5 percent of the provincial sheep flock in 1986. Because of the heterogeneous nature of producers within this group, any attempt to model supply response for this group would be extremely complex and would add little extra precision in attempting to derive an industry supply function. Therefore, this group has been omitted from further analysis with respect to the programming of supply response in this chapter.

Reference farms were constructed using the alternative approach, that is, the homogeneous restriction method as outlined earlier in this chapter. Two sample farms were selected from the Census categories, one from the medium size sheep farm category and one from the large size category. These sample farms were used to identify the most limiting restrictions common to the individual farms in their respective groups. These restrictions were then used in the construction of representative farms. The number of holdings extracted from the Census data (1986) serve as weights to scale reference farm results to give information at an aggregate or industry level. In this study the model is a one period model, therefore no change in these weights is allowed for in the analysis. The data used to construct the reference farms were averaged over the three year period, 1986 to 1988. The relevant resources were identified to give the reference farm situations which were then expanded to the aggregate level.

10 The medium and large sheep producers essentially represent the commercial lamb industry in Alberta.

The reference farms were programmed over a range of lamb prices and the output expanded to provide step supply schedules for the farm. The optimization problem is then solved using the Mathematical Programming System 360 computer programming procedure (1971).

Basically there are two types of data input required for construction of the model: data related to the structure and data related to the technical coefficients. Parameters related to the structure have unique empirical values and are expressed per unit of production activity. Each production activity in a reference farm can use only one technology expressed as a unique combination of input-output and yield coefficients. The production activities specified in the reference farm matrices include crop and livestock activities. The crop activities are wheat, oats, barley, hay and pasture while the livestock activities are lambs, sheep and cow-calf activities. The unit of a production activity is one acre for crops and pasture and one head of breeding stock for livestock breeding activities. The technical coefficients for the model, in terms of the yield of crop and livestock activities, were based on data from the sample farms in conjunction with the annual provincial production surveys for the relevant years. There is no provision made for technological change within the model.

The programming model has two reference farm sizes, with the difference between the two farm sizes related to their level of resource endowments. Resource activities include buying and selling equations for all crops and livestock. Also included are purchase activities for arable and pasture land as well as a rental activity for pasture land. A machinery activity is allowed for as well as a building expansion activity. The model is sufficiently flexible to allow for mixed crop and cattle activities or complete specialization in crops or livestock.

The financial segment of the linear programming matrices incorporates a yearly cash flow, opportunity cost of capital and a maximum borrowing constraint. Included in the model are term deposit activities, credit activities, a mortgage restriction and an absolute constraint on loans available to the farm. A mortgage restriction is imposed on the model at 50 percent of the real estate value of the reference farm. The financial constraints play an important role in that they prevent unlimited acquisition of plant, breeding stock, machinery or land[11]. In order to avoid having the farmer make a trading profit by simply engaging in buying and selling activities, the buying and selling activities in the linear programming model must be at least equal.

The model assumes that the prices of all farm products and of resources are the same for all reference farms. Empirical values for crop prices were extracted from Alberta Agriculture *Production Costs and Returns Tables For Crops* (various issues). Livestock prices were obtained from Agriculture Canada *Livestock Market Review* (various issues). Variable costs are not a constraint in the linear programming matrices and are used only to calculate the value of the gross margin in the objective function.

Gross margin is defined per acre for crops and pasture, per ewe for the sheep activity and per cow for the cow-calf activity. In order to take account of the fact that the gross margin of some activities such as the sheep activity is composed of several products, the gross margin for sheep has components for the sale of wool, lambs and cull sheep. Beef activities include sales from one main product namely, yearlings. Finally, the gross margin for crop activities has components for both the sale and on farm feeding of grain and alfalfa hay activities. The farm gross margins are calculated by the computer algorithm for each production activity as revenue less variable costs.

11 The production and financial restrictions imposed on the activity set of the medium and large reference farms are shown in Table B:2 (Appendix B).

The solution vector of the linear program yields the representative farm's plan. However, the optimal solution in this model does not include payment to labor or other overhead costs (costs not attributable to a given production activity). The following sections of this chapter are concerned with the estimation, reporting and testing the supply elasticity estimates from the normative supply model.

2.4 Empirical Results

In this section, the direct and cross price elasticity estimates derived from the linear programming models are reported and discussed[12]. The analysis of individual supply curves is based on observing wool, lamb and cull sheep supply when all other prices and other elements of the model are held constant. The reference farms were analyzed over a range of prices (parametric programming) for lamb, wool and cull sheep independently, to provide step-supply schedules for the products. In this study, supply elasticities are measured as average or arc elasticities and are calculated as follows:

$$E_s = \frac{(IO - FO)/(IO + FO)}{(IP - FP)/(IP + FP)}$$

where IO is the initial level of output

FO is the final level of output

IP is the initial price of output

FP is the final price of output

12 The activities included in the optimal solution, unused resources and activities excluded from the optimal solution of the programming model for both the medium and large reference farms are shown in Tables B:3 to B:8 (Appendix B).

The elasticity of supply measures the percentage change in quantity supplied due to a 1 percent change in the price of the product. More specifically, the estimated supply elasticities show the rate of change of lamb, wool and cull sheep output with respect to changes in their market price levels. The arc elasticity is defined between values obtained for the optimal solution of the linear programming model and those obtained in the first change of basis. Elasticity estimates can be used to compare the response of a given output variable in different representative farms or to compare changes over different price ranges.

The empirical results are reported in two parts. The first part presents the elasticity estimates for the medium size reference farm while the second part presents the supply elasticity estimates for the large size reference farm. The direct price elasticity estimates for lamb for the medium size reference farm are shown in Table 2.2. The reported elasticities are given over three price ranges.

Table 2.2. Supply Elasticity Estimates for Lamb for the Medium Size Reference Farm.

Price Range ($)	Elasticity Coefficient
52.46 - 85.00	1.11
63.37 - 85.00	1.71
60.89 - 63.37	0.70
< 52.46	----

Table 2.2 shows that the supply of lamb is inelastic at low lamb prices, but as lamb prices increase supply becomes more elastic. At the upper end of the price range, that is, from $63.37 to $85.00 per head, a 10 percent increase in the price of lamb results in

a 17 percent increase in supply, ceteris paribus. At intermediate price levels, that is, from $60.89 to $63.37 per head, supply is inelastic. On average the estimated elasticity coefficient over the complete price range is 1.11, that is, the supply of lamb is elastic. Finally, when the lamb price falls below $52.46 per head, sheep production is no longer profitable and farm resources are switched to alternative enterprises.

The aggregate supply of lambs for all sheep farms in the medium size category can be derived by horizontal summation of the reference farm's supply function. More specifically, multiplying the optimum output of the reference farm at different price levels by the number of farms in the medium size farm category (Table 2.1) yields the aggregate supply of lamb from this farm group. The aggregate supply of lamb from the medium size sheep farms is shown in Table 2.3, at several price levels.

Table 2.3. Aggregate Lamb Supply from the Medium Sheep Farms.

Price Level ($)	Ref. Farm Supply (no.)	Number of Farms (no.)	Total Lamb Supply (no.)
85.00	960	593	569,280
63.37	576	593	341,568
60.89	560	593	332,080
52.46	----	----	---------

The total supply of lamb from the medium size sheep producers varies considerably over the price levels shown. Specifically, the supply of lamb varies by 71 percent from 332,080 head to 569,280 head over the price range $61.00 to $85.00 per head.

With respect to the elasticity of supply for wool, *a priori* one would expect a low elasticity of supply, as revenue from wool accounts for less than five percent of total income per livestock unit (ewe). The elasticity of supply for wool is estimated as 0.12 (inelastic) over the price range from $0.37 to $2.46 per kilogram. For cull sheep prices, *a priori* one would expect that the elasticity of supply to be closely related to the culling rate, with higher elasticities associated with higher culling rates. The estimated supply elasticity for cull sheep varies from 0.11 over the price range from $40.00 to $246.34 to 0.28 over the price range from $246.34 to $352.00 per head. The cross price elasticity estimates for wool, cull sheep, beef, wheat and barley are shown in Table 2.4.

Table 2.4. Cross Price Elasticities of Supply for the Medium Size Reference Farm.

Commodity	Lamb with respect to the price of:
Wool	0.12
Cull Sheep	0.11
Beef	-1.61
Wheat	-0.84
Barley	-1.11

The estimated cross price elasticities are consistent with prior expectations in that they have the appropriate sign. That is, beef, wheat and barley can be regarded as substitute products with respect to lamb production. For example, a one percent increase in the price of beef results in a 1.61 percent decrease in lamb output, ceteris paribus. The cross elasticity estimates for wool and cull sheep are low as they are relatively unimportant with respect to total income from sheep production[13].

The own price elasticity estimates for lamb for the large size reference farm are shown in Table 2.5. The elasticities are given for the price range $38.64 to $85.00 per head.

Table 2.5. Supply Elasticity Estimates for Lamb for the Large Size Reference Farm.

Price Range ($)	Elasticity Coefficient
---------------	------------------------
38.64 - 85.00	1.47
57.79 - 65.29	3.60
65.29 - 85.00	2.83
< 38.64	----

The supply of lamb is elastic over all price levels from $38.64 to $85.00 for the large sheep reference farm. More specifically, over the price range from $57.79 to $65.29 the own price elasticity is 3.6, that is, for a 1 percent increase in the output price of lamb, supply will increase by 3.6 percent. Over the price range from $65.29 to $85.00, supply is less elastic at 2.83. Finally, over the complete price range from $38.64 to $85.00, the estimated elasticity of supply is 1.47, that is, for a 10 percent increase in the price of lamb, the quantity supplied will increase by almost 15 percent. The aggregate supply of lambs for farms in the large size sheep category are derived from the above reference farm results and are shown in Table 2.6.

13 The total revenue from wool and cull sheep account for less than 10 percent of the total income per livestock unit.

Table 2.6. Aggregate Lamb Supply from the Large Sheep Farms.

Price Level ($)	Ref. Farm Supply (no.)	Number of Farms (no.)	Total Lamb Supply (no.)
85.00	2,160	72	155,520
65.29	990	72	71,280
57.79	630	72	45,360

Large sheep producers are more sensitive to changes in the market price for lambs. For example, over the price range $58.00 to $85.00 per head, lamb output increases by 243 percent from 45,360 head to 155,520 head.

The supply of wool for the large sheep reference farms is inelastic at 0.09, that is, for a 10 percent increase in the price of wool, supply increases by 0.9 percent over the price range from $0.37 to $2.39 per kilogram. Also, the own price elasticity of supply for cull sheep is low and varies from 0.07 over the price range from $40.00 to $163.00 per head, to 0.14 over the price range from $163.00 to $235.00 per head. Over the complete price range, that is, from $40.00 to $235.20, the estimated elasticity of supply is 0.09, thus, for a 10 percent increase in the price of cull sheep, supply will increase by less than 1 percent. The cross price elasticity estimates for the large sheep reference farm for wool, cull sheep, beef, wheat and barley are shown in Table 2.7.

Table 2.7. Cross Price Elasticities of Supply for the Large Size Reference Farms.

Commodity	Lamb with respect to the price of:
Wool	0.06
Cull Sheep	0.05
Beef	-0.95
Wheat	-0.89
Barley	-0.80

The signs on all the cross price elasticity coefficients for the large reference farm are consistent with prior expectations. The remaining sections of this chapter are concerned with testing the reliability and stability of the elasticity estimates, starting with sensitivity analysis and proceeding to the verification and validation of the empirical results.

2.5 Sensitivity Analysis

This section of the study tests the sensitivity of the price elasticity estimates presented in the previous section. Basically, sensitivity analysis relates to the stability of the estimated elasticity coefficients. Stability of the estimated elasticities is normally expressed in terms of a range of values over which the coefficients are stationary. In this section, the magnitude of change required to bring about a change in the elasticity estimates is calculated and presented. But first of all, the activities in the optimal solution of the linear programming matrix for the two reference farms are presented in Table 2.8.

Table 2.8. Activities in the Optimal Solution of the Linear Programming Matrix for the Two Reference Farms.

Activity	Medium Ref. Farm	Large Ref. Farm
Production:		
Lambs	B	B
Wool	B	B
Sheep	B	B
Alfalfa Hay	B	B
Barley	B	B
Wheat	-	-
Oats	B	-
Cow	-	-
Feed Barley	-	B
Feed Alfalfa	B	B
Resource:		
Sell Wool	B	B
Sell Lambs	B	B
Sell Sheep	B	B
Sell Hay	B	B
Sell Barley	B	-
Sell Wheat	-	-
Sell Oats	B	-
Buy Ewes	B	B
Buy Arable	-	-
Land	B	B
Buy Pasture	-	-
Land	B	B
Rent Land	-	B
Buildings	B	B
Machinery	-	B
Financial:		
Term Deposit		
Activities	B	B
Credit Activities	B	B
Mortgage Limit	B	B

Note: B denotes activity is in the basis solution

no entry denotes activity is not in the basis solution

The activities included in the basis solution of both the medium and large size reference farms are similar with respect to the financial activities, however, there are some differences in terms of production and resource activities. Table 2.8 shows that the only difference in production activities between the two reference farms relates to the production of oats on the medium size reference farm and the feeding of barley on the large size reference farm. The major differences, however, between the two reference farms are in resource activities. The medium size reference farm includes selling activities for barley and oats which are not in the optimal solution for the large reference farm. Conversely, the large reference farm has a land rental activity and a machinery purchase activity which are not in the optimal solution of the medium size reference farm.

Sensitivity analysis measures the magnitude of price change permitted for the particular commodity before a change in the estimated elasticity coefficient occurs. The extent of the price range over which the price elasticities are stable can be calculated by expressing the level of the price variable at the first change of basis as a percentage of the level in the initial linear programming solution. The change in the value of the objective function required to produce the first change of basis when the particular coefficients are parametized individually are shown in Table 2.9.

Table 2.9. Values in the Objective Function at which the First Change of Basis Occurs, Expressed as a Percentage of the Initial Level for the Two Reference Farms.

Activity	Medium	Large
	%	%
Lamb	25	23
Wool	419	341
Cull Sheep	515	307

Changes in the value of the lamb, wool and cull sheep gross margins required to produce the first change of basis cover a considerable range. For example, the wool activity coefficient in the objective function for the medium representative sheep farm has to increase 419 percent in the linear programming matrix for the first change of basis to occur. Table 2.10 shows the range over which the cross price elasticities are stable.

Table 2.10. Range of Price Values over which the Cross Price Elasticities are Stable, for the Two Reference Farms.

Activity	Medium	Large
--------	-------	-----
	%	%
Wool	419	619
Cull Sheep	516	307
Beef	39	16
Wheat	85	23
Barley	58	18

The values in Table 2.10 for beef, wheat and barley indicate the levels at which the non-basic activities become basic activities during the parametric procedure. The elasticity estimates reported in the preceding section indicate the rate of change for the relevant activities, while Tables 2.10 and 2.11 show the magnitude of change between the initial linear programming solution and the first change of basis in the parametric procedure. For example, if the initial gross margin of wool is set at 100 percent, the wool gross margin must increase 419 percent for the first change of basis to occur. However, during this increase a 1 percent increase in gross margin produces a 0.12 percent increase in wool output.

2.6 Verification and Validation of Results

Verification of a model involves comparing the output of the model with *a priori* theory or experience. In this study, the criteria for verification of the linear programming model are adapted from the *Aggregate Programming Model of Australian Agriculture* (Monypenny, 1975, pp. 100-120). The own and cross price supply elasticity estimates are verified in terms of the following criteria.

(1) The reference farm's supply curves for lamb, wool and cull sheep have non-negative slopes, i.e., an increase in market prices for these products results in an increase in supply.

(2) Since the sheep enterprise produces joint products, namely, sheepmeat and wool, economic theory suggests that the cross price elasticity estimates are positive.

(3) The slope of the aggregate supply curve for lamb, wool and cull sheep is steeper at the top and bottom regions of the price scale than in the center. This occurs because at low lamb prices some farms have no possibility for change and as the price declines only minor changes in supply occurs. At high lamb prices stocking rates will be close to maximum carrying capacity and further increases in lamb prices result in only minor changes in supply.

The own price elasticity estimates for lamb, wool and cull sheep are all positive for the two reference farms as shown and discussed in Section 2.5 of this chapter.

The final verification criterion as suggested by Monypenny (1975) relates to the cross price elasticity estimates between lamb prices, wool and cull sheep output. Because sheep farming involves the production of joint products one would expect *a priori* a positive cross price elasticity between lamb price and wool output, and a negative cross price elasticity between lamb prices and cull sheep output. For the medium and large reference farms the cross price elasticity estimates for wool are 0.12 and 0.06 respectively. Furthermore, the cross price elasticity estimates for cull sheep are low, but positive at 0.11 for the medium and 0.05 for the large reference farms.

Naylor and Finger (1967) argue that there is no generally accepted methodology for validation of a programming model. However, Anderson (1974) points out that validation of a model's performance is a subjective process that takes into account the objectives in constructing the model. A linear programming model can be validated by comparing the results from the synthetic model with what actually occurs or with estimates derived from other linear programming studies. Monypenny (1975) points out that validation of a model's results by comparison with the real world gives rise to a number of conceptual difficulties. The first problem relates to identifying the appropriate results of the model to be compared to what actually occurs. The second problem pertains to selecting the appropriate real world results to be compared with the results of the linear programming model. These two problems make it difficult to validate the results from a linear programming model with actual results on a comparable basis. Therefore, in this study the alternative approach to validation is taken.

More specifically, the elasticity estimates derived in this study are validated by comparing the results from this study with elasticity estimates from other linear programming studies of the sheep industry[14]. Programming studies of the sheep industry differ with respect to the time period, composition of the programming model and whether the price of the product increases or decreases during the period of analysis. Thus, a direct comparison between elasticity estimates from different studies is not possible. However, supply elasticity estimates from other studies provide some guidance with respect to the approximate magnitude of the elasticities that could be expected for the industry. In Table 2.11, direct and cross price elasticity estimates are presented from a number of programming studies of the sheep industry[15].

14 The author is not aware of any comprehensive programming study of supply for the Canadian sheep industry. Most of the programming studies of sheep supply relate to the Australian sheep industry.

15 Supply elasticity estimates from positive econometric supply models are discussed in Chapter 3.

Table 2.11. Comparison of Direct and Cross Price Elasticity Estimates from a Number of Normative Supply Studies.

Source	Direct Price Elasticity Estimates for:			Cross Price Elasticity of Lamb Supply with respect to the Price of:				
	Lamb	Wool	Sheepmeat	Wool	Sheep	Beef	Wheat	Barley
Monypenny (1975)	0.02				-0.67			
Hall and Menz (1985)		2.02	1.04					
Cornell and Hone (1978)	0.27-3.44		5.29-9.64		-0.47-4.39			
Wicks and Dillon (1978)		0.25-0.36						
This Study								
Med. Size Ref. Farm	0.70-1.71	0.12	0.11-0.28	0.12	0.11	-1.61	-0.84	-1.11
Large Size Ref. Farm	1.47-3.60	0.09	0.07-0.14	0.06	0.05	-5.15	-0.89	-0.80

Note: Monypenny's study focuses on New South Wales and is a sub-model of the Aggregate Programming Model of Australian Agriculture. Essentially, the model yields medium term elasticity estimates. The studies by Hall and Menz, Cornell and Hone are based on the regional programming models for Australia and also yield medium term supply elasticity estimates. Lastly, the Wicks and Dillon study relates to the Aggregate Programming Model of Australian Agriculture and gives short to medium term supply elasticities for Australian wool.

The supply elasticity estimates derived in this study are comparable to elasticity estimates derived from other programming studies of the industry. More specifically, the direct price elasticities for the medium and large size reference farms are similar to the Cornell and Hone (1978) study. However, the direct price elasticity estimates for wool and sheepmeat in this study are low compared to other studies. This could be partly attributed to the fact that returns from wool and sheepmeat make a relatively minor contribution to gross income from sheep farming in Alberta.

Buse and Bromley (1975, p. 209) discuss the factors which influence the magnitude of the supply elasticity estimates. These include the shape of the firm's marginal cost curve, differences in the firm's cost structure, the time allowed for adjustments to take place, expectations of the entrepreneur, storability of the product and alternative opportunities for inputs. Differences in the per unit cost curves of existing and potential firms in the industry are an important factor influencing the magnitude of the supply elasticity estimates. Where the cost structure of potential firms is slightly higher than existing firms, the industry supply curve will be more elastic than in the case where potential firm's cost curves are substantially higher than the existing firms. For example, where potential firms have cost curves which are only slightly higher than the market price for the product, small increases in price will make it profitable for new firms to enter the industry. In this case, the individual firm's marginal cost curve could be relatively steep, but the industry's supply curve would be highly elastic because of the tendency of new producers to enter the industry when relatively small changes in price occur. Thus, a small change in the price of the product may lead to a large expansion in the number of farms producing a particular commodity. If the price of lamb increases relative to the price of cattle, farmers will divert some resources from cattle production to sheep production. Sheep output will therefore increase substantially in response to a slight increase in relative prices.

One of the major sources of error in the programming type analysis relates to over estimation of supply at the industry level due to the failure to take account of changes in the industry's structure. This problem can be overcome by adopting a trend technique such as a Markov chain process which takes into consideration the number of existing and potential farms in the industry. Thus, a joint linear programming Markov chain model could provide a more accurate estimate of the aggregate supply response in the sheep industry. The following section adapts the Markov chain process to examine the effects of price changes on the structure of the Alberta sheep industry.

2.7 Structural Change

An understanding of the process of structural change within an industry is important in order to evaluate alternative policy options for the industry. Structural change includes not only technical change but also relates to entry and exit of firms and the number and size distribution of firms within the industry. The net entry equation approach has been used in some studies to analyze the entry and exit of firms from an industry: Mansfield (1962), Peltzman (1965) and Telser et al. (1975). However, this approach provides no information on the structure of surviving firms within the industry and is therefore of limited value in analyzing structural change. This section of the study applies the traditional Markov model to measure structural change within the Alberta sheep industry. Both stationary and non-stationary transitional probability matrices will be estimated from aggregate Census data.

2.7.1 Relevant Literature

The Markov chain process is a widely used technique for analyzing structural change in an industry. The Markov process focuses on the movement of firms from one size category to another and attributes discrete probabilities to these movements. Essentially, the standard first order Markov process is a stochastic process whereby the probability of a firm moving from one size category in period t, to another size category in period t+1, depends only on the outcome in period t, and this dependence is assumed to hold over all time periods. A further necessary assumption for using Markov models is that the observed movement of firms between different size categories provide a satisfactory measure of the underlying probabilities (Disney et al., 1988). The assumption of stationary (constant) transition probabilities, i.e., the probability that movement between different size groups does not change over time has been applied in many studies, e.g., Adelman (1958), Collins and Preston (1961). Stationary transition Markov chain models have been used to project the number and size of dairy farms in New York (Stanton and Kettunen, 1967), farm structure in England and Wales (Power and Harris, 1971), cotton share of the U.S. fiber market (Smith and Dardis, 1972) and the structure of the British dairy industry (Colman, 1967). Padberg (1962) has queried the stationary transition probability assumption and in his study of the Californian dairy industry, he rejected the hypothesis of constancy.

Hallberg (1969) points out that when a series of transition probability matrices are found to be changing over time the Markov chain model can be modified to incorporate this variability. In his study, Hallberg defined a procedure to incorporate a non-stationary assumption into the Markov chain model by replacing the stationary probabilities with probabilities that are a function of exogenous factors subject to change throughout the sequence of outcomes (Hallberg, 1969, pp. 289-302). This procedure entails estimating each cell of the transition matrix by the least squares regression procedure. However, a problem with Hallberg's model relates to meeting the requirements that (a) the transition probabilities are non negative and (b) the sum of the probabilities for any particular row are equal to one. The least squares approach does not automatically satisfy these constraints. Hallberg dealt with these problems in a somewhat ad hoc manner by adjusting any negative transition probabilities in the probability matrix to zero.

Padberg (1962) outlines the type of conditions under which a Markov process is appropriate for modeling structural change in an industry. He suggests that where environmental factors dictate a general type of structural development in an industry, the Markov model may be useful in approximating the development pattern. This type of industry development is characterized by low barriers to entry and consequently a high rate of entry when the industry is in the start-up stage. Once the industry is established entry barriers exist in that potential entrants encounter scale economies, lack of experience and inadequate financing resulting in few firms entering the industry during this stage. However, competition between incumbent firms in the industry results in a decline in the number of firms. Firms which are successful in adopting new technology expand while those which are unsuccessful leave the industry. Padberg concludes that where technological progress contributes to the growth of the firm then the Markov model is an appropriate technique to analyze structural change in the industry.

The conditions described by Padberg are applicable to the sheep industry as sheep farming has become more capital intensive during the 1980s. Sheep production is often a part-time farming activity for many small and medium sized sheep farmers. In the case of larger farms there is almost no new entry because of the specialized management skills required to successfully raise sheep. Furthermore, the level of capital investment increases as sheep farms increase in size, due to the substitution of capital for the farmer's fixed supply of labor.

This study adopts the Markov chain process to estimate transition probabilities for the Alberta sheep industry under the assumptions of both stationary and non-stationary transition probabilities. The procedure involves categorizing sheep producers into different size categories (states) and tracing changes in "states" of producers over the time period 1951 to 1986. Finally, the probability of movement between "states" is estimated and presented. The regression equations are estimated using Zellner's Seemingly Unrelated Regression Technique which links the explanatory variables to the probability of producers moving between states. Both stationary and non-stationary transition probabilities can then be used to project the future structure of the sheep industry.

2.7.2 The Markov Model

A first order Markov chain process postulates that the probability of an outcome of a given trial depends only on the outcome of the immediately preceding trial and this probability is assumed to be the same for each trial in the sequence. Consistent with this definition of the Markov process the general model may be outlined as follows:

Where S_i denotes possible states or outcomes, i = 1, ... n.

W_{it} denotes the probability that S_i occurs on trial t ($Pr(S_{it})$) or the proportion of occurrences of S_i in time period t of a multinomial population based on a sample of size n.

P_{ij} denotes the transitional probability which represents the probability that for any time t, the process is in state S_i and that it moves in the next time period to state S_j i.e., $Pr(S_{j(t+1)}/S_{it}) = P_{ij}$.

$P = p_{ij}$ denotes the transitional probability matrix which represents the transitional probability for every pair of states (i, j = 1, 2 ... n) and is subject to the following constraints on the elements of the matrix.

(4) $P_{ij} \geq 0$ for all i and j

(5) $\sum_j P_{ij} = 1$, for all i

In the case of the first order Markov chain, the probability of a particular change from S_i in time t to S_j in time t+1 is:

(6) $Pr(S_{it}, S_{j(t+1)}) = Pr(S_{it}) Pr(S_{j(t+1)}/S_{it}) = W_{it} P_{ij}$

and the probability of S_j occurring at time t+1 is:

(7) $Pr(S_{j(t+1)}) = \sum_i W_{it} P_{ij} = W_{j(t+1)}$

Equation (7) shows the sample observations $W_{j(t+1)}$ as a linear function of the realized values W_{it}. In a sampling theory context, if errors are admitted in equation (4) which account for the difference between the actual and estimated occurrence of $W_{j(t+1)}$, then the sample observations may be assumed to be generated by the linear statistical model shown in equation (8).

(8) $W_{j(t+1)} = \sum_i W_{it} P_{ij} + U_{jt}$

Estimation of transition probabilities from the above statistical model requires the assumption that the P_{ij}'s are functions of the price of commodity i. The average transition probabilities may be derived from the following estimation equation.

(9) $$W_{j(t-1)} = \beta_0 + \beta_1 w_{jt} + \beta_2 P_t + u_t$$

2.8 Econometric Estimation of the Transition Probabilities from Aggregate Data

In estimating the stationary and non-stationary transition probabilities, no explicit account is taken in the estimation procedure of the condition that, $0 \leq p_{ij} \leq 1$. However, when this condition is used in conjunction with the constraint $\sum_j p_{ij} = 1$, the condition becomes $p_{ij} \geq 0$. These conditions ensure that the probability of farm movement between different states fall within the range of logical probabilities and that farms are in one of the defined states after each transition (Lee et al., 1965). To enable both conditions to be explicitly included in the least squares formulation the problem may be specified by making use of either the Goodman criterion (1953, p. 247) or alternatively Telser's (1963) iterative adjustment procedure. Telser developed a methodology using the least squares technique to estimate stationary transition probabilities from aggregate data. This approach has been used by many researchers including Disney et al. (1988), who examined the pork farm size distribution in the South Atlantic Census division of the U.S. Basically, Telser's approach involves developing a system of N equations which can be estimated as follows:

(10) $$S_{jt} = \sum_i P_{ij} S_{i(t-1)}$$

i, j = 1, ... n, where N is the number of states, S is the percentage of observations occurring in each state, P is the transition probability to be estimated and t represents time. Telser (1963) has shown that when using the unrestricted least squares technique, the constraint, $\sum_j P_{ij} = 1$ is automatically satisfied. However, the unrestricted least squares technique does not overcome the problems of non-negativity values occurring in the transition probability matrix and estimates of P_{ij} greater than unity.

Telser (1963) proposed an adjustment procedure to circumvent the problems of non-negativity and probability estimates greater than unity. This procedure involves making adjustments in the non-admissible transition probability estimates by assigning extreme permissible values to the in-admissible elements and then to re-estimate the linear relations in which they appear (Telser, 1963, p. 279). An iterative procedure is applied to obtain admissible estimates of the elements of the probability system. All the zero and one alternatives are evaluated and the specification that minimizes the error term is selected.

Application of the Markov chain approach to the estimation of non-stationary transition probabilities involves the estimation of regression equations in which the transition probabilities are expressed as a function of specified exogenous variables. The values in the cells of the transition probability matrix constitute the dependent variable observations for the regression equations (Hallberg, 1969). A regression equation is estimated for each cell of the probability matrix. Projections of the structure of the industry with the non-stationary transition probabilities may be determined as follows: $X_{(t+1)} = X_t(\hat{p}_{ij})$ where the $\hat{p}_{ij}$ is composed of transition probabilities estimated for each cell in the matrix.

Telser (1963) has shown that the assumption of proportional disappearance is implicitly enforced when no explicit account is made in the Markov model for entry and exit of firms. By modifying the model to include an "exit" state, non proportional movement between states can be explicitly taken into account. Thus, the model of industry structure under the assumption of non proportionality includes not only size categories but also an "exit" category[16]. This allows firms in time period t+1 to move not only between size categories, but also into and out of the industry, irrespective of their position in the industry. In this study, stationary transitional probabilities are estimated for sheep farms assuming proportional movement between the three size categories. Non-stationary probabilities are also estimated which assumes non proportional movement between the farm size categories including the "exit" category.

2.9 Data Used

Data used in this analysis were obtained from Statistics Canada, *Census of Agriculture* (Alberta), 1951 to 1986. Information on the number of sheep farms in each of three different size categories were collected and converted to percentage of farms by size. Table 2.12 shows the total number of farms and the percentage in the different size categories over the period 1951 to 1986.

16 The exit category refers to a net exit of producers from the industry since both entry and exit are included in this category. In the case of the exit category, shares are developed using a base year and defunct farms make up the fourth category in the analysis.

Table 2.12. Sheep Farm Size Distribution in Alberta, 1951 to 1986.

Census Year	Total Number of Farms Reported	Small %	Medium %	Large %
1951	5,327	77.755	20.575	1.670
1956	5,785	73.207	24.719	2.074
1961	5,274	63.974	32.784	3.242
1966	3,203	63.940	32.751	3.309
1971	2,063	58.652	36.840	4.508
1976	2,244	67.157	29.412	3.431
1981	2,332	66.595	30.146	3.259
1986	2,148	69.041	27.607	3.352

Note: Small farms are farms with 1 to 47 head of sheep.
Medium farms are farms with 48 to 527 head of sheep.
Large farms are farms with 528 head of sheep or more.

The total number of farms in the sheep industry have declined by 60 percent over the period 1951 to 1986. The largest decline has occurred in the small sheep category (64 %) while the medium and large sheep categories have declined by 46 percent and 19 percent, respectively. A major limitation of this analysis is that reliable data are only available for eight observation points over the period 1951 to 1986. The following empirical section presents the results on the movement of farms between different size categories over the period for which data is available.

2.10 Empirical Results and Discussion

Telser's methodology for estimating transition probabilities using the least squares technique is adopted in this analysis. In this study, the regression equations are estimated using the Seemingly Unrelated Regression Estimation Technique (SUR)[17].

Both stationary and non-stationary transition probabilities are reported in this section. The estimated stationary transition probabilities are based on the assumption that the micro observation units behave according to a stationary first order Markov chain process. This allows for the estimation of the probabilities from aggregate data and permits structural inferences to be made from the results. The least squares estimates for the stationary transition probabilities are shown in Table 2.13[18].

Table 2.13. Least Squares Estimates of the Stationary Transition Probability Matrix.

Dependent Variable	Small (t)	Medium (t)	Large (t)
Small (t+1)	0.7197	0.2662	0.0141
Medium (t+1)	0.1206	0.8620	0.0174
Large (t+1)	0.0211	0.0758	0.9031

The diagonal elements in Table 2.13 indicate the probabilities of farms remaining in the same size category from period t, to period t+1. For example, the estimated

17 Adopting the econometric estimator (SUR) to estimate transition probabilities for the Markov chain process implies that no binding constraints are imposed on the estimated transition probabilities and thus, estimates may occur outside the admissible range.

18 Alternative estimators of transition probabilities include, the probability constrained quadratic programming (QP) method (Lee et al., 1965), the probability constrained minimum absolute deviations (MAD) method and the probability constrained minimum median absolute deviations (MOMMAD) method (Kim and Schaible, 1988).

results reveal that a small farm in period t has a 72 percent probability of remaining small in period t+1 and a 12 percent probability of moving to a medium size farm category. In the case of the medium and large sheep producers there is an 86 percent and 90 percent probability, respectively, of remaining in the medium or large size categories in the period t+1. The estimated probabilities of medium farms becoming small in time period t+1 is 27 percent and large farms becoming small approximately 1 percent. Finally, the probability of a small farm becoming large is 2 percent while the probability of a medium farm becoming large is higher at 8 percent.

In the case of the non-stationary transition probabilities a fourth category was included to take account of entry and exit (Hallberg, 1969; Disney et al., 1988). The inclusion of this extra category not only permits movement between different size categories but also allows farms to leave the industry and new farms to enter. Table 2.14 shows the least squares estimates for the non-stationary transition probabilities.

Table 2.14. Least Squares Estimates of the Non-Stationary Transition Probability Matrix.

Dependent Variable	Small (t)	Medium (t)	Large (t)	Exit (t)
Small (t+1)	0.4947	0.1244	0.0262	0.3547
Medium (t+1)	0.1333	0.6020	0.1658	0.0989
Large (t+1)	0.0004	0.0312	0.7669	0.2015
Exit (t+1)	0.3805	0.0073	0.0517	0.5605

Table 2.14 shows that under the assumption of non proportional disappearance the probability of remaining small declines to 49 percent. This decrease occurs because there is a high estimated probability (38 percent) that small farms leave the industry. The probability of medium and large sheep farms remaining in their respective size categories is 60 percent and 77 percent, respectively. The model also indicates that the most likely shift upwards in size occurs as small farms become medium size farms. Finally, the probability of large farms leaving the industry is 5 percent while less than 1 percent of the medium size producers leave the industry.

The non-stationary Markov chain procedure provides a method of examining the effects of exogenous forces on the structure of the Alberta sheep industry. The primary limitation of the non-stationary procedure used in this study is the inadequacy of the data. The non-stationary Markov chain procedure predicts more rapid adjustment in the industry structure than the stationary model and is more consistent with what has actually taken place in the industry over the last 30 years.

Table 2.15 shows the total supply of lamb from both the medium and large sheep farms when the Markov transition probabilities are combined with the normative programming elasticity estimates of supply.

Table 2.15. Aggregate Lamb Supply from the Joint Model for Both the Medium and Large Reference Farms over Different Price Levels.

Price Level ($)	Ref. Farm Supply (no.)	Number of Farms (no.) Stationary	Number of Farms (no.) Non-Stationary	Total Lamb Supply (no.) Stationary	Total Lamb Supply (no.) Non-Stationary
		Medium Reference Farm:			
85.00	960	511	357	490,560	342,720
63.37	576	511	357	294,336	205,632
60.89	560	511	357	286,160	199,920
		Large Reference Farm:			
85.00	2,160	65	55	140,400	118,80C
65.29	990	65	55	64,350	54,450
57.79	630	65	55	40,950	34,650

Table 2.15 shows that lamb supply can vary substantially depending on whether stationary or non-stationary transition probabilities are considered. In the case of the medium size sheep farms lamb supply is 30 percent lower when non-stationary probabilities are incorporated into the model. For the large sheep farms the predicted lamb supply is 15 percent lower for the model with non-stationary probabilities.

The Markov transition probabilities can be combined with the normative programming supply model for predicting lamb supply for both the medium and large sheep farms. In the case of the medium size sheep farms the joint model predicts a 14 percent and a 40 percent reduction in lamb supply with stationary and non-stationary transition probabilities compared to the base model for this group (Table 2.3). However, the joint model for the large sheep farms with stationary and non-stationary transition probabilities predict a 10 percent and a 24 percent lower lamb supply compared to the base model for the large sheep producers (Table 2.6).

The projection of industry structure under the assumptions of the Markov model suggests that there will continue to be a decline in the total number of sheep farms, an increase in both medium and large sheep farms while small sheep farms will decrease. This increased concentration in the industry will have implications with respect to developing future marketing policies for the industry. A discussion of the marketing options available to the industry is developed in Chapter 5 of the thesis.

In summary, the direct and cross price elasticities of supply were estimated using the representative farm linear programming model. The price elasticities of supply for lamb are elastic while the price elasticities of supply for wool and cull sheep are highly inelastic. The structure of the sheep industry was also examined using the Markov chain process. The Markov process indicates that there is a trend toward increased concentration in the industry. A joint linear programming Markov chain model was used to predict lamb output from both the medium and large sheep farms. The results from the joint model indicate that changes in the structure of the industry can play an important role in determining the supply of lamb. In the next chapter supply elasticities will be estimated for lamb, wool and cull sheep using an econometric model of supply response. The results from the two approaches to supply estimation will be discussed in Chapter 4.

Chapter 3: An Econometric Approach To The Estimation of Supply Functions

3.1 Introduction

The theory of supply emphasizes the importance of differentiating between the short-run and long-run supply elasticity estimates. Knowledge of both short-run and long-run elasticity estimates provide information on industry adjustments to price changes over time. In the livestock sector, production occurs in a changing environment due to the biological lags associated with the growth process. Thus, time can play a major role in supply response adjustments in the livestock industry. For example, short-run supply elasticity estimates for lamb vary from 0.01 (Whipple and Menkhaus, 1989) to 0.50 (Jones, 1965). In the long-run supply elasticities also show wide variation from 1.12 (Powell and Gruen, 1967) to 11.38 (Whipple and Menkhaus, 1989). A thorough understanding of the speed and magnitude of adjustments in the lamb industry to economic stimuli would provide valuable information in anticipating the long-run production effects of alternative sheep policy options.

The purpose of this chapter is to estimate econometrically both the short-run and long-run supply elasticities for lamb, cull sheep and wool for the Alberta sheep industry. Econometrically estimated aggregate short-run and long-run supply elasticities in conjunction with the medium term normative supply elasticity estimates reported in Chapter 2 provide a more comprehensive understanding of the industry. Moreover, accurate supply elasticity estimates lead to greater clarification of issues and policy options available to the industry. The remainder of this chapter is organized as follows. A brief review of the relevant theoretical supply literature as well as the econometric estimating techniques is given. This is followed by a presentation and description of the simultaneous equation model that is used in the estimation process. Finally, estimates of both the short-run and long-run supply elasticities are reported and compared to elasticity estimates from other econometric studies of sheep and wool supply response.

3.2 Review of the Relevant Supply Literature

There is an extensive body of literature on agricultural supply response that relates to the formulation of expectations and estimation procedures. One of the earliest explanations of agricultural price expectations is embodied in the cobweb model (Ezekiel, 1938). In this model, producers form naive expectations of price in that last period prices are assumed to prevail in the current period. Goodwin (1947) developed a more sophisticated approach to expectations which incorporates a learning process into the formulation of prices. Specifically, the Goodwin approach involves formulating expected price as actual price in the last period plus (minus) some proportion of the change in actual price between two periods ago and the last period. This adaptive expectations approach has been extended by Koyck (1964) to form a multi-period lag model. Basically, Koyck's approach involves specifying an infinite lag model within which a greater weighting is given to more recent information. Several modifications of the multi-period lag procedure have been developed including the polynomial lag model (Almon, 1965).

Nerlove (1956, 1958) developed a single equation approach to supply estimation based on the hypothesis that in each period producers revise their notion of 'normal' prices in proportion to the difference between the then current price and their previous ideal of 'normal' price. Nerlove (1958) demonstrated that agricultural supply models which incorporate adaptive expectations produce larger estimates of supply elasticities for agricultural commodities. A comprehensive survey of the earlier applications of the single equation Nerlovian type model to the estimation of livestock supply response is discussed in Askari and Cummings (1976). Some of the more relevant sheep supply studies are outlined in the following section.

Jones (1965) analyzed the supply of mutton and lamb in the U. K. by regressing the number of ewes available for breeding on one and two year lagged prices, a weather index and a trend variable. Powell and Gruen (1967) examined the interaction between cereals and livestock in Australia and concluded that the supply response of sheep producers can be satisfactorily described with the Nerlovian supply model. Other studies of the sheep industry which have used the Nerlovian lag formulation include: Witherell (1969), Court (1967), Duane (1973), Malecky (1975), Debertin et al. (1983) and Guthrie (1988). The supply elasticity estimates from these studies are reported and discussed in the context of the supply elasticities derived in this study in a later section of this chapter.

More recent developments in the supply literature have attempted to incorporate rational expectations (Muth 1961) into the estimation of supply response. For example, Rucker et al. (1984) adopted a rational distributive lag model in deriving a cattle supply function for the U.S. cattle industry.

Heady and Dillon (1961) point out that historically supply models have been predominantly static in nature. However, more recent studies of livestock production have been formulated in a dynamic framework. Dillon (1977, p. 73) suggests specifying production response as a function of: length of the response period, number of response periods and inputs used during the response period as a means of incorporating dynamics into supply models. Fawcett (1973) however, argues in favor of an alternative approach namely, a differential equation approach which essentially characterizes the growth process to incorporate dynamics into the production process. Basically, the differential equation approach to dynamic modeling of livestock production corresponds to the 'state equation' specification in modern optimal control theory (Bryson and Ho, 1975).

Many livestock supply models have adopted a lag structure to accommodate changes in the livestock industry. Partial adjustment and/or adaptive expectation models are frequently invoked to justify the introduction of lagged values of dependent variables as explanatory variables in regression equations. Eckstein (1985) compares the traditional Nerlovian type model to a rational expectations equilibrium model of supply response. He concludes that the traditional Nerlovian approach performed as well as the more sophisticated rational expectations model.

A further variant in the estimation of supply response relates to the capital theory approach which involves treating the particular commodity as a capital good. However, an increase in the price of a commodity can have two divergent effects on producers. For example, an increase in the price of sheep may cause producers to expect higher prices in the future and therefore to increase the size of their breeding flocks to take advantage of potentially higher future prices. Thus, this gives rise to an apparant backward bending supply curve for the commodity. Conversely, a price increase may encourage sheep producers to sell sheep immediately to profit from the current high prices. Empirical studies indicate however, that the former effect (apparant backward bending supply response) outweighs the latter for the breeding flock (Rucker et al., 1984, p. 135).

Some of the more recent studies which have adopted the capital stock approach to represent producer's investment (disinvestment) decisions are outlined in the following section. Jarvis (1974) developed a dynamic model of the Argentine cattle sector in which cattle were treated as capital goods and producers as portfolio managers. Reynolds and Gardiner (1980) also adopted the capital theory approach to estimate supply response for the Australian sheep industry. Other studies which have used the capital stock approach include Chavas and Klemme (1985) for the U.S. dairy industry, and Whipple and Menkhaus (1989) for the U.S. sheep industry.

3.3 Econometric Estimation Techniques and Limitations

In the following section, the econometric approaches to estimating supply response are outlined. The econometric approaches can be classified into three broad groups: a single equation approach, an indirect or two-stage approach and a systems approach.

The single equation procedure involves direct estimation of supply functions from aggregate time series or pooled data. With this procedure the behavioral parameters are obtained directly from statistical analysis of historical time series data. The single equation procedure attempts to find a way of explaining output in a particular period as a function of the factors determining investment decisions. For example, in the case of livestock production, output can be explained explicitly in terms of the number of particular classes of livestock on the farms and of the yield of these animals. Alternatively, a reduced form approach may be employed in which output is related directly to the factors assumed to influence investment.

There are a number of important features associated with adopting the single equation approach to estimating supply functions. First of all, this approach is less restrictive in that profit maximizing or cost minimizing assumptions are not imposed on the behavior of agricultural producers. Second, the single equation technique operates directly on the aggregate or market level supply data. A further advantage of this approach relates to the ability of the specified equations to capture the underlying dynamic aspects of agricultural supply. Finally, the single equation econometric procedure is well developed with respect to the estimation method and data requirements and entails a more direct approach to estimating supply response coefficients.

Despite the merits of the single equation estimation technique, there are, however, a number of limitations associated with adopting this methodology to estimating supply response. A major limitation of regression analysis is that regression models based on time series observations reflect historic relationships and therefore cannot predict future supplies in light of new variables previously unencountered. In addition, the single equation econometric procedure represents a partial equilibrium approach to the estimation of supply response. One of the fundamental assumptions of the regression model is that the parameters of the system remain constant over the period of analysis, therefore, this class of model cannot completely account for structural change over time. Heady et al. (1961, p. 70-71), outline a number of approaches including proxy and trend variables, which partially take account of structural change in regression models. Finally, the theory of supply gives little guidance with respect to the specification of supply equations or choice of functional form to be used in the analysis.

The two-stage approach to supply estimation involves estimating a production function and imposing a profit maximizing or cost minimizing condition on the econometric results. As pointed out by Blackorby et al. (1978), duality theory implies that there is a direct equivalence between the cost, profit and production functions. Thus, any one of these functions can be econometrically estimated in the first stage and used to derive supply response parameters. The theoretical relationship between the optimal output and input levels also allow for supply functions to be algebraically derived from a set of directly estimated input demand functions. These input demand functions are substituted into the production function to obtain an estimate of the supply function expressed in terms of exogenous variables.

Some of the more recent agricultural supply studies have adopted the duality approach to estimating supply response. This approach involves specifying an aggregate profit function from which a supply function is obtained by applying Hotelling's lemma[19]. Studies which have used the profit function or cost function approach to estimate aggregate supply response include Yotopoulos and Lau (1979), Griliches (1963), Rosine and Helmberger (1974), Ball (1988), Whipple and Menkhaus (1989).

The directly estimated supply systems approach (Powell and Gruen, 1967) adopts the neoclassical theory of the firm to generate restricted systems of estimable supply functions. Basically, this approach assumes the existence of an agricultural production possibility frontier which is determined by the assumed fixity of inputs within the time period of the analysis. Powell and Gruen's supply systems approach parallels the demand systems theory, where a fixed bundle of factors are allocated to the production of products in such a way as to maximize profits. The assumption is made that the production possibility curve displays constant elasticity of transformation (CET) and that within a system of equations the supply of each product can be expressed as a linear function of the expected prices of all products.

19 For a detailed proof see Varian 1984, p. 52-53.

A limitation of this approach relates to the constant elasticity of transformation assumption which is restrictive in that it involves constraining all pairwise partial transformation elasticities to be equal. Further limitations of this approach relate to the fact that the model is static in nature, there are no specific time lags associated with short and long-run responses and all inputs are taken as fixed and not product specific. Finally, difficulties arise with respect to the degree of bias and distortions when the model is used for making projections outside the range used in the estimation (Colman, 1983, pp. 201-230).

In this study, a simultaneous equation model is used to estimate the short-run supply elasticities for lamb, wool and cull sheep. The procedure adopted in this study is similar to the approach outlined by Tryfos (1974). Tryfos, in his study of Canadian livestock and meat supply, used a simultaneous equation approach which demonstrated the interdependence between livestock supply and inventories. The formulation of the simultaneous equation model is discussed in the following section.

3.4 Model Formulation

The formulation of the econometric model that is used to derive supply elasticity estimates for the sheep industry is discussed under the following sub-headings, theoretical framework, model selection, description and data sources.

3.4.1 Theoretical Framework

Labys (1973) outlines a three stage approach to constructing an econometric model to represent the behavior of economic agents. The first stage involves the identification and specification of variables to be included in the structural model. Labys (1973, pp. 122-123) argues that specification of the model depends primarily upon the structure of the economic environment that is represented by the model. Specifically, the first stage involves a review of the particular industry's structure and identification of the economic variables that describes this structure. The selected variables are then grouped into two broad classes, namely, endogenous or exogenous variables.

The second stage in the process of constructing an economic model involves determining the lines of causation within the model. Determining causality or interdependence is crucial in order to prevent specification errors and/or having estimated parameters that do not meet *a priori* expectations. Where interdependence occurs between endogenous variables the system of equations is either recursive or simultaneous in nature. In a recursive model, variables interact in a sequential manner resulting in a one way causal chain while no correlation exists between disturbance terms of separate equations.

However, in the case of a simultaneous equation system there is two-way causation, that is, the variables within the system are jointly determined. In a simultaneous model, endogenous variables are included as explanatory variables in some equations. Application of the ordinary least squares estimation technique to a simultaneous equation model results in inconsistent and biased parameter estimates due to the possible correlation between the disturbance term and endogenous variables which are included as explanatory variables in the equations. Furthermore, the disturbance terms of each structural equation may be contemporaneously correlated with the disturbance terms of other structural equations. Therefore, a more sophisticated estimation technique such as the systems estimation procedure is required to provide efficient estimates of the structural parameters in a simultaneous equation model.

The final stage in model formulation relates to the identification of the model. More specifically, identification involves determining whether unique estimates can be derived for the reduced form equations and whether these estimates are a true reflection of the parameters of the original structural model. The reduced form equations express the endogenous variable as a function of the predetermined variables, structural parameters and error terms of the model. Basically, identification of a system of equations involves the identification of each equation within the system by either the order or the rank condition (Thomas, 1985). These conditions are mathematical conditions which are necessary (order) and sufficient (rank) to ensure that the system of equations is properly identified. Basically, the order condition involves counting the number of variables excluded from each equation. The system is identified if the total number of exogenous variables excluded from a particular equation but included in other equations is greater than or equal to one less than the number of equations in the model.

The rank condition is both a necessary and a sufficient condition for identification of each equation in a system. The rank condition requires that at least one non-zero determinant can be constructed from the matrix of the coefficients excluded from that particular equation but contained in other equations of the model. This permits mathematical solutions to be found for the structural parameters from the reduced form equations. For a system of equations there are three possible identification states: under-identification, exact identification and over identification. Exact and over identified equations can be estimated using the normal estimation procedures (Kennedy, 1987, pp. 126-141).

The identification stage in model formulation is crucial as it determines the most appropriate estimation technique to derive the parameter values for the model. Labys (1973) points out that in the case of commodity models identification is not normally a problem as most systems contain a large number of predetermined variables which generally result in over identification.

3.4.2 Model Selection

In this study, the purpose of estimating an econometric model of supply response for the sheep industry is to differentiate between short-run and long-run elasticity estimates for lamb, wool and cull sheep. The model that is used to derive the supply elasticities is outlined in the following section.

The supply of a commodity during the current time period (t) can be expressed in a linear form as a function of inventories (I) at the end of the previous time period (t-1).

$$(1) \quad Q_t^s = a_0 + a_1 I_{(t-1)}$$

where $a_1 > 0$

It is assumed that the desired levels of inventories (I_t^*) are determined by the expected price of the commodity (P_t^*) and the expected cost of inputs (W_t^*). This relationship can be approximated by a linear function of the form:

$$(2) \quad I_t^* = b_0 + b_1 P_t^* + b_2 W_t^*$$

The following assumption is also made, that higher inventories are held in anticipation of higher prices or lower expected costs. Therefore, this permits the following *a priori* expectations with respect to the coefficients on output prices and input costs, i.e., $b_1 > 0$, and $b_2 < 0$. In livestock econometric models an additional assumption which relates to expectations is often adopted, that is, current prices (P_t) and current costs (W_t)

may be used as proxies for expected market prices and expected input costs (Nerlove, 1958). This allows for the substitution of P_t^* and W_t^* by P_t and W_t, respectively.

$$(3) \quad I_t^* = b_0 + b_1 P_t + b_2 W_t$$

Thus, the relationship between the actual inventory level and desired inventory can be expressed as follows:

$$(4) \quad I_t - I_{(t-1)} = \Psi\{I_t^* - I_{(t-1)}\}$$

where $0 < \Psi \leq 1$, indicates a "partial adjustment" of actual inventory to deviations of desired inventory from the actual level at the end of the previous period. Substituting equation (3) into equation (4) gives:

$$(5) \quad I_t = \psi b_0 + \psi b_1 P_t + \psi b_2 W_t + (1-\psi) I_{(t-1)}$$

Therefore, total supply can be expressed as a function of the difference between the quantity of the commodity available during the current period (Q_t^s) and of inventory change as follows:

$$(6) \quad S_t = Q_t^s - \sigma(I_t - I_{(t-1)})$$

where σ is a positive number between zero and one. Substituting equation (1) into equation (6) yields the following:

$$(7) \quad S_t = \alpha_0 + (\alpha_1 + \sigma) I_{(t-1)} - \sigma I_t$$

The theoretical model outlined above requires the simultaneous estimation of the following system of equations:

$$(8) \quad I_t = \alpha_0 + \alpha_1 P_t - \alpha_2 W_t + \alpha_3 I_{(t-1)} + \alpha_4 I_{(t-2)} + U_{1t}$$

$$(9) \quad S_t = \beta_0 + \beta_1 I_t + \beta_2 I_{(t-1)} + U_{2t}$$

where $U_1 t$ and $U_2 t$ are error terms, and the expected signs of the parameters are:

$\alpha_1 > 0$

$\alpha_2 < 0$

$0 < \alpha_3 < 1$

$\beta_1 > 0$, and

$\beta_2 > 0$.

The endogenous variables in the simultaneous equation model are I_t and S_t and the predetermined variables are P_t, W_t, and $I_{(t-1)}$.

3.4.3 Model Description and Estimation Technique

The system to be estimated consists of two equations (equations (8) and (9)) within which inventory is determined by prices and costs while output is determined by flock size. Inventory or flock size is postulated to be explained by flock size lagged two periods, market prices and input costs. The lines of causation in the above model run from prices and costs to inventory levels which in turn determine lamb, wool and cull sheep output.

The existence of the endogenous variable I_t in the set of explanatory variables in equation (9) indicates that there is a feedback effect between the variables of the model. Therefore, the model is simultaneous in nature if the explanatory endogenous variable is correlated with the disturbance terms of other structural equations. In order to provide unbiased estimates of the parameters of a simultaneous equation model an estimation technique which is capable of taking account of the simultaneous equation bias is required. Selecting the appropriate estimation technique involves taking account of the following factors: sample size, dependence or independence of the stochastic disturbance terms, likelihood of model specification error and finally, measurement error in the data concerning the different structural equations. However, before selecting the estimation technique it is necessary to determine the identification status of the model. This involves examining the structural equations of the model to determine whether the model is under, over or just identified. The order condition of identification indicates that the model is over identified. Thus, the selection of the estimation technique is restricted to methods which can deal with simultaneous equation bias in over identified equations.

Intriligator (1978, pp. 373-375) outlines three approaches for estimating simultaneous equations based on the amount of information used in the estimation process. The three approaches are the ordinary least squares (OLS) approach, the limited information (LI) approach and the full information (FI) approach. The OLS and the LI approaches estimate each equation independently, while the FI approach involves estimation of the complete system of equations. Intriligator (1978, p. 420) argues that in a correctly specified systems model the full information approaches of three stage least squares (3SLS) and full information maximum likelihood (FIML) are the most desirable in terms of least bias and mean square error. In this study, the FI - "Seemingly Unrelated Regression" (SUR) estimation technique is adopted. The results are reported following an outline of the data sources used in the analysis.

3.4.4 Sources of Data

Data for the parameters of the simultaneous equation model were collected from several different sources. The basic sources of data were the publications of Statistics Canada and Alberta Agriculture.

The data series selected has 18 data points for each variable representing 18 years of annual values. This encompasses the time period from 1970 to 1987. Data on sheep and lamb prices were collected from the *Agriculture Statistics Yearbook* for Alberta and converted to dollars per tonne of sheep and lamb output. The consumer price index (Consumer Price Index (CPI), 1981=100) for all goods was used as the deflator of livestock prices and input prices in the model. The CPI data were collected from Statistics Canada *The Consumer Price Index*, Catalogue number 62-001.

The cost of hay is taken as a proxy of input costs in the sheep industry. The data on inputs were extracted from the *Farm Input Price Index*, Catalogue 62-004. Finally, the remaining data on output quantities for sheep and lamb were collected from Statistics Canada *Livestock and Animal Products Statistics* and T. W. Manning (1986) *Alberta Agricultural Productivity: Methodology and Data Used.*

3.5 Empirical Results

This section presents the results from the Seemingly Unrelated Regression Estimation Technique that is employed to estimate the supply response for lamb, cull sheep and wool. The supply model includes six behavioral equations that describe the responses of the dependent variable. While the estimated parameters of the endogenous variables are determined within the model the values of the exogenous variables are established by factors outside the sphere of influence of the Alberta sheep industry. Lagged variables are classified as predetermined because their values in the current time period are known.

The six behavioral equations are estimated in three groups using Shazam, version 6.1 (White et al., 1988) econometric computer program. The following equations outline the results obtained when the Seemingly Unrelated Regression Estimation Technique is applied to the supply and inventory models for lamb, wool and cull sheep[20].

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20 The t-ratios are shown in parentheses below each estimated coefficient.

Lamb :

$$(10a)\quad \hat{S}_t^l = -1046.7 + \underset{(0.9634)}{0.03745 I_t} + \underset{(4.2461)}{0.03037 I_{(t-1)}}$$

$R^2 = 0.74$

$$(10b)\quad \hat{I}_t = 6225 + \underset{(15.807)}{0.1984 I_{(t-1)}} - \underset{(-6.8156)}{0.6971 I_{(t-2)}} + \underset{(4.0082)}{28.078 P_t} - \underset{(-2.188)}{195.95 W_t}$$

$R^2 = 0.94$

Wool :

$$(11a)\quad \hat{S}_t^w = -29.603 + \underset{(2.6967)}{0.0017 I_t} + \underset{(0.9304)}{0.0006 I_{(t-1)}}$$

$R^2 = 0.76$

$$(11b)\quad \hat{I}_t = 25901 + \underset{(11.792)}{0.3184 I_{(t-1)}} - \underset{(-4.724)}{0.5129 I_{(t-2)}} + \underset{(2.1076)}{16.208 P_t} - \underset{(-1.1575)}{134.57 W_t}$$

$R^2 = 0.93$

Cull Sheep :

$$(12a)\quad \hat{S}_t^s = -198.71 + \underset{(2.5521)}{0.0020 I_t} + \underset{(3.2592)}{0.01782 P_t}$$

$R^2 = 0.22$

$$(12b)\quad \hat{P}_t = \underset{(1.1471)}{457.83} + \underset{(0.9560)}{0.0071 I_t} - \underset{(-1.5489)}{0.1593 I_{(t-1)}} + \underset{(5.7424)}{9.1666 W_t}$$

$R^2 = 0.76$

The overall explanatory power of the lamb and wool equations and the magnitudes of the coefficients are satisfactory. The parameter estimates in these equations have signs which are consistent with the theoretical model developed earlier in this chapter. In the stock formation equations the price coefficients are positive while all input cost coefficients are negative. The coefficients on price are significant in all equations at the

5 percent level of significance as are the coefficients on the input cost parameters with the exception of the inventory equation with respect to wool supply. One period lagged inventory coefficients in the stock formation equations for lamb and wool are positive while the two period lagged coefficients are negative in the lamb and wool equations. In the case of the cull sheep equation the lines of causation run from inventory levels to price to output supply. The estimated coefficients for inventory and sheep prices are significant in the supply equation at the 5 percent level of significance.

In the estimation of supply response for the three commodities lagged inventory is used as a proxy measure of short-run capacity. This approach to locating short-run production frontiers permits formal equivalence to Nerlove's distributed lag model of supply adjustment (Nerlove, 1958). Thus, short-run price elasticities can be estimated directly from the linear supply system using the following formula:

$$\eta_{(ij)} = \beta_{(ij)}\{P^{*}_{j}/Q^{*}_{i}\}$$

where, $\eta_{(ij)}$ = short-run price elasticity of supply for product i with respect to expected price j;

$\beta_{(ij)}$ = parameter estimate;

P^{*}_{j} = sample mean of expected output prices; and

Q^{*}_{i} = sample mean of expected output quantities.

The long-run supply elasticities can be calculated from the short-run estimates by multiplying the short-run elasticities by the factor $\{1 - \hat{I}_{(t-1)}{}^{(-1)}\}$ where $\hat{I}_{(t-1)}$ is the estimated one period lagged inventory coefficient within the supply equation. Powell and Gruen (1967, p. 72) point out that long-run elasticities are operationally obscure and more sensitive to arbitrary assumptions with respect to the structure of price expectations than are short-run elasticities. The long-run supply elasticities are calculated as follows:

$$\eta^{l}_{(ij)} = \eta_{(ij)} \{ 1 - \lambda_{(t-1)}^{\ (-1)} \}$$

The own price supply elasticities for lamb, wool and cull sheep are computed from the livestock supply and inventory equations and are presented in Table 3.1.

Table 3.1. Own Price Elasticities of Supply for Lamb, Wool and Cull Sheep, Calculated at Point of Means.

Supply of:	Short-Run Elasticity	Long-Run Elasticity
Lamb	0.3615	1.2187
Wool	0.0743	0.1586
Cull Sheep	0.0384	0.2795

For lamb, wool and cull sheep the short-run supply elasticity estimates are low, implying that the supply of these commodities is highly inelastic. Livestock supply in the short-run is related to output prices and input costs in previous periods rather than to current prices and costs. This is due to the relatively long production period required to bring livestock to the market. For example, a rise in the market price for livestock cannot be accompanied by an immediate increase in supply. Favorable market prices and input costs are expected to increase the current level of livestock inventories. The long-run supply estimate for lamb is elastic while the estimates for wool and cull sheep are inelastic. The above elasticity estimates are compared in the following section to supply elasticity estimates from other econometric studies of the sheep industry.

3.6 Comparison with Other Studies

This section presents both the short-run and long-run supply elasticity estimates from a number of supply studies over different time periods and different countries. Table 3.2 shows the supply elasticity estimates for lamb and wool by author, region and time period.

Table 3.2. Supply Elasticity Estimates by Author, Region and Time Period for Lamb, Wool and Cull Sheep.

Author	Period	Region	Short Run Elasticity	Long Run Elasticity
		Lamb		
Powell & Gruen (1967)	1947-1964	Australia	0.32	1.38
Jones (1961)	1907-1958	U.K.	0.32	2.31
Jones (1965)	1955-1964	U.K.	0.28-0.50	1.51-4.00
Papaioannou & Jones (1972)	1952-1965	Greece	0.49	
Court (1967)		N.Z.	0.09	2.00
Tryfos (1974)	1951-1971	Canada	0.21	
Whipple & Menkhaus(1989)	1924-1983	U.S.	0.01	11.38
		Wool		
Witherell (1969)	1949-1965	Australia	0.07-0.08	0.13-0.28
Powell/Gruen (1967)	1947-1964	Australia	0.07	0.33
Dahlberg (1964)	1949-1961	S.Australia	0.08	
Witherell (1969)	1949-1965	N.Z.	0.03	0.72
Witherell (1969)	1949-1965	S.Africa	0.08	0.76
Jones (1961)	1927-1955	U.K.		0.20
Witherell (1969)	1950-1964	Argentina	0.04	0.20
Witherell (1969)	1950-1964	Uruguay	0.21	0.48
Witherell (1969)	1948-1965	U.S.	0.14-0.15	0.32-0.35
Duane (1973)		Australia	0.15	
Malecky (1975)		Australia	0.10-0.20	
Whipple & Menkhaus (1989)	1924-1983	U.S.	0	4.24
Findlay et al. (1989)	1970-1986	Argentina & Uruguay	0.10-0.36	0.5-0.59

The elasticity of supply for lamb can vary substantially between the short-run and the long-run. In the short-run the lamb supply elasticities are low (inelastic) and vary from 0.01 to 0.50. This inelastic supply response is attributed to insufficient time for producers to adjust to changing market prices. However, in the long-run, structural adjustments would have taken place in response to higher market prices and supply elasticities would be substantially higher. In the long-run, all studies show that the supply elasticity estimates for lamb are elastic and range from 1.38 to 11.38.

The supply elasticity estimates for wool are inelastic in both the short-run and the long-run with the exception of the Whipple and Menkhaus (1989) study. The short-run elasticities vary from 0 to 0.36, while in the long-run the estimated elasticities ranged from 0.13 to 4.24.

In this study the short-run and long-run elasticity estimates for lamb are 0.36 and 1.22, respectively. These estimates appear reasonable when compared to supply elasticities from other studies as shown in Table 3.6. For wool, both the short-run and long-run elasticity estimates are extremely low and fall in the lower region of the elasticity estimates presented. Lastly, the supply elasticity estimates for cull sheep are also low at 0.04 for the short-run and 0.28 for the long-run. The low supply elasticity estimates for wool and cull sheep may be attributed to the fact that these products are not a major component of sheep producers' returns in Alberta.

The econometric supply elasticities in this chapter differ from the normative supply elasticities in Chapter 2. The following chapter discusses the divergent supply elasticity estimates derived from the programming and econometric models.

Chapter 4: A Comparison of Supply Elasticities Derived from the Programming Model and the Econometric Model

4.1 Introduction

There are two approaches to the estimation of agricultural supply response namely, a normative programming approach and a positive econometric approach. Each estimation approach has its own particular procedure and the choice of approach is influenced by factors such as objectives of the study, data, time, expertise and finance available for the study in addition to the availability of computing facilities.

Historically, the positive econometric least squares approach has been widely used to estimate agricultural commodity supply parameters. The econometric approach to deriving supply response relates to "what is" or what "will be" and tends to measure producers actual supply response based on historic time series, cross section or pooled data. Econometric supply models can be divided into three broad classes, namely, directly estimated single commodity models, directly estimated supply response systems and two stage profit or cost function systems. The directly estimated single commodity models include models in which several supply functions are independently estimated as well as models in which a system of supply equations are simultaneously estimated.

Where the purpose of the study is for forecasting the supply of a particular commodity the directly estimated econometric procedure with market level data is often used. However, where the objective of the study is agricultural policy impact analysis, the need for consistency and comprehensiveness of the model may favor the use of a programming approach based on the reference farm concept. The normative programming approach relates to what "ought" to be or "should" be and is characterized by an optimization routine. Basically, all programming approaches are some variant of the linear programming algorithm. The positive econometric and normative programming approaches differ in terms of data use, interpretation and testing of results.

The primary purpose of this chapter is to compare and discuss the divergent empirical supply elasticity estimates derived from the programming model in Chapter 2 with the results obtained from the econometric model in Chapter 3. But first of all a brief critique of the two approaches is given in the following section.

4.2 A Critique of the Programming and Econometric Supply Estimation Procedures

Normative programming models involve an optimization procedure which shows the optimal organization of the farm in order to maximize net income subject to constraints on prices, resource availability and production processes. The solution to a programming problem is contingent on the structure of the underlying model. The supply function derived from the normative model reflects the optimum supply reaction to product price changes in terms of the stated norm, rather than an estimate of the actual supply reaction of producers to changes in product prices. Conversely, the positive econometric estimates of supply response are based on fitting a linear regression to historical data to describe what has actually occurred in the past and to derive estimates of the behavioral parameters.

4.2.1 Characteristics of the Linear Programming Procedure

Linear programming models are synthetic constructs based on an economic analysis of the conditions underlying the production process. The reference farm linear programming approach to supply estimation is characterized by a number of features. First of all, the model estimates aggregate supply response from micro analysis of individual producer's behavior. Therefore, this procedure is capable of taking account at the farm level of the effects upon supply of all product prices, input prices and relevant institutional, technological and physical restrictions.

Second, since the model takes account of the fact that most farms are multiproduct and multiresource entities, this approach provides valuable planning information at the farm level. For example, within the constraint set it is possible to include constraints for available land area and to allow for crop rotations. This allows the reference farm approach to take account of important technical factors which affect supply response to a degree not possible in alternative supply estimation techniques. The comprehensiveness of the reference farm programming method makes it suitable for studying the effects on output of future changes in production conditions. For example, programming models permit simulation of the effects of exogenous forces and policies for which historical observations are not available, thus circumventing one of the major limitations of regression models. Furthermore, the results remain fully consistent with the resource and technical constraints imposed on the model.

Linear programming is also a useful analytical approach for estimating a range of cross price elasticities not possible with alternative estimation techniques. By carefully selecting the manner in which variables are parametrized the data problems that limit econometric estimation of cross relationships (high correlation among independent variables) can be avoided. Theoretically satisfactory estimates of cross price supply relationships can be obtained more readily from normative linear programming models than from positive econometric models.

Other features of the reference farm linear programming model relate to the fact that the model embodies a complete causal system of the functioning of the individual farm. The programming approach allows for both independent and interdependent activities to be incorporated into the programming model. Furthermore, the reference farm programming approach to supply estimation is a static deterministic approach in which complete certainty is assumed. Linear programming solutions are timeless and assume instantaneous adjustments. Finally, because of the stepped nature of the programming production function perfectly elastic or inelastic estimates of supply can be obtained over relatively small price ranges.

The reference farm linear programming approach to estimating supply response encounters a number of difficulties. One major area of difficulty relates to obtaining a suitable classification of farms in order to allow the reference strata to be defined such that aggregation bias is minimized. Buckwell and Hazell (1972) argue that in practice it is not possible to devise stratification procedures which completely eliminate aggregation bias, but suggest a number of methods which help to reduce the extent of bias in programming models. Difficulties also arise with respect to defining the objective function and to specification of the activity set and resource constraints. In the case of the activity set there are difficulties in defining alternative activities not currently employed in the reference farm model but should be included as possibilities under future conditions.

The profit maximizing assumption of producers implicit in programming models has been criticized by various researchers. Since profit maximization may not be the only goal of producers, models that fail to consider risk and nonmonetary objectives in the analyses may overestimate supply response. Furthermore, producers' output decisions may change with respect to changes in the level of uncertainty about expected profits. Various attempts have been made to develop alternative objective functions to profit maximization in programming models. These approaches fall into two groups. First there are those approaches that attempt to optimize net receipts, disposable income or utility. The second group attempt to place a constraint on profit maximization and include focus loss constraints or flexibility constraints.

In addition to the above limitations there is also a need to allow for changing farm structure, technical change and to accommodate non linear functions. Linear programming models implicitly assume constant returns to scale in production, that is, the production process assumes proportional changes in all inputs and outputs (replication). The reference farm linear programming model assumes that the production function is linearly homogeneous and therefore consistent with constant returns to scale. An implication of this restriction is that the programming model's ability to capture the dynamics of supply response is limited. Thus, limiting the usefulness of linear programming models for forecasting purposes. However, there are gains in that these methods make allowance in a theoretically consistent way for the technical/economic relationship between all inputs and outputs specified in the models.

Other difficulties which arise with the programming model relate to testing the validity of the model. Since programming models are deterministic in nature, testing the validity of the reference farm approach involves testing the underlying assumptions of the model. However, much of the data necessary for constructing linear programming supply models (crop budgets and resource constraints) are difficult to verify external to the model. In many cases, data can be validated only indirectly by comparing the initial results of the model with a historical reference.

4.2.2 Characteristics of the Econometric Procedure

With the econometric approach, the statistical analysis tries to find an explanation of output in terms of a set of explanatory variables chosen on the basis of economic theory and knowledge of the technical conditions of production. The role which the theory of production and the firm plays in the specification and estimation of the models is limited to taking a reduced form of the derived output supply function in which output is assumed to be a function of product and input prices. Essentially, regression analysis is an objective approach to finding an average relationship between past output and prices.

Output projections from regression analysis are developed by extending past relationships into the future and where past policies and relationships remain stable among variables the econometric approach predicts more accurately than the linear programming approach. Predictions are based upon the assumption that producers will continue to act in the future as they have in the past. However, if one or more of the standard statistical assumptions underlying the regression model are violated then the positive estimates do not accurately describe the past or predict future output levels. This may arise from errors in data measurement, aggregation, high correlation among independent variables, omission of relevant variables or incorrect specification of the form of the relationship.

Econometric models which characterize the positive approach imply both prediction and testability. In contrast to normative programming models where the normal way of testing a model is to examine its assumptions, the procedure used to test the positive econometric model is to test its conclusions. Basically, a positive model expresses what is apparent fact as revealed by the empirical analysis.

There are a number of inherent limitations associated with the multiple regression procedure. One of the more serious limitations relates to the degrees of freedom problem, that is, the number of observations must exceed the number of explanatory variables. Furthermore, an implicit assumption of regression analysis is that no unknown structural change has occurred throughout the time period under analysis. Therefore, in regression models there tends to be some conflict between the above problems. For example, in a model developed for predictive purposes estimates of current parameters are required. However, this creates pressure to reduce the length of time series used in the analysis which in turn creates pressure to reduce the number of explanatory variables.

Moreover, the reduction in the number of statistical degrees of freedom as the number of parameters increase for any given length of time series limits the degree of product and input disaggregation the econometric approach can accommodate. Therefore, regression models tend to be highly restrictive in that only a subset of variables which could theoretically affect supply are examined. This results in a limited number of cross price effects estimable with this class of model.

In regression analysis it is often difficult to distinguish between the influence of closely related variables especially when these variables change in a similar fashion through time. This is the problem of multicollinearity which in turn is associated with a number of statistical problems including high standard error of estimates, unstable parameter estimates, and sensitivity of parameter estimates to model misspecification. Addition or elimination of a variable in the explanatory set may have a marked effect on the estimated parameters of other variables. Therefore, multiple regression analysis cannot measure the true underlying relationship (based on the technical production relationship) in supply functions but merely the degree of association as revealed by movements in the time series data. Thus, the usefulness of supply price responses estimated by multiple regression techniques may be of limited value in terms of policy impact analysis.

A further feature of econometric models which also limits the usefulness of the derived supply elasticity estimates is that the theoretical underpinnings of regression studies are essentially of an ad hoc nature. These studies are generally based on time series data in which supply response is measured at the aggregate (market) level.

Agricultural production is not instantaneous but is dependent upon past investment in the industry. Therefore, supply may be specified as a function not only of current economic conditions but also expectations about future conditions. Incorporating expectational variables for prices, revenue or profits into supply functions represents a reduced form approach to dealing with the role of investment in supply analysis (e.g Nerloves' partial adjustment theory). In other studies however, investment plays a more direct role in explaining production. For example, livestock models in which the principal response functions explain the stocks of various categories of livestock. As pointed out by Hildreth and Jarrett (1955, p. 21) livestock can be regarded as a finished good, a good in process or as part of fixed capital. Essentially, these characteristics imply the need for simultaneous equation systems to explain output and inventories. Current prices affect the number of animals supplied for slaughter while prices in turn are affected by current supplies. Hence the interdependency between supplies and current prices.

Econometric models have a number of important merits. The most significant factor is that they operate directly upon the aggregate supply data which are the object of interest for projection purposes. The econometric procedure is a relatively simple procedure in terms of estimational methods and data requirements. Furthermore, the procedure entails a smaller number of steps to generate supply response coefficients. This gives the econometric procedure an important advantage over the programming procedure as it minimizes the capacity for specification errors to accumulate through successive stages. Finally, it is a technique which is capable of dealing with dynamic adjustments in supply in a theoretically consistent manner.

4.3 Review of the Relevant Literature

Zepp and McAlexander (1969) examined the supply prediction performance of a number of models including a linear programming, recursive programming and a regression model in estimating the short run (1-5 years) changes in milk production in Southeast Pennsylvania between 1961 and 1965. The predictiveness of each model was evaluated by comparing the estimates of aggregate milk production from each model with actual production for the respective years. They found that the linear programming models generated larger predictive errors than time series regression models.

Wipf and Bawden (1969) assessed the descriptive and predictive reliability of supply functions derived directly from regression analysis with those derived indirectly from empirically estimated production functions. Supply equations were derived from production functions for a number of selected agricultural commodities and used to estimate supply elasticities and predict output. The estimated supply elasticities were compared with actual output and with elasticities estimated directly by regression analysis of time series data. They found that the supply elasticities estimated using regression analysis showed firms to be less responsive to price changes as compared to supply elasticities derived from production functions. Moreover, the supply elasticities derived from production functions tended to overestimate actual output. They concluded that supply equations derived from production functions are not empirically reliable compared to supply equations estimated by regression analysis.

Quance and Tweeten (1971) compared supply elasticity estimates from linear programming models with regression estimates for three subsectors, wheat, cotton and the feed grain livestock sector. Greater variability and larger elasticity estimates were found with the normative linear programming models as compared to the time series estimates. Quance and Tweeten argue that linear programming models provide realistic long-term elasticity estimates for commodities which are characterized by well defined resource constraints and cash markets. They suggest that the linear programming approach to supply analysis is useful to measure the long-term impacts of price changes on the output of a commodity where flexibility, timeliness and the need to consider policies outside the range of historic experience are important. Furthermore, they point out that linear programming estimates may be unreliable where absolute as well as relative production potentials are important and predictions of short-run response are desired. In such cases econometric estimates are more reliable to predict short-run supply response especially where no significant changes have occurred in the structure of the economy.

Shumway and Chang (1977) attempted to test the reliability of elasticity estimates derived from a normative linear programming model with estimates derived from a single commodity partial adjustment model. Both long-run direct and cross price elasticities were estimated for fifteen crops using the linear programming technique while only direct supply elasticities were estimated with the econometric model. The authors found that the linear programming long-run direct supply elasticity estimates for individual crops differed substantially from the econometric estimates, but that the average magnitudes of the linear programming estimates were only slightly higher than the econometric estimates. Furthermore, they found that the standard deviation of elasticities across crops to be higher for the time series estimates. They conclude that the direct elasticity estimates derived from the linear programming procedure compare reasonably well with estimates from time series analysis. In addition, they argue that the linear programming technique provides a more feasible method for estimating cross price supply elasticities.

4.4 A Discussion of the Empirical Supply Elasticity Estimates Derived from the Programming and Econometric Techniques.

The empirical supply elasticity estimates derived from the linear programming and econometric models are discussed in the following section. Table 4.1 provides a summary of the supply elasticities derived in the preceding chapters of this study.

Table 4.1. A Summary of the Supply Elasticity Estimates Derived from the Linear Programming and Econometric Models.

Model	Elasticity Estimates for:		
	Lamb	Wool	Cull Sheep
Linear Programming Model:			
Medium Size Ref. Farm	1.11	0.12	0.19
Large Size Ref. Farm	1.47	0.09	0.11
Econometric Model:			
Short Run	0.36	0.07	0.04
Long Run	1.22	0.16	0.28

In Table 4.1 the supply elasticity estimates derived from the linear programming model for lamb are elastic while the econometric model shows lamb supply to be inelastic in the short-run but elastic in the long-run. For wool and cull sheep both the programming and econometric models show that the supply of these products is highly inelastic. The remainder of this section outlines the major factors which contribute to these divergent elasticity estimates.

The divergent magnitudes of the supply elasticities can be attributed to differences in the underlying assumptions of the programming and econometric models. However, before discussing the assumptions of the alternative models, the characteristics of the supply curves derived from the programming and econometric procedures are outlined. The linear programming supply curve for lamb is characterized by the phenomenon that at low lamb prices production is not profitable and therefore, the supply curve rises steeply. As prices increase the inelastic portion of the curve gives way to a horizontal elastic portion as the commodity becomes competitive with other enterprises at the farm level. With higher prices the supply curve becomes more steeply sloped and inelastic as available resources are used and marginal inputs experience diminishing returns. Thus, this phenomenon suggests that the supply elasticity varies substantially over a linear programming supply curve. Conversely, econometric supply curves estimated here are characterized by a constant elasticity. In the case of time series observations this gives rise to a short segment of the supply curve that can be approximated by a straight line.

One of the major differences between the alternative estimation procedures used in this study relates to the data used in the analyses. In the linear programming model, micro economic (farm level) data were used in the construction of the reference farm programming models. More specifically, the average values for activities over the period 1986 to 1988 for Alberta were used in the construction of the synthetic programming model. The reference farm supply functions were then aggregated to provide industry supply response. Conversely, macro data (market level) were used to estimate supply elasticities with the econometric model. The data used in the econometric model covered the time period from 1970 to 1987.

A fundamental assumption of the programming approach to supply estimation is that producers are profit maximizers. In this study no allowance is made for non monetary goals in the programming methodology. Activities are combined in such a manner as to maximize farm profit (gross margin) which may result in overestimation of farmers' actual response to price changes. In this study, the econometric approach does not impose the optimization restriction on producers' behavior as output is explained in terms of historical time series supply data.

The programming model is more comprehensive in that a larger range of activities are included in the model, therefore, a greater range of cross price elasticities can be obtained. Theoretically, all existing and potential activities should be included in the linear programming algorithm. However, in this study the dimensions of the linear programming algorithm are restricted to include only activities which are considered relevant, given the structure of agriculture in Alberta. In the econometric procedure product and input disaggregation is limited because of the reduction in the number of degrees of freedom as the number of parameters increase for any given time period. Furthermore, the statistical problems associated with collinearity limit the number of included parameters to a few close substitutes.

The time dimension of the supply elasticities derived from the alternative approaches differ. Both short-run and long-run supply elasticities are derived from the econometric partial adjustment type model. However, with the linear programming model, only medium term supply elasticities are derived. The programming model can be regarded as generating medium term elasticities because no allowance is made in the model for technical change while resources are allowed to vary subject to budgetary constraints.

In this study, the linear programming models take no account of producers' attitude towards risk. Incorporating risk into the linear programming models would involve restricting producers' reaction to price changes to some proportion of adjustments in previous periods. This would severely restrict the fundamental assumption of profit maximization.

For policy impact analysis, the greater adaptability of the programming procedure gives it an important advantage over econometric models. The programming model, in addition to being more comprehensive in terms of included activities, can also accommodate potential future policy variables. The impact of these variables on supply can be assessed within the framework of the model. However, econometric supply models based on historic supply data do not permit the evaluation of future policy variables concerning the industry.

Basically, supply elasticities can be used for two purposes, to show the magnitude of output of a commodity or to predict farm output in response to future price changes. Regression analysis is more suitable than linear programming as a predictive tool provided that the conditions which have influenced supply in the past continue to do so in the future.

A useful feature of the regression model is that aggregate time series data are usually more readily available than the technological, price, and resource data required for the linear programming analysis. An additional feature of regression analysis is that results can be obtained within a short period of time as less research resources are required compared to the programming approach.

In addition to the differences outlined above with respect to the assumptions underlying the structure of the programming and econometric models, there are various other reasons why farmers in the aggregate may not optimize in the real world situation. These include constraints with respect to marketing, labor and management.

In the case of marketing constraints a feature of the Alberta sheep industry has been the rationalization of marketing channels for lamb resulting from the decline in the size of the provincial flock. This may have imposed constraints on producers marketing options which in turn may have restricted optimization behavior at the farm level. On the input side, the availability of skilled labor and management required for sheep production is an important factor which may also have contributed to lower than optimum technical performance in the industry. Other constraints which may have played a role in influencing lamb output, especially on a localized basis include climatic factors, predators, disease and pest problems.

Finally, the lack of reliable data has posed problems in analyzing the sheep industry. Farm gate sales of lamb are an important feature of the sheep industry. However, due to the lack of data, the actual volume of farm gate sales is difficult to analyze .

The above discussion has attempted to explain the divergent results from the programming and econometric models. An understanding of aggregate supply response is of paramount importance in designing marketing policies for the industry. The following chapter outlines some marketing options for the sheep industry and assesses the welfare effects of a supply management marketing scenario by drawing on the supply elasticity estimates derived in this study and combining these with demand elasticity estimates from the literature.

Chapter 5: Evaluation of Supply Management as a Marketing Option for the Alberta Sheep Industry

5.1 Introduction

This chapter outlines the marketing options available to the sheep industry and examines the welfare effects of one such option, namely, supply management. The potential marketing options open to the industry can be divided into two broad groups, demand management programs and supply management type programs.

Demand management policies have a twofold objective: to shift the product demand curve to the right and to make the demand for the product more inelastic. The demand management programs focus primarily on advertising and promotional efforts which directly expand the demand for the particular product or group of products. These programs include both brand and generic promotional efforts. In addition to advertising and promotional policies, other types of demand management policies include product policies (e.g. differentiation, proliferation) and price policies (e.g. price discrimination).

The alternative marketing options focus on the supply side of the industry and involve some variant of the supply management scenario. Basically, the supply management approach operates via restrictions on output or inputs used in the industry. Output control can be achieved through direct production or marketing quotas. Production or marketing quotas may be mandatory or voluntary in nature depending on the comprehensiveness of the supply management program. In principle, supply management can be an effective means of controlling marketable supplies and of raising and stabilizing prices and incomes in agriculture provided that the demand for the product is price inelastic. Less restrictive forms of marketing boards include negotiating boards and centralized selling (single desk) boards. A centralized selling board often improves operational efficiency in the industry by providing a more coherent and coordinated approach to marketing and consequently, returns to producers. The pricing and operational efficiency of a centralized selling system have been analyzed by Leavitt et al. (1983), Adamowicz et al. (1984) and Higginson et al. (1988).

In this chapter the comparative static welfare economics framework is used to assess the economic effects of supply management as a potential marketing option for the Alberta sheep industry. The effectiveness of supply management as a marketing tool depends not only on the magnitude of the supply and demand elasticity estimates but also on the extent of restrictions on imports of the product. Domestic demand for a particular product can be influenced where a supply management marketing option with domestic production quotas is accompanied by some type of import control for the product. In general, the more price inelastic the demand for a given product, the greater the opportunity to transfer income from consumers to producers through a supply management program.

The remainder of this chapter is organized as follows. The next section provides a brief overview of demand elasticity estimates for lamb in Canada. This is followed by an outline of the theoretical welfare framework that is used to examine the supply management marketing scenario for the industry. The supply and demand elasticity estimates are incorporated into the welfare economics framework in order to assess the aggregate sectoral efficiency and distributional impacts on consumers and producers of a supply management marketing option for lamb. The final section discusses the empirical results and economic implications of a supply management marketing option on the structure of the industry.

5.2 Review of Some Relevant Demand Studies

The demand for meats is determined not only by the traditional economic variables of prices and income but also by demographic and socioeconomic factors. Demographic factors include population characteristics such as size, distribution, age structure and ethnicity. On the other hand socioeconomic factors include employment patterns, household size, composition, consumer tastes and preferences. Demographic and socioeconomic variables play an important role in influencing the demand for some meats especially lamb which tends to have a more seasonal pattern of consumption. Historically, meat demand studies have attributed per capita consumption to the price of the product, prices of other meats and an income or expenditure variable. This section reports and discusses the price and income elasticity estimates for lamb from some Canadian meat demand studies.

Economic theory provides some guidance with respect to certain *a priori* expectations between demand elasticity estimates. For example, the own price elasticity of demand for a product is normally negative. The own price elasticity refers to the percentage change in the quantity demanded caused by a 1 percent change in price, ceteris paribus. In the case of cross price elasticities, these indicate whether a good is a substitute (positive cross price elasticities) or a complement (negative cross price elasticities). The cross price elasticity refers to the percentage change in quantity demanded of a particular product caused by a 1 percent change in the price of another product.

The income elasticity of demand refers to the percentage increase in quantity demanded caused by a 1 percent change in income. For most goods the income elasticity is positive, that is, an increase in income will result in an increase in consumption.

However, inferior goods have a negative income elasticity of demand. Conversely, luxury goods have an income elasticity greater than 1 while necessities have an income elasticity less than 1.

There are a number of factors which determine the magnitude of the elasticity estimates including the levels of prices, number of substitutes, preferences and the size of the budget share. More specifically, it is expected that the higher the price of a product the higher the own price elasticity (more elastic), and the lower the product price the lower the own price elasticity (inelastic), ceteris paribus. In terms of the cross price elasticity estimates, the larger the elasticity estimate between two products the greater the degree of substitutability between the products. That is, the availability of close substitutes allows consumers to switch to similar products if the price of one product increases. Furthermore, the demand for a particular product is likely to be price elastic where a large number of substitutes are available. Lastly, the stronger the preference of consumers for a particular product, the lower the magnitude of the own price elasticity. Similarly, the demand for a product which accounts for a small share of the consumer's budget is expected to be price inelastic.

Table 5.1 provides a summary of results for lamb from some studies of the demand for meats in Canada and includes the source of the study, time period of the sample, estimation method, direct, cross price and income elasticity estimates for lamb.

Table 5.1. A Summary of Some Canadian Meat Demand Studies Showing the Price, Cross Price and Income Elasticity Estimates for Lamb.

Source	Period	Method of Estimation	Income Elasticity	Direct Price Elasticity	Cross Price elasticity w.r.t. the price of: Pork	Veal	Beef
Tryfos and Tryphonopoulos (1973)	1954-1970	SUR	-2.909	-1.801			
Reimer and Kulshreshtha (1974)	1949-1971	TSLS	-0.113	-1.043			
Hassan and Johnson(1976)	1957-1972	SUR	0.390	-1.862	0.968		
"	1957-1972	FIML	0.393	-1.866	0.964		
Hassan and Katz (1975)	1954-1972	SUR	0.488	-2.042	0.834		
"	1954-1972	FIML	0.487	-2.067	0.843		
"	1954-1972	SUR	0.390	-1.862	0.968		
"	1954-1972	FIML	0.393	-1.866	0.964		
McIntosh (1972)	1953-1969	OLS		-1.323		3.625	-2.337

where: SUR = Seemingly Unrelated Regression
TSLS = Two Stage Least Squares
FIML = Full Information Maximum Likelihood
OLS = Ordinary Least Squares

The range of price and income elasticity estimates reported in Table 5.1 can be attributed to the following factors: different model specifications, functional forms, time periods and estimation methods. The direct price elasticity estimates for lamb have the correct sign and range in magnitude from -1.043 to -2.067. Thus, the demand for lamb is elastic, i.e., for a 10 percent increase in price the quantity of lamb demanded will fall by 10 to 21 percent. As pointed out by Hassan and Katz (1975), lamb, veal and turkey are seasonal commodities with peak consumption occurring during public holidays. Therefore these meats are more price elastic than pork, beef or chicken which are characterized by more frequent consumption.

The estimated cross price elasticities are all positive with the exception of beef in the McIntosh (1972) study. This implies that consumers view these meats as substitutes rather than as complements. The estimates indicate that lamb consumption is affected by changes in pork prices. For example, the cross price elasticity estimates for lamb with respect to the price of pork varies from 0.834 to 0.968. That is, for a 1 percent increase in the price of pork, the consumption of lamb increases by 0.8 to 1 percent, ceteris paribus.

The income elasticity estimates are all positive with the exception of the Tryfos and Tryphonopoulos (1973), and Reimer and Kulshreshtha (1974) studies. The estimated income elasticities for lamb vary from 0.390 to 0.487, i.e., a 10 percent increase in income is associated with a 4 to 5 percent increase in lamb consumption. Hassan and Katz (1975) point out that estimating income elasticities from time series data may encounter statistical problems such as high correlation between prices and income. In addition, persistent annual increases in per capita disposable income makes it difficult to statistically distinguish the effects of income from trend and to obtain accurate estimates of these parameters.

In order to overcome some of these statistical problems some researchers have attempted to estimate income elasticities for meats from cross sectional data. More specifically, Hassan and Lu (1974) have estimated the income elasticity for lamb from cross sectional data to be 0.676. Curtin et al. (1987) in their study of the demand for food in Canada, estimated the own and cross price elasticities from time series data but income elasticities were estimated from both time series and cross sectional data. They found that the income elasticities based on aggregate time series data were strongly negative and varied from -1.4 to -2.8. Conversely, the income elasticity estimate derived from the survey data was 0.715.

The following section provides a brief review of the welfare economics framework used in assessing the income transfers and social costs of a supply management program for the Alberta sheep industry. The review focuses in particular on the underlying assumptions and economic implications of the model.

5.3 Theoretical Framework for Welfare Analysis

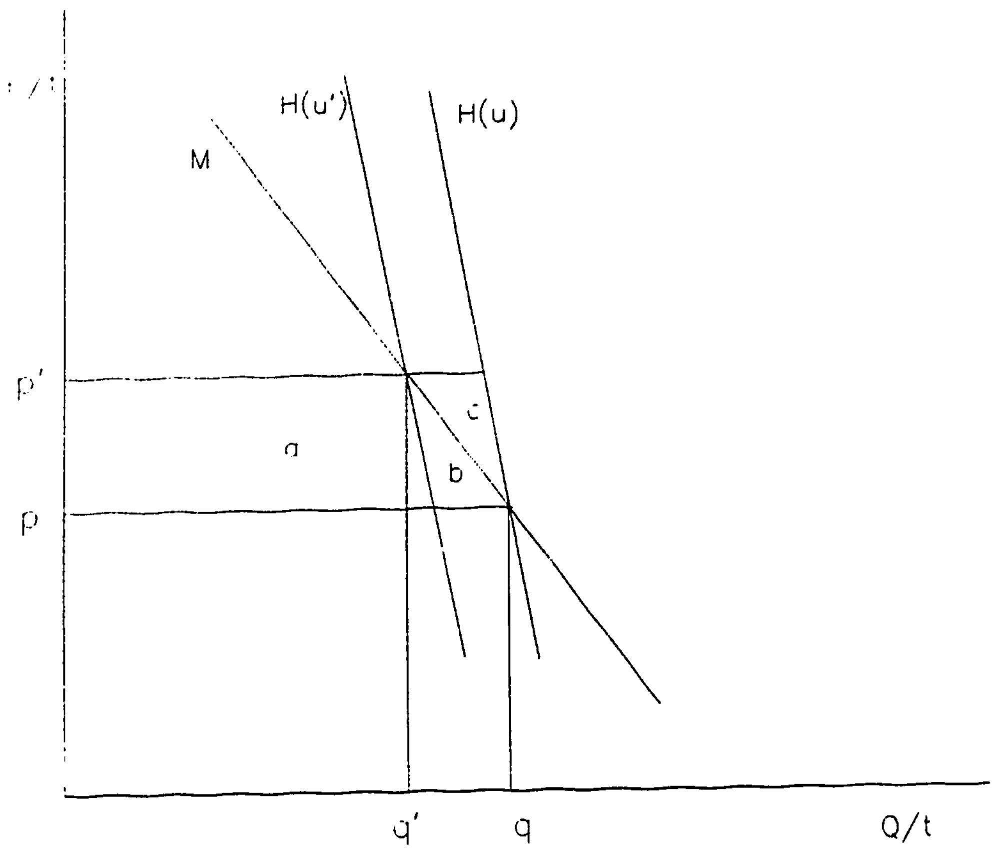
The concept of economic surplus, that is, producer and consumer surplus, forms the basis for empirical studies of economic welfare. The concept of producer surplus or economic rent was first introduced by Ricardo (1829) while the consumer surplus concept is attributed to Dupuit (1844). Marshall (1948) adapted, refined and extended these concepts to the problem of measuring the gains and losses resulting from the implementation of different policy scenarios. The fundamental underlying assumption of classical welfare economics is that the perfectly competitive market is Pareto optimal. Therefore, any deviation from the competitive equilibrium results in a welfare loss to society. Furthermore, the welfare economics framework focuses on the welfare effects of a change in a single market assuming that the effects in other markets are negligible. In essence, these welfare economics concepts hold that the area to the left of the demand curve and above the competitive price line is a money measure of utility or consumer surplus in a market and that the area to the left of the supply curve and below the price line is a money measure of welfare or producer surplus in a market. Thus, changes in producer and consumer surplus can be used to measure welfare changes to society.

Just et al. (1982, p. 93) outline a number of limitations associated with the classical welfare economics framework. These limitations arise from measuring consumer welfare changes via the Marshallian consumer surplus approach. First, consumer surplus is not a unique money measure of utility or welfare change. In order for consumer surplus to be a unique measure of welfare change requires restrictive path independent conditions on the utility function. Second, the consumer surplus concept requires the constant marginal utility of income condition to ensure that there is an ordinal association with the actual change in utility. Third, a unique change in consumer surplus is difficult to define where price changes occur simultaneously or where income changes together with price.

Kaldor (1939) and Hicks (1939) extended the conventional normative welfare economics approach to include the "compensation principle", that is, a change should be made if the potential gains allow for everyone to be made better off by some redistribution of goods or income following the change. The associated measurement problem was addressed by Hicks (1943) who developed two alternative money measures of welfare, namely, compensating variation and equivalent variation. These measures of welfare change are income adjustments which maintain the consumer at a particular level of welfare. Compensating variation (C) is defined as the amount of income which must be taken away from a consumer after a price and/or income change to restore the consumer's original welfare level. Conversely, equivalent variation (E) is the amount of income that must be given to a consumer in lieu of price and income changes to leave the consumer as well off as before the change (Just et al., 1982, p. 85).

The compensating and equivalent variation measures form the basis of the new classical welfare economics. These measures can be directly employed in performing the compensation tests of the new welfare economics. The compensating and equivalent variation measures of consumer welfare are unique (non ambiguous) and are ordinally related to actual changes in utility. They are difficult to determine empirically since actual utility levels cannot be observed. However, compensating and equivalent variations can be related to the observable Marshallian consumer surplus via the Hicksian or compensated demand function. The Hicksian demand function shows the relationship between the quantity demanded at different prices by varying income with utility held constant. Conversely, the Marshallian demand function shows the relationship between quantity demanded at various prices by varying utility with income held constant. The compensating and equivalent variation measures of consumer welfare can be expressed as areas under the Hicksian demand curves between the original and new price lines. Figure 5.1 illustrates the relationship between the Marshallian consumer surplus, compensating and equivalent variation measures of consumer welfare.

Figure 5.1. Consumer Surplus, Compensating Variation and Equivalent Variation Measures of Consumer Welfare.



The initial price level is denoted by p while the new price level is denoted by p'. A price increase causes the quantity consumed to fall from q to q'. The Marshallian demand curve (M) intersects the Hicksian demand curves (H) at the original utility level (u) and new utility level (u'). The consumer surplus measure of the change in consumer welfare is given by the area (a+b) while the compensating and equivalent variation measures are given by the areas (a) and (a+b+c), respectively. From Figure 5.1 a number of important implications can be deduced. First, if the areas (b) and (c) are negligible, then the change in consumer surplus can be used directly as an approximation of both compensating and equivalent variations. Second, if the areas (b) and (c) can be estimated from observable phenomenon, the consumer surplus change can be modified to produce approximations of both compensating and equivalent variations[21]. More specifically, compensating variation (C) can be approximated by subtracting area (b) from area (a+b) to give:

$$(1) \qquad \hat{C} = \Delta S - \frac{\eta}{2Y}(\Delta S)^2 = \Delta S - \hat{\epsilon}\,|\,\Delta S\,|$$

where $\hat{C}$ is the approximate measure of compensating variation, $\hat{\epsilon} = \frac{\eta|S|}{2}$ is the approximate fraction of error, Y is real income, η is the income elasticity of demand and ΔS denotes the change in ordinary consumer surplus. Similarly, equivalent variation (E) can be expressed as:

$$(2) \qquad \hat{E} = \Delta S + \frac{\eta}{2Y}(\Delta s)^2 = \Delta S + \hat{\epsilon}\,|\,\Delta S\,|$$

where $\hat{E}$ is the approximate measure of equivalent variation. As pointed out by Willig (1976) for any reasonable income elasticity, a maximum error of 5 percent occurs when consumer surplus is used as a measure of either compensating or equivalent variation, that is, ($|\,\hat{\epsilon}\,| = |\,\eta\frac{(S)}{2}\,| \leq 0.05$). Just et al. (1982, p. 101) point out that for most goods the percentage of income spent at any price is small enough that the condition $|\,\eta\frac{(S)}{2}\,| < 0.05$ is not violated even if the income elasticity is 2 or 3. However, where the income equivalent of a large price change represents a substantial proportion of income an error in excess of 5 percent occurs if consumer surplus is used as a direct estimate of compensating or equivalent variation. That is, if $|\,\eta\frac{(S)}{2}\,| > 0.05$ or if a more precise

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21 Areas (b) and (c) can be estimated at least for small price changes since the height of each triangle is given by the price change while the base of each triangle is essentially an income effect.

estimate of the willingness to pay concept is desired, compensating or equivalent variation can be estimated following (1) or (2)[22]. However, if $|\hat{\epsilon}| = |\eta \frac{(S)}{2}| \leq 0.05$ and errors up to 5 percent are permitted, then Marshallian consumer surplus can be used directly as an estimate of compensating or equivalent variation.

Hausman (1981), however, has pointed out that the Marshallian deadweight loss measure can be a poor approximation for the theoretically correct Hicksian measure of deadweight loss. To overcome this problem he suggests the use of the compensated demand curve to calculate the exact deadweight loss rather than the Marshallian approximation.

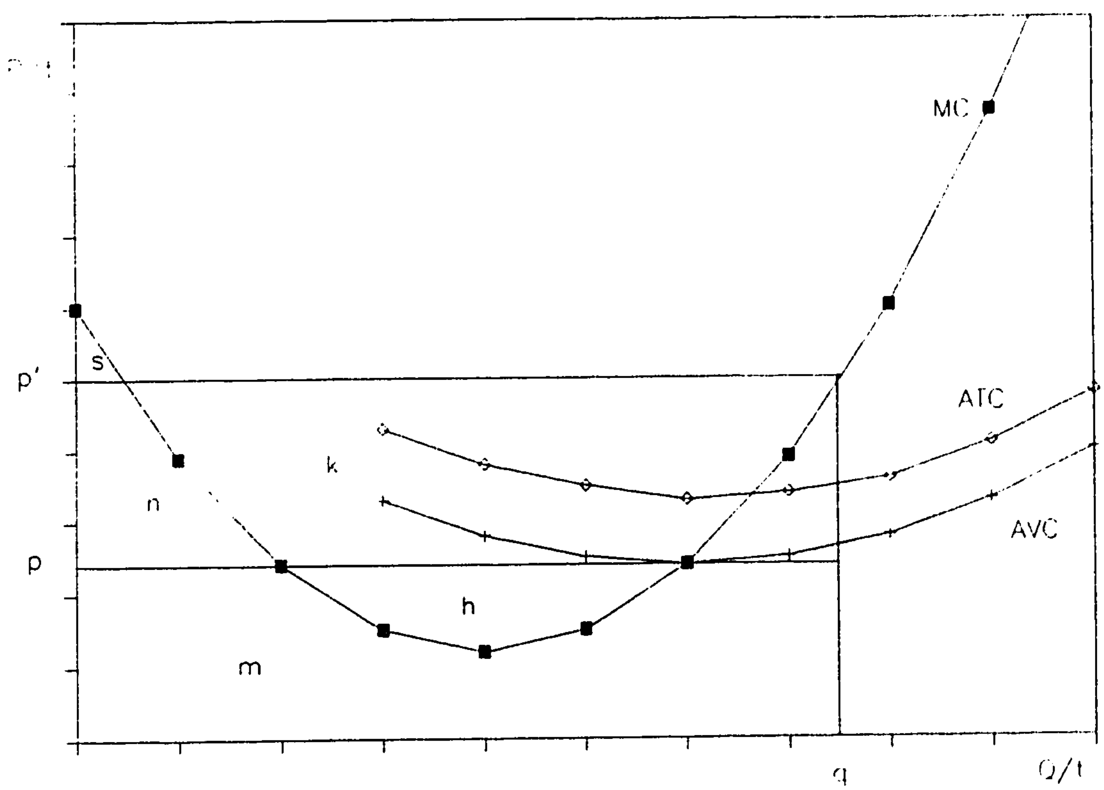
The consumer surplus welfare measurement approach has been employed in many applied welfare studies including Borcherding and Dorosh (1981), Veeman (1982), Van Kooten and Spriggs (1984), and Lermer and Stanbury (1985). Van Kooten (1988) demonstrates that the conventional Marshallian consumer surplus measure of consumer welfare gives a close approximation of the equivalent and compensating variation measures of welfare changes resulting from supply management programs.

With respect to producer welfare, producer surplus provides an exact measure of producer welfare and of the compensating and equivalent variations of a price change. The short-run supply curve is equivalent to the marginal cost curve for the industry with producer's surplus derived as profits plus rent attributable to the specialized factors that initially confer advantages on the firms employing them. The neoclassical model of supply provides the basic framework for producer welfare analysis in this study. This framework is based on the assumption of profit maximization where the producer equates price to marginal cost, assuming that price exceeds the minimum of the average

22 Just et al. (1982, p. 97-111) provides a more detailed discussion of the formulae outlined above.

variable cost curve. Producer welfare gains can be computed via a number of approaches based on the definition of quasi-rent (Just et al., 1982, p. 65). Figure 5.2 shows the relationship between the marginal cost, average total and average variable cost curves[23].

Figure 5.2. Marginal Cost, Average Total and Average Variable Costs.



The profit maximizing total revenue (TR) can be gleaned from Figure 5.2 as the area to the left of q and below p', that is, TR = p.q = area k+h+m+n. Total variable

23 In this study producer surplus and quasi-rent are equivalent, that is, PS=QR=TR-TVC.

costs (TVC) can be measured as the area below the marginal cost curve, i.e. TVC = area m+n+s. Therefore, quasi-rent or producer surplus can be calculated as; PS = TR - TVC = area k+h-s.

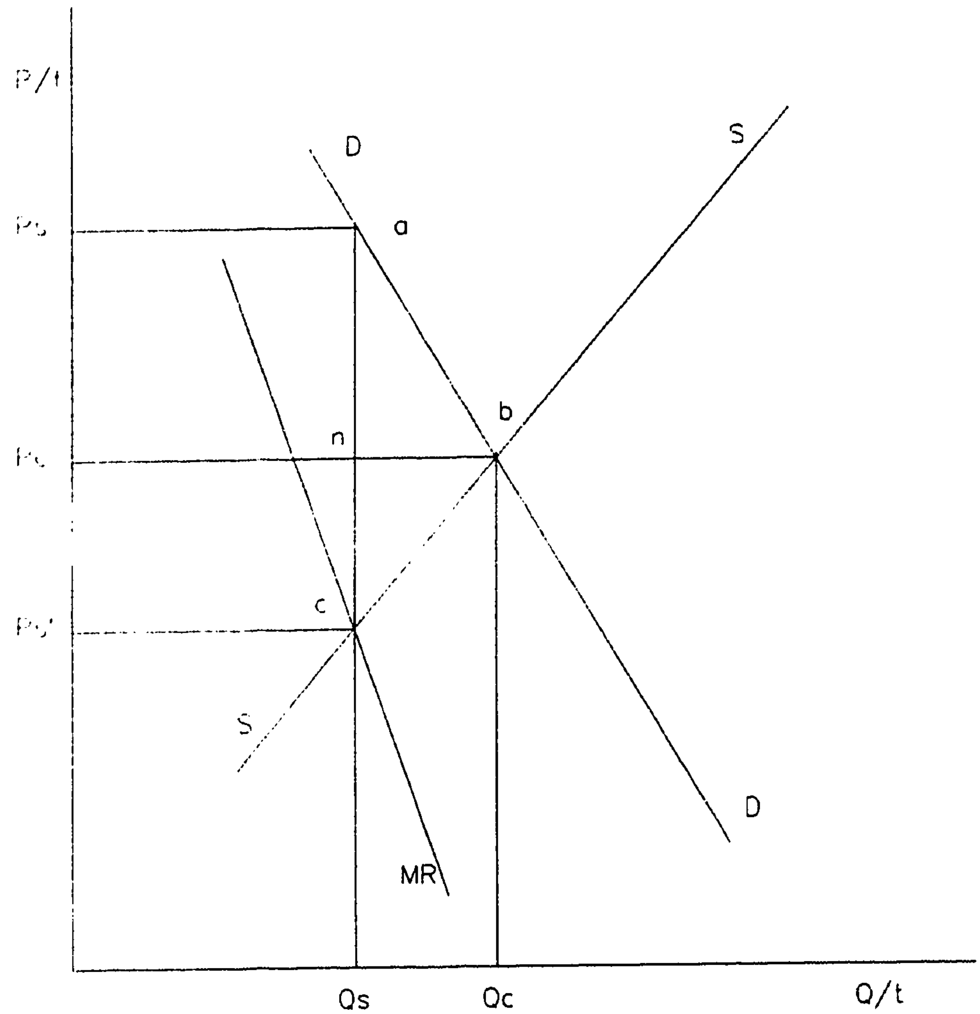
In a perfectly competitive market, the long-run supply curve may be horizontal or upward sloping depending on the shape of the input supply curves for the industry. Where input prices increase as the industry expands gives rise to an increasing cost industry. Thus, the long-run supply curve for such an industry is upward sloping. However, if input prices do not change as the industry expands, the industry is a constant cost industry and the long-run supply curve is horizontal. As Mishan (1981, p. 228) points out any movement along a long-run industry supply curve is basically a movement from one long-run equilibrium to another. Therefore, the competitive firm will be earning normal profits at all points on the long-run supply curve. Thus, producer surplus defined as the area below a price line and above the long-run supply curve has no economic meaning as a welfare measure (Mishan, pp. 225-30).

Gardner (1981) points out that welfare analyses of the major commodity programs in agriculture have generally used competitive equilibrium as the benchmark to compare program performance. This procedure can be justified by arguing that the major commodity programs are not designed specifically to overcome the traditional forms of market failure such as externalities and public goods. In this study it is proposed to adopt the producer surplus concept in conjunction with consumer surplus to analyze the potential welfare effects of introducing a supply restricting marketing program for lamb. The following section discusses the estimation model that will be used for calculating the income transfer and allocative efficiency losses of a supply management program.

5.4 Estimation Model for Analyzing the Supply Management Marketing Option

This section outlines the estimation model that is used to identify and quantify the short-run transfer and social costs of a supply management marketing option for the industry. The standard neoclassical partial equilibrium static model is used for the welfare analysis. The analysis begins with the industry in long-run competitive equilibrium into which a supply management program with transferable quotas is introduced. The short-run welfare impacts of this program are examined for both producers and consumers. Furthermore, it is assumed that in the short-run plant size is fixed and there is no entry or exit from the industry. In Figure 5.3 the aggregate effects of a short-run supply management marketing scenario are illustrated.

Figure 5.3. Market Level Impact of a Supply Management Scenario (Short-Run).



In the above figure, DD and SS are the market demand and supply curves, and MR the corresponding marginal revenue curve. The competitive price and quantity are denoted by P_c and Q_c, respectively, while P_s denotes the administered price and Q_s the quota supply level which is consistent with achieving P_s. A perfectly competitive industry would produce Q_c whereas a monopolist would produce Q_s where marginal revenue equals marginal cost. The existing lamb market structure approximates the perfectly competitive situation, that is, the base model to which the welfare changes associated with the introduction of a supply management program are compared. The supply management approach requires the imposition of quantitative restrictions on imports and output so as to facilitate the setting and maintenance of the desired price level.

The first step in the estimation procedure involves taking the observed market equilibrium price and quantity for lamb for the base period. The base period price and quantity are calculated as the average price and quantity of lamb over the three year period 1985 to 1987. With control over one essential input (quota), the supply management marketing board can limit marketed domestic supply. The optimal trade off between higher price and higher costs depends on the specific parameters of demand and production technology. A supply restricting marketing board with transferable quotas would attempt to restrict output to Q_s in order to maximize industry profits. Essentially, this is equivalent to moving the marginal cost curve (supply curve) to a vertical position by making it prohibitively expensive to produce more than Q_s.

The exertion of monopoly power to achieve price P_s provides an incentive for increased supplies not only from existing sheep producers but also from new entrants. Therefore, the administered price level (P_s) will only be maintained if the domestic production quotas in conjunction with import quotas limit supplies to Q_s. The extent to which administered prices can be raised above the competitive price level is limited to the extent of quantitative restrictions on imports. The aggregate income transfer from consumers to producers and the social costs of the program can be gleaned from Figure 5.3.

This study follows the usual approach in that the short-run social costs of the program are given by the area of the triangle abc, assuming that the displaced variable inputs $(Q_s c b Q_c)$ find alternative productive uses in the economy[24]. Specifically, the loss in consumer surplus is given by the areas $P_c P_s a n + abn$ while the increase in producer's surplus is shown by the areas $P_c P_s a n - ncb$. The comparative static analysis applies only to producer level prices and ignores any impacts of the program on the marketing sector. In addition, administrative costs of the program are also ignored. Since a system of production/marketing quotas is required to gain access to higher market prices, quota rights acquire a capital value. This value provides a measure of economic rent and is shown by the extent to which the administered price (P_s) exceeds the supply price (P_s'). The immediate short-run effects of the supply management marketing program is for higher producer and consumer prices.

Just et al. (1982, pp. 65-66) point out that there is an adjustment period between the pre-marketing board equilibrium and the post-marketing board long-run equilibrium. During this transition period, producers lower production and adjust plant size accordingly. The elasticity of supply may increase as the supply curve used in measuring welfare impacts changes from the short to the long-run curve. Therefore, the annual welfare gains and losses may be in a state of flux during the transition period. Furthermore, there will be adjustment costs associated with the movement of resources

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24 The welfare loss approach is the conventional analytical approach to measuring efficiency losses presuming transferable quotas.

out of the industry to other areas in the economy. The following section presents some short-run empirical estimates of the effects of a supply management program on the sheep industry.

5.5 Empirical Results and Discussion

This section presents some empirical estimates of the aggregate annual short-run income transfers and losses in allocative efficiency due to a supply management program. In order to quantify the market outcome of the program the analyses draws on the supply elasticity estimates derived earlier in this study and the demand elasticities reported in the preceding section of this chapter[25]. The losses in consumer surplus, gains in producer surplus and social costs associated with a supply management marketing program are calculated from the following formulae:

$$(3)\quad CONSUMER\ SURPLUS\ LOSS = Q_s(P_s - P_c) + 0.5(Q_c - Q_s)(P_s - P_c)$$

$$(4)\quad PRODUCER\ SURPLUS\ GAIN = Q_s(P_s - P_c) - 0.5(Q_c - Q_s)(P_c - P_s')$$

$$(5)\quad SOCIAL\ COSTS = 0.5(P_s - P_s')(Q_c - Q_s)$$

The parameters in the above formulae are defined earlier in this chapter and relate to Figure 5.3. The empirical results are reported for two scenarios with four different supply elasticities and three different demand elasticities for lamb. More specifically, Scenario A relates to a 10 percent increase in the market price for lamb while Scenario B relates to a 5 percent increase in market prices arising from the introduction of a supply management marketing program. Furthermore, for each scenario it is assumed that there is no change in imports or exports of lamb from historic levels[26]. Table 5.2

25 The estimates are derived by solving for linear demand and supply functions.

26 In practice, the GATT rules which relate to supply management (Article 11) require that the proportion of imports to production remain unchanged.

shows the range of supply and demand elasticities used in the estimation together with the annual losses in consumer welfare, gains in producer welfare and allocative efficiency losses associated with a supply management marketing program for the Alberta sheep industry.

Table 5.2. Estimates of Short-Run Income Transfers and Social Costs of a Supply Management Marketing Option under Different Elasticity Estimates.

Supply Elasticity	Demand Elasticity	Consumer Surplus Loss ('000 $)	Producer Surplus Gain ('000 $)	Social Costs (000 $)
		Scenario A		
1.47	-2.067	626.59	452.65	173.94
	-1.748	637.73	503.96	133.77
	-1.043	662.40	600.08	62.32
1.22	-2.067	626.59	431.94	194.65
	-1.748	637.73	488.99	148.74
	-1.043	662.40	594.76	67.64
1.11	-2.067	626.59	419.52	207.07
	-1.748	637.73	480.39	157.34
	-1.043	662.40	591.72	70.68
0.36	-2.067	626.59	339.40	287.19
	-1.748	637.73	405.32	232.41
	-1.043	662.40	520.28	142.12
		Scenario B		
1.47	-2.067	331.34	287.80	43.54
	-1.748	334.18	300.79	33.39
	-1.043	340.32	324.74	15.58
1.22	-2.067	331.34	282.52	48.82
	-1.748	334.18	297.13	37.05
	-1.043	340.32	323.41	16.91
1.11	-2.067	331.34	279.51	51.84
	-1.748	334.18	294.90	39.28
	-1.043	340.32	322.65	17.67
0.36	-2.067	331.34	209.20	122.14
	-1.748	334.18	244.82	89.36
	-1.043	340.32	304.79	35.53

Note: In Table 5.2, changes in consumer and producer surplus were calculated relative to a base period price and quantity level. These values were estimated as annual averages over the time period 1985 to 1987. The base period price was taken as $1,920 per tonne and quantity as 3,640 tonnes of lamb.

Table 5.2 shows that the annual income transfers and social costs of a supply management marketing program can vary substantially depending on the magnitude of the supply and demand elasticity estimates. For example, the largest estimates of changes in producer surplus and consumer surplus are $600,080 and $662,400, respectively. These estimates amount to 8.6 percent and 9.5 percent of the gross value of lamb in the reference period. Conversely, the smallest estimates of producer surplus and consumer surplus changes are $209,200 and $331,340, respectively, which amount to 3 percent and 4.7 percent of the gross value of lamb in the reference period. In general, as the supply elasticity estimates increase from 0.36 to 1.47, the producer surplus gains increase while the social costs of the program decrease. More specifically, producer surplus increases by 23 percent for Scenario A and by 20 percent for Scenario B while the social costs of the program decrease by approximately 44 percent for Scenario A and by 63 percent for Scenario B. Moving from Scenario B to Scenario A, the gains in producer surplus increase by 70 percent for the large supply elasticity (1.47) and by 67 percent for the low supply elasticity (0.36).

With respect to the demand elasticity estimates, as the magnitude of the own price elasticities increase, the losses in consumer surplus decrease, gains in producer surplus decline while the social costs of the program increase. Specifically, as the demand elasticity increases from -1.043 to -2.067, the losses in consumer surplus decrease by 5 percent for Scenario A and by 3 percent for Scenario B. Lastly, the social costs of the program increase by approximately two fold for Scenarios A and B as the demand elasticity estimates change from -1.043 to -2.067 and supply elasticities vary from 0.36 to 1.47. In the long-run, the potential efficiency losses of the supply control program can be substantial and have been discussed by Veeman (1987) and others. These losses are briefly outlined in the following section.

A supply management program may result in quota rights acquiring a capitalized value which in turn may increase the overall cost structure of future generation quota holders. In the long-run, this increase in the cost structure of firms in the industry may cause the industry supply curve to shift upward and to the left. However, improvements in technology may have the opposite effect. That is, may reduce the cost of production and thus cause a downward shift in the industry supply curve. Therefore, the position of the long-run supply curve will be determined by the extent of the trade-off between increasing quota values and adoption of new production technology in the industry.

The existence of production or marketing quotas may adversely affect the long term structure of the industry. More specifically, the supply control program may encourage relatively inefficient high cost producers to remain in the industry and may reduce the economic incentives to adopt cost reducing technology. In addition, supply management may inhibit the operation of comparative advantage in production. Thus, losses in specialization and trade add to the overall welfare costs of the program. Moreover, bureaucratic restrictions on the transfer of quota not only increase transaction costs but may also limit the ability of many producers to achieve economies of scale in production. Lastly, an increase in welfare costs may also occur where restrictions on the transfer of quota result in underutilization of existing productive capacity.

Additional sources of welfare costs of a supply management program include the administrative costs of the program as borne by producers, provincial boards and government. These costs arise primarily from monitoring and enforcing quota and levy regulations. Other costs include rent seeking activities by producers and producer organizations. In addition, quotas on imports of the supply managed commodity may also give rise to rent seeking activities induced by the rents associated with the allocation of import licenses. Supply management programs reduce the market risks to producers in the industry and consequently may reduce the production costs of risk averse producers. However, in many cases these risks may be substituted by additional bureaucratic risks which may offset the benefits arising from reduced market risks. Bureaucratic risks and uncertainties are often induced by the possibility of bureaucratic or legislative changes in the supply management program. Finally, a supply management program tends to promote the status quo in the industry and thus may reduce the incentives required for the development of new products and new markets.

The comparative static welfare analysis focuses on the short-run allocative efficiency losses and income transfers from consumers to producers. However, the distributional or equity consequences of a supply management program among different size producers within the sheep industry are not explicitly addressed. In general, because the benefits of a supply management program are based on units of production, the largest quota holders (producers) acquire a larger share of the program benefits compared to the smaller quota holders.

In summary, the welfare losses associated with a supply management marketing program are substantial and as such this form of marketing option may not be the most economically suitable option for the industry. More specifically, the potential costs of a supply program may outweigh the potential benefits in the case of the sheep industry. This occurs because the demand elasticity estimates for lamb are highly elastic. A supply management marketing option is effective in increasing farm income when the demand elasticity for the product is inelastic. Therefore, demand management type programs would appear to be a more suitable marketing option for the industry.

Chapter 6: Summary and Conclusions

The supply responsiveness of the Alberta sheep sector continues to be of importance to producers and policy makers. The industry has shown adaptability in coping with product price fluctuations and increased competition from imports. In order to retain competitiveness in the domestic market the industry is seeking to improve its marketing policies for lamb. The overall objective of this study is to provide an economic analysis of the industry focusing in particular on supply response in order to derive accurate supply elasticities which would aid in developing appropriate marketing policies for the industry. In essence, this study consists of two parts: in the first part the major focus of the thesis was to estimate the supply response of the Alberta sheep industry using alternative estimation procedures namely, a normative programming model and a positive econometric model. A summary of the methodologies, limitations and results of the supply analyses part of the study is provided in the following section. The final part of the study focused on the welfare changes associated with the introduction of a supply management marketing option for the sheep industry. The last section of the chapter provides a brief overview of the welfare impacts of the supply management marketing program in addition to making recommendations for some useful extensions of the study.

6.1 A Summary of the Supply Estimation Procedures and Results

The Alberta sheep sector accounts for almost one-third of the Canadian sheep flock but is small in size relative to the beef or hog sectors. The industry is fairly concentrated with approximately 2,100 producers of which almost 50 percent have flock sizes of less than 17 head. Sheep provide a useful means of enterprise diversification on many farms, particularly those located in the drier regions of the province. The industry is characterized by seasonality in both production and consumption. Peak production occurs in the second half of the year while peak consumption occurs during holiday periods, primarily, Christmas and Easter. The consumption of sheepmeat is low and represents less than one percent of total meat consumption in Canada. The market for lamb can be segmented into two parts; fresh and frozen, with fresh lamb predominantly of domestic origin. Imports consist primarily of frozen lamb and mutton with some chilled lamb and live imports for slaughter. At this juncture, the industry has been forced to re-assess its marketing policies and overall direction due to increased competition from imports together with falling or static demand for lamb. The remainder of this section provides a summary of the programming and econometric methodologies used in the study, limitations and supply elasticity estimates.

The programming approach to the estimation of supply elasticities taken in this study rests on some important conceptual foundations. The microeconomic representative farm concept was used to derive individual farm supply functions which were then summed to provide estimates of the aggregate market level supply response. The reference farm concept involves categorizing sheep producers into three categories based on flock size. The small category of sheep producer which accounted for approximately 11.5 percent of the provincial flock was excluded from the analysis due to the heterogeneous nature of this group. Reference farms were constructed for both the medium and large size sheep producers. The production, financial and marketing data used to construct reference farms were collected from a number of selected farms in the respective groups and used in conjunction with secondary survey data. The data used in constructing the reference farms were annual data for the period 1986 to 1988.

The following assumptions were made in developing the linear programming model for the industry. These assumptions relate to specification of the objective function, production activities, resource, financial and technical constraints in addition to the standard linear programming assumptions of linearity, additivity, divisibility, finiteness, non-negativity, proportionality and exogenously determined input prices. Furthermore, it was assumed that the objective function, resource constraints and input-output coefficients are known with certainty. The prices of all farm products and of resource inputs were assumed to be identical for the reference farms. Finally, transportation costs from production to marketing centers and alternative marketing strategies were not included in the model.

The programming procedure involved constructing a complete linear model to describe the production system of a number of reference farm types. The estimated supply functions describe the optimum adjustment to alternative product price levels at a particular point in time. However, adjustments over time due to changes in the farm organization and technological developments were not considered. The structure of the equations in the model follow a process approach in that the activities in the model were taken as interdependent. This approach allows for material balance equations to be specified and permits the transfer of resources between activities within the farm operation. Unlimited acquisition of breeding stock, machinery and land is prevented by the specification of financial constraints.

The own price supply elasticity estimates for lamb are larger and more variable for the large reference farms. More specifically, the own price supply elasticities vary from 0.70 to 1.71 for the medium size sheep farms while for the large sheep farms the supply elasticities vary from 1.47 to 3.60. These results suggest that the large sheep farms are more price responsive than the medium size units. Moreover, the wool and cull sheep supply elasticity estimates were inelastic for both the medium and large size farms. For the medium size sheep farm the wool supply elasticity estimate was 0.12 while the cull sheep elasticity estimates ranged from 0.11 to 0.28. In the case of the large sheep farms the wool elasticity estimate was 0.09 while the cull sheep elasticities ranged from 0.07 to 0.14. These low elasticity estimates suggest that wool and cull sheep prices are not important variables in determining sheep supply. The cross price elasticities for both the medium and large size sheep farms for beef, wheat and barley were negative, indicating that these products are substitute enterprises for lamb production at the farm level. Specifically, the cross elasticity estimates for the medium sheep farms were -1.61, -0.84 and -1.11 for beef, wheat and barley, respectively. Finally, for the large farms, the estimated cross elasticities for the three products were -0.95, -0.89 and -0.80.

The stability of the supply elasticity estimates derived from the linear programming model was tested via sensitivity analysis. Essentially, sensitivity analysis gives the range of values over which the supply elasticity coefficients are stable. The magnitude of the price range over which the price elasticities were stable was calculated by expressing the level of the price variable at the first change of basis as a percentage of the level in the initial linear programming solution. For the medium reference farm the wool, lamb and cull sheep activities would have to increase 419 percent, 25 percent and 515 percent, respectively, in order for a change to occur in the estimated supply coefficients for the three products. In the case of the large reference farm the wool, lamb and cull sheep activities would have to change by 341 percent, 23 percent and 307 percent, respectively, in order for a change in the estimated elasticity coefficients.

The linear programming models were verified by comparing the estimated supply elasticities with the theoretically expected results. Essentially, this involved verifying that the own price supply curves have positive slopes, that the cross elasticities between wool and lamb are positive and that the slopes of the supply curves are steeper at the top and bottom regions of the price range than in the center. The final test of the programming models relate to validation of the supply elasticity estimates. This involved comparing the normative supply elasticities derived in this study with supply elasticity estimates from other linear programming studies of the sheep industry. This test indicates that the supply elasticity estimates for lamb, wool and cull sheep derived in this study are reasonable when compared to the elasticity estimates from other programming studies.

The traditional Markov chain model was used to measure structural change in the sheep industry. The Markov chain process was selected to examine structural change as the sheep industry satisfies the conditions required for the application of the Markov process. Specifically, these conditions include low entry barriers at the early stage of development followed by economies of scale, high management expertise and high capital requirements for established firms. Moreover, the Markov model is considered an appropriate technique to analyze structural change where technological progress has contributed to growth of the industry. The Markov process focuses on the movement of firms from one size category to another and attributes discrete probabilities to these movements.

The following assumptions were made in examining structural change via the Markov process. First, an implicit assumption in the first order Markov process is that the probability of a firm moving from one size category in period t, to another size category in period t+1 depends only on the outcome in the immediately preceding period. Furthermore, this dependence is assumed to hold over all time periods. Second, the use of the Markov model also requires the assumption that the observed movement of firms between different size categories yield a satisfactory measure of the underlying probabilities. The conventional Markov model estimates stationary (constant) transition probabilities, i.e., the probability that movement between different size groups is assumed to be constant over time. However, this model can be modified to incorporate a non-stationary assumption into the procedure by replacing the stationary probabilities with probabilities that are a function of exogenous factors which are subject to change throughout the sequence of outcomes. Third, estimation of stationary transition probabilities are based on the assumption that the micro observation units behave according to a stationary first order Markov chain process. This allows for the estimation of the probabilities from aggregate data and permits structural inferences to be made from the results. In this study, both stationary and non-stationary transition probabilities were estimated from aggregate census data.

Application of the Markov process involves the regression analysis technique to investigate the movement of firms between different size categories in the industry. The regression equations were estimated using Zellner's Seemingly Unrelated Regression Technique which links the explanatory variables to the probability of producers moving between states. The data used in this analysis were obtained from Statistics Canada, *Census of Agriculture (Alberta)*, 1951 to 1986.

The stationary transition probability results reveal that a small farm in period t has a 72 percent probability of remaining small in period t+1 and a 12 percent probability of moving to a medium size farm category. In the case of the medium and large sheep producers there was an 86 percent and 90 percent probability, respectively, of remaining in the medium or large size categories in the period t+1. The estimated probability of medium farms becoming small in time period t+1 was 27 percent and large farms becoming small approximately one percent. The probability of remaining small declines to 49 percent in the non-stationary transition probabilities model. This decrease occurred because there was a high estimated probability of 38 percent that small farms leave the industry. Finally, the probability of medium and large sheep farms remaining in their respective size categories was 60 percent and 77 percent, respectively. The model also suggests that the most likely movement upwards in size occurs as small farms become medium size farms.

The Markov transition probabilities were combined with the normative programming estimates of supply elasticities to predict lamb supply from both the medium and large sheep farms. Compared to the base model where no account is taken of structural change in the industry, the medium size farm with stationary and non-stationary transition probabilities predicts a 14 percent and 40 percent reduction in lamb supply. For the large sheep farms the stationary and non-stationary transition probabilities predict a 10 percent and a 24 percent reduction in the supply of lamb relative to the base model. However, in comparing the stationary and non-stationary transition probabilities for the medium and large sheep farms, the non-stationary transition model predicts a 30 percent and a 15 percent lower supply of lamb. In essence, the empirical estimates show that the non-stationary Markov model predicts a more rapid adjustment in the structure of the sheep industry. Furthermore, the Markov model suggests that the total number of sheep farms will continue to decline with the largest decline occurring in the small sheep farm category and a slight increase in the medium and large sheep farms.

Short-run and long-run supply elasticity estimates for lamb, wool and cull sheep were derived using an econometric estimation procedure. In estimating supply elasticities the econometric procedure is less restrictive in that the profit maximization assumption is not imposed on the behavior of agricultural producers. A simultaneous equation econometric model was selected for the analyses as the lines of causation were considered to run from prices and costs to inventory levels which in turn determines sheep output. The system to be estimated consisted of two equations, a stock formation equation and a supply equation within which inventory was determined by prices and costs while output was determined by flock size. Inventory or flock size was specified to be explained by flock size lagged two periods, market prices and input costs. Selecting the appropriate estimation technique involved taking account of the following factors: sample size, dependence or independence of the stochastic disturbance terms, likelihood of model specification error and measurement error in the data concerning the different structural equations.

In formulating the econometric model the following assumptions were made. That higher inventories are held in anticipation of higher prices or lower expected costs. That is, an increase in the price of lamb will cause producers to expect higher prices in the future and therefore to increase the size of their breeding flocks. Other assumptions relate to the formulation of expectations, that is, current prices and current costs were used as proxies for expected market prices and expected input costs. This assumption permits an explicit expression of the relationship between actual and desired inventory levels.

The short-run direct price elasticities for lamb, wool and cull sheep were 0.36, 0.07 and 0.04, respectively. In the short-run livestock supply is related to output prices and input costs in previous periods rather than to current prices and costs. This is attributed to the time lags involved in bringing livestock to the market. In the long-run, structural adjustments would have taken place in response to higher prices and supply elasticities would be expected to be substantially higher. However, in this study only lamb supply was elastic at 1.22 in the long-run while the estimates for wool and cull sheep were 0.16 and 0.28, respectively. The short-run and long-run supply elasticity estimates differ from the normative estimates but appear reasonable when compared to supply elasticity estimates from other econometric studies of the sheep industry.

The divergent supply elasticity estimates derived from the normative programming and positive econometric models can be attributed to the different underlying assumptions of both approaches. The rest of this section summarizes the main features of the programming and econometric models of supply response.

The reference farm linear programming model embodies a complete causal system of the functioning of the individual farm. This approach allows for both independent and interdependent activities to be incorporated into the programming model. Moreover, the programming approach closely follows the steps as prescribed by neoclassical supply theory and takes account of the multi-product and multi-resource nature of farms. More specifically, the programming approach takes account at the farm level of the effects upon supply of all product prices, input prices and relevant institutional, technological and physical restrictions. An important merit of the programming approach is that aggregate supply elasticities can be derived where only limited farm data are available. Another feature of the linear programming approach to supply estimation is that it is a static deterministic approach in which complete certainty is assumed.

The programming approach is more comprehensive than alternative supply estimation procedures and therefore more suitable for policy impact analysis and for deriving a broader range of cross price supply elasticities. Linear programming solutions are timeless and assume instantaneous adjustments to price changes. The linear programming approach is of limited use with respect to incorporating the dynamics of supply response due to the implicit assumption of constant returns to scale in production. Other problems relate to aggregation and specification issues in formulating the model in addition to testing the validity of the model's results. In programming models testing the validity of the reference farm approach involves testing the underlying assumptions of the model since the data used are difficult to verify external to the model. Supply curves derived from the programming procedure are characterized by being stepped in nature which enables perfectly elastic or inelastic estimates of supply over relatively small price ranges.

The positive econometric estimates of supply response are based on fitting a linear regression to historical data to describe what has actually occurred in the past and to derive estimates of the behavioral parameters. Econometric models are more suitable for making predictions or forecasts as predictions are based upon the assumption that producers will continue to act in the future as they have in the past. However, violation of any of the standard statistical assumptions underlying the regression model such as errors in data measurement, aggregation, high correlation among independent variables, omission of relevant variables or incorrect specification of the form of the relationship reduces the accuracy of the supply elasticity estimates.

A major limitation of the econometric methodology relates to the fact that since regression models are based on historic observations they cannot account for new variables. One of the fundamental underlying assumptions of the econometric procedure relates to the parameters of the system which are assumed to remain constant over the period of the analyses. That is, no structural change is assumed to have occurred over the period of the study. A further limitation of regression models is the reduction in the number of statistical degrees of freedom as the number of parameters in the model increase. This limits the degree of product and input disaggregation the econometric approach can accommodate. Therefore, regression models tend to be restrictive in that only a subset of variables which could theoretically affect supply are examined. Furthermore, these statistical problems associated with the econometric technique limit the number of cross price elasticities estimable with this class of model. Lastly, collinearity is a serious problem in regression models and is associated with a number of statistical problems including high standard error of estimates, unstable parameter estimates and sensitivity of parameter estimates to model misspecification.

The supply curves derived from the simultaneous equation econometric procedure have a constant elasticity. Finally, an important merit of the econometric approach to supply estimation is that the procedure entails a smaller number of steps to generate supply response coefficients, thus minimizing the potential for specification errors to accumulate through successive stages.

The major differences between the elasticity estimates derived in this study can be attributed to the data used in the alternative estimations. The reference farm linear programming model used the average values for activities over the period 1986 to 1988. However, in the case of the econometric model, the aggregate market level data over the period 1970 to 1987 were used in the estimation. Furthermore, the programming model imposes profit maximization on producers' behavior whereas the econometric model is based on actual supply response of producers. Finally, the time dimension of the supply elasticities derived from the alternative approaches differ. Both short-run and long-run supply elasticities were derived from the econometric partial adjustment type model. However, with the linear programming model only medium term supply elasticities were derived. In essence, the programming model can be regarded as generating medium term elasticities because no allowance is made in the model for technical change while resources are allowed to vary subject to budgetary constraints.

With respect to the hypotheses outlined in Chapter 1, the elasticity of supply for lamb is low and inelastic in the short-run but elastic in both the medium and long-run. However, the elasticity of supply for both wool and cull sheep are highly inelastic in the short, medium and long-run. Finally, with respect to structural change in the industry, there has been a decrease in the overall number of sheep producers. This decrease can be attributed primarily to a decline in the number of small sheep producers with medium and large sheep producers representing an increasing share of the industry.

In summary, both the linear programming technique and the econometric technique show that the medium and long-run supply of lamb in Alberta is responsive to changes in market prices. Although lamb supply from the commercial sheep industry is elastic in the medium term, large sheep producers have a higher price elasticity of supply than medium size producers. The linear programming technique is suitable for deriving medium term supply elasticity estimates for the commercial sheep industry and for medium term policy analysis. Conversely, for deriving short-run and long-run supply elasticities and for forecasting purposes the econometric procedure is preferred. In the case of wool and cull sheep, supply is highly inelastic for the commercial industry over all time periods. The sheep industry has shown structural adjustment over the last 35 years resulting in a decline in the overall number of producers. The major source of decline has occurred with the small size sheep producers while large and medium size producers have increased in number leading to greater concentration in the industry.

6.2 A Summary of the Welfare Effects of a Supply Management Program and Future Research Recommendations

The marketing options available to the sheep industry can be broadly divided into two groups, demand expansion policies and supply management type policies. The demand expansion policies attempt to increase demand for lamb directly through advertising and promotional programs. On the other hand, supply management policies attempt to increase farm income by restricting production or marketing of the particular product. This study used the comparative static welfare economics framework to assess the income transfers and allocative efficiency losses of a supply management marketing program for lamb. The remainder of this section provides a brief overview of the welfare economics approach to policy analysis and empirical results, but first of all a summary of the demand elasticities for lamb are given in the next paragraph.

The demand for lamb is determined not only by the traditional economic variables of income and prices but also by demographic and socioeconomic factors. Population characteristics such as size, distribution, age structure, and ethnic background in addition to employment patterns, household size, tastes and preferences play an important role in influencing the demand for lamb. The demand for lamb is elastic with the direct price elasticities ranging from -1.043 to -2.067. That is, for a 10 percent increase in price the quantity of lamb demanded falls by 10 to 21 percent. In addition, the cross price elasticities between pork and lamb varies in magnitude from 0.83 to 0.97 and suggests that pork is a substitute for lamb. Finally, the demand for lamb is income inelastic with estimates ranging from 0.39 to 0.49, that is, a 10 percent increase in income is associated with a 4 to 5 percent increase in lamb consumption.

A fundamental assumption of the classical welfare economics approach is that the perfectly competitive market is Pareto optimal. Therefore, any deviation from the competitive equilibrium results in a welfare loss to society. The welfare economic concepts of producer and consumer surplus were used to estimate the welfare effects of a supply management marketing program for lamb. In this study, consumer surplus was defined as the area to the left of the demand curve and above the price line while the area to the left of the supply curve and below the price line is a money measure of producer surplus in a market. The alternative measures of consumer welfare namely, compensating and equivalent variation can be approximated by the consumer surplus measure under certain conditions. These apply if the particular product represents only a small share of the consumers budget, a feature that applies with sheepmeat consumption in Canada.

The standard neoclassical partial equilibrium static model was used to estimate the short-run income transfers and social costs of a supply management marketing program for the lamb industry. The short-run is defined such that plant size is fixed and there is no entry or exit from the industry. In essence, the analyses involved estimating the welfare changes to producers and consumers as a result of introducing a supply restricting program into an industry in competitive equilibrium. A supply management program requires the imposition of quantitative restrictions on imports and domestic output so as to facilitate the setting and maintenance of the desired price level. The extent to which the administered prices can be raised above the competitive equilibrium is limited to the extent of quantitative restrictions on imports.

The empirical results relate to two scenarios: These involve a 5 percent and a 10 percent increase in market prices under a potential supply management program. The impacts of these two scenarios on producer and consumer welfare were estimated for a range of supply and demand elasticities. The short-run income transfers and social costs of a supply management marketing program vary substantially with the magnitude of the supply and demand elasticity estimates. Specifically, as the supply elasticities increase from 0.36 to 1.47, producer surplus gains increase by 23 percent for Scenario A and by 20 percent for Scenario B while the social costs of the program decrease by approximately 44 percent for Scenario A and by 63 percent for Scenario B. With respect to the demand elasticity estimates as the magnitude of the elasticities increase from -1.043 to -2.067 the losses in consumer surplus decrease by 5 percent and 3 percent for Scenarios A and B, respectively. Lastly, the overall social costs of the program increase approximately two fold for Scenarios A and B, respectively.

With respect to the hypothesis regarding a supply management marketing program for the Alberta sheep industry, the empirical results indicate that there are some short-run gains for producers but that in the long-run substantial additional costs may be incurred. Furthermore, as the benefits of a supply management program are based on the number of units of production, larger producers would gain a larger share of the potential benefits under this program.

There are several useful extensions of this study which could be undertaken. First, there could be more explicit account taken of the impacts of transportation factors and alternative marketing strategies on lamb production in different regions of the province. Second, a study could examine the effects of modifying the linear programming model assumptions in order to allow for risks and uncertainties in production and marketing to be taken into account. Third, there could be research into developing a more comprehensive and refined data base with respect to lamb consumption. This could permit separate demand elasticity estimates to be derived for chilled and frozen lamb. Fourth, there could be more research relating to the demand expansion prospects for lamb and possible constraints. Fifth, there could be more explicit modeling of lamb supply in eastern Canada, in particular, Ontario and Quebec. Finally, it is desirable in future research to adopt a general equilibrium framework which would take account of the economic linkages with other sectors in the economy.

In summary, a supply management marketing option for the sheep industry provides some gains to producers in the short-run but also results in some losses to society. The gains to producers vary with the magnitude of the supply and demand elasticities, decreasing as the demand elasticities increase and increasing as the supply elasticities increase.

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Appendix A

Table A:1. Number of Sheep on Farms by Province, July 1, 1988 and 1989.

Province	Total Sheep and Lambs		
	1988	1989	1989/1988
	('000)	('000)	%
Nfld.	7.1	7.4	104
P.E.I.	6.1	5.8	95
N.S.	38.0	36.0	95
N.B.	9.0	9.0	100
Que.	111.0	114.0	103
Ont.	201.0	212.0	105
Man.	22.0	23.0	105
Sask.	51.0	52.0	102
Alta.	198.0	212.0	107
B.C.	53.5	57.0	107
Canada	696.7	728.2	105

Source. Statistics Canada, Livestock and Animal Products Statistics, 1989.

Appendix B

Table B:1. Structural Components of the Linear Programming Matrices For The Reference Farms.

	Value RHS	Production Activities Crops (ac)	Beef (cow)	Sheep (ewe)	Pasture (ac)	Resource Activities Buy ewes	Buy cows	Buy land	Sell ewes	Sell cows	Sell land	Financial Activit's Borrowing	Savings
Objective Function		-GM	-GM	-GM	-GM	-GM	-GM	-GM	GM	GM	GM	-Ir	Ir
Production:													
Crop Land	+	1											
Grazing Land	+				1								
Feed Balance	0		1	1									
Resource:													
Ewes	+			1		-1			1				
Cows	+		1				-1			1			
Land	+	1			1			-1			1		
Finance:													
Maximum Borrowing	+											1	
Mortgage Bal.	0							1				-1	
Operating Capital Bal.	0	GM	GM	GM	GM	GM	GM	GM				-Ir	Ir

Note: + or - indicates the sign on the elements of the matrix;
- GM indicates the negative of the gross margin;
- Ir indicates the interest rate for borrowing capital; and
Ir indicates the interest rate on savings.

Table B:2. Production and Financial Restrictions Imposed on the Activity Set of the Medium and Large Reference Farms.

Activity	Med. Ref. Farm	Large Ref. Farm
Arable Land (ac)	120.00	510.00
Pasture Land (ac)	180.00	90.00
Buy Arable Land (ac)	640.00	640.00
Buy Pasture Land (ac)	640.00	640.00
Rent Pasture (ac)	---------	350.00
Ewe Balance (nos)	350.00	550.00
Buy Feed Lambs (nos)	350.00	6,000.00
Swath Grain Bal. (hrs)	4200.00	1,500.00
Seeding Bal. (hrs)	6650.00	23,500.00
Swath Forage Bal.(hrs)	4200.00	15,000.00
Mortgage Limit ($)	140,000.00	275,000.00
Max. Borrowing ($)	200,000.00	450,000.00
Term Deposit Limit ($)	100,000.00	170,000.00
Line of Credit Limit to:		
Cow Purchase ($)	70,000.00	135,000.00
Ewe Purchase ($)	70,000.00	135,000.00
Machinery Purchase ($)	30,000.00	95,000.00
Operating Capital ($)	100,000.00	180,000.00
Buildings ($)	50,000.00	115,000.00

Table B:3. List of Activities in the Optimal Solution for the Medium Size Reference Sheep Farm.

Basic Activities	Amount	Basic Activities	Amount
Objective Function:	72,282.699		
		Sell Alfalfa (t)	421.839
Production:		Sell Oats (t)	97.242
		Buy Ewes (no)	250.000
Arable Area (ac)	453.977	Ewe Balance (no)	600.000
Alfalfa (5 years)	324.276		
Barley (ac)	64.828	Financial:	
Oats (ac)	64.828		
Feed Alfalfa (t)	550.987		
		Term Deposit to Operating Capital($)	14,152.484
Resource:		Term Deposit to Land ($)	85,847.516
Buy Arable Land (ac)	333.978	Line of Credit to Operating Capital ($)	10,000.000
Buy Pasture Land (ac)	120.000	Line of Credit to Ewe Purchase ($)	22,500.000
Sell Wool (lbs)	5,400.000	Mortgage ($)	140,000.000
Sell Lambs (no)	960.000		
Sell Cull Sheep(no)	90.000		
Sell Barley (t)	110.207		

Table B.4: Level of Unused Resources in the Optimal Solution for the Medium Size Reference Sheep Farm

Unused Resources	Amount	Unused Resources	Amount
Buy Arable Land (ac)	306.022	Line of Credit to Ewe ($)	47,500.00
Buy Pasture Land (ac)	520.000	Line of Credit to Cows ($)	70,000.00
Loan Total Limit ($)	27,500.000	Line of Credit to Machinery ($)	30,000.00
Buy Feeder Lambs: (no)	350.000	Line of Credit to Buildings ($)	50,000.00

Table B:5. List of Activities Included in the Linear Programming Model but Excluded from the Optimal Solution for the Medium Size Reference Farm.

Non Basic Activities	Non Basic Activities	Non Basic Activities
Continuous Wheat	Feed Oats to Cows	Term Deposit to Ewe
Continuous Barley	Buy Alfalfa	Term Deposit to Cows
Sell Wheat	Buy Barley	Term Deposit to Buildings
Sell Ewes	Buy Oats	Term Deposit to Machinery
Buy Cows	Lamb Feedlot	Line of Credit to Cows
Feed Alfalfa to Cows	Sell Feed Lambs	Line of Credit to Machinery
Feed Barley to Ewes	Buy Screenings	Line of Credit to Buildings
Feed Barley to Cows	Feed Alfalfa to Lambs	
Feed Oats to Ewes	Feed Barley to Lambs	

Table B:6. List of Activities in the Optimal Solution for the Large Size Reference Sheep Farm.

Basic Activities	Amount	Basic Activities	Amount
Objective Function	156,138.36	Sell Alfalfa (t)	2,854.95
		Buy Ewes (no)	650.00
Production:		Ewe Balance (no)	1,200.00
		Rent Pasture (ac)	350.00
Arable Area (ac)	838.67		
Alfalfa (3 years)	[illegible]	Financial:	
Barley (ac)	[illegible]		
Feed Alfalfa (t)	456.59	Term Deposit to Land ($)	170,000.00
Feed Barley (t)	440.89		
		Line of Credit to Operating Capital ($)	80,825.45
Resource:		Line of Credit to Ewe Purchase ($)	58,500.00
Buy Arable Land (ac)	328.67	Mortgage ($)	275,000.00
Buy Pasture Land (ac)	305.99		
Sell Wool (lbs)	12,000.00		
Sell Lambs (no)	1,920.00		
Sell Cull Sheep(no)	180.00		

Table B:7. Level of Unused Resources in the Optimal Solution for the Large Size Reference Sheep Farm

Unused Resources	Amount	Unused Resources	Amount
Buy Arable Land(ac)	311.34	Line of Credit to Operating Capital ($)	99,174.55
Buy Pasture Land(ac)	334.00	Line of Credit to Cows ($)	135,000.00
Loan Total Limit ($)	35,674.55	Line of Credit to Machinery ($)	95,000.00
Buy Feeder Lambs (no)	6,000.00	Line of Credit to Buildings ($)	115,000.00
Line of Credit to Ewes ($)	76,500.00		

Table B:8. List of Activities Included in the Linear Programming Model but Excluded from the Optimal Solution for the Large Reference Sheep Farm.

Non Basic Activities	Non Basic Activities	Non Basic Activities
Continuous Wheat	Feed Oats to Cows	Term Deposit to Cows
Continuous Barley	Buy Alfalfa	Term Deposit to Buildings
Sell Wheat	Buy Barley	Term Deposit to Machinery
Sell Barley	Buy Oats	Term Deposit to Operating Capital
Sell Ewes	Feedlot Lambs	Line of Credit to Cows
Buy Cows	Sell Feed Lambs	Line of Credit to Machinery
Cow Calf	Buy Screenings	Line of Credit to Buildings
Feed Alfalfa to Cows	Feed Alfalfa to Lambs	
Feed Barley to Cows	Feed Barley to Lambs	
Feed Oats to Ewes	Term Deposit to Ewes	