Swine

THE NORTH AMERICAN PORK SECTOR – ANALYSIS OF ITS ECONOMIC INTERRELATIONSHIPS AND A MODEL FOR POLICY EVALUATION

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AE/74/10

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FOREWORD

This publication reports on a study which was undertaken to measure the effects of a number of factors on pork production, prices, consumption and trade in Eastern and Western Canada and the U.S. The research reported here differs from many previous analyses of the Canadian pork sector in that it specifically includes the United States as a closely related and competing pork producing region. This is done by including the two regions of Canada and the United States in a mathematical programming model which is designed to generate prices, production, consumption and storage of pork in each of the three regions, as well as trade in pork between the regions.

The model is constructed in a manner that makes it an extremely flexible tool for evaluating the effects of changes, such as governmental or marketing agency policies, which could affect the pork sector. The authors have used the model to analyze the effects of several policy changes. These have been reported elsewhere. Two very different policy situations are analysed and reported here to illustrate the model's usefulness.

This study has benefitted immeasurably from the assistance of several people. The authors are particularly indebted to R. G. Marshall and K. D. Meilke of the University of Guelph who provided considerable advice during the initial period when the model was being constructed and during subsequent analyses. The authors also wish to thank the reviewers, T. K. Warley, T. F. Funk, J. H. Clarke and K. D. Meilke who provided valuable comments on earlier drafts of this manuscript. Considerable assistance was also received from several officials of the Economics Branch, Agriculture Canada and members of the Ontario Pork Producers Marketing Board at various points in the research process.

In addition to their professional assistance, Economics Branch, Agriculture Canada also made this study possible under two research contracts. Research funds were also provided under an on-going research contract with the Ontario Ministry of Agriculture and Food.

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1.0 INTRODUCTION

Data reported by Statistics Canada indicate that pork production increased by 54.8 percent (from 975 million lbs. to 1,510 million lbs.) between 1961 and 1971. While these figures reflect the overall growth in pork production, they do not reflect fluctuations which occurred in production, prices and trade in pork over this period, and thus in income generated by the sector. The reasons for these fluctuations arise from a set of complex factors. One of the most important is the phenomenon known as the hog cycle, which implies that changes in production are constrained by the time and resources necessary for producers to adjust production plans to changes in hog prices. Other important factors include: seasonal production and demand characteristics; interactions with related sectors such as feedgrains and beef; relatively low trade barriers between the U.S. and Canada which allow trade and, more importantly, closely related prices in the two countries; and finally, significant storage activities which help to smooth prices over time in response to seasonal production and consumption patterns.

At the present time, several important issues face Canada's pork sector. Among these are: possible changes in trade arrangements resulting from G.A.T.T. negotiations; imminent changes in domestic transportation and marketing policies for feedgrain and livestock products; the decision of the federal government to enhance the strength of agricultural stabilization programs; and the development of long term export contracts between some regions of Canada and offshore markets for exports. There has been no empirical framework available in which the major interrelationships listed above could be combined to evaluate the effects of these existing or potential policy changes on the Canadian pork sector.

This paper reports on a study undertaken with the general objectives of measuring these major interrelationships and developing a simulation model which will aid in evaluating the spatial and temporal repercussions of policy changes. Specific objectives and a brief outline of the study are presented below.

1.1 Objectives of the Study

The specific objectives are as follows:

Objective 1. To describe and analyze the major factors which affect supply, demand and prices in the North American pork sector. This objective is carried out in sections 2.0 and 5.0. In section 2.0 the linkages reflecting Canada-United States trade, Eastern and Western Canada trade and the seasonal nature of pork supply and demand are described. In section 5.0 econometric estimates of supply, demand for consumption and demand for stocks in Eastern and Western Canada and the United States are analyzed to measure the effects of a number of variables on these relationships.

Objective 2. To construct a spatial and temporal model of the North American pork sector in which the relationships derived in objective 1 can be incorporated to explain changes in Canada's production, prices, storage, consumption and trade of pork products. This objective is carried out in sections 3.0, 4.0 and 6.0. In section 3.0 the theoretical considerations relating to the spatial and temporal nature of the pork sector are presented. These are then combined into a generalized recursive spatial equilibrium model in section 4.0. The generalized model is also modified in this section to incorporate a specialized demand for Canadian fresh and frozen heavy hams in the U.S. and to reflect the export demand for pork in non-North American markets. In section 6.0 the model is validated over a forty-one quarter period between 1963 and 1973 to test its ability to simulate events in the pork sector.

Objective 3. To illustrate the usefulness of the model in evaluating the effects of policy changes on the Canadian pork sector. This objective is carried out in section 6.0 where two policies - an export expansion policy and a pork sector stabilization program - are evaluated.

The summary and conclusions arising from the study are presented in section 7.0.

2.0 INTERRELATIONSHIPS IN THE NORTH AMERICAN PORK SECTOR

This section briefly outlines the major spatial and temporal interrelationships which exist within the North American market. These must be considered in evaluating policy and potential structural changes in the pork industry. The nature of these dependencies can be observed from the trade patterns and the production and consumption characteristics.

2.1 Canada - U.S. Trade in Pork

Since 1950, when pork trade agreements with the United Kingdom terminated, Canada has been largely dependent on the U.S. as an export market for pork products. The level of this trade has remained relatively constant from 1961 to 1971 at approximately 50 million pounds per annum or seven per cent of Canada's total pork production (see Table 2.1). The major categories of product exported are fresh and frozen pork which have increased from 59 per cent of Canada's total pork exports in 1961 to 89 per cent in 1971. The most important product within these categories are fresh and frozen heavy hams which are supplied mainly to a specialized market in the Eastern United States. Fresh and frozen hams accounted for approximately 70 to 80 per cent of Canada's exports of pork to the United States from 1967-1971 [53].

Exports of Canadian pork to other countries have been relatively unimportant (approximately ten per cent of exports) until 1970 when there were increased sales to Japan. Trade with Japan has been increasing since 1970 and in 1972 made up 50 per cent of Canada's total pork exports.

Table 2.1: Annual Pork Production and Trade Canada and U.S. (mill. lb.)

	Production		Canada's Trade			
	Canada	U.S. Commercial	Exports To U.S.	Total Exports	Imports From U.S.	Total Imports
1961	975	10,730	44	58	42	42
1962	984	11,224	46	52	36	36
1963	980	11,863	47	52	88	88
1964	1,060	12,019	51	59	54	54
1965	1,006	10,736	56	61	28	37
1966	1,014	11,130	46	51	25	37
1967	1,181	12,377	55	61	28	29
1968	1,181	12,867	56	63	40	41
1969	1,134	12,774	50	58	68	70
1970	1,328	13,248	60	72	24	26
1971	1,510	14,608	68	98	15	17
1972	1,392	13,460	62	115	35	45

Sources: [50], [65].

Canada also imports pork products from the United States. Between 1952 and 1960 an outbreak of vesicular exanthema in the U.S. prohibited the importation of fresh U.S. pork into Canada, but since then imports of U.S. pork have been important to the Canadian market. The level of this trade has varied considerably over time. During the period 1961-1971 imports ranged from a low of 15 million pounds in 1971 to a high of 88 million pounds in 1963 [50]. The greatest variation in imports from the U.S. has been in fresh and frozen cuts, while there has been constant trade of ten million pounds per annum of processed products.

Imports from countries other than the U.S. have also fluctuated considerably over the same period (1961-1971) and vary in importance from .02 million pounds in 1961 to 12.8 million pounds in 1966 [50]. These imports came largely from U.K., Ireland and Denmark and generally consist of specialized processed products.

Two important factors emerge from this brief discussion of Canada's trade in pork.

(1) Canada is largely dependent on the U.S. for both its imports and exports of pork products.

(2) This trade is made up of:

  (i) a relatively stable level of exports, largely in heavy hams and processed pork such as bacon supplied to the Eastern U.S. market.

  (ii) a more variable level of imports from the U.S. in fresh and frozen cuts.

A recent study [8] has shown the importance of product quality in this trade. Heavy weight Canadian hams sell at premium prices in the Eastern U.S. market due mainly to the relatively lean nature of the meat. Canada's imports from the U.S., however, tend to sell at a slightly lower price than comparable Canadian products and appear to be responsive to changes in the relative prices and supply levels between Canada and the U.S. Figures 2.1 and 2.2 show the relationships between exports and imports of pork and relative prices in Toronto and the U.S. It can be seen that exports (Figure 2.2) have remained relatively constant and do not appear to respond to price changes. Imports (Figure 2.1), however, have an inverse relationship with the Toronto - U.S. hog price differential and a similar relationship holds for Calgary - U.S. hog price difference.

These characteristics show that the Canadian pork market is linked to the U.S. pork market and trade flows occur depending upon relative prices in the two countries, especially with respect to the level of imports into Canada from the U.S.

2.2 Trade Within Canada

There are no data available to show the volume of trade in pork between Eastern and Western Canada. However data in [10] show that Toronto prices maintain a relatively constant differential above those of Calgary. This differential is less variable than that between Calgary and the U.S. or Toronto and the U.S. This would imply that the flow of pork from Western to Eastern Canada adjusts rapidly to short run changes in supply

FIGURE 2.1: CANADIAN IMPORTS FROM THE U.S.

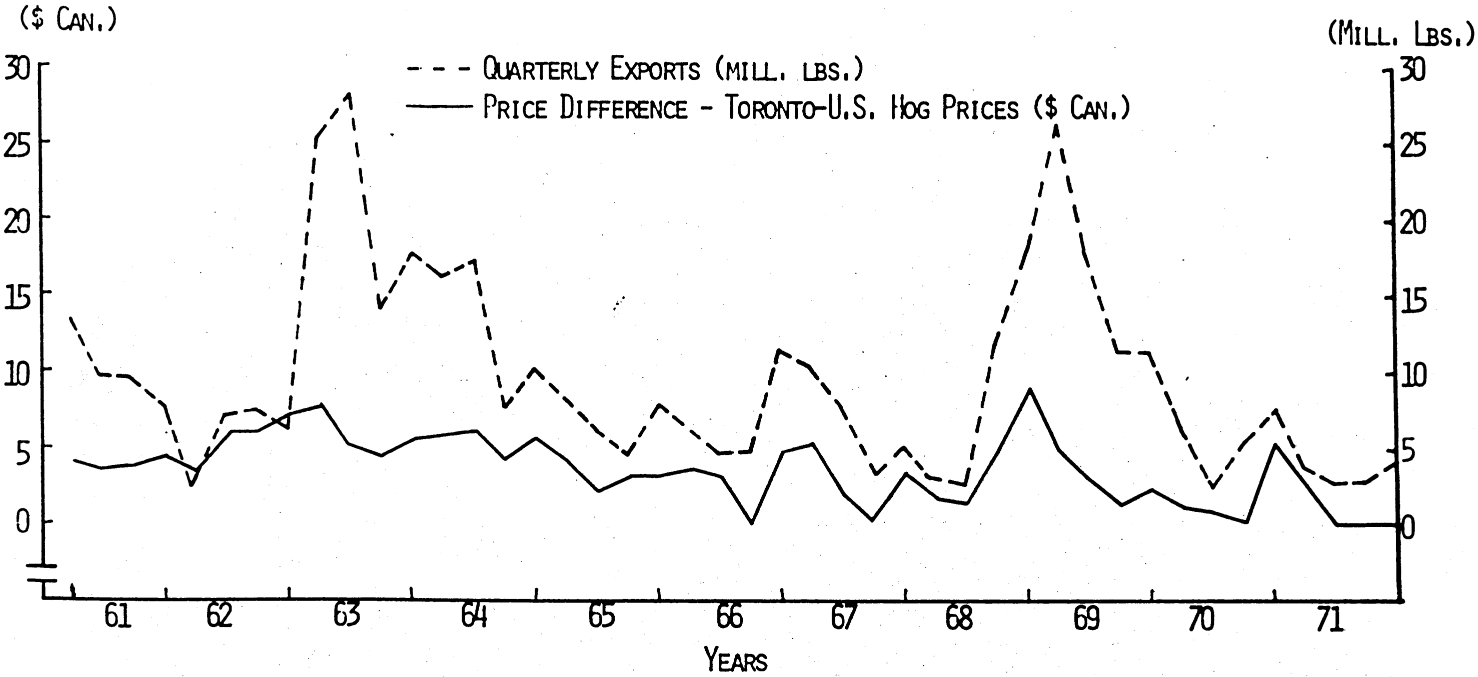
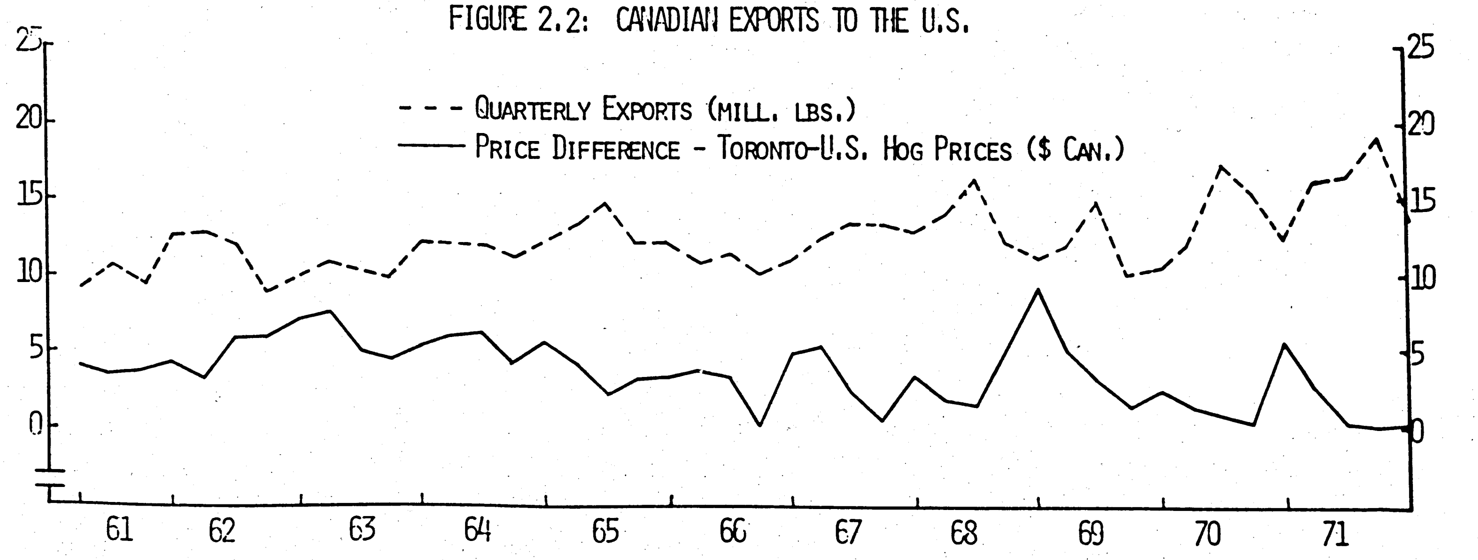


FIGURE 2.2: CANADIAN EXPORTS TO THE U.S.



and demand and hence is important in price determination in both regions.

2.3 Production and Consumption Characteristics

Hog production and consumption in Canada and the U.S. have been characterised by both seasonal and longer term fluctuation. The factors which cause these fluctuations will be discussed in detail in section 5.0 where econometric supply and demand equations are developed. These fluctuations are discussed here briefly to underline the importance of considering temporal relationships in the model developed in section 3.0.

Seasonality is probably more important on the supply side since producers have traditionally adjusted farrowings to avoid adverse winter weather conditions. The seasonality in consumption is due to changes in consumer preferences between seasons. These distinct seasonal characteristics have meant that storage has become an important part of marketing pork in both the United States and Canada. Storage stocks also have a distinct seasonal pattern and serve to shift pork from periods of high production to periods of low production.

Canadian production and consumption also has the same long term cycles as the U.S. These four year cycles, caused by producers' expectations of prices, are closely linked through trade and similarities in production techniques. Seasonal and cyclical characteristics are important in considering the structure of the North American pork sector and will be discussed in greater detail in later sections.

2.4 Implications for the Analysis

The types of dependencies and relationships outlined in the above section can generally be broken down into two broad categories - spatial relationships and temporal relationships. Both of these are necessary in considering the effects or repercussions that could result from a change in one sector of the North American market.

2.4.1 Spatial Relationships

These are the relationships between regions of the North American market which make it necessary to simultaneously consider all the major producing and consuming regions within the market. The spatial dependencies mean that a change in production, consumption, or an exogenous factor in one region of the market will have repercussions on all other regions.

The choice criteria in selecting analytical regions depend on political and economic factors. The important political regions are those separated by trade barriers such as the U.S. - Canada border, while economic regions can be included as those regions which appear to have different factors influencing the level of production. In the Priairie Provinces, pork production is strongly influenced by the state of the grain industry, while Eastern Canadian production is more dependent on other factors such as alternative production opportunities and costs of feed grains. Given the three broad regions of the United States, Eastern and Western Canada, it can be seen that policy or structural changes in one of the regions will influence the other regions, merely because they trade with each other.

2.4.2 Temporal Relationships

These are the seasonal and cyclical relationships that must be considered in the North American hog sector where there are both long and short term variations in supply and demand. Obviously policy or structural changes will have repercussions over time as well as over space. These considerations make it necessary to evaluate the linkages between time periods that cause changes in production, consumption and the basic comparative advantage of the regions.

The above relationships provide a basis for developing the model for this study. The relationships are developed theoretically below in section 3.0 and translated into a mathematical programming model in section 4.0.

3.0 THEORETICAL CONSIDERATIONS

The preceding section has stated the importance of considering the spatial and temporal dependencies existing in the pork sector. This section gives a theoretical analysis of these relationships, starting from a simple two region trading model and concluding with a description of a multi-region recursive system.

3.1 Spatial Equilibrium and Interregional Trade

Consider a simple case with two regions trading a single commodity with known supply and demand functions in each region. If there is no cost of shipping the commodity and trade occurs, then the resulting equilibrium in the combined market would be at the intersection of the summed supply and demand curves of the two markets. However if the markets were separated by a sufficiently high transfer cost to preclude trade in the commodity, then equilibrium prices, consumption and production in the two regions will depend entirely on the internal supply and demand conditions.

These two extremes indicate the importance of transfer costs in determining spatial equilibrium and can be clearly shown in a simple graphical analysis.

Figure 3.1A shows the simple case where there are no transfer costs between two regions. S_2 and D_2 are the supply and demand schedules in region 2 and P_2 is the price that would be realized in region 2 if no trade were to take place. In region 1 the schedules are reversed but similar notation is used to denote the supply and demand schedules. The centre graph represents the level of excess supply and demand in each region at varying price levels. For example, ES_2 is derived by calculating the level of surplus or deficit of the commodity over a range of prices in region 2. It can be seen that at price P_2 there is no excess supply in region 2 and supply would exactly equal demand. At any price above P_2 region 2 would be willing to export since supply would be greater than internal demand. At prices below P_2 it would be willing to import.

The curve ES_1 can be derived in an identical manner for region 1 and incorporated on the same axis.

The intersection of the curves ES_1 and ES_2 represent the price at which the excess demand of region 2 will be equal to the excess supply of region 1. With the assumption of no transfer costs and perfect competition this represents the equilibrium price and trade flow between the two regions. In the diagram, P' becomes the equilibrium price and OQ' is the quantity shipped from region 1 to region 2.

Figure 3.1B shows the effect of including transfer costs in the graphical analysis. A transfer cost of t reduces the level of trade at equilibrium from OQ' to OQ''. It can also be seen that if the difference between the equilibrium prices in the two regions, $(P_2 - P_1)$ is less than the transfer cost between the regions there will be no trade. From this it is apparent that when transfer costs are relatively low there is a much greater price dependency between regions than when they are high.

FIGURE 3.1A: TRADE WITH NO TRANSFER COST

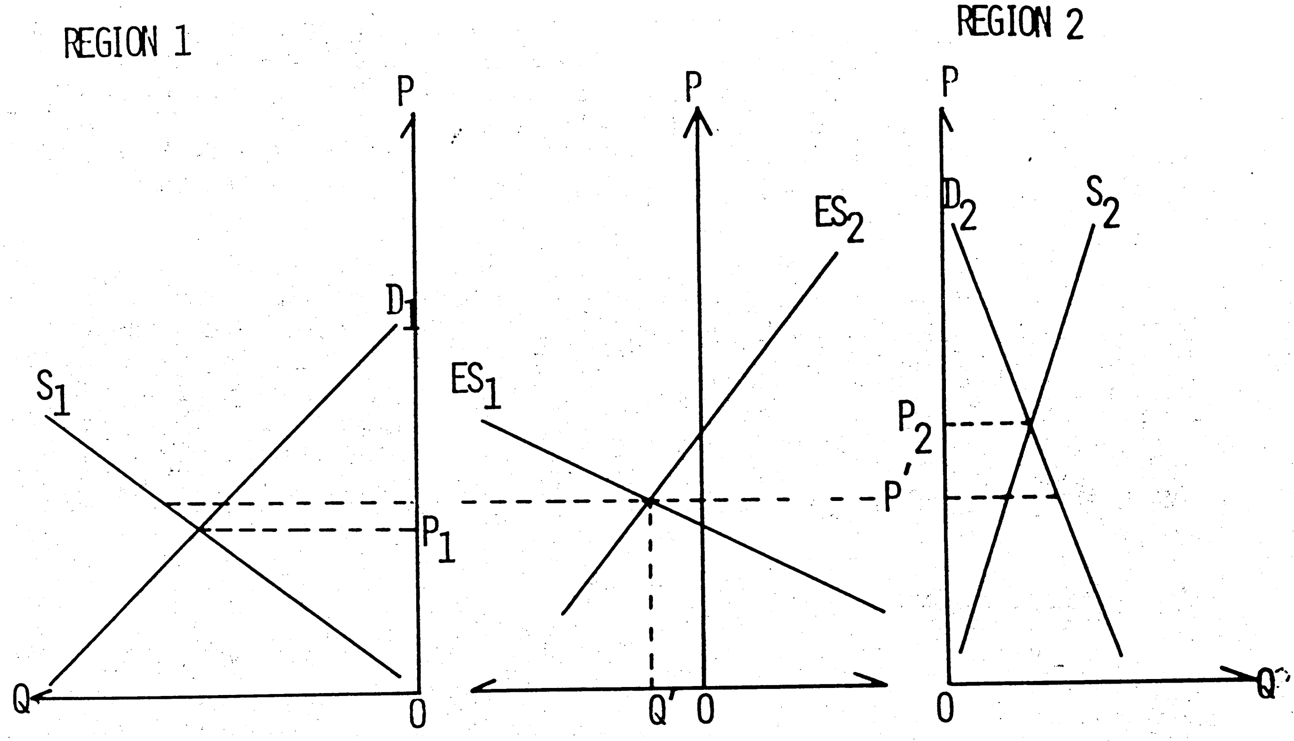
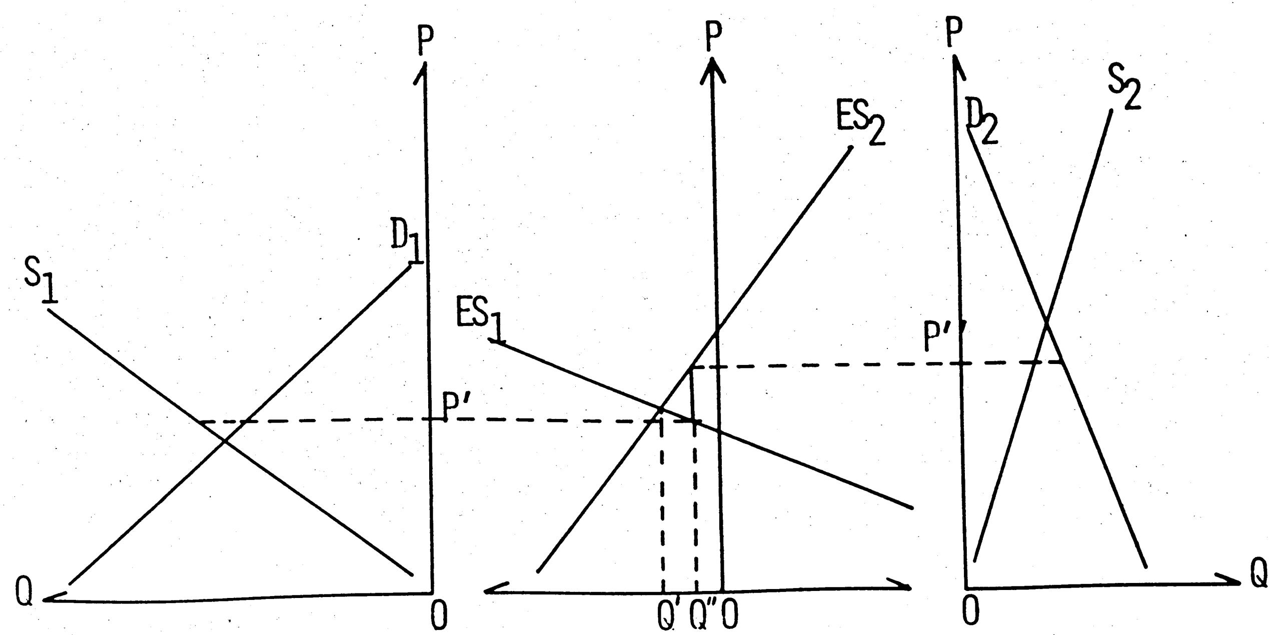


FIGURE 3.1B: TRADE WITH TRANSFER COST



This simple model of interregional price determination captures the major relationships in a competitive industry and forms the basic building block in a spatial model. Effects of policy or structural changes which influence supply and demand functions or transfer costs can be simply analyzed in such a framework. For example, Dean and Collins [13] have used a model such as this to evaluate the effects of changes in EEC tariffs on oranges.

Although this simple model is useful in policy analysis, it is static in nature since it only considers one time period and assumes that all production is consumed in that period. The structure of the North American pork sector outlined in section 2.0 would suggest the need for a more dynamic model which incorporates inter-temporal relationships. These linkages can be included by extending this basic model in two ways: 1) specifying relationships that include storage between periods and 2) specifying the long run production response. These relationships are discussed below.

3.2 Storage Stocks

Bressler and King [7, p. 205] have shown that storage stocks can be important in short-run price determination for products which have seasonal production or demand characteristics. The interaction of changes in stocks with changes in production and demand will cause a leveling of prices within a year. In peak production periods, a build up of stocks would raise prices higher than they would be without stock holdings. In low production periods, stocks will be depleted to force prices lower. The motives for holding these stocks are based on packer and wholesaler expectations of production and prices in future time periods, as well as their stock requirement for current transactions which are a fixed proportion of production.[1/]

The above would suggest that price in any one period is jointly determined by the demand for fresh consumption and the demand for storage stocks.

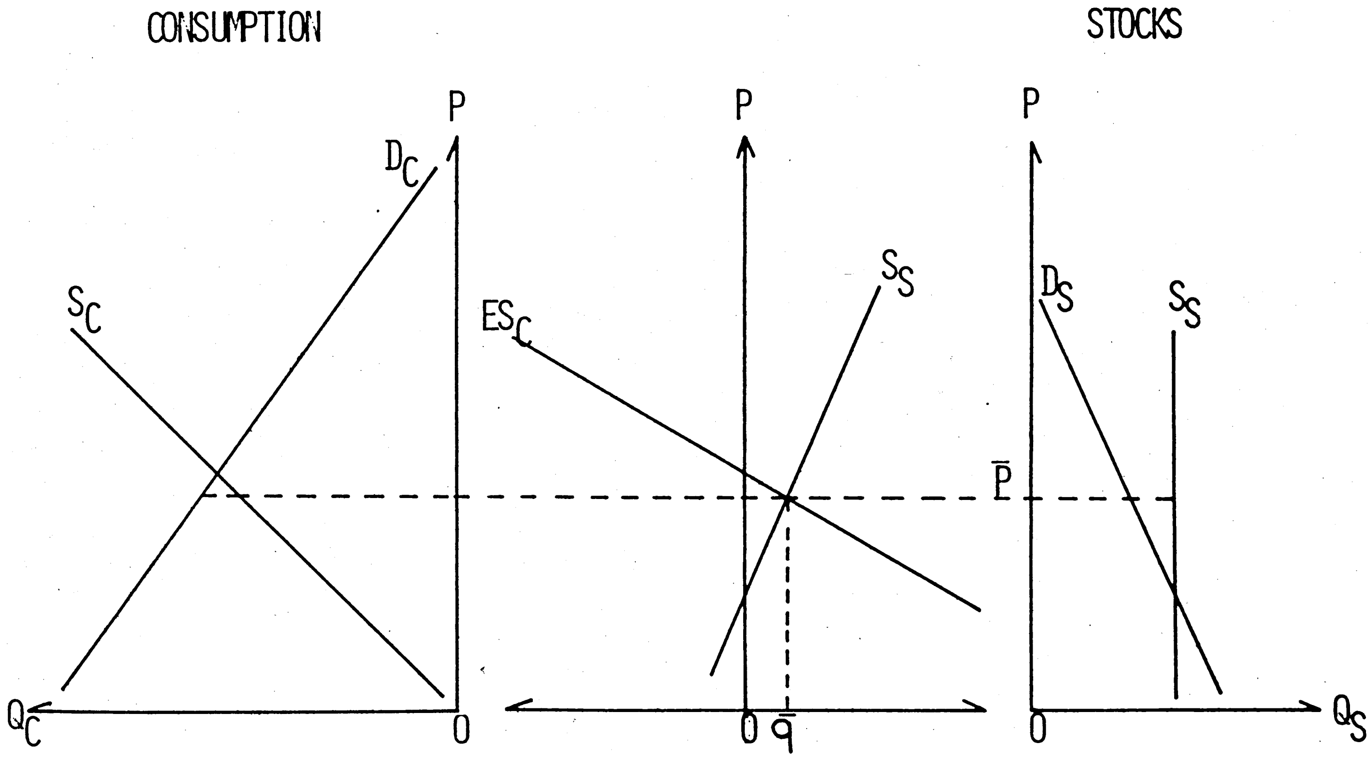
Given the following basic equilibrium condition for a region with no trade in a given time period;

opening stocks + production = consumption + closing stocks

it is possible to consider the above system in a simple graphical analysis. Figure 3.2 shows the relationship for a single period and region with known supply and demand schedules for fresh and stored product. The supply curve for stocks (S_s) will always be perfectly inelastic since it consists only of the stocks on hand at the end of the previous time period. The demand for stocks (D_s) can be expressed as the desired level of ending stocks and is an inverse function of the price in that period. The demand (D_c) and supply (S_c) for consumption are the supply and demand for consumption schedules.

1/ This discussion is based on the theoretical inventory models developed by Klein and presented in [15].

FIGURE 3.2: MOVEMENT BETWEEN STORAGE AND CONSUMPTION



The equilibrium price and quantity moved into and out of stocks is derived in a manner similar to the previous examples of interregional trade. Excess supply schedules are derived for storage stocks (ES_s) and for consumption (ES_c). The intersection of these two schedules represents the price level ($\bar{p}$) at which the amount moved from stocks ($o\bar{q}$) exactly equals the extra amount demanded for consumption. This describes the same system of equilibrating forces discussed above for interregional trade with the exception that, in the present case, the influence of changes in stocks in each region during a given period can be viewed as an added dimension of the excess supply and demand concept.

The inherent seasonality in hog production in North America is caused largely by climatic conditions and management practices, and has resulted in a storage pattern in which there is normally a build up of stocks over the period between October and March and a depletion of stocks from April to September when hog slaughter is normally at its lowest level (see section 5.0). These relationships make the interaction of stocks and fresh production important in considering temporal variations in the hog industry in that they provide a linkage between time periods. Many spatial equilibrium models have not considered these temporal factors. For example, Bawden et. al. [4], in a study of the U.S. turkey industry, noted the problems arising from the inability to include storage stocks in their analysis. They made the assumption that the quantity consumed in any one period was equal to slaughter in that period. This assumption is only valid under conditions where the storage stocks remain constant from period to period, or where stocks do not exist. The relationship presented in Figure 3.2 can be used to overcome this problem in studying the North American pork industry, and is readily compatible with a spatial equilibrium analysis.

3.3 The Multi Region Model

The preceding has shown that it is possible to develop a simple market model which includes both temporal and spatial aspects of market equilibrium. The basic structure of this model implies a competitive method of price determination. Prices are determined by the competitive interaction of supply and demand for consumption as well as the supply and demand for stocks.

The simple models presented above involve only two regions, and can be readily solved to determine prices and trade flows. The problem however, becomes considerably more complicated with the inclusion of more than two regions and the inclusion of stocks relationships. This problem has interested economists and over the last two decades methods of solving large models have been developed. Enke [14] provided the first solution using a relatively simple "electric analog" which allowed him to derive the following information, given known regional supply and demand relationships and transfer costs:

(1) The price in each region,
(2) The quantity of exports of imports in each region,
(3) Which regions import, export or do neither,
(4) The aggregate trade among regions in the community,

(5) The volume and direction of trade between each possible pair of regions.

Samuelson [44] converted this same problem to a maximising problem and showed that it could be solved iteratively using linear programming. He stated the problem in terms of maximising net social payoff, which is an analogous concept to net consumer and producer surplus and is defined as the social payoff in region 1 plus social payoff in region 2 minus transfer costs. Social payoff in any region is the area under the excess demand curve which is equivalent but opposite in sign to the area under the excess supply curve.

Using the same concept of maximising net social payoff, Takayama and Judge [57] converted the problem to a quadratic programming problem. They showed that given linear supply and demand functions and unit transfer costs, net social payoff becomes a quadratic function, and can be optimized using quadratic programming routines. In a later publication [56] they developed techniques for solving spatial equilibrium problems with fixed supply or demand levels and with more than one product. Tramel and Seale [60] have developed an alternative procedure for solving the problem using reactive programming which will allow inclusion of semi-log supply and demand functions. These techniques provide alternative methods for solving spatial equilibrium problems for a large number of regions, and in most cases, for more than one commodity.

The techniques described above have not been widely used,[1/] presumably because of their dependence on modified linear or quadratic programming algorithums and the lack of accurate interregional trade data. Most models that have been developed have dealt with single period spatial markets and have not been directly concerned with temporal relationships caused by production lags and storage activities. In a market such as that for pork where the current level of supply is completely inelastic and the long run supply fairly elastic, these relationships are important and are necessary to determine the long run response to policy and structural changes in the market. If supply is predetermined and dependent on lagged prices, then a structural or policy change will have a short run effect on prices as well as a longer run effect when supply responds to the short run price change. Such considerations make it necessary to develop a recursive model which can measure the effects of changes over several periods.

3.4 The Recursive Model

The spatial model described above has two types of supply relationships both of which are functions of lagged variables in a quarterly model.

3.4.1 The Supply of Stocks

The most simple recursive relationship that can be incorporated

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1/ The work of Kottke [34] has been a notable exception in developing spatial and temporal allocation models using reactive programming.

in the suggested model is a predetermined level of stocks at the beginning of a period which is equal to the closing level of stocks from the previous period. Although this is an obvious relationship in such a system, it is very important in that it provides an intertemporal linkage in the model.

3.4.2 The Supply Relationship

A second important intertemporal linkage in the model is provided by the fact that the supply of slaughter hogs in the current period is predetermined. It is predetermined in the sense that hog slaughter in a given quarter is dependent on previous prices. These relationships have been well documented for the U.S. by Harlow [23] and, on a semi-annual basis in Canada by Kerr [31].

The lagged supply relationships of hogs for slaughter and stocks of pork provide the necessary inter-temporal or recursive links to construct a dynamic model of the pork sector in North America. The following section looks in detail at the model developed in this study based on the inter-temporal and spatial dependencies discussed above.

4.0 THE PROGRAMMING MODEL

Using the theoretical considerations developed in the previous section it is possible to specify a mathematical programming model of the North American pork sector. The following section presents a brief description of the inputs for the model, its optimality conditions and the types of results generated. Section 4.1 presents a verbal description of the model, followed in section 4.2 by a mathematical development and section 4.3 discusses the full recursive model. For the reader who is not interested in mathematics section 4.2 can be passed over as sections 4.1 and 4.3 provide an adequate description.

4.1 The Quadratic Programming Model - Single Period

The basic input requirements for the spatial equilibrium model in this study are the following quantity dependent relationships.

1. A demand function for pork consumption in each region where all the independent variables other than the hog prices are collapsed at their appropriate level for that quarter into the intercept term. The function used in the model is then a simple linear relationship between the quantity of pork consumed in that region and the price of hogs in that region.
2. A demand for ending stocks function in each region. This function is again a simple price-quantity linear relationship when the relevant exogenous variables are collapsed into the intercept term.
3. A fixed level of pork supply in each region. As the supply of pork in any region is dependent on the values of lagged variables, the amount of fresh pork available for consumption in any period is assumed to be known.
4. A fixed level of opening stocks in each region. This is also assumed to be known as the supply of stocks available for use in a given quarter and is equal to the closing stocks from the previous period.

These components along with a known matrix of transfer costs between each of the regions in the model are used in the mathematical programming model to determine a spatially competitive equilibrium over all regions for a given period. The three conditions which determine a spatially competitive equilibrium are well known and can be stated as follows. First, the quantity demanded in each region for fresh consumption and storage must be less than or equal to the sum of all shipments into that region. Second, the quantity available in each region (production plus stocks) must be greater than or equal to the total amount shipped from that region. Third, the price difference between any two regions must be less than or equal to the transfer cost between the two regions. Satisfaction of these conditions implies an optimal competitive trade pattern between all regions and storage sectors such that no group (consumers, producers, or stockholders) could be made better off by a change in the trade flow which in turn implies a maximisation of welfare for all groups in the market. The solution to this single period problem determines optimum levels of prices, consumption, stocks, stock movements and trade flows for each region in the model. The temporal linkages discussed in 3.0 allow this single period model to be used in a simple recursive simulation model.

4.2 The Quadratic Programming Model - Mathematical Development

The basic input requirements for the single period model are the following quantity dependent relationships.

1. A demand function for pork consumption in each region

$$y_{ic} = a_{ic} - b_{ic}P_i \tag{1}$$

where,

y_{ic} = quantity of pork consumed in region i (i = 1, 2, ... n)

a_{ic} = intercept term for region i

b_{ic} = slope coefficient in demand function for region i

P_i = demand price in region i.

Over all regions this can be generalized in matrix notation to

$$Y_c = A_c - B_c P_y \tag{2}$$

or

$$\underset{(nx1)}{\begin{bmatrix} y_{1c} \\ \cdot \\ \cdot \\ \cdot \\ y_{nc} \end{bmatrix}} = \underset{(nx1)}{\begin{bmatrix} a_{1c} \\ \cdot \\ \cdot \\ \cdot \\ a_{nc} \end{bmatrix}} - \underset{(nxn)}{\begin{bmatrix} b_{1c} & & & \\ & \cdot & & \\ & & \cdot & \\ & & & \cdot \\ & & & & b_{nc} \end{bmatrix}} \underset{(nx1)}{\begin{bmatrix} P_1 \\ \cdot \\ \cdot \\ \cdot \\ P_n \end{bmatrix}}$$

where,

P_y = an nx1 vector of P_i

2. A demand function for closing stocks in each region

$$y_{is} = a_{is} - b_{is}P_i \tag{3}$$

where,

y_{is} = closing level of stocks in region i, (i = 1, 2, ... n)

a_{is} = intercept term for region i

b_{is} = slope coefficient for region i

P_i = demand price for region i,

or generalizing over all regions and expressing in matrix notation;

$$\underset{(nx1)}{Y_s} = \underset{(nx1)}{A_s} - \underset{(nxn)}{B_s}\ \underset{(nx1)}{P_y} \tag{4}$$

3. A fixed level of pork production in each region defined as X_{ic}. For

n regions X_c is an nx1 column vector of X_{ic},

$$X_c = (X_{1c}, X_{2c}, \ldots X_{nc})'. \quad (5)$$

4. A fixed level of opening stocks in each region X_{is}. For n regions X_s is an nx1 column vector of X_{is},

$$X_s = (X_{1s}, X_{2s}, \ldots X_{ns})'. \quad (6)$$

5. A $4n^2$x1 column vector of per unit transfer costs

$$T = (C_{ij}, D_{ij}, E_{ij}, F_{ij})' \quad (7)$$

where,

$\underset{(1xn)}{C_{ij}}$ = the cost of shipping fresh pork from region i to region j

$\underset{(1xn)}{D_{ij}}$ = the cost of shipping fresh pork from region i to storage in region j

$\underset{(1xn)}{E_{ij}}$ = the cost of shipping pork from storage in region i to consumption in region j

$\underset{(1xn)}{F_{ij}}$ = the cost of shipping pork from storage in region i to storage in region j

Following Takayama and Judge, [56, p. 157] excess demand is defined as the difference between the quantity demanded at price p_i and the quantity supplied at price p^i,1/ where p^i is the supply price in region i.

For region i excess demand can be defined as;

$$(y_{ic} + y_{is}) - (x_{ic} + x_{is}) = a_{ic} - b_{ic}\, p_i + a_{is} - b_{is}\, p_i - x_{ic} - x_{is}. \quad (8)$$

Takayama and Judge [56], following Samuelson [43], defined the area under this curve as "indirect welfare". Indirect welfare for a single region is defined as:

$$\text{Indw}_i = \int_{\hat{P}_i}^{P_i} (a_{ic} - b_{ic}\, p_i + a_{is} - b_{is}\, p_i)\, dp_i$$

$$- \int_{\hat{P}_i}^{p^i} (x_{ic} + x_{is})\, dp^i \quad (9)$$

$$= a_{ic}\, p_i - \tfrac{1}{2} b_{ic}\, p^2_i + a_{is}\, p_i - \tfrac{1}{2} b_{is}\, p^2_i - p^i x_{ic} - p^i x_{is} + \text{constant} \quad (10)$$

where,

$\hat{p}_i$ = the pre-trade equilibrium price

1/ Differing from Takayama and Judge the assumption is made that excess demand consists of the excess demand for fresh product plus the excess demand for stocks.

p^i = the supply price in region i (i = 1...n)

p_i = demand price in region i (i = 1...n). (11)

It is now possible to define a total indirect welfare function over all regions as below.

$$\text{IndW} = \sum_{i=1}^{n} \text{Indw}_i = A_c'P_y - \tfrac{1}{2}P_y'B_cP_y + A_s'P_y - P_y'\tfrac{1}{2}B_sP_y - P_x'X_c - P_x'X_s + \text{Constant} \tag{12}$$

where,

P_x = an nx1 vector of p^i

The total indirect welfare function provides the objective function in a maximisation problem subject to the following constraints;

$$T - G\begin{bmatrix} P_y \\ P_y \\ P_x \\ P_x \end{bmatrix} \geq 0 \tag{13}$$

and,

$$(P_y, P_x,) \geq 0 \tag{14}$$

$$\text{where } G = \begin{bmatrix} G_y & & G_x & \\ & G_y & G_x & \\ G_y & & & G_x \\ & G_y & & G_x \end{bmatrix}$$

$$\text{and} \quad G_y = \begin{bmatrix} 1 & & & & 1 & & & & & 1 & & & \\ & 1 & & & & 1 & & & & & 1 & & \\ & & \cdot & & & & \cdot & & & & & \cdot & \\ & & & \cdot & & & & \cdot & \cdots & & & & \cdot \\ & & & & \cdot & & & & \cdot & & & & \cdot \\ & & & & 1 & & & & 1 & & & & 1 \end{bmatrix}_{nxn^2}$$

and $G_x = \begin{bmatrix} -1 & -1 & \cdots & -1 & & & & & & & & \\ & & & & -1 & -1 & \cdots & -1 & & & & \\ & & & & & & & & \ddots & & & \\ & & & & & & & & & -1 & -1 & \cdots & -1 \end{bmatrix}_{nxn^2}$

Given this non-linear maximization problem, the Lagrangian function may be defined, ignoring the constant term, as;

$$\phi(P_y, P_x, \xi_x) = A_c'P_y - \tfrac{1}{2}P_y'B_cP_y + A_s'P_y - \tfrac{1}{2}P_y'B_sP_y - P_x'X_c$$

$$- P_x'X_s + \xi_x' \left(T - G' \begin{bmatrix} P_y \\ P_y \\ P_x \\ P_x \end{bmatrix}\right) \tag{15}$$

where ξ_x = a vector of Lagrangian multipliers

$= (\xi_{11}, \xi_{12} \ldots \xi_{nn})$.

From this function the Kuhn-Tucker optimality conditions may be derived as follows:

1. $$\frac{\partial\phi}{\partial P_y} = A_c - B_c\bar{P}_y + A_s - B_s\bar{P}_y - G_y\xi_x \leq 0 \tag{16}$$

   and $$\left(\frac{\partial\phi}{\partial P_y}\right) .\bar{P}_y = 0 \tag{17}$$

2. $$\frac{\partial\phi}{\partial P_x} = -X_c - X_s - G_x\bar{\xi}_x \leq 0 \tag{18}$$

   and $$\left(\frac{\partial\phi}{\partial P_x}\right) .\bar{P}_x = 0 \tag{19}$$

3. $$\frac{\partial\phi}{\partial \xi_x} = T - G' \begin{bmatrix} \bar{P}_y \\ \bar{P}_y \\ \bar{P}_x \\ \bar{P}_x \end{bmatrix} \geq 0 \tag{20}$$

$$\text{and} \left(\frac{\partial \phi}{\partial \xi_x} \right)' . \bar{\xi}_x = 0 \tag{21}$$

These conditions specify the existence of an optimal solution to the problem which can be obtained using Wolfe's simplex quadratic programming algorithim [69].

The solution determines optimum values of;

$\bar{P}_y$ = price in demanding regions,

$\bar{P}_x$ = price in producing regions,

$\bar{\xi}_x$ = level of shipments in optimal solution.

The absolute levels of demand for consumption and storage stocks can be obtained by simple substitution of optimal prices into the original relationships.

The three Kuhn-Tucker conditions derived above state the conditions for an optimal spatial equilibrium solution. They can be interpreted respectively as follows.

1. The quantity demanded in each region for fresh consumption and storage must be less than or equal to the sum of all shipments into that region.
2. The quantity available in each region (new production plus stocks) must be greater than or equal to the total amount shipped from that region.
3. The price difference between the regions must be less than or equal to the transfer cost between those two regions.

The mathematical programming model outlined above is used to determine quarterly spatial equilibrium solutions for the three regions in the model. Figure 4.1 presents a generalized example tableau for the single period spatial equilibrium model which can be solved with the Rand QP 360 quadratic programming code.1/ This tableau shows the primal solution variables which are the supply and demand prices for pork in each region. The dual solution to this problem provides the level of transfer and storage activities which can be used along with supply information, to determine the consumption and storage level of pork in each region. It should be noted that the objective function defined in the above formulation is in a sense arbitrary. In the Takayama-Judge formulation [56] net indirect welfare is the sum of the areas under the excess supply and demand schedules. In this slightly modified formulation the objective function also includes the net summed area under the excess stocks supply and demand schedules. The major significance of this objective function is that it, along with the conditions specified in the constraint set, determine competitive equilibrium prices and quantities at its maxima as can be seen from Figures 3.1 and 3.2 in the previous section. This single period problem determines the optimum level of prices, and trade flows through the interaction of the predetermined levels of supply and the demands for consumption and storage.

1/ See [12] for a complete listing of this computer program.

FIGURE 4.1: THE QUADRATIC PROGRAMMING TABLEAU

			Primal Solution Variables	Demand Prices		Supply Prices
	RHS		P_Y	P_Y	P_X	P_X
Linear Objective Function			A_C'	A_S'	X_C'	X_S'
Quadratic Objective Function			B_C			
				B_S		
					0	
						0
	C_{IJ}	$\geq$	G_Y		G_X	
Linear Constraint Set	D_{IJ}	$\geq$		G_Y	G_X	
	E_{IJ}	$\geq$	G_Y			G_X
	F_{IJ}	$\geq$		G_Y		G_X

4.3 The Recursive Model

The dependence of the supply of fresh pork and the supply of stocks on levels of variables in previous periods, determines the major linkages between time periods. These effects, which are transmitted through the prices and solution levels of storage stocks, provide the model with the ability to measure both the long and short run repercussions of structural changes in one or more of the regions. Figure 4.2 provides a schematic representation of the simulation model.

The basic input to the model is seen in the upper portion of the figure. The exogenous data,[1/] which are mainly derived from sectors other than the pork sector are used in two basic ways. First, along with previously determined price levels, exogenous data are used to generate the fixed levels of supply. A complete description of the actual variables is included in the following section. Second, exogenous data on the demand side are used to calculate the intercept terms in the demand for stocks and demand for consumption functions equivalent to equations (2) and (4). These equations along with the predetermined supplies of fresh and stored pork, equations (5) and (6), provide, with a vector of transfer costs, the basic input to the quadratic programming model. The recursive links in the model are seen in the use of solution levels of stocks and prices to determine supplies in later periods.

The overall model is set up in a computer simulation program which has been developed at the University of Guelph. Given levels of exogenous variables and initial values of lagged endogenous variables, the program has been used to simulate market adjustments in each of the three regions for up to forty quarters or ten years. The program also provides graphs of some of the results and measures of economic welfare, which are discussed in later sections of this paper.

The model presented above is generalized and would be applicable to a perfect system. In order to more accurately describe the market characteristics as outlined in section 2.0 four modifications and constraints are imposed.

4.3.1 Adjustments for External Trade

A requirement for a spatial equilibrium model of the type suggested above is that all the possible sources of supply and demand in the market are accounted for. Since there is some trade between North America and off-shore countries, this must be accounted for in the model.

For this reason demand for Canadian and U.S. pork in countries other than Canada and the U.S. is included in the dependent variables of the demand functions for fresh consumption on the assumption that they are

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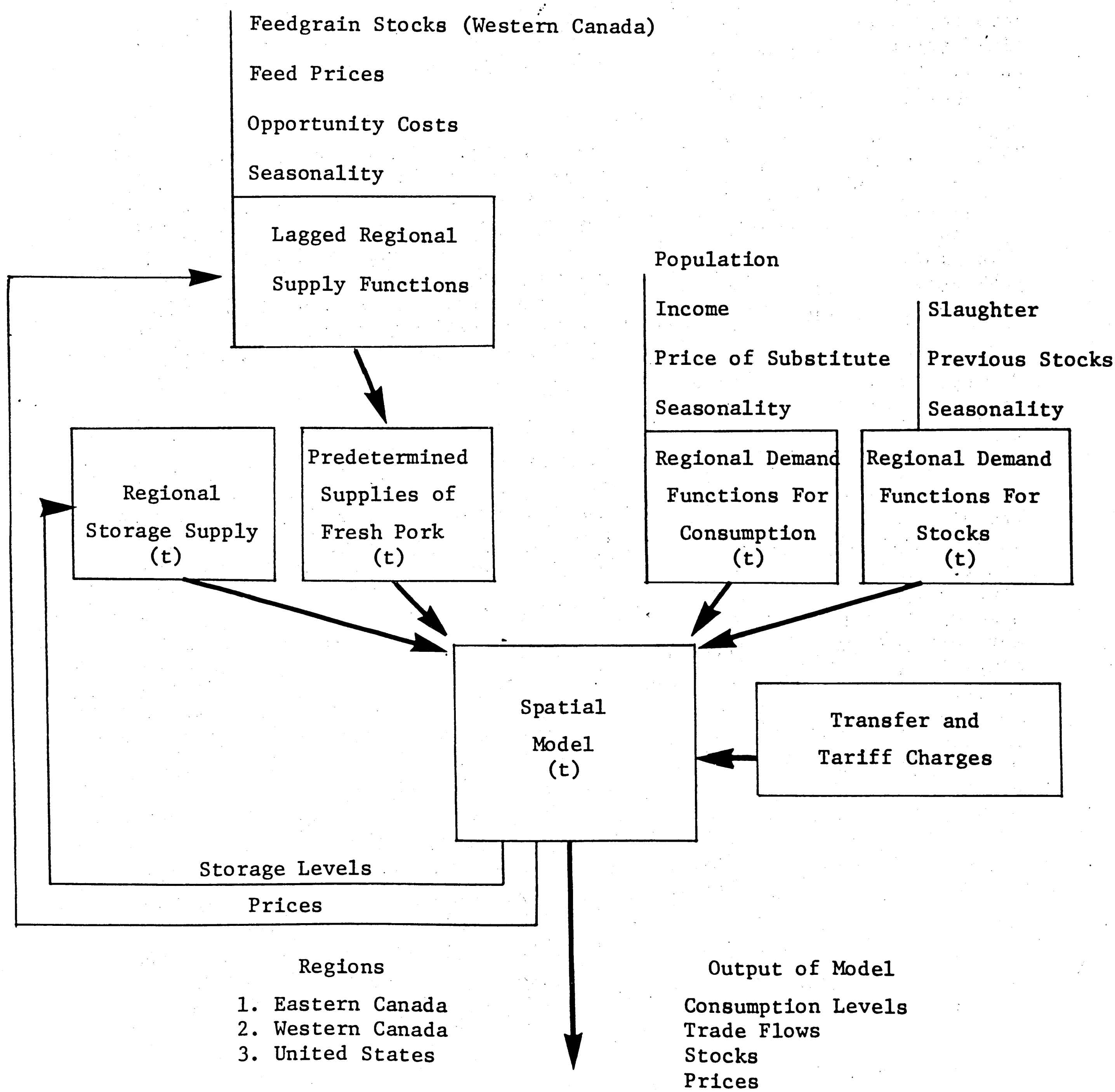
1/ Exogenous in terms of the simulation model refers to variables whose levels are not determined in the normative programming model.

FIGURE 4.2: SCHEMATIC REPRESENTATION OF THE MODEL



responsive to internal changes.[1/] Supplies of pork from countries other than Canada or the U.S., however, are of a more specialized nature and have tended to increase over the last decade [65]. For this reason imports into each region were treated as exogenous variables and included in the fixed supply quantities. These adjustments account for the entire supply and disposition of pork and pork products within North America and allow for specification of a complete trading system.

4.3.2 Adjustments for Specialized Ham Trade

As outlined in section 2.0, a large part of Canada's export trade with the U.S. is made up of specialized ham products which do not appear to respond to price changes. In the model, this trade was also treated as exogenous, and included by creating an extra region with a zero level of pork supply and a fixed demand level consistent with the level of trade in that quarter. The appropriate transfer costs were adjusted to ensure that it was only feasible to satisfy the demand by shipping pork from Eastern or Western Canada. This artificial region has the effect of constraining a supply of ham to be shipped from Canada to the U.S. at the lowest possible cost.

4.3.3 Adjustments for Non-feasible Shipments

The transfer costs that are included in the model only pertain to the element C_{ij} in equation (7) where fresh pork is shipped between regions. It was assumed that shipments out of storage in one region into fresh consumption or storage in another region are infeasible. Likewise shipments from fresh production in one region into storage in another region were also considered to be infeasible. These infeasible transfer activities were dropped completely from the linear constraint matrix in the programming tableau (Figure 4.2). Shipments in and out of storage within a region however, were assumed to occur at zero costs. This does not assume that there are no storage costs, only that there are no costs associated with movements to and from storage. Storage costs are not directly estimated but are implicit in the demand for storage functions which determine the amount of stocks wholesalers are prepared to hold at any given level of price and production.

4.3.4 Adjustments for Exchange Rates

It should be noted that price variables used in estimating the United States supply, demand and stocks equations were estimated in Canadian dollars. In the spatial equilibrium model it would not be meaningful to intersect equations estimated in different currencies. In converting the U.S. equations to Canadian currency a procedure suggested by Schmitz and Bawden [45] is followed. This procedure however is only valid in a case

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1/ Alternatively these exports could be treated as entirely exogenous variables to the model, and could be included by adding the quantities to the demand function intercept.

such as this where fluctuations in the exchange rate are small.

The complete model described above can be used to simulate the interregional and intertemporal structure of the North American pork market. The following section discusses the behavioral relationships and the derivation of the transfer costs used in the study.

5.0 ESTIMATION OF BEHAVIORAL EQUATIONS AND TRANSFER COSTS BETWEEN REGIONS

This section outlines the estimation of the behavioral relationships and transfer costs necessary for the model developed in the previous section. The behavioral relationships are very important in providing linkages between the pork sector and other sectors such as beef and feed grains. Quarterly equations are estimated for the supply of pork, demand for consumption, and demand for stocks of pork in each of the three regions in the model using data from 1961 to the end of the second quarter in 1973 for the demand functions and from 1961 to the second quarter 1972 for the supply. The three regions are the U.S., Eastern Canada and Western Canada, where Eastern Canada includes the Maritimes, Quebec and Ontario, and Western Canada consists of British Columbia and the Prairie Provinces.

5.1 Supply Response Functions[1/]

Supply response in hog production has been widely studied, [23], [31], [11], [36], [25], at varying levels of complexity and aggregation. The most commonly used analytical tool in such studies of the hog industry is the cobweb theorem as developed by Ezekiel [17] which is based on the assumption that there is a time lag between a change in price and a production response. This characteristic of hog production, caused mainly by the physical and temporal factors involved in changing the level of production, has been used to explain the cycles in production and prices that have occurred over the last twenty years.[2/]

5.1.1 Specification

In this study the most appropriate lag for the price of hogs was found to be a distributed lag of five quarters. Such a lag represents the time elapsed between the decision to change the level of production and the final response as measured by changes in the level of slaughter. A distributed lag structure was used to allow for the quarterly nature of the model. This is based on the assumption that a price change would need to be maintained for a period longer than a quarter to cause a response in production at the farm level. For this reason the one period lagged dependent variable was included as an independent variable in the estimated equations.[3/]

1/ A further and more complete analysis of these functions is presented in Meilke, Zwart and Martin [41].

2/ Harlow [23] and Maki [35] present a full description of the cause and effect relationships involved in the price and production cycles of the hog industry.

3/ Johnston [29, p. 298] shows the procedure for deriving such a structure, using a Koyk transformation.

Other independent variables used in the estimation of the supply response account for changes in costs of producing hogs, and the opportunity costs of alternative farming operations. The measure of production costs varied between regions but all included the cost of, or availability of feed supplies. Opportunity costs of alternative activities were included for beef production in the form of price differences between slaughter and feeder cattle, at an appropriate market in each region.

Dummy variables were included to account for the seasonality of supply in each region. Initially, dummy variables were included on both the intercepts and the price variables but in the final equations the dummy variables on prices were not included due to a lack of statistical significance.

Since the level of hog slaughter in a given quarter is not a function of the price of hogs in that quarter [21], [23], supply is estimated independently of demand using an ordinary least squares regression.

The supply equations are specified in the general form:

$$X_c = F(PH_{t-5}, PF_{t-5}, FS_{t-5}, BPD_{t-5}, QS_{t-1}, D_i) \qquad (22)$$

where the variables are as defined below:

X_c = the dependent variable = commercial slaughter of hogs in each region expressed in millions of pounds carcass weight. These were obtained from [9] and [65] in Canada and the U.S. respectively.

PH_{t-5} = is the price of slaughter hogs lagged five quarters. In the U.S. model, this is specified as the average of seven market prices for barrows and gilts as reported in [65], adjusted to carcass weights and converted to Canadian dollars. For the Eastern and Western Canada models, it is specified as the Toronto and Calgary prices of index 100 hogs as reported in [10].

PF_{t-5} = a lagged feed-price variable included in the U.S. and Eastern Canadian equation. For the U.S. this variable is specified as a weighted price per ton of hog feed (.88 times the corn price on farms plus .12 times the price of 44 per cent soybean meal at Decatur, Illinois) derived from [63]. For the Eastern Canada equation this variable, measured in dollars per ton, is an average of corn and barley prices in Eastern Canada weighted by the production levels of each plus the annual levels of shipments under feed freight assistance, and the levels of imports of U.S. corn into Eastern Canada. Data were obtained from [49] and [50].

FS_{t-5} = a five quarter lagged variable included only in the Western Canada equation as a measure of feedgrain availability in that region. It is specified as stocks of wheat and barley on farms in the Prairie Provinces at

March 31st, measured in tons as reported in [49].

BPD_{t-5} = an opportunity cost variable lagged five quarters to measure the effects of changes in beef prices on hog production in each region. For Eastern and Western Canada this variable is specified as the good slaughter steer price minus the good feeder price at Toronto and Calgary respectively as reported in [10]. For the U.S. model the variable is specified similarly for feeder steers and slaughter steers at Omaha [65].

QS_{t-1} = the quantity supplied in each region lagged one quarter. This variable is the lagged dependent variable and completes the distributed lag specification.

D_i = a set of dummy intercept variables for each quarter.

5.1.2 Results

Table 5.1 contains the estimated regression coefficients for the supply of pork in each region, and their levels of significance.

The initial equation estimated for Western Canada was modified because of a high degree of serial correlation in the residuals as measured by the Durbin-Watson statistics. The Hildreth-Lu procedure [28] was used to reestimate the supply equation and showed that the equation had a first-order serial correlation coefficient of .4.[1/]

In order to demonstrate the significance of seasonality in hog production, F tests were calculated for the dummy variables and were found to be significant at the 5 per cent probability level.[2/] Such a test does not prove conclusively that all the quarters are significantly different from each other, but rather that there is a significant seasonal effect over all quarters. The pattern of seasonality is shown in Table 5.1 by including the intercept terms for each quarter. In all regions the first and fourth quarters have the highest production while the second and third quarters are relatively lower. This observation is supported by a previous study [23] and is caused mainly by management and climatic factors which affect farrowing patterns.

Table 5.2 presents the short and long run direct and cross elasticities calculated from the functions. The lagged dependent variable allows calculation of the long run elasticity using the formula provided in [47,

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1/ It is noted [29, p. 313] that the Durbin-Watson statistic is biased in a case where lagged dependent variables are included, but the extremely low level of the Durbin-Watson statistic indicated a serious level of serial correlation.

2/ Johnston [29, p. 204] outlines the procedure used in testing the significance of the dummy intercept terms.

TABLE 5.1: Estimated Supply Relationships

Region	Intercept (Million Pounds)		Regression Coefficients (t-Statistics in Parentheses) PH_{t-5}	PF_{t-5}	FS_{t-5}	BPD_{t-5}	QS_{t-1}	R^2
Eastern Canada	First Quarter	8.97	1.08	-.09		-.45	.75	.96
	Second Quarter	1.38	(4.49)***	(-.33)		(-.54)	(8.06)***	
	Third Quarter	7.28						
	Fourth Quarter	18.78						
Western Canada	First Quarter	27.32	.369		1.06	-3.61	.49	.96
	Second Quarter	21.90	(1.05)		(2.73)***	(-3.01)***	(4.96)***	
	Third Quarter	3.76						
	Fourth Quarter	27.16						
United States	First Quarter	581.6	18.26	-.71		-16.31	.63	.91
	Second Quarter	490.8	(3.46)***	(-.15)		(-1.35)**	(5.30)***	
	Third Quarter	424.3						
	Fourth Quarter	1047.4						

***Significant at the .01 probability level.

**Significant at the .05 probability level.

TABLE 5.2: Supply Elasticities and Cross Elasticities[1/]**

Independent Variable	Eastern Canada	Western Canada	United States
Hog Price			
Short Run	.22	.10*	.16
Long Run	.89	.20*	.43
Feed Price or Stocks			
Short Run	-.03*	.19	-.01*
Long Run	-.12*	.37	-.027*
Beef Price Margin			
Short Run	-.002*	-.02	-.02
Long Run	-.008*	-.039	-.054

* Estimated from a statistically insignificant regression coefficient.
** Elasticities are calculated on an average quarterly basis using mean values of the variables.

p. 77].[1/] This formula measures the cumulative effect of a maintained change in the independent variable by assuming that in the long run the lagged dependent variable will equal the dependent variable.

The significance of the regression coefficients presented in Table 5.1 and the level of their elasticities in Table 5.2 would suggest that the major determinant of supply in Eastern Canada and the U.S. is the lagged price variable. The price elasticities of supply are .16 and .22 for Eastern Canada and the U.S. respectively in the short run and .43 and .89 in the long run. These results are similar to annual estimates of .82 for the United States [23] and semi-annual estimates of .66 and .33 for Saskatchewan and Ontario respectively [43].

The relatively low direct price elasticities for Western Canada coupled with the cross elasticity for feed stocks supports the conclusions of Kerr [31], regarding hog supply in the West. In Western Canada hog output is largely determined by the state of the wheat and feed grain economy, and is influenced to a great extent by the policies of the Canadian Wheat Board.

1/ The formula is as follows: $E_{LR} = \frac{E_{SR}}{1-b}$

where E_{LR} is the long run elasticity estimate, E_{SR} is the short run elasticity estimate, b is the regression coefficient for the lagged dependent variable.

In years of open quota, wheat board prices of grain are representative of the opportunity costs of feeding grain to hogs. But in years when quotas are closed there is a build up of stocks on farms and a lower priced off-board market for feed grains develops - primarily between producers. In these circumstances, producers have little opportunity to market their surplus feed grains except through livestock. This is reflected in a much stronger cross elasticity for the feed stock variable in Western Canada (.37 in the long run) compared to those of feed prices in the Eastern Canada and the U.S. (-.12 and -.027 respectively).[1/] The relatively low cross elasticities in the latter regions (which are estimated from statistically insignificant regression coefficients) imply that hog production in Eastern Canada and the U.S. is much more stable and, most likely, that swine enterprises are more specialized.

The cross elasticities associated with the beef price variable indicates that there is a larger degree of substitution between hog and beef production in Western Canada and the U.S. than in Eastern Canada. The long run cross elasticities of -.039 and -.054 in these regions imply that a relatively small change in the apparent profitability of raising beef, as reflected in the slaughter-feeder margin, has a substantial effect on hog production. The long run elasticity of -.008 for Eastern Canada indicates that hog production is affected very little by the beef margin. This further supports the inference above, that hog production is highly specialized in the East.

In summary, the estimated supply functions appear to explain the major part of the variation in pork supply, and suggest that the most important factors explaining the level of supply are previous prices and seasonality in Eastern Canada and the U.S., and the feed grain stocks in Western Canada.

5.2 Demand Equations for Consumption and Storage Stocks

The demand for consumption and storage equations were estimated quarterly using two stage least squares since it was hypothesized that the hog price in a given quarter is jointly determined by demand for consumption and demand for storage stocks in that quarter. Following Fox [20, p. 12] a simultaneous estimation should be theoretically more correct, although it was found in the present case that ordinary least squares estimates of the equations were not significantly different from those obtained from the simultaneous estimation.

The structural equations estimated were of the following general form:

1/ Note that the signs on the elasticities are correct. When feed stocks are high in Western Canada, production increases. When feed prices are high in Eastern Canada and the United States, production declines.

Demand for fresh consumption,[1/]

$$Y^{F*}/C = f' \ (PH_t{*},\ PP_t,\ PB_t,\ I_t,\ D^c) \tag{23}$$

and demand for stocks,

$$Y^{S*} = f'' \ (PH_t{*},\ QS_t,\ YS_{t-1},\ D^s) \tag{24}$$

* - endogenous variables in simultaneous system where the variables were defined as follows.

where,

Y^F/C_t = the dependent variable in the demand for consumption function. This is made up of the demand for consumption plus the demand for exports to countries other than Canada and the U.S. In the estimation this variable was expressed in pounds per capita and derived from [9] and [65] in Canada and the U.S. respectively.

PP_t = retail price index for poultry in Canada [51], and the U.S. [64] reported in Canadian dollars.

PB_t = retail price index for beef in Canada [51], and the U.S. average retail price for choice beef as reported in [65] and converted to Canadian dollars.

I_t = per capita disposable income for Canada and the U.S. measured in terms of thousands of Canadian dollars. These variables were derived from [48] and [67] for Canada and the U.S. respectively.

YS_t = the dependent variable in the demand for stocks equations, and is made up of the end of quarter cold storage stocks of pork expressed in millions of pounds and derived from [65] and [52].

QS_t = regional slaughter levels in million pounds as defined in section 4.1.

D^c and D^s = quarterly intercept dummy variables used in both the demand for fresh consumption and the demand for stocks equations.

PH_t = is the farm hog price as defined in section 5.1.

5.2.1 The Demand for Consumption Functions

The structure of the demand for consumption equations in terms of the variables included is based on traditional concepts of demand. These include income and the prices of substitute products. Fox [20] and George

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[1/] Since consumption in Canada was only available on a nationwide basis [9] only one equation was fitted, and equations for Eastern and Western Canadian demand were based on relative populations.

TABLE 5.3: Estimated Demand for Consumption Relationships

Region		Intercept (Pounds/Capita)	Regression Coefficients (t-Statistics in Parentheses)				
			PH_t	PP_t	PB_t	I_t	R^2
Canada	First Quarter	10.080	-.2101	.0367	.0025	1.933	.88
	Second Quarter	9.770	(-10.72)***	(3.27)***	(.25)	(4.92)***	
	Third Quarter	9.881					
	Fourth Quarter	10.427					
United States	First Quarter	12.936	-.2080	.0071	.0281	1.890	.98
	Second Quarter	12.339	(-28.41)***	(1.21)	(4.17)***	(15.67)***	
	Third Quarter	12.609					
	Fourth Quarter	13.717					

***Significant at the .01 probability level.

**Significant at the .05 probability level.

and King [22] present excellent discussions of the basic theoretical concepts underlying the specification.

Table 5.3 presents the linear estimates of the regression coefficients derived from the two stage least squares procedure. The dummy variables were again tested for significance with an F test based on the OLS estimates of the functions, and were found to be significant at the 5 per cent level.

Table 5.4 contains the estimated elasticities and cross elasticities estimated from the regression equations in Table 5.3. These elasticities are compared with those of other studies. The U.S. results are similar to previous studies and have signs consistent with economic logic. However, the Canadian results do not appear as consistent. The study by Tryphos and Tryphonopolos [62] is the only other recent study on the demand for pork using time series data. Their relationships were estimated simultaneously with the demand for other meat products using annual data from 1954-1970.

TABLE 5.4: Comparison of Calculated Elasticities and Cross Elasticities[1/]

Demand for Pork in the U.S.

	Variables			
	PH	PB	PP	I
Present Study	-.37	.17	.05	.38
George & King [22]	-.24	.05	.02	.133
Harlow [23]	-.35			
Maki [36]	-.37			

Demand for Pork in Canada

	Variables			
	PH	PB	PP	I
Present Study (1961-1973)	-.47	.025	.32	.33
Yeh [70] (1930-1958)	-.343	.20	-	-.438
Tryphos & Tryphonopolos [62] (1954-1970)	-1.05	.276	-	-.004

1/ These elasticities were calculated at the mean values of the variables and using farm level prices in the direct elasticities.

Their calculated direct price elasticity is considerably larger than those of the present study but some bias in this direction would be expected from their use of the retail price index rather than farm level prices as used in this study. The income elasticity is also larger and positive in the present study. It would appear from considering an even earlier study [70] that the income elasticity of demand for pork has changed from negative to positive over time since the three studies cover consecutive time periods.

The cross elasticity relationships between beef and pork can be seen to vary considerably between the United States and Canada. Previous studies in both countries would indicate that the cross elasticity between beef and pork in Canada should be larger than that estimated in this study. The most probable cause of such a discrepancy is a relatively high degree of multicollinearity between beef and income, due to the constant upward trend in these variables. However, these relationships explain most of the variation in the derived demand for pork in both Canada and U.S. A derived demand function for pork is estimated here since it is necessary in a spatial equilibrium system to have the same price variable in both the supply and demand functions. As is seen in equations (1), (3), (5) and (6) in section 4.2, it is also necessary to use a common measure of quantity in these estimated relationships, in this case millions of pounds of pork.

5.2.2 The Demand for Stocks Function

The demand for stocks equations were specified as a distributed lag of price with the inclusion of a lagged variable for the level of slaughter and dummy variables to measure seasonality. This specification includes major theoretical factors which are considered to be important in determining the level of stocks or inventories [15]. These factors are transaction demand and speculative demand and are summarised briefly below.

Transactions demand is dependent upon the level of activity in the market. It implies, in the case of pork, that packing houses will hold a given fraction of their current period kill for transactions. This element of storage demand is incorporated in our equations by including the current period slaughter level as a variable.

Speculative demand for inventory is dependent upon stockholders' expectations about future prices and future production and consumption levels. Expectations about future prices and supplies are incorporated in the storage demand equations by including a geometrically distributed lag on the variables. Expectations about future production and consumption imply that stockholders recognize the seasonal nature of production and consumption in the pork sector. Thus, we incorporate seasonality in the demand for stock equations through the inclusion of dummy variables on the intercept terms.

The estimated equations are presented in Table 5.5. It can be seen that the price coefficients are negative, hence, as expected, an increase in hog prices in any one quarter will tend to reduce the level of stocks at the end of the quarter. The variable for the level of slaughter has a positive sign consistent with the logic behind the transaction demand for stocks. Seasonality of stocks was again found to be significant as measured by an F test on the ordinary least squares estimates of the equations, and has a similar seasonal pattern to that seen in the supply and demand functions. There tends to be a build up of stocks in the fourth and first quarters at the end of which stocks are at their highest level. Following this, stocks decline in the second and third quarters of each year

TABLE 5.5: Estimated Demand for Storage Relationships

Region	Intercept (Million Pounds)		Regression Coefficients (t-Statistics in Parentheses)			
			PH_t	QS_t	YS_{t-1}	R^2
Eastern Canada	First Quarter	.210	-.0930	.0685	.6175	.80
	Second Quarter	-1.368	(-1.34)*	(2.41)***	(3.31)***	
	Third Quarter	-6.395				
	Fourth Quarter	-4.437				
Western Canada	First Quarter	1.567	-.0886	.1026	.1493	.86
	Second Quarter	1.760	(1.67)**	(5.58)***	(1.11)	
	Third Quarter	-2.978				
	Fourth Quarter	-1.289				
United States	First Quarter	25.133	-4.267	.1084	.2519	.89
	Second Quarter	25.314	(5.95)***	(6.65)***	(2.74)***	
	Third Quarter	-67.980				
	Fourth Quarter	-41.721				

***Significant at the .01 probability level.

**Significant at the .05 probability level.

*Significant at the .10 probability level.

and reach their lowest level at the end of the third quarter. Stocks in Western Canada differ slightly in that they continue to build up slowly until the end of the second quarter and only decrease in the third.

The calculated price elasticities range from -.26 in Eastern Canada to -.47 in the U.S. These results differ from those in [23] and [36] where signs on price coefficients in similar equations are positive. These previous equations were derived from earlier time periods which may have caused the discrepancy. Elasticities derived from slaughter variables are higher than those of the price variables. They are .89 in Eastern Canada, 1.14 in Western Canada and 1.26 in the U.S. This indicates that the level of slaughter is more important in determining the level of stocks held than the price paid for the stocks. Signs on these variables indicate that an increased level of slaughter is related to an increased amount of storage at the end of that quarter, which is consistent with the transaction demand hypothesis.

5.3 Estimation of Transfer Costs

An essential element of a spatial model such as that discussed in section 4.0 are estimates of the unit costs of shipping pork between regions. In this study the normal problem of assessing transfer costs is compounded by the large size and proximity of the producing and consuming regions. The problems are clearly seen when it is realized that Canada's exports of pork move to both the Eastern and Western seaboards of the U.S. while Canada's imports from the United States come primarily from the corn belt.

In order to overcome these problems it is necessary to assume that each of the regions in the model could have a consumption centre which is different from the production centre in that region. The production to consumption centre costs for shipping were based on data provided by the Canadian Livestock Feed Board which estimated transfer costs between major centres in North America for 1972. A cost matrix was then determined for the costs of shipping between the major producing and consuming centres in each of the census regions in the U.S., and provinces in Canada. This cost matrix was then reduced to the three producing and consuming regions that are in the model, by weighting the costs between the census regions and provinces by the volume of trade along each route and aggregating the costs into the larger regions. The pork trade data is derived from figures provided by the Canada Department of Agriculture for the years 1969-1971 and the average trade flows of these years are used in weighting the transfer cost data. The final estimates of the cost per pound of shipping pork between the regions are presented in Table 5.6 and it should be noted that although they include loading and unloading charges involved in shipment they do not include tariff charges.

TABLE 5.6: Estimated Interregional Transfer Costs
(dollars per cwt.)

From \ To	United States	Western Canada	Eastern Canada
United States	-	4.00	2.50
Western Canada	3.39	-	2.91
Eastern Canada	1.53	2.91	-

6.0 MARKET SIMULATIONS

This section presents the results of a series of market simulations using the mathematical programming model which incorporates the econometric equations presented in section 5.0. The simulation experiments are divided into two general groups. First, the model is validated by simulating actual market conditions over the forty-one quarter period from the second quarter of 1963 through the second quarter of 1973. Secondly, the model is used to simulate the effects of alternative government and producer group policies over the same period as an indication of the value of the model in policy analysis.

6.1 The Validation Procedure

The model was used to simulate levels of production, consumption, trade, stocks and prices in each of the three regions included in the model. The model is set up in such a manner that the exogenous variables which relate to sectors other than the pork sector are prespecified, and actual levels of lagged hog prices and stocks are specified for the initial periods. After the fifth quarter the model relies entirely on generated levels of the endogenous variables such as lagged hog prices, supplies and storage stocks.

The quadratic programming portion of the overall model makes this type of simulation considerably different from econometric simulations which merely recreate the estimated behavioral relationships. The normative structure means that the validation tests not only the accuracy of the model, but also the implicit hypothesis that the hog market behaves in a spatially competitive manner. The quadratic programming portion of the model determines competitively optimum prices and trade flows in any one period. The model therefore can be used to test the hypothesis that the actual market behaves in such a manner.[1/]

Figure 6.1 presents graphs of actual and predicted levels of prices, supplies and stocks over the validation period. Although these graphs give some visual evidence of the accuracy of the model, they do not provide a rigorous statistical test of its ability to simulate events in the sector. The graphs do show the ability of the model to predict seasonal and longer term cycles in the market but visual appraisal of the accuracy of predictions is confused by the scale of the graph and the varied levels of the variables.

6.1.1 Accuracy of the Validation

Probably the most widely used statistical measures of the accuracy of predictions are those derived by Theil [57]. Theil's measure of the accuracy of a forecast is based on a quadratic loss function which assumes that it is reasonable to measure the seriousness of a prediction error by

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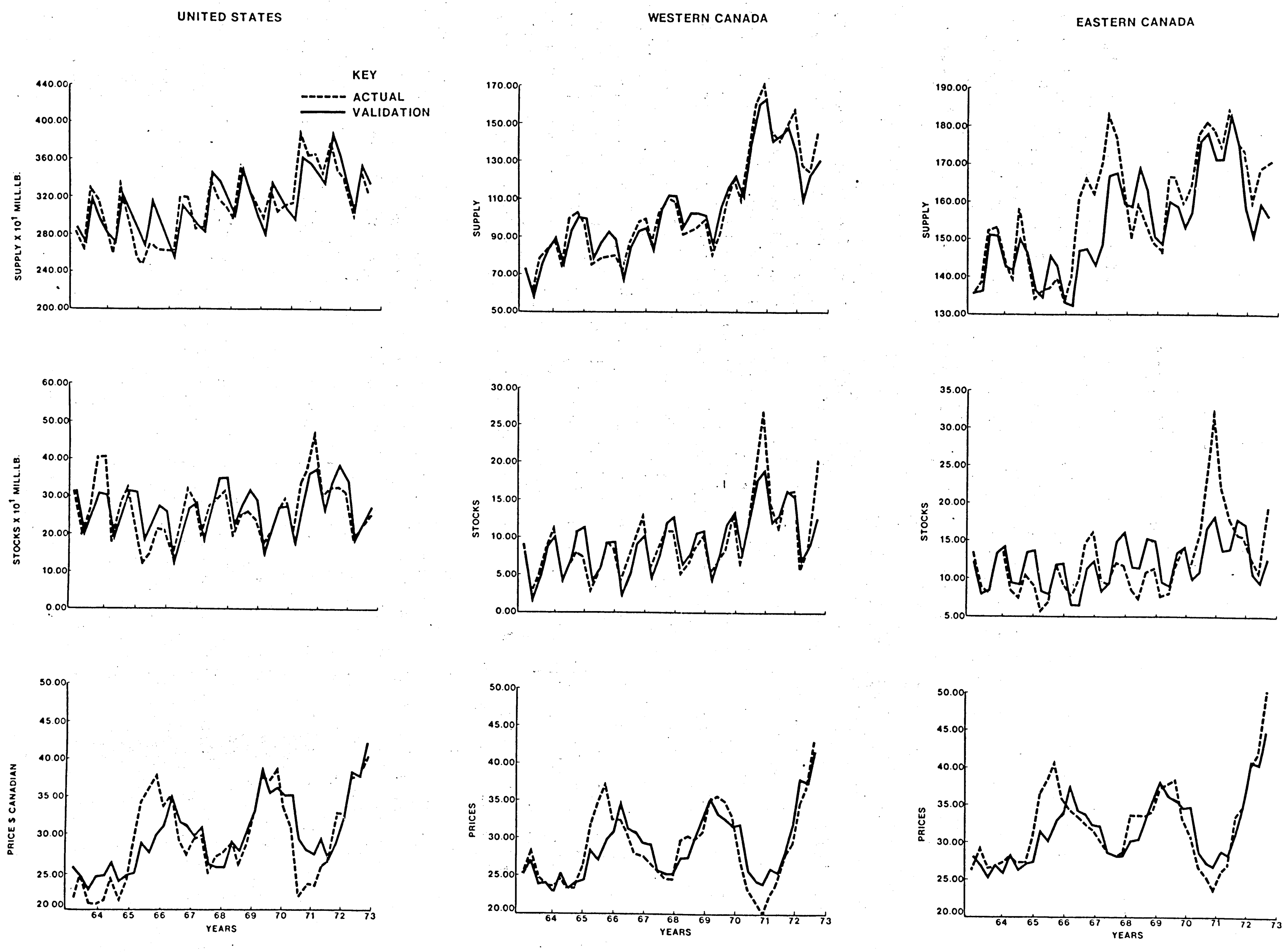
1/ Such a model is not necessarily constrained to the analysis of a perfectly competitive market. For instance, Takayama and Judge [55] also consider other types of competition such as monopoly.

FIGURE 6.1: ACTUAL AND GENERATED SUPPLY, STOCKS AND PRICES, UNITED STATES, EASTERN AND WESTERN CANADA, 1963-1973



its square. Using this concept a measure of prediction error is derived in the form of the mean square prediction error, which is equivalent to the variance of the predicted values around the actual values. The mean square error is then

$$\frac{1}{n}\sum_{i=1}^{n}(P_i - A_i)^2, \tag{25}$$

where,

P_i and A_i are a set of n pairs of predicted and actual observations on a variable.

The similarity of this measure with a simple variance formula would suggest that it is possible to make probabilistic statements about the accuracy of the prediction, but it should be noted that this is possible only in cases where the expected value of $(P_i - A_i)$ is equal to zero. This is dependent on the type of prediction that is used in the simulation. In the simulation model used in this study there is no prior knowledge on the bias of the prediction, or the expected values of the errors but it is valuable to test for the presence of such errors.

Theil has shown that the above formula for the mean square error can be decomposed into what he calls "inequality proportions" which measure the major types of error that can occur in a prediction or validation [58, 29].

This decomposition shows that the mean square error term is made up of three major sources of error;

(i) $(\bar{P} - \bar{A})^2$, which shows the degree of bias in the validation and is called the bias proportion,

where,

$\bar{P}$ = the mean of the predicted values

$\bar{A}$ = the mean of the actual values.

(ii) $(S_P - S_A)^2$, which measures the degree of error that would be caused by unequal variation between the validation and the actual values.

where,

S_P = the standard deviation of the predicted values

S_A = the standard deviation of the actual values.

(iii) $2(1 - r)S_PS_A$, which measures the degree of error caused by the lack of covariation between actual and validation,

where,

r = the simple correlation between predicted and actual.

Theil has used the mean square error to determine acoefficient which measures the accuracy of predictions and is comparable between variables. The Theil "U-coefficient" is expressed as the positive square root of

$$U^2 = \frac{\Sigma(P_i - A_i)^2}{\Sigma A_i^2} \tag{26}$$

where the numerator is equivalent to the sum of the inequality proportions and the denominator is a scaling factor to make the coefficient comparable between variables. It can be seen that in the case of perfect prediction where $P_i = A_i$ the U-coefficient has a value of zero since all the three error components become zero. This is the minimum value that the coefficient can attain. The coefficient used in this study does not have an upper limit but would have a value of 1 in a case where the P_i would always be equal to zero.[1/]

The above discussion has shown that it is possible to derive a coefficient which measures the accuracy of the validation procedure and that this coefficient can be broken down to reveal the source of the errors. The basic sources of these errors in the model would be due to bias, unequal variation and lack of covariation or turning point errors.

6.1.2 Results of Validation

Table 6.1 presents the calculated values of the Theil U-coefficients for each of the thirteen variables simulated in the recursive spatial equilibrium model. The table also gives the percentage of the U-coefficient which is due to each type of prediction error.

The U-coefficients for all variables except the trade flows would suggest that the model has been reasonably accurate in predicting past changes in the North American pork sector. The high values of the coefficients for the trade flows are not surprising since the level of these flows rarely amounts to as much as one percent of the total pork produced in North America. It can be seen however, from the inequality proportions that a major source of these errors is the biased levels of the trade flows, and that turning point errors are not excessive. This would suggest that the model has predicted the direction of the trade flows reasonably well although the levels of the trade were not accurately predicted. The inequality proportions for the remaining variables show that turning point errors are the major cause of prediction error in the validation, but the size of these proportions must be considered in relation to the size of the coefficient for each individual variable.

Even though the U-coefficients do not provide a rigorous statistical test to "accept" or "reject" the validation of the model, their level would suggest that the model has predicted well over the validation period.

1/ In an earlier discussion of the coefficient, Theil used a different numerator which gave a range of the coefficient between zero and one, and has been widely used in other studies, e.g. [71].

TABLE 6.1: Results of Theil U-Coefficient Test

Predicted Variable	U-Coeff.	Proportion of Prediction Error by Source		
		(P - A)	(S_p - S_A)	2(1 - r)$S_p S_A$
Hog Prices				
United States	.15	.51	.08	.41
Western Canada	.09	.00	.05	.95
Eastern Canada	.08	.07	.09	.84
Supplies of Pork				
United States	.05	.00	.10	.89
Western Canada	.07	.01	.15	.82
Eastern Canada	.06	.28	.05	.66
Stocks of Pork				
United States	.16	.02	.08	.90
Western Canada	.19	.03	.11	.86
Eastern Canada	.28	.01	.28	.71
Demand for Pork				
United States	.04	.01	.13	.86
Canada	.06	.39	.14	.47
Trade				
Canada's Imports [1/]	.89	.81	.06	.13
Canada's Exports [1/]	.70	.37	.00	.63

1/ These were calculated from exports net of the ham trade.

This result would lead the authors to accept their basic hypothesis concerning the competitive nature of the North American pork sector. Based on this acceptance, the model can be used to analyze the effects of possible policy or structural changes in the market.

6.2 Simulation of Policies

Spatial equilibrium models lend themselves to the analysis of a wide range of policy or structural market changes, especially where consideration is given to the effects of the changes in alternative regions. Examples of these types of analyses can be found in [56], [13], and [45]. A major problem with these models has arisen with their inability to consider the temporal effects of changes, but these have been considered in a wide range of single market recursive models [11], [23]. The ability of the model used in this study to incorporate both the temporal and spatial repercussions from a structural change allows a wide range of policies to be analysed. In previous studies [38], [39], this model has been used to analyze the effects of changes in tariff policies for pork traded between Canada and the U.S., and a wide range of stabilization policies that could be used in an attempt to stabilize hog production and prices in Canada.

The following sections present illustrations of the model's applications to two widely different types of policy. The objective of the first simulation is to measure the effectiveness or gains from expanding Canada's export market for pork products. The second policy evaluated is a stabilization scheme implemented by deficiency payments. The following sections describe the policies and the results to show the usefulness and the flexibility of the model.

6.2.1 Simulation 1
The Effectiveness of Export Promotion for Canadian Pork

As outlined in section 2.0, Canada has been a consistent exporter of heavy weight hams to the United States. The quantity of heavy hams exported has been relatively stable over the past decade. This stability has led producer marketing boards and governments to consider the possibility of attempting to increase exports of these and other high quality pork products through promotional campaigns. A 1969 study [8] has outlined the problems and advantages of expanding Canada's exports in this area and recommended promotional campaigns to achieve this objective. In this simulation it is assumed that the export of high quality pork products from Canada to the United States is increased from its actual level of approximately 10 million lbs. per quarter over the validation period to a constant level of 20 million lbs. per quarter or 80 million lbs. per year. This level of trade is constrained into the model in a similar manner to the original ham exports, so that the increased demand for pork in the United States is supplied from Eastern or Western Canada. The increase in exports from Canada would presumably decrease the excess supply of pork in Canada and increase the excess supply in the U.S. which could increase Canada's imports of lower quality pork products. The counteracting imports of other pork products could neutralize the effects of export expansion in the high quality pork trade. The simulation provides a measure of these effects over a long term period when Canada's basic comparative advantage and trade position changes relative to the U.S., and effectively provides a measure of the long term benefits and costs of export expansion.

The results from this simulation are reported in terms of changes in endogenous variables as well as changes in welfare variables. Endogenous variables include prices, supply, demand, and trade while the welfare measures used are producer and consumer surplus in each region. Producer and consumer welfare are calculated for each quarter of the simulation using the solution price and the supply and demand functions for each region. Since the supply level in each quarter is predetermined or completely inelastic, producer surplus is equivalent to producer gross revenue in any one quarter.[1/] These welfare measures allow evaluation of market changes in terms of their effects on producers as well as consumers and aid the use of cost-benefit analyses in evaluating the overall returns from a policy.

Tables 6.2 through 6.5 present the changes in prices, supplies and trade resulting from the constrained increase in high quality pork exports. The results of the ten year simulation from 1964-1972 have been summarized, on an annual basis, from the original quarterly data.

The results show that with a constrained increase in exports, there would have been an increase in the level of imports of other pork products into Canada. This flow however, would not have been equal and opposite to the increase in exports. Thus the net result would have been an increase in Canadian prices and a reduction in U.S. prices. The reason for this difference is that over the period (1963-1972) Canada was not always a net importer of pork. It is possible for the independent market prices in Canada and the U.S. to vary by less than the transfer cost between the two regions, which allows relative prices to change with no response in the level of trade. The transfer cost barrier and the fact that Canada is at times an exporter of pork to the U.S. allows an increase in average prices and hence producer surplus in Canada. Had Canada been on a permanent importing basis for lower quality pork products over the entire period there would not have been any benefit in terms of an increase in net trade. The increased producer surplus of $19.7 million and $29.1 million in the East and West respectively is greater than the loss of welfare for the consumers of $30.3 million in total. The reason that producer welfare or supply changes are greater in Western Canada than Eastern Canada is because of the relative sizes of the markets and supply response elasticities (see Table 5.2). Eastern Canada is a larger producer of pork than Western Canada and has a larger response in production when price changes.

In summary, it would appear that a policy to expand the trade in high quality hams to the United States would increase producer welfare through increased production or higher prices in Canada. It should, however, be noted that this conclusion is conditional on the fact that Canada is not always a net importer of other pork products. If this were the case then

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[1/] Consumer surplus is calculated for each region in each quarter using the following formula.

$$CS = \frac{1}{2}\frac{a_{ic}^2}{b_{ic}} - (a_{ic}\hat{P}_i - \frac{1}{2}b_{ic}\hat{P}_i^2)$$

where,

a_{ic} = the demand curve intercept in region i

b_{ic} = the demand curve price coefficient in region i

$\hat{P}_i$ = the equilibrium price in region i.

from equation (1) section 4.2.

TABLE 6.2: Validation Prices and the Change in Prices From Increased Ham Exports

$Can/100 Lb.

VALIDATION PRICES[1/]

	United States	Western Canada	Eastern Canada
1964	$24.63	$23.87	$26.78
1965	26.35	25.99	28.91
1966	31.86	31.51	34.43
1967	29.43	28.77	31.68
1968	26.98	26.31	29.22
1969	34.39	32.76	35.67
1970	33.95	30.56	33.47
1971	27.87	24.97	27.89
1972	34.29	33.87	36.78

Price Changes with Increased Ham Exports (VALIDATION-POLICY)

	United States	Western Canada	Eastern Canada
1964	$-0.05	$1.07	$0.36
1965	0.01	0.01	0.01
1966	-0.01	0.74	-0.015
1967	-0.04	0.27	0.27
1968	-0.02	0.30	0.30
1969	-0.10	1.03	1.03
1970	-0.05	0.34	0.34
1971	-0.01	0.25	0.25
1972	-0.02	0.06	0.057

1/ Validation prices are the results from the validation simulation which are assumed to represent the "non policy" or "normal" prices.

TABLE 6.3: Levels of Supply and Changes Caused by Increased Ham Exports

Mill. Lb. per Annum

VALIDATION SUPPLY

	United States	Western Canada	Eastern Canada
1964	11,676	338	584
1965	11,730	363	561
1966	11,277	330	554
1967	12,170	370	604
1968	13,020	417	652
1969	12,376	394	622
1970	12,806	484	644
1971	14,226	604	702
1972	13,518	512	643

Changes in Supply (VALIDATION-POLICY)

	United States	Western Canada	Eastern Canada
1964	0	1	2
1965	-9	3	3
1966	-3	1	2
1967	2	1	1
1968	-6	3	2
1969	-6	-1	4
1970	-6	2	7
1971	-22	4	16
1972	-5	0	5

TABLE 6.4: Validation Trade Levels and Changes
Caused by Increased Ham Exports

Mill. Lb. per Annum

VALIDATION RADE FLOWS

	Canada's Trade With United States		Other
	Imports	Exports	Ham Exports
1964	14.81	–	36
1965	18.21	–	36
1966	30.90	–	36
1967	21.07	–	37.47
1968	12.06	–	38.59
1969	2.88	1.32	38.61
1970	–	40.95	39.92
1971	–	57.49	43.72
1972	32.81	–	37.28

Changes from Validation (VALIDATION-POLICY)

	Imports	Exports	Ham Exports
1964	+34.59		+44
1965	+38.38		+44
1966	+37.29		+44
1967	+36.15		+42.53
1968	+32.87		+41.41
1969	+16.75	-1.32	+41.39
1970		-26.21	+40.08
1971	+2.70	-14.15	+36.28
1972	+35.83		+42.72

TABLE 6.5: Welfare Changes with Increased Exports of High Quality Pork Products

Difference From Validation Mill. Dollars Canadian Over the 10 Years

	United States	Western Canada	Eastern Canada
Producer Surplus			
	-54	+19.7	+29.1
Consumer Surplus			
	1/	-11.6	-18.7

1/ The computed value is not comparable with the data from other experiments as the calculated consumer surplus does not include the surplus from the imported hams.

the only benefits to producers would be due to the differences in the relative prices of hams in Canada and the U.S. Unfortunately, the model used does not allow for the fact that the hams are sold at premium prices. It assumes that the ham sold has the same value and quality as the imports. Adjustments for this discrepancy would tend to bias the benefits of the program upwards by the value of the more expensive exports relative to the lower quality imports. The size of the increase in revenue generated over the 10 year period only average $4.8 million per year which is small in relation to the average revenue per year for Canadian producers. The size of these benefits from trade means that increased producer revenues will rely largely on how much more the cut of meat can be sold for in the U.S. than in Canada.

Results of this simple policy analysis show the value of the model in evaluating trade policies where Canada's trade position relative to the United States is changing over time. A simple static analysis of a similar problem would necessitate the use of assumptions about Canada's relative position in the North American market. Either Canada would be on an importing or exporting basis, both of which would have vastly different results. The model used here, has allowed an evaluation over time where these conditions represent the recent history of the market.

A second major advantage of a simulation such as that described above is that it provides long term information on the welfare effects of marketing programs, in this case export development or promotion, that may not normally be available in analyzing such programs. More intensive analysis of such programs could provide information on the costs and benefits of such programs that could be extremely useful to governments and producer groups alike.

The example policy analysis discussed above relies on changing the constraints in the basic quadratic programming model to increase the trade flow between the regions in the model. The following section presents an example policy analysis which relies on modifying the recursive part of the overall model to represent a government stabilization program.

6.2.2 Simulation 2
A Government Deficiency Payment Program

Stabilization programs have been a part of Canadian agriculture since 1958 when the Agricultural Stabilization Act was passed to support producer prices for a number of commodities at 80 per cent of the previous ten years moving average price. The policy however, has not been effective due to the low level of support. There has been discussion, of a modified program that would be more effective, and other research by the authors [39] has outlined a number of alternative programs that could be used in stabilizing the prices and production of pork in Canada. The policy discussed in this paper is a simple appropriation and deficiency payment scheme with a stabilization fund. The typical structure of such a policy is that the stabilization fund contributes to producers' income in periods of low prices and producers contribute to the stabilization fund in periods of higher prices.

The policy presented here is a more practical attempt to attain such a scheme. It is assumed that over the original validation period, government supports the hog price in each region at the twenty quarter or five year moving average price and that producer contributions are made to the government when the hog price in a region exceeds 110 percent of this moving average price. The policy is assumed to affect only producer prices and the market is allowed to clear in the normal manner. With commodities such as pork, where long term storage is difficult and expensive, short term market clearing is essential in such a policy.

It can be seen that in any one quarter the effects of the policy will be only to change producers' revenue by the amount of the government payment or the amount of their appropriation. There are no additional short run effects since the market is allowed to clear in the normal manner. Long run effects however, are caused by the assumption that producers change their production in response to the policy price rather than the market clearing price. This response mechanism means that over the longer run supplies are stabilized and consumer welfare is influenced.

This scheme is easily included in the recursive spatial equilibrium model by comparing the resulting market price in each quarter with the moving average price, from this a producer response price is derived which may be different from the market price by the amount of payment, and the response prices are used to calculate the level of production in subsequent quarters. From this discussion it is seen that the policy is imposed on the model simply by influencing prices to which producers respond.[1/] The policy is

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1/ The theory of risk-income preference would presume that producers would also respond to a lower level of variability in their prices. This hypothesis is not included in this simulation but simulations in [39] have made assumptions of a positive change in the supply intercepts resulting from reduced price variability.

applied with the same degree of support in Eastern and Western Canada, and no similar scheme is included in the United States market. This makes it possible to determine how effective such a stabilization policy would be for Canada which makes up only a relatively small proportion of the total North American market.

Further economic measures can be derived from this simulation in terms of the cost of the policy to the producers or the government in any quarter. These economic measures provide an indication of the short run cash flows that could be involved in such a policy as well as the ability of the policy to be self financing in the longer run.

The results are presented in the form of annual summaries in Tables 6.6 - 6.10. Table 6.6 and 6.7 show the effects that the stabilization policy would have had on the market clearing prices and supplies in each region over this period. These prices represent the annual average prices and changes in prices. The effects were higher in some quarters than is evident from the annual summary but in general it can be seen that the effects of the policy on market clearing prices are negligible even though in later quarters the supply from Canada was relatively stable. These small changes merely show the importance of the United States in determining the market prices in Canada.

Annual producer prices and supplies are stabilized as is seen in Figures 6.2 through 6.5, and the substantial producer and government payments in some periods do not appear to affect market prices significantly in the United States or Canada. The stabilization of supplies and producer prices would mean greater stability of gross revenue to producers but it should be noted that this does not necessarily imply more stable net incomes since the costs of inputs are still variable. The more stable level of prices would not have caused the same degree of supply stability in Western Canada as Eastern Canada because of the relatively low price elasticity of supply in the West. Feed grain stocks are the major determinants of the level of hog supply in that region, hence the price stabilization succeeds in stabilizing western prices but not necessarily the supply or gross revenue. This relationship is seen in Figure 6.6 and 6.7 which show the stabilized and the validation gross producer revenue in the West and the East.

Net trade flows would not appear to change significantly under this stabilization policy. In some quarters the level of imports would have increased and in others the imports would have decreased which could be expected from a more stable level of supply in Canada. Rather than following the traditional North American hog cycle, the more stable supply would tend to increase the level of exports when United States production is low and increase the imports when U.S. production is high. As can be seen from Table 6.8 the net change in pork trade between Canada and the United States over the whole ten year period is very small but in some periods there are large changes. Although not large in relation to the production level in North America, they are large in relation to the validation trade levels. It is these changes in trade flows which would obviously determine the effect of a Canadian price stabilization policy on the U.S. hog market. The trade pattern that has been established under this hypothetical stabilization

TABLE 6.6: Validation Prices and the Change in Market Prices From the Stabilization Policy
$ Canadian per 100 Lb. Pork[1/]

	VALIDATION PRICES		
	United States	Western Canada	Eastern Canada
1964	$24.63	$23.87	$26.78
1965	26.35	25.99	28.91
1966	31.87	31.52	34.43
1967	29.43	28.77	31.68
1968	26.98	26.31	29.22
1969	34.39	32.76	35.67
1970	33.95	30.56	33.47
1971	27.87	24.98	27.88
1972	34.29	33.87	36.78

	Changes from Validation (VALIDATION-POLICY)		
	United States	Western Canada	Eastern Canada
1964	$ 0	$ 0	$ 0
1965	-.03	-.20	-.16
1966	-.04	-.06	-.07
1967	+.10	+.35	+.35
1968	+.16	+.48	+.48
1969	-.16	-.34	-.34
1970	-.01	-.01	-.01
1971	+.22	+.34	+.34
1972	-.28	-.87	-.87

1/ These results are summarized on an annual basis from the quarterly output of the simulation model.

TABLE 6.7: Supplies and Changes in Supplies Resulting From the Stabilization Prices

Mill. Lbs. of Pork Per Annum

	VALIDATION SUPPLY		
	United States	Western Canada	Eastern Canada
1964	11,676	338	584
1965	11,730	363	561
1966	11,277	330	554
1967	12,170	370	604
1968	13,020	417	652
1969	12,376	394	622
1970	12,806	484	644
1971	14,226	604	702
1972	13,518	512	643

	Changes from Validation (VALIDATION-POLICY)		
	United States	Western Canada	Eastern Canada
1964	0	+.35	+1.40
1965	0	+1.80	8.80
1966	-1	+2.20	7.40
1967	-5	-3.00	-13.11
1968	+1	-2.50	-26.80
1969	+31	+2.20	+4.40
1970	+2	+.66	-.30
1971	-25	-2.20	-13.50
1972	+26	+11.50	+36.20

TABLE 6.8: Trade Levels and Changes in Trade Resulting From the Stabilization Policy

Mill. Lb. Pork Per Annum

VALIDATION
Canada's Trade With United States

	Imports	Exports	Ham Exports
1964	14.81	-	36
1965	18.21	-	36
1966	30.90	-	36
1967	21.07	-	37.47
1968	12.06	-	38.59
1969	2.88	1.32	38.61
1970	-	40.95	39.92
1971	-	57.49	43.72
1972	32.81	-	37.28

VALIDATION-POLICY
Change in Trade From the Stabilization Policy

	Imports	Exports
1964	-.67	-
1965	-4.11	-
1966	-7.87	-
1967	+10.64	-
1968	+25.00	-
1969	+1.88	+1.71
1970	-	-2.22
1971	-	-12.15
1972	-27.77	-
Net Change	-2.90	-12.66

FIGURE 6.2: SUPPLY IN WESTERN CANADA

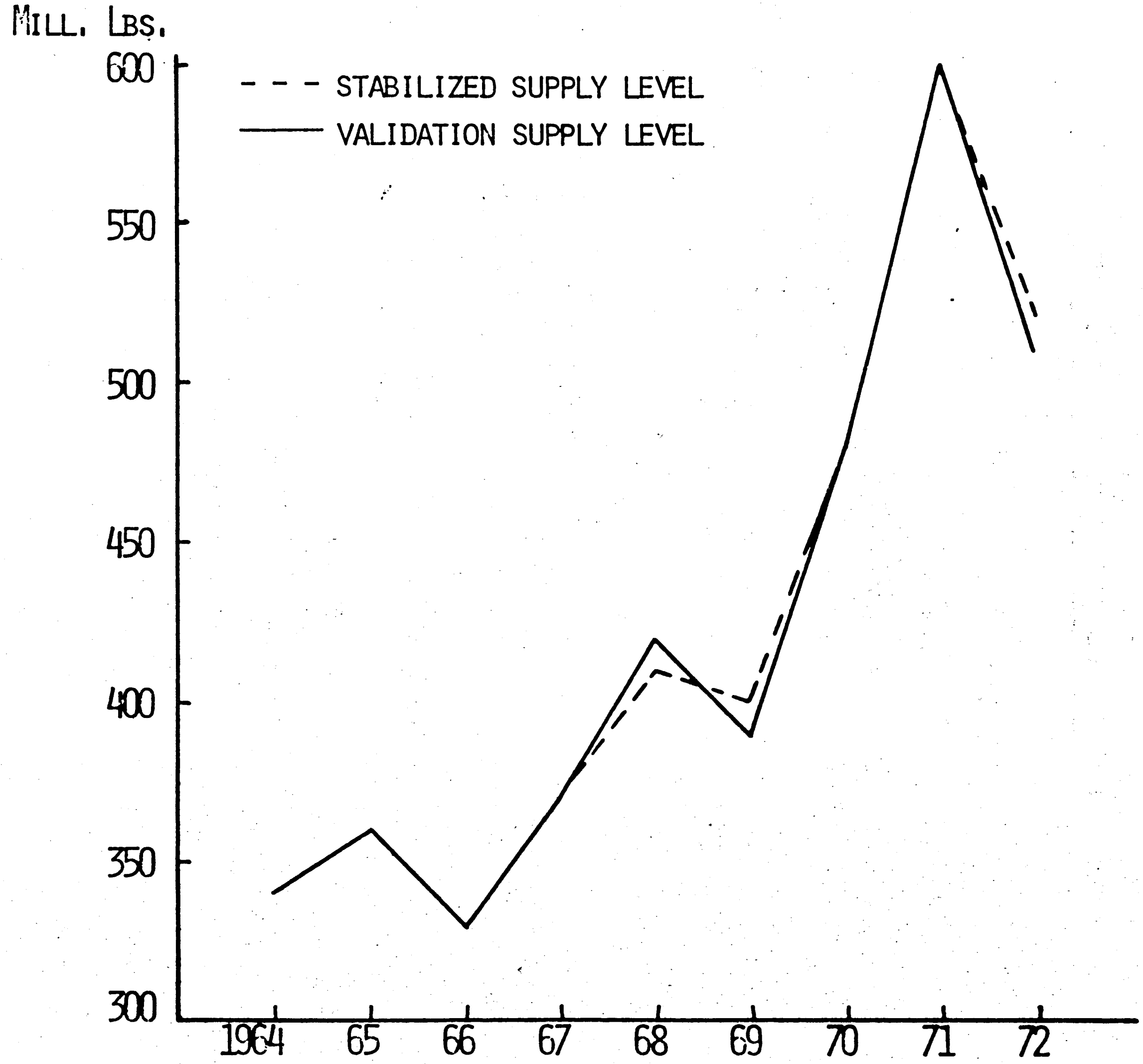


FIGURE 6.3: SUPPLY IN EASTERN CANADA

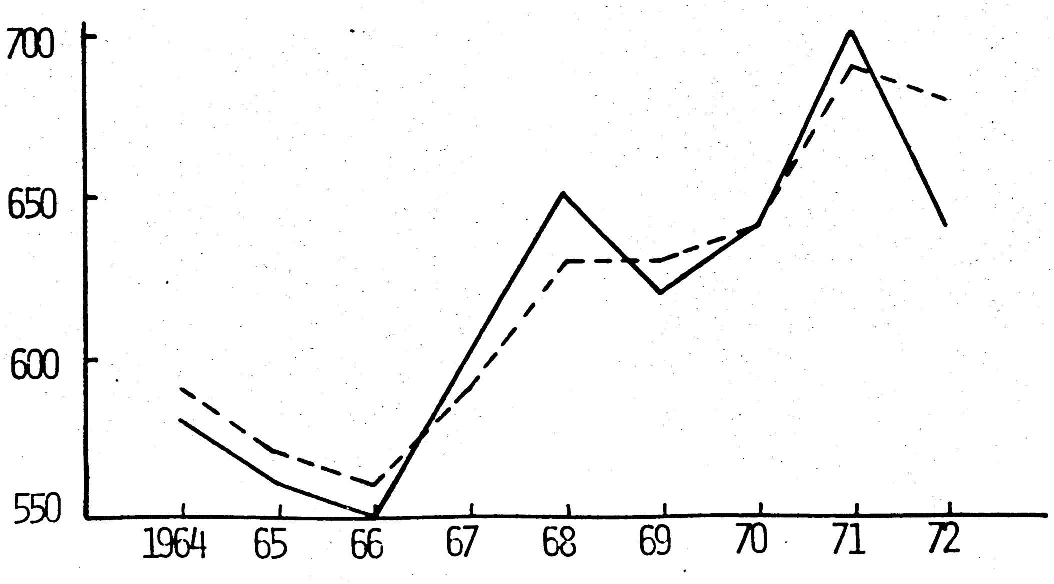


FIGURE 6.4: PRICE IN WESTERN CANADA

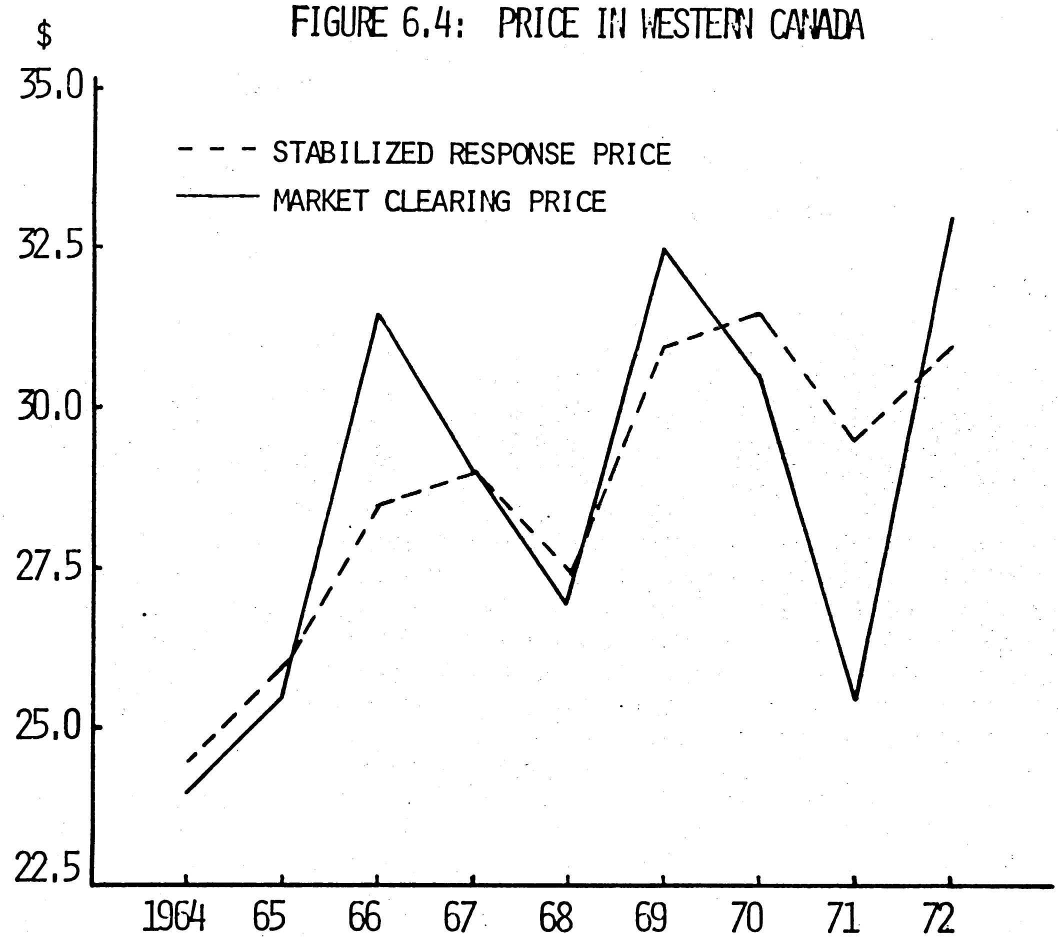


FIGURE 6.5: PRICE IN EASTERN CANADA

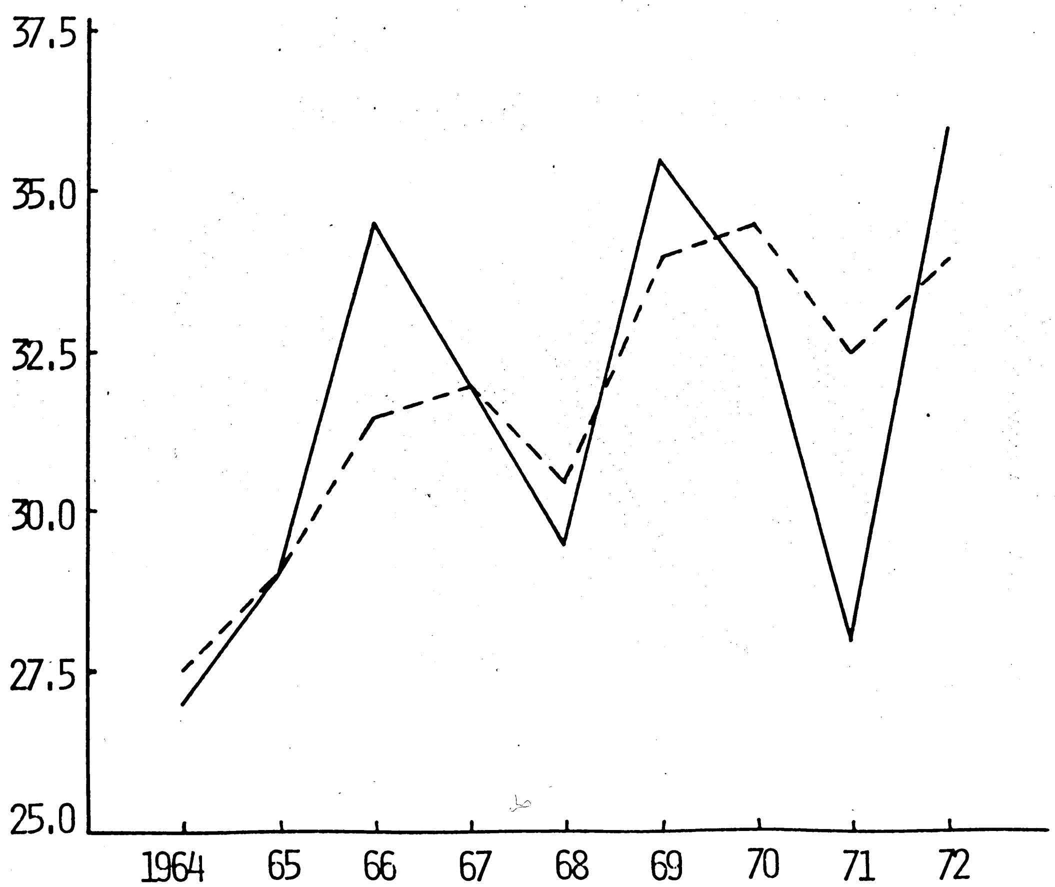


FIGURE 6.6: STABILIZED AND VALIDATION LEVEL OF GROSS FARM INCOME IN WESTERN CANADA

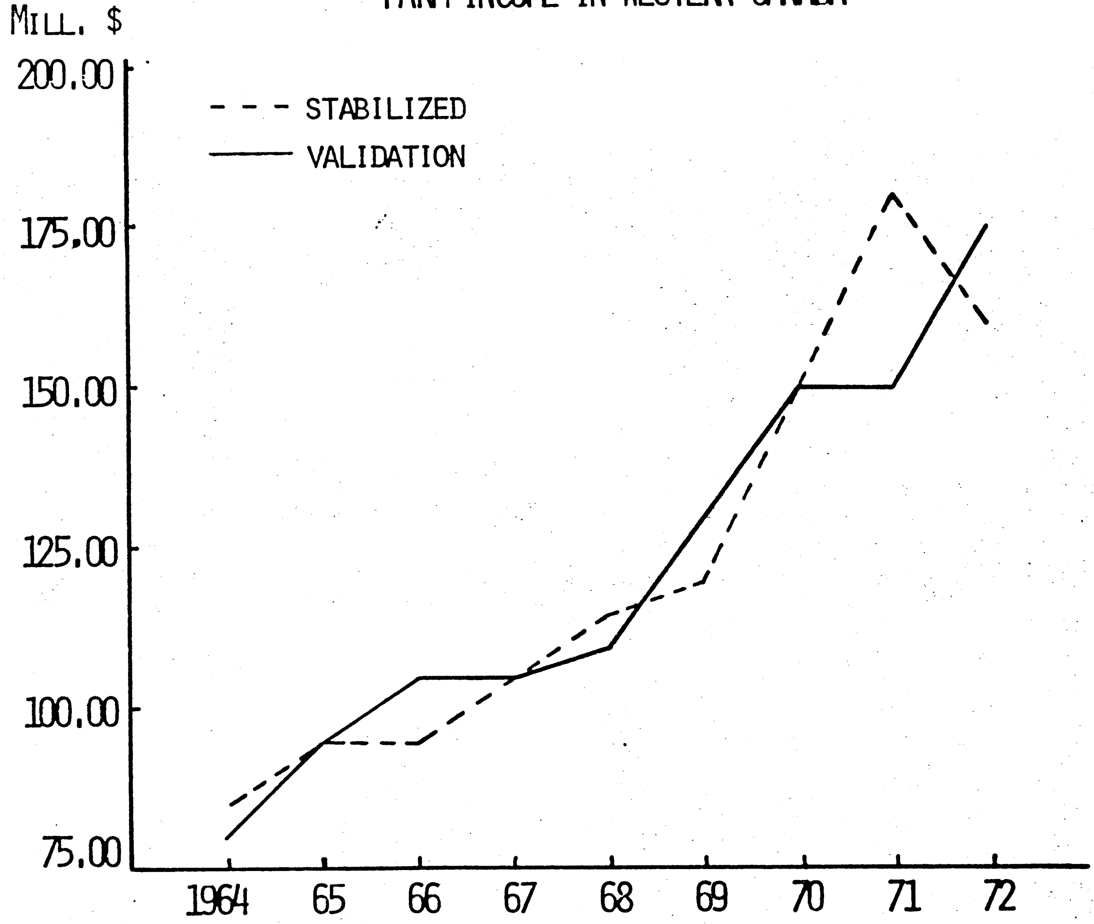
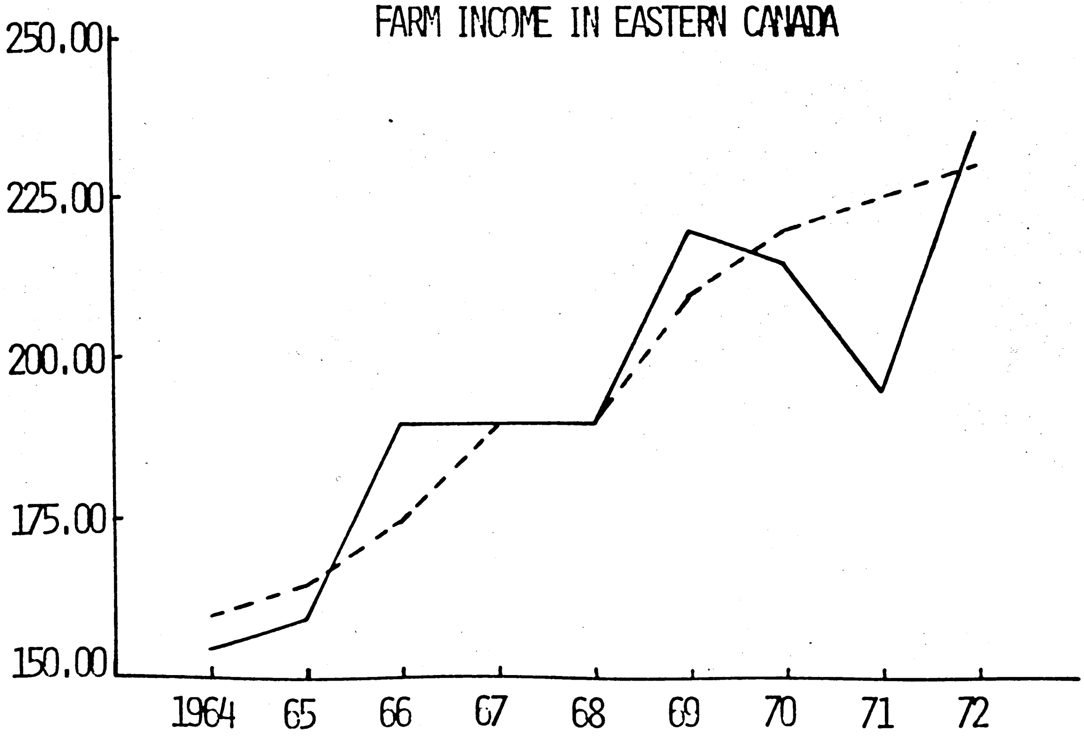


FIGURE 6.7: STABILIZED AND VALIDATION LEVEL OF GROSS FARM INCOME IN EASTERN CANADA



policy has actually tended to stabilize prices in the U.S. market. This can be seen in Table 6.6 where U.S. prices have been increased slightly in low price periods and reduced in high price periods.

Measures of the changes in consumer and producer welfare over the period are presented in Table 6.9 Table 6.10 shows the annual cost of the program to producers and the government and also the total cost over the ten year period. The calculated producer revenue or producer welfare is net of the revenue which would be contributed to the stabilization fund. Although the welfare gains over the period are seen to be small, Table 6.10 shows that the costs of financing the stabilization program are evenly shared between producers and the government. This analysis does not attempt to consider whether such a policy would be politically acceptable to producers or government. The analysis merely outlines the benefits, costs, and effects had this policy been instituted over the simulation period.

TABLE 6.9: Welfare Changes Resulting From the Imposition of the Stabilization Policy

From 2nd Quarter 1963 to 2nd Quarter 1973

Difference From Validation Measured in Mill. Dollars Canadian Over the 10 Year Period

	United States	Western Canada	Eastern Canada
Producer Surplus	+1.67	+.89	+2.51
Consumer Surplus	+4.01	+7.29	+2.82

In summary, this policy analysis has shown that a simple price stabilization, deficiency payment and appropriation scheme could be used satisfactorily in Canada. Such a policy would result in small over-all increases in producer and consumer welfare, but would stabilize the level of gross producer revenue over this period. Gross revenue would be more stable in Eastern Canada than in the west due to the lower price elasticity of supply in the latter region and it should be noted that a stable gross revenue implies nothing about the stability of net revenue which finally determines producers income. The analysis also showed that over this simulation period the policy would have had beneficial effects on the United States hog industry, in that prices were stabilized and consumer and producer welfare was increased.

TABLE 6.10: Average Annual Appropriation or Deficiency Payment in Eastern and Western Canada

Average Annual Payment per 100 Lbs. of Pork

	Eastern Canada		Western Canada	
	Producer	Government	Producer	Government
1964	–	.54	–	.67
1965	–	.15	–	.34
1966	3.02	–	3.06	–
1967	.19	–	.07	–
1968	–	.67	–	.79
1969	1.45	–	1.67	–
1970	–	.94	–	.87
1971	–	4.31	–	4.31
1972	1.82	–	1.99	–

Total Annual Payments From Both Groups - Mill. Dollars

	Eastern Canada		Western Canada	
	Producer	Government	Producer	Government
1964	0	3.171	0	2.405
1965	.204	1.622	.150	1.546
1966	16.693	0	9.542	0
1967	2.562	1.565	1.419	1.310
1968	0	4.138	0	3.453
1969	8.847	0	6.232	0
1970	.296	6.733	.550	5.424
1971	0	29.55	0	26.332
1972	14.401	2.24	11.023	1.880
Total Cost	43.00	49.02	28.91	42.35

7.0 SUMMARY AND CONCLUSIONS

The initial objectives of this study were to: first, describe and analyze major spatial and temporal factors which affect the North American pork sector, second to construct from these relationships a model of the sector which can be used to explain changes in production, prices, consumption, and trade in pork products for Eastern and Western Canada and the U.S., third, to use the model to analyze spatial and temporal repercussions on each of these regions arising from policy changes within Canada.

In analyzing the North American pork sector a regional recursive model was developed. The model utilizes behavioral estimates of supply, demand, and stock functions for each of three regions, Eastern and Western Canada, and the United States. Behavioral equations for these relationships were derived and it was shown that the independent variables explained the greater part of the variation in quarterly production, consumption, and storage levels for the period 1961 to 1973.

The estimated supply relationships reflected the basic differences in production patterns between the regions. Results showed that hog production in Eastern Canada was largely determined by the levels of hog prices and previous production. Production was not significantly influenced by the level of feed costs or the profitability of beef production which would suggest that Eastern hog producers are more specialized than those in other regions. The Western Canadian results indicate that the major determinant of hog supply in that region is the state of the grain economy and that hog supply was not significantly affected by prices over this period. However the level of profitability in beef production was found to be important in determining hog supply in Western Canada. These results suggest that Western livestock production is determined by the state of the feed grain economy as reflected in the level of on-farm stocks of feed grains. Producers also consider the relative profitability of alternative livestock production activities in determining hog supply in Western Canada. Results for the United States suggest that previous hog prices were the major determinant of supply in that region and that there was some degree of substitution between beef and hog production. The estimated supply relationships show the basic differences in production characteristics between the three regions and suggests the importance of treating them individually in such a model.

The demand for consumption equations estimated for Canada and the United States show that the direct price and income elasticities are similar in each region. Both regions had similar patterns of seasonal consumption of pork. These results suggest that there are no major differences in the demand relationships between Canada and the U.S.

The demand for stocks relationships which were estimated for each region of the model conform with the theoretical model of inventory accumulation. The theoretical model states that the demand for closing stocks in any quarter is made up of transaction or "pipe-line" demand, and a speculative demand for stocks. The equations used expected supplies and expected prices to represent these respective types of demand. As well, seasonal dummy variables were included to account for the known seasonality in supply and demand. The results show that the holders of pork stocks behave in a manner such that prices are smoothed over time. The dummy variables show that stocks change within a year so that the seasonality in production and consumption is smoothed by the action of stockholders. Their actions further smooth prices by increasing levels of stocks in low price periods and decreasing stocks in high price periods.

In general the estimated behavioral relationships appear to have captured the important structural components of the industry in each region. The spatial model was used to link these regional structures into a North American sector model.

The spatial equilibrium model was solved using a quadratic programming routine which provided competitive equilibrium prices, stocks, consumption, and trade in successive quarters. Inherent in such a model is the basic assumption that the market behaves in a competitive manner between regions. The validation procedure in section 6.0 showed that such an assumption is indeed valid. The model appears to provide a reasonable simulation of market behavior, based on Theil inequality coefficients and the model's ability to indicate turning points in the major endogenous variables over the forty quarter period from 1963 to 1973.

The ability of the model to incorporate intertemporal considerations utilizing the recursive nature of the market, and the supply and demand for stocks considerably enhances the usefulness of the model in evaluating the effects of policy or structural stocks on the market. The inclusion of storage activities in the model allows consideration of the importance of stockholding in spatial models. This has previously been considered important but has not been included directly in the models [4].

Two policy simulations were presented in the study which demonstrate the usefulness of the model in evaluating alternative policies or structural changes. The model allows policies to be evaluated in terms of their effects on different regions and over time. Measures of the quarterly changes in prices, stocks, supplies, demands, and trade can be derived from policy simulations as well as measures of producer and consumer surplus and costs of a policy to the government and producers. The example simulations presented in this study are only two of the many possible alternatives, and no mention has been made of the possibility of using the model as a general prediction model for the North American pork sector. The wide range of potential uses for such a model and its ability to account for the major structural components of the industry should make the model a valuable analytical tool for policymaking and planning within the pork sector.

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