A RECURSIVE SPATIAL ANALYSIS OF THE NORTH AMERICAN PORK SECTOR WITH SPECIAL REFERENCE TO CANADIAN POLICY IMPLICATIONS [1/]

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1.0 Introduction

Several important issues are presently facing Canada's livestock sector. Among these are: the initiation, in a few months, of a new round of international trade negotiations; imminent changes in Canadian domestic policy regarding regional transfer of feedgrains and livestock products; and concern with marketing efficiency caused by rising meat prices.

There has been no framework available in which major spatial and temporal characteristics of the Canadian livestock sector are linked in a manner which would allow an evaluation of policy or structural changes on the general level of prices, regional production, and trade. Analyses of this nature have been suggested or implied by several researchers in recent years. For example, King [16], in arguing for economic integration of U.S. and Canadian agriculture, has made a strong case for building spatial models to analyze the regional impacts of policy changes within the context of the total North American market. Ghosh [12] and Marshall and Huff [19] have recently proposed comparable studies.

The purpose of this paper is to report on a study undertaken to build a normative spatial equilibrium model of the North American pork sector which emphasises the Canadian subsector. Objectives of the paper are as follows.

1. Structural characteristics of the sector are discussed and a working hypothesis is developed for market behaviour.
2. A normative structural model of the sector based on this hypothesis is specified and validated.
3. Several potential applications of the model are suggested and the results of a policy experiment are presented.

2.0 Structural Characteristics of the Pork Sector and Their Implications

In attempting to model the pork sector, several important spatial and temporal linkages affecting equilibrium prices and production levels must be considered. The following discussion briefly characterizes these linkages and indicates the nature of their interactions to arrive at a price equilibrium.

2.1 Canadian and U.S. Production and Trade Linkages

The Canadian market is closely linked to the U.S. through both imports and exports of pork products. Table 1 contains data which indicates the total commercial production and trade of the U.S. and Canada during the past decade. These data indicate that over most of this period, the U.S. was Canada's major trading partner. On the export side, Canadian exports to the U.S. have remained relatively constant. Between 70 and 80 percent of Canada's total exports to the U.S. is made up of high quality fresh and frozen heavy hams which have a specialized market in the Eastern U.S. This trade is largely unresponsive to price changes since the market is dependent on a high degree of quality differentiation.[1/] Until 1970, exports of Canadian pork to countries other than the U.S. made up only about ten percent of total Canadian exports. This has changed somewhat since 1970 because of the entry of Japan into the Canadian market.

[1/] This element of the export market has been analyzed in detail in [14].

Table 1

Annual Pork Production and Trade - Canada and U.S. 1961-1971

Year	Production (M lbs)		Canada's Trade (M lbs)			
	Canada	U.S.	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	35	35
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

Sources: Livestock and Meat Statistics, U.S.D.A.

Livestock and Animal Products Statistics, A.P.B.S.

Table 1 indicates that imports of U.S. pork into Canada have been much more volatile than Canadian exports to the U.S. The Federal Task Force on Agriculture [10] and the USDA [9] have shown that this volatility results largely from short run price differences between Canada and the U.S.[2/] This indicates that the U.S. and Canadian markets are directly linked through trade and that arbitrage takes place when price differentials exceed transfer costs and tariff charges.

2.2 Linkages and Structural Characteristics Within the Canadian Market

Although no data exist on within Canada trade flows, it can be inferred from spatial price differentials that trade between Eastern and Western Canadian markets[3/] is carried out under competitive conditions. Over the past two decades quarterly wholesale prices in the major market centres of Toronto and Calgary have been characterized by a nearly constant price differential [4]. This implies rapid adjustment to price differences between the two markets.

There are major structural differences in the nature of supply response in the two regions. These are mainly because of Canadian Wheat Board operations relating to Western produced feedgrains. Kerr [15] has shown that because of these operations, the two major regions have very different structural characteristics. Specifically, while both Eastern and Western Canadian production responds to pork price changes, in the

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2/ As was noted above, the export market was less strongly related to relative prices because of the specialized U.S. market for Canadian pork. However, since 1968, due to a relatively faster growth in Canadian pork production, quarterly Canadian exports to the U.S. have shown some response to the same price differential.

3/ Eastern Canada is made up of the Provinces of Ontario, Quebec and the Atlantic Provinces. Western Canada is made up of the Prairie Provinces and British Columbia.

Prairie Provinces, pork production is also a function of the state of the grain economy as exemplified by stocks of Western feedgrains. Eastern Canadian production is more dependent on such factors as alternative production opportunities and feed grain prices. Most studies of the U.S. market (e.g. Crom [6] and Harlow [13]) do not suggest that similar structural differences exist there.

2.3 Seasonal and Cyclical Characteristics of the Sector

Seasonal variation exists in both supply and consumption of pork. Seasonality is probably most important on the supply side since producers have traditionally adjusted farrowings to avoid adverse winter weather conditions. While this factor is becoming less important over time because of technological improvements in farrowing facilities, most studies of the U.S. pork market, including those cited above by Harlow [13] and Crom [6], have included seasonal variables in behavioural equations with statistical success. In Canada, studies by Marshall [17], Pando [21] and C.D.A. [5] have shown a definite seasonality in pork supply.

Seasonality in consumption exists because of shifts in consumer preferences between seasons. The study by Crom indicated some seasonality exists in the U.S. market. Preliminary analysis of demand relationships for the present study [29] indicates that significant seasonality exists in both the Canadian and U.S. markets.

Because of this seasonality, cold storage stocks of pork carcasses and cuts play an important role in smoothing seasonal price fluctuations by rationing product over time. In periods when production is high, we would expect inventories to build up since wholesalers expect that in forthcoming periods production will be low and prices will be higher. Given these expectations, the interaction of changes in stocks with changes in production and demand will cause a leveling off of prices within a particular year. In peak production periods, a build up of stocks will bid prices higher than they would be without stock holdings. In low production periods, stocks will be depleted to force prices lower. This implies that the demand by the marketing system for cold storage stocks is closely related to both pork prices and traders' knowledge of the seasonal production pattern.

Added to the seasonality of the hog market is its well known cyclical property caused by lagged producer response to price changes. The hog cycle has been investigated in depth in the U.S. and Marshall [18] has shown that the Canadian cycle has been very closely tied to that of the U.S. except when extreme surpluses or deficits of Western Canadian feedgrains occur.

2.4 Market Equilibrium in a Single Period and Successive Periods

Given the structural characteristics described in the above sections, we may establish a working hypothesis that the pork sector behaves as a competitive spatial system which arrives at a market equilibrium through the process described below.

Existence of a lagged price relationship causes pork production in a given region and time period to be predetermined. Likewise, we may consider that initial storage stocks in a given region and time period are also predetermined.4/ Equilibrium prices, consumption and trade flows in a given period are therefore jointly determined by interaction of the

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4/ Initial stocks in t = initial stocks in t-1 + additions to stocks in t-1 - reductions in stocks in t-1.

predetermined production and storage stocks with demands for consumption and demands for stocks during the period and by transfer costs between regions. This describes the same system of equilibrating forces as was presented by Samuelson [22] in analysing a simple spatial equilibrium system except that the effects of stocks in rationing the product over time are included. 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.

Over successive periods market equilibrium is linked recursively for two reasons. First, since levels of stocks can be considered endogenous to the system, prices, consumption and trade in period t+1 will be partly a function of prices, consumption and trade in period t. Second there is a recursive relationship because of the lagged price response. That is, assuming the relevant price lag is five (quarterly) periods, then market equilibrium in period t+1 is related not only to that of period t, but also to the prices observed by producers in t-5.

3.0 The Model

Section 2.0 indicates that a complex set of factors and interrelationships are involved in bringing about a given quarterly market situation in the three major regions. The model specified incorporates these into a quadratic price equilibrium format. In Figure 1, a schematic representation of the model is presented. The figure indicates all exogenous and endogenous variables which interact to determine the three region equilibrium. The upper segment of Figure 1 indicates the exogenous variables included in the analysis of supply, demand, and demand for stocks. These variables form the exogenous part of the quadratic programming model. Quarterly demand for consumption and stocks equations are incorporated directly in the model while the supply equations are used to estimate predetermined quarterly production levels. Initial storage supply is also predetermined. The spatial equilibrium model is specified as a price formulation model, (see [24, chp. 8]). The model endogenously determines optimum regional prices for a given period in its primal formulation and the resulting regional consumption, trade and storage levels are obtained from its dual. The model is run recursively for successive quarters by specifying structural quarterly demand and demand for stock equations from their exogenous variable parameters and feeding back storage stocks into the objective function for each successive quarter. A second recursive element appears in the feed back of generated prices into the five quarter lagged supply functions.

3.1 Mathematical Formulation

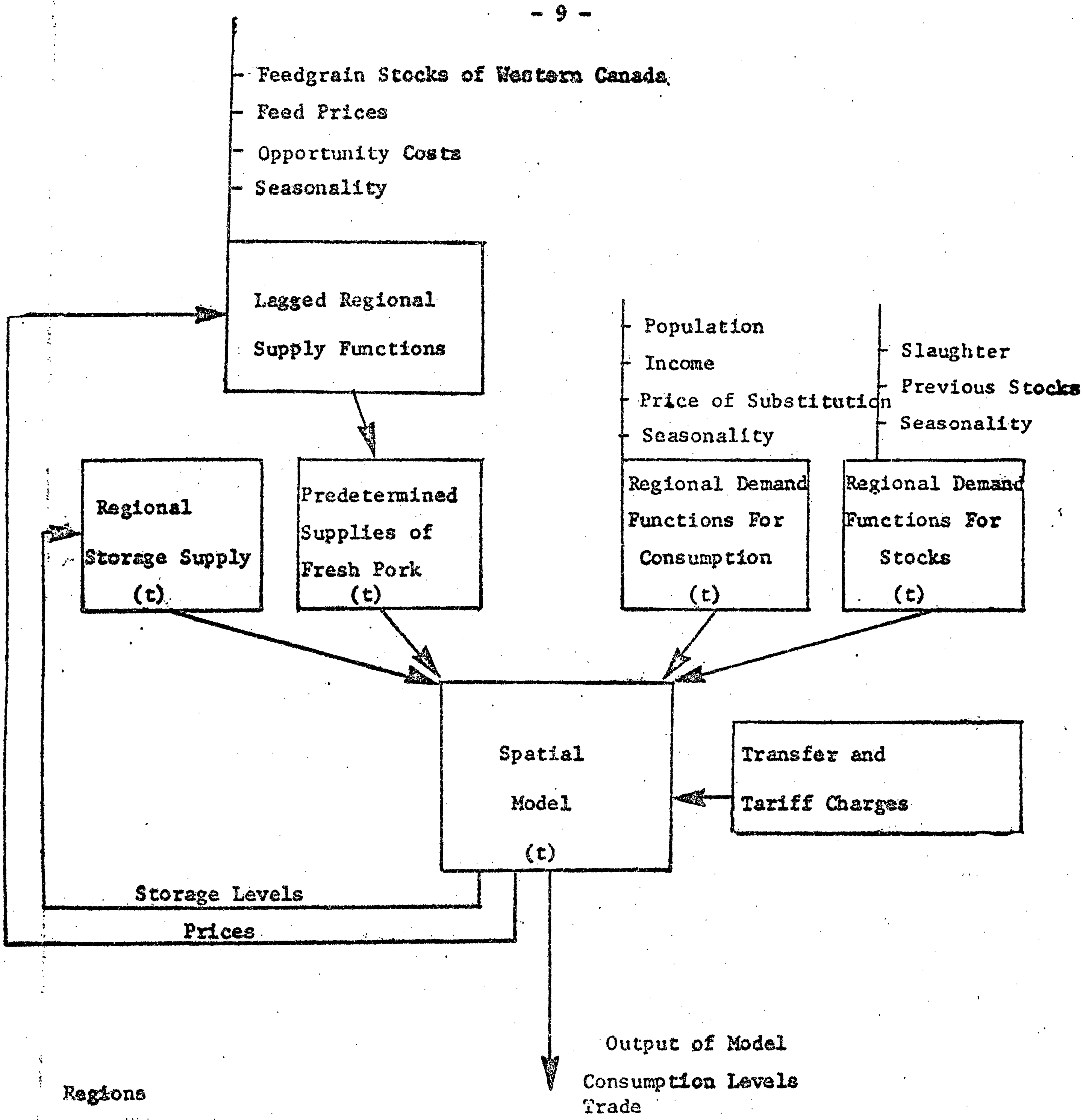
Mathematically the model is formulated as a recursive quadratic programming model which determines multiregion spatial equilibrium solutions over consecutive time periods.

Considering only one quarterly time period, we can define the following structural equations and identities which are included in the model.

(3.1.1) A demand function for pork consumption in each region,

$$y_i^c = a_i^c - b_i^c p_i \qquad (1)$$

where,



Regions

1. Whole U.S.
2. Eastern Canada
3. Western Canada

Figure 1.—Schematic Representation of the Model

y_i^c = quantity of pork consumed in region i, (i=1,...,n),

a_i^c = intercept for pork consumption function in region i,

b_i^c = price response coefficient for consumption in region i,

and p_i = demand price in region i.

Over all regions, the consumption functions can be generalized in matrix notation to,[5/]

$$Y^c = A^c - B^c P_y \ . \qquad (2)$$

(3.1.2) A demand function for stocks of pork in each region

$$y_i^s = a_i^s - b_i^s p_i , \qquad (3)$$

where,

y_i^s = closing level of stocks in region i,

a_i^s = intercept term for stock function in region i,

b_i^s = response of stock demand to changes in pork prices in region i,

p_i = demand price for pork in region i.

As with equation (1), we can generalize (3) in matrix form to

$$Y^s = A^s - B^s P_y \ . \qquad (4)$$

5/ To include consideration of the relatively constant quantity of high quality hams sold by Canada to the Eastern U.S., an extra "dummy" region is also included in the model. This region merely has an associated intercept term equal to actual shipments for model validation or estimated from a trend line for prediction. Inclusion of this element allows the model to fulfill the specialized demand and, at the same time, respond to price changes with possible trade between any pair of regions.

(3.1.3) A fixed level of production in each region defined as x_i^f. This is predetermined from estimated behavioural supply functions for each region. For n regions we define a vector X^f, an n x 1 vector of the predetermined regional supply quantities. That is,

$$X^f = (x_1^f, x_2^f, \ldots, x_n^f)' . \tag{5}$$

(3.1.4) A fixed level of initial stocks in each region, x_i^s, which is equal to closing stocks from the previous period. For n regions we define the vector X_1^s, an n x 1 vector containing initial stocks. That is,

$$X^s = (x_1^s, x_2^s, \ldots x_n^s)' . \tag{6}$$

(3.1.5) A $4n^2$ x 1 vector of per unit transfer costs denoted as,

$$T = (C, D, E, F)' \tag{7}$$

where,

$C = (c_{11}, c_{12}, \ldots c_{1n}, c_{21}, \ldots c_{nn})'$, an n^2 x 1 vector of transfer costs for shipping fresh pork to the ith consuming region from the jth producing region,

$D = (d_{11}, d_{12}, \ldots d_{1n}, d_{21}, \ldots d_{nn})'$, an n^2 x 1 vector of transfer costs for shipping fresh pork from the ith consuming region to storage in the jth region,

$E = (e_{11}, e_{12}, \ldots e_{1n}, e_{21}, \ldots e_{nn})'$, an n^2 x 1 vector of transfer cost for shipping fresh pork for consumption in the ith consuming region from storage in the jth region,

$F = (f_{11}, f_{12}, \ldots f_{1n}, f_{21}, \ldots f_{nn})'$, an n^2 x 1 vector of transfer costs for shipping pork for storage to the ith region from storage in the jth region.

(3.1.6) The Single Period Model

Using equations (2), (4), (5), (6), and (7) an optimizing model for one period is constructed based on the fixed supply spatial price equilibrium model developed by Takayama and Judge [24, chp. 8]. Takayama and Judge call the objective function of their model net indirect welfare in the price formulation. They have shown in an earlier article [25] that this formulation results in a welfare function which is exactly equivalent to the net summed areas under excess regional demand and supply functions at equilibrium. After integration, the following primal quadratic programming problem results,[6/]

$$\text{Maximise N.I.W.} = AP_y - \tfrac{1}{2}P_y'BP_y - XP_x \tag{8}$$

subject to,

$$G'P \leq T \tag{9}$$

$$P, X \geq 0 \tag{10}$$

where,

A = an n x 1 vector of regional demand intercepts,

B = an n x n matrix of regional demand price response coefficients,

X = an n x 1 vector of predetermined regional supply quantities,

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6/ In the Takayama and Judge context, the problem is finally specified in a primal-dual formulation and P_y and P_x are specified with slack activities (i.e. $P_y = \rho_y - w$, $P_x = \rho_x + v$) to insure quantities in the dual which are non-negative. In the present formulation these two characteristics are not described for the following reasons. First, the primal-dual formulation is not needed for our solution algorithm described in Cutler and Pass [7] which insures that the Kuhn-Tucker conditions for the model are met. Second, in programming the model, we found that there was no danger of non-positive quantities in the dual. Thus, for simplicity, the slack activities are omitted although they were included in the original specification, see Zwart [29].

P_y = an n x 1 vector of regional demand prices,

P_x = an n x 1 vector of regional supply prices,

P = the 2n x 1 vector $[P_y, P_x]'$,

G' = an n^2 x n transfer matrix $[G_y', G_x']$ of the form

$$\begin{bmatrix} 1 & & & -1 & & & \\ & 1 & & -1 & & & \\ & & 1 & -1 & & & \\ 1 & & & & -1 & & \\ & 1 & & & -1 & & \\ & & 1 & & -1 & & \\ & \cdot & & & & \cdot & \\ & \cdot & & & & & \cdot \\ & \cdot & & & & & & \cdot \\ 1 & & & & & & & & -1 \\ & 1 & & & & & & & -1 \\ & & 1 & & & & & & -1 \end{bmatrix}$$

which relates regional prices to transfer costs,

and T = an n^2 x 1 vector of transfer costs.

In the present model, (8) and (9) are adjusted to add the stock considerations described in (4), (6) and (7). This results in a primal quadratic programming model presented below in (11) through (15) which optimizes a net indirect welfare function adjusted for the storage activities.

$$\text{Maximise N.I.W.} = A^cP_y - \tfrac{1}{2}P_yB^cP_y + A^sP_y - \tfrac{1}{2}P_yB^sP_y - X^fP_x - X^sP_x \qquad (11)$$

subject to,

$$G'P \leq C \tag{12}$$

$$G'P \leq D \tag{13}$$

$$G'P \leq E \tag{14}$$

$$G'P \leq F \tag{15}$$

$$P, X^f, X^s \geq 0$$

where the symbols are as defined above.

The model becomes recursive by specifying alternative demand, stock and supply relations estimated for the various periods (quarters). Then, closing stocks from period t-1 are inserted into the X_i^s objective function elements for period t and actual or generated prices (depending upon the quarter) from period t-5 are fed back into the behavioural supply equations to predetermine regional supply quantities in period t.

4.0 Behavioural Equations

Behavioural equations analyzing regional supply, demand and stock response were estimated econometrically from quarterly time series data observed from 1961 through 1971. For the purposes of this paper, a discussion of the basis for specification of the econometric equations will not be presented. However, the estimated equations for the United States, Eastern Canada and Western Canada are presented below.

4.1 Behavioural Supply Equations

Following the argument of Fox [11] that quantity supplied in a period is largely predetermined because of lagged specifications of price expectations, the regional supply functions are estimated using ordinary least squares regression methods. All three supply models are estimated using distributed lag specifications with lags as explained below. Empirical estimates of the structural coefficients are presented in Table 2. Variables included in the supply models are identified as follows:

Dependent variable is quantity of hogs slaughtered (millions of lbs. carcass wt.) in a region,

PH_{t-5} is slaughter price of 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 [27] adjusted to Canadian dollars and converted to carcass weights. For the Eastern and Western Canada models, it is specified as the Toronto and Calgary prices of index 100 hogs as reported in [4].

PF_{t-5} is a feed price variable included in the U.S. and Eastern Canadian models. For the U.S. this variable is specified as a weighted price per ton of hog feed (.88 times corn price plus .12 times price of 44% soybean meal at Decatur, Illinois) derived from [26]. For the Eastern Canada model, PF is an average of feedgrain prices in Eastern Canada derived from [1] and [23].

FS_{t-5} is included in only the Western Canada model 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 as reported in [23].

Table 2

Estimated Structural Supply Equation

Region		Intercept	Estimated Coefficients (t-statistics in parentheses) PH_{t-5}	PF_{t-5}	FS_{t-5}	BPD_{t-5}	QS_{t-1}	R^2
United States	First Quarter	630.150	18.55* (3.30)	-1.40 (-.28)		-16.25*** (-1.31)	.617* (5.04)	.904
	Second Quarter	547.150						
	Third Quarter	476.260						
	Fourth Quarter	1,096.450						
Eastern Canada	First Quarter	10.487	1.148* (4.42)	-.149 (-.50)		-.372 (-.45)	.746* (7.85)	.95
	Second Quarter	3.293						
	Third Quarter	9.343						
	Fourth Quarter	20.731						
Western Canada	First Quarter	9.240	1.21* (2.71)		.388 (.83)	-3.74* (-2.51)	.559* (5.10)	.86
	Second Quarter	4.442						
	Third Quarter	-13.112						
	Fourth Quarter	10.035						

* Significant at .01 probability level
*** Significant at .10 probability level

BPD_{t-5} is an opportunity cost variable included 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 margin between good feeder and good slaughter steers at Toronto and Calgary respectively, as reported in [4]. For the U.S. model, the variable is specified similarly for the Omaha market [27] in Canadian dollars.

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

In addition to these variables, slope and intercept dummy variables were also included in the equations to test hypotheses about seasonality of production. Seasonal dummies on the direct price response coefficients were tested with partial F statistics and the hypothesis that there was seasonal variation in price response was not accepted. However, the seasonal intercept dummies resulted in highly significant partial F statistics (at the one percent level in the U.S. model and at the five percent level for both Canadian models). These provided the estimated quarterly intercept terms indicated in Table 2.

4.2 Behavioural Demand for Consumption and Demand for Stock Equations

Quarterly demand and demand for stock equations were estimated simultaneously for each region as it was hypothesized that both quantity consumed and quantity held in stock are, in part, related to current period prices. The demand for consumption equations are specified on a per capita basis with exogenous variables included relating prices of competing meat commodities and aggregate per capita income to per capita consumption. Since per capita consumption is not available on a regional basis in Canada, an aggregate pork demand function was estimated, which was finally disaggregated to the two region levels based on regional population. The latter, disaggregated consumption functions were used for the structural equations in the spatial model.

The demand for stocks models were specified as distributed lag equations with an exogenous variable included to measure stock response to the relative number of hogs slaughtered in a given period.

Empirical structural parameters of these equations from two stage least squares regression are presented in Tables 3 and 4. The t-statistics reported in Tables 3 and 4 are the unadjusted two stage least squares t values. The equations were also fitted using ordinary least squares. Both the structural coefficients and the t values were nearly identical for the two procedures. Thus, we assume that any bias introduced by the simultaneous procedure is minimal.

Variable specifications for the demand and demand for stocks equations are as follows.

Dependent variable is quarterly per capita consumption of pork in lbs. as reported in [27] and [3] for the U.S. and Canada demand functions respectively. The dependent variable for the stock equations is the end of quarter cold storage stocks held in a region as reported by [27] and [3] for the U.S. and Canada respectively.

Table 3

Estimated Structural Demand Equations

Region		Intercept	Estimated Coefficients (t-statistics in parentheses)				R^2
			P_h	P_p	P_b	Y	
United States	First Quarter	10.457	-.213*	.099*	.018***	2.195*	.98
			(-26.29)	(4.91)	(1.49)	(22.98)	
	Second Quarter	9.840					
	Third Quarter	10.136					
	Fourth Quarter	11.334					
Canada	First Quarter	14.785	-.219*			2.175*	.94
			(-16.72)			(19.76)	
	Second Quarter	14.354					
	Third Quarter	14.517					
	Fourth Quarter	15.043					

* Significant at the .01 probability level
*** Significant at the .10 probability level

Table 4

Estimated Structural Stock Equations

Region		Intercept	Estimated Coefficients (t-statistics in parentheses) P_h	Q_s	EI_{t-1}	R^2
United States	First Quarter	5.992	-3.827* (-4.14)	.109* (6.19)	.278* (2.77)	.89
	Second Quarter	2.632				
	Third Quarter	-92.932				
	Fourth Quarter	-61.101				
Eastern Canada	First Quarter	1.767	-.124 (-1.16)	.687* (5.30)	.060** (2.17)	.83
	Second Quarter	.231				
	Third Quarter	-5.390				
	Fourth Quarter	-2.780				
Western Canada	First Quarter	-.730	-.041 (-.51)	.217*** (1.64)	.105* (5.15)	.86
	Second Quarter	-.160				
	Third Quarter	-4.984				
	Fourth Quarter	-3.125				

* Significant at .01 probability level
** Significant at .05 probability level
*** Significant at .10 probability level

P_h is current wholesale price of hogs as observed in the supply models.

P_p is price of broilers in retail stores in urban areas (converted to Canadian dollars) as reported in [28].

P_b is the wholesale price of fresh choice steer carcasses 600 to 700 lbs. at New York (converted to Canadian dollars) as reported in [28].

Y is per capita disposable income measured in Canadian dollars.

Q_s is the quantity slaughtered during a given quarter in each region.

EI_{t-1} is the ending stock of cold storage pork products in each region at the end of the previous period.

As with the supply functions, seasonal dummy slope and intercept variables representing the four quarters were specified for both the demand and demand for consumption equations. Partial F statistics for the slope dummies were not significant, but the intercept dummies was significant at the one percent probability level for both U.S. equations, and at the five percent level for all the Canadian equations. These resulted in the quarterly intercepts reported in Tables 3 and 4.

5.0 Validation of the Model

The model was validated over twelve periods from the beginning of 1968 through the end of 1970 by comparing generated to actual regional prices, consumption, production, trade and stocks. As the North American pork sector does not exist as a closed system, trade with other regions was treated exogenously by adjusting regional supply functions for trade levels with other countries.

Results of the validation procedure are presented below. Actual and generated price, consumption and trade levels are included in Table 5. Production and stock levels are presented in Table 6. These are also shown graphically in figures 2 through 6. For each endogenous variable and region, an inequality coefficient (U) as defined by Naylor [20] was estimated as a measure of the predictive power of the model. These are included in the Tables.

It is clear that the model was able to predict all the major cyclical turning points over this period. Also, the relatively low inequality coefficients are indicative of the model's ability to predict actual levels of the endogenous variables.

6.0 A Policy Experiment

As one possible application of the model, an experiment was undertaken to measure the impact of a change in tariff policy over time. The experiment concerned reduction of tariff charges between the two countries. Prior to 1968, tariff levels for pork were $1.25 per hundredweight for products moving into both countries. Beginning in 1968 these levels were reduced according to agreements reached under the Kennedy Round of G.A.T.T. negotiations to a level of $.50 per hundred over most of the period through 1970. Our experiment was aimed at determining the effects of a change in tariff charges on all endogenous variables in the model as well as on consumer and producer welfare in each region.[7/] To carry out the experiment,

7/ Since the prevailing tariff charges over the period were relatively negligible the experiment was conducted assuming that tariffs were eliminated completely over the period.

Table 5

Actual and Generated Regional Prices, Consumption and Trade

Period	Prices (C$/cwt)						Consumption (M. lbs)				Exports From (M. lbs)			
	United States		Eastern Canada		Western Canada		United States		Canada		United States		Canada	
	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated
1968														
Quarter 1	$27.38	$27.51	$28.23	$28.91	$24.62	$26.00	3281	3305.9	272.4	270.8	3.17	0	14.06	9.6
2	27.93	29.68	28.69	32.25	24.66	29.34	3203	3126.8	261.3	260.3	2.64	.59	16.63	11.0
3	29.31	30.74	33.59	32.55	29.80	29.64	3219	3159.6	249.9	255.7	11.94	0	12.20	9.0
4	26.20	29.14	33.60	31.70	30.37	28.79	3573	3474.6	260.3	272.8	18.67	23.19	11.35	9.0
1969														
Quarter 1	29.06	30.98	33.61	33.54	29.77	30.63	3403	3259.2	248.1	260.8	26.42	25.27	12.00	10.0
2	32.87	33.16	34.19	35.72	30.80	32.81	3263	3137.5	250.4	248.6	18.02	18.45	14.96	12.4
3	37.82	37.05	37.13	38.98	35.11	36.07	3143	3125.7	238.7	250.0	11.20	0	10.46	7.9
4	37.40	34.26	37.81	36.81	35.67	33.91	3352	3456.9	261.1	263.5	11.26	9.53	10.96	8.9
1970														
Quarter 1	38.88	34.58	38.34	37.14	35.01	34.23	3103	3296.9	263.2	258.7	6.68	5.45	12.42	9.4
2	33.75	33.34	33.40	35.81	32.99	32.89	3215	3218.8	259.1	255.8	2.94	0	17.42	11.7
3	30.72	33.98	30.85	34.78	27.18	31.87	3346	3188.2	280.3	261.0	5.53	0	15.73	9.0
4	22.32	28.99	26.99	31.26	23.15	28.35	3885	3624.9	303.4	297.0	7.78	0	12.93	9.8
U coefficient	.044		.035		.043		.019		.016		.239			

Table 6

Actual and Generated Production and Stocks

Period	Production (M. lbs)						Stock (M. lbs)					
	United States		Eastern Canada		Western Canada		United States		Eastern Canada		Western Canada	
	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated	Actual	Generated
1968												
Quarter 1	3197	3262.2	177.83	178.52	110.22	110.83	306	336	12.21	15.21	10.92	11.79
2	3118	3011.7	165.27	165.62	108.67	107.19	326	311	11.71	16.61	10.81	12.47
3	2998	2948.3	150.37	161.72	90.53	91.66	197	197	8.34	11.67	5.25	6.15
4	3554	3476.1	159.44	160.25	92.60	98.88	256	261	7.11	10.91	6.56	7.40
1969												
Quarter 1	3351	3259.4	153.79	155.32	94.64	96.04	270	316	11.01	14.42	8.82	9.72
2	3137	3038.1	148.80	145.81	98.98	97.94	246	303	11.51	14.45	10.29	10.91
3	2986	2902.5	147.09	149.57	81.76	87.79	174	166	7.67	8.67	5.42	5.15
4	3300	3440.6	166.55	162.97	91.75	101.44	211	229	8.07	8.66	7.06	7.28
1970												
Quarter 1	3056	3268.6	166.47	162.50	107.25	107.88	268	294	11.91	12.85	8.60	10.80
2	3133	3114.9	159.68	156.88	120.29	114.15	304	296	14.35	14.01	13.18	12.85
3	3154	2989.3	164.61	160.59	108.12	105.10	210	185	11.54	9.56	6.67	7.56
4	3905	3611.7	178.18	179.44	138.52	132.49	336	273	15.28	10.67	11.59	11.28
Coefficient of Inequality	.021		.013		.021		.059		.125		.053	

the model was run with and without tariffs for each of the twelve quarters in these three years.

6.1 Effects on Endogenous Variables

In a static equilibrium framework, a reduction in tariffs would have the effect of increasing trade between the two countries. This, in turn, would increase prices (and production) in the U.S. and decrease prices (and production) in Canada.[8/] In the present case, since supply in a given period is predetermined through the lagged price response function, initial price changes occurring from changes in tariffs would be expected to have repercussions in later periods. This is borne out in Tables 7 and 8 where the results of the twelve period analysis with and without tariffs are presented. Table 7 indicates that abolishing tariffs caused the model to generate increased exports from the U.S. in some early periods. These resulted in price changes as expected. However, because of the lagged price response, price changes in early periods caused production to increase in the U.S. and to decrease in Canada in later periods as indicated in Table 8. Thus, the change in tariff policy, in fact, affected later periods in a manner which was opposite to static expectations.

6.2 Effects on Producer and Consumer Surplus

Following the above analysis, the static expectations concerning changes in prices and production from a decrease in tariffs would lead to static expectations of gains in economic surplus for consumers in the importing region and producers in the exporting region and losses in

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8/ This is due to the fact that Canada was on a net import basis during the period.

Table 7

Prices and Trade With Continued Tariff and No Tariff

Period	Prices ($/100 Lb)						Exports From U.S. to Canada (mill lb)	
	United States		Eastern Canada		Western Canada			
	Tariff	No Tariff	Tariff	No Tariff	Tariff	No Tariff	Tariff	No Tariff
1968								
Quarter 1	27.51	27.51	28.91	28.91	26.00	26.00	0	0
2	29.67	29.68	32.37	32.25	29.46	29.34	0	.59
3	30.74	30.74	32.56	32.55	29.65	29.64	0	0
4	29.02	29.14	32.83	31.70	29.92	28.79	17.83	23.19
1969								
Quarter 1	30.91	30.98	34.71	33.54	31.81	30.63	22.09	25.27
2	33.13	33.16	36.94	35.72	34.03	32.81	12.77	18.45
3	37.00	37.05	38.98	38.98	36.07	36.07	0	0
4	34.12	34.26	37.93	36.81	35.02	33.91	3.00	9.53
1970								
Quarter 1	34.49	35.58	37.72	37.14	34.81	34.23	0	5.45
2	33.62	33.34	34.81	35.81	31.90	32.90	0	0
3	33.87	33.98	33.51	34.78	30.6	31.87	0	0
4	29.23	28.99	30.36	31.26	27.45	28.35	0	0

Table 8

Consumption and Production With and Without Tariff

Period	Consumption (mill lb)				Production (mill lb)					
	United States		Canada		United States		Eastern Canada		Western Canada	
	Tariff	No Tariff	Tariff	No Tariff	Tariff	No Tariff	Tariff	No Tariff	Tariff	No Tariff
1968										
Quarter 1	3305	3305	270.79	270.79	3262	3262	178.52	178.52	110.83	110.83
2	3126	3127	259.71	260.29	3011	3011	165.02	165.62	107.19	107.19
3	3159	3159	255.64	255.68	2948	2948	161.72	161.72	91.66	91.66
4	3474	3479	267.63	272.80	3470	3476	160.25	160.25	98.88	98.88
1969										
Quarter 1	3259	3262	257.75	260.80	3259	3259	155.32	155.32	96.04	96.04
2	3137	3138	243.03	248.60	3038	3038	145.81	145.81	97.94	97.94
3	3125	3128	240.94	240.98	2902	2902	149.71	149.57	87.96	87.79
4	3456	3463	253.45	263.46	3440	3440	163.52	162.97	101.55	101.44
1970										
Quarter 1	3296	3301	256.04	258.74	3266	3268	164.19	162.56	109.31	107.88
2	3215	3203	260.44	255.81	3112	3115	159.56	156.58	116.38	114.15
3	3188	3193	272.29	261.11	2987	2989	164.21	160.59	107.83	105.10
4	3624	3614	301.45	297.24	3608	3611	182.15	179.44	134.02	132.49

economic surplus to producers in the importing region and consumers in the exporting region.

In Table 9, we present percentage changes in consumer and producer surplus in each region and period which resulted from removal of the tariff.[9] This information indicates that in early periods, the model provided results consistent with static expectations. However, when production responded to early period price changes in later periods, the welfare effects were different than would have been expected from static analysis.

7.0 Conclusions and Suggested Further Applications of the Model

The analysis above leads us to the following two conclusions.

Our basic hypothesis in undertaking this analysis was that the North American pork sector behaves competitively. This hypothesis led to the specification of a competitive spatial equilibrium model. Validation of the model in section 4.0 indicates that a high degree of reliability is attained by the model. Although the inequality coefficients do not provide a rigorous statistical test, their levels are sufficiently small to suggest that a competitive model can be used to represent the market and therefore that the competitive hypothesis can be accepted.

A second conclusion concerns the observed impacts of a policy change over time when the system affected has dynamic elements. Analysis in section 6.0 shows that when interdependence between time periods exists, the effects of a change in policy can be substantially different than static analysis would imply. We resist a temptation to attempt to generalize our results here since the complete reversal of the effects of a tariff policy

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[9] Formulas for calculating consumer and producer surplus are presented in Zwart [29].

Table 9

Percentage Loss or Gain in Producer and Consumer Surplus From A Tariff Decrease of $1.25

Period	United States		Western Canada		Eastern Canada	
	Consumer Surplus	Producer Surplus	Consumer Surplus	Producer Surplus	Consumer Surplus	Producer Surplus
1968						
Quarter 1	0	0	0	0	0	0
2	-.02	+.03	+.41	-.41	+.42	-.37
3	0	0	+.03	-.03	+.03	-.03
4	-.29	+.41	+3.61	-3.92	+3.78	-3.56
1969						
Quarter 1	-.18	+.22	+3.95	-3.85	+4.11	-3.48
2	-.08	+.12	+4.28	-3.72	+4.51	-3.41
3	-.13	+.14	0	-.19	0	-.09
4	-.35	+.41	+3.72	-3.38	+3.94	-3.39
1970						
Quarter 1	-.23	+.32	+1.98	-3.04	+2.09	-2.62
2	+.75	-.76	-3.48	+1.11	-3.71	+.94
3	-.30	+.39	-4.33	+1.49	-4.55	+1.48
4	+.58	-.75	-2.73	+2.02	-2.01	+.53

change in later periods resulted from a lack of trade in these periods. However, the observed effects over time are important enough to conclude that consideration of the temporal linkages of markets are basic to assessing the economic impacts of decisions made by policy makers.

Since the model reflects the spatial structure of the sector and, at the same time, includes several exogenous variables in the underlying behavioural equations, a number of additional applications can be suggested.

First, the model can be used to evaluate the effects of any structural or policy changes which would influence the supply or demand functions in any of the regions. Examples presently relevant in Canada would include changes in any of the following: the Feed Freight Assistance Program, formula pricing of feedgrains, proposed pork supply control programs, or price ceilings on pork or pork substitutes. The recursive nature of the model allows analysis of these changes not only in static terms, but also in terms of their affects over time and at particular points on the lag cycle.

Second, the recursive nature of the model will also allow it to be used for short run predictions of price and production pattern. It's predictive ability will be partly dependent on extrapolation of trends in the exogenous variables.

Figure 2

FARM HOG PRICES

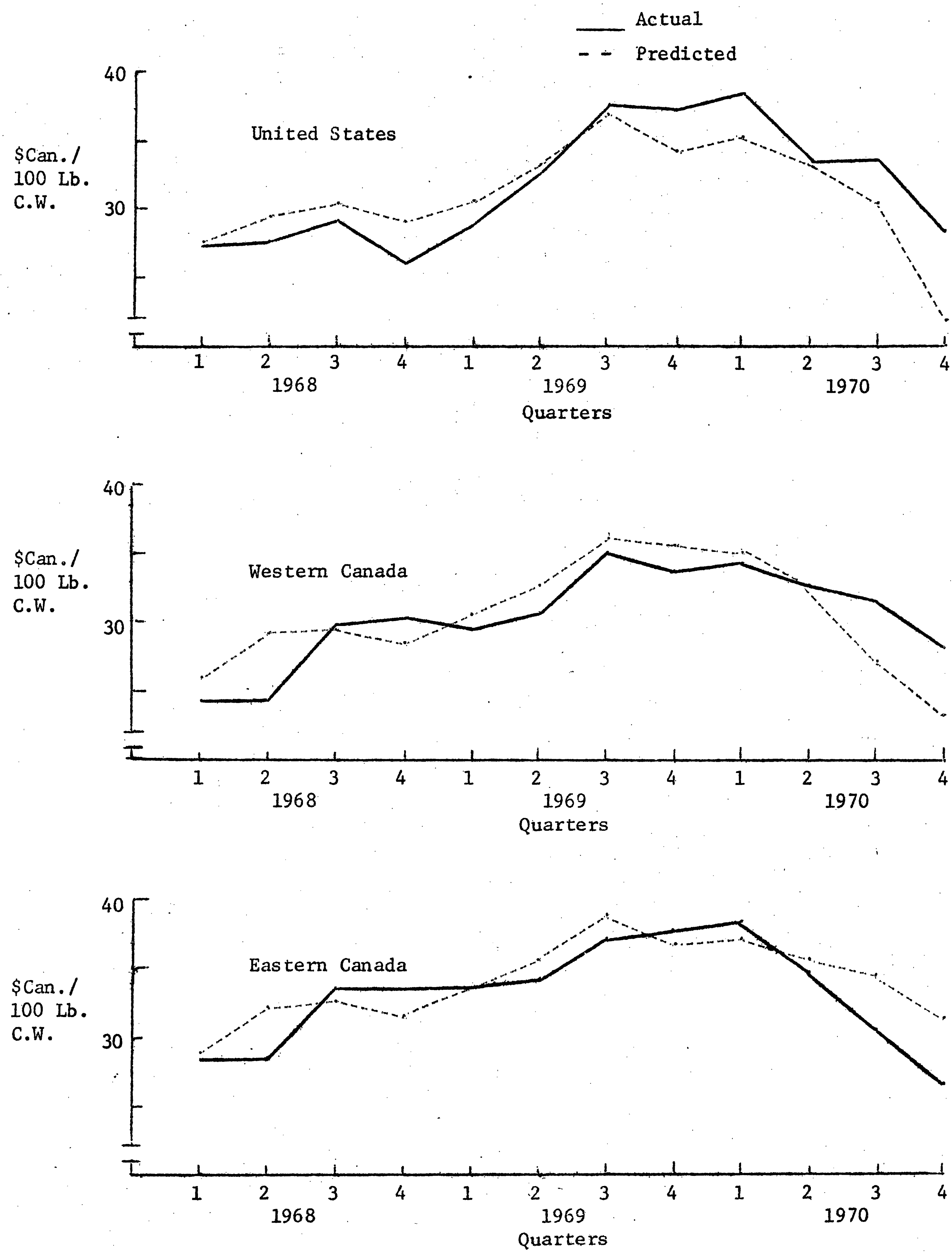
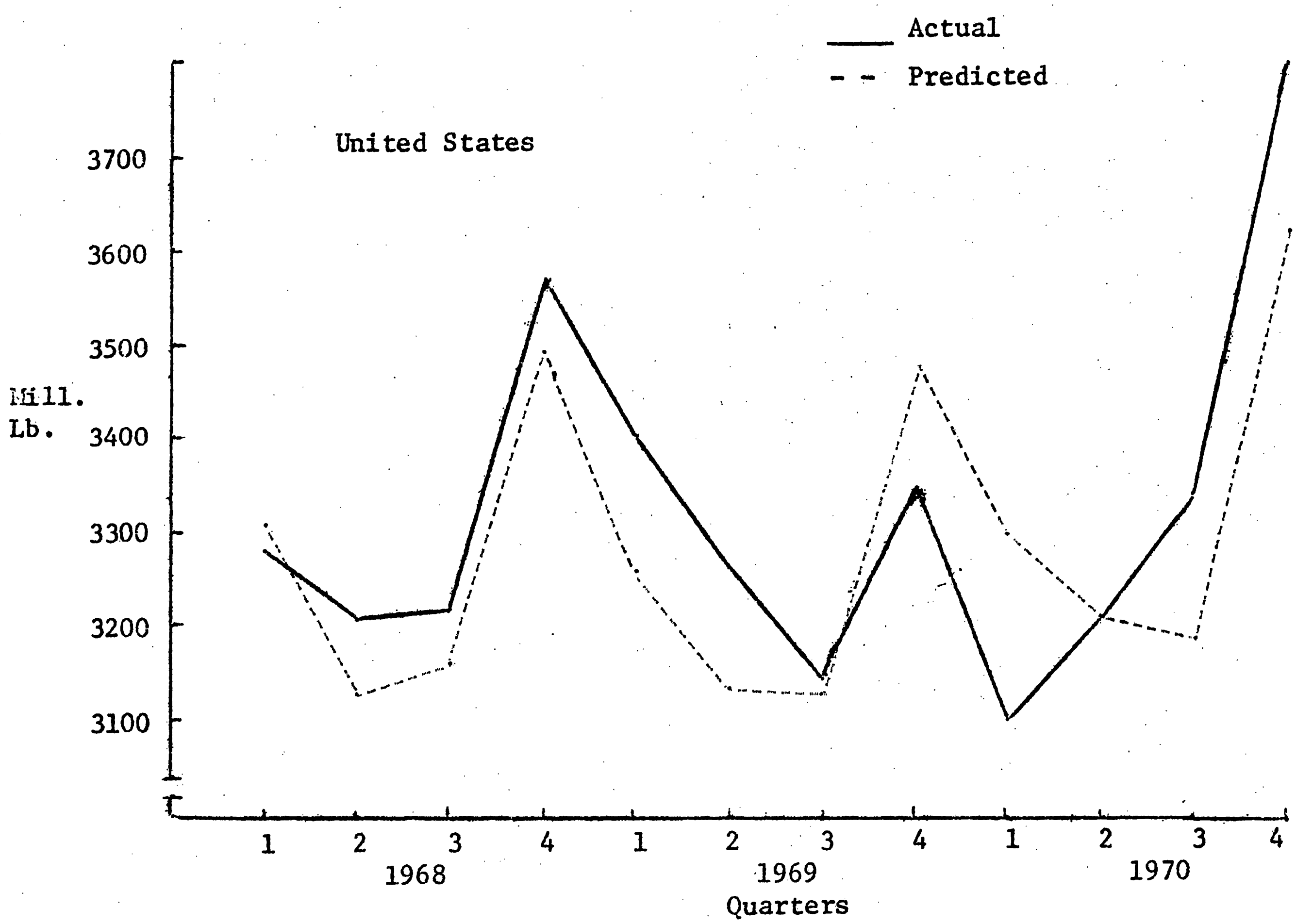


Figure 3

CONSUMPTION OF PORK



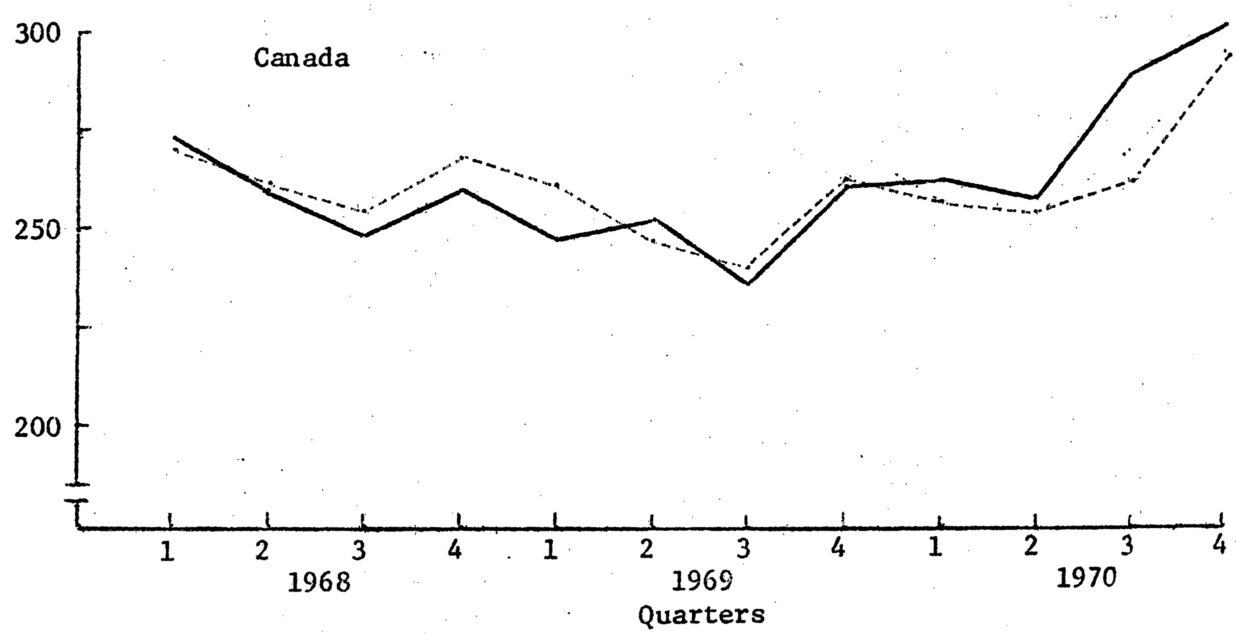
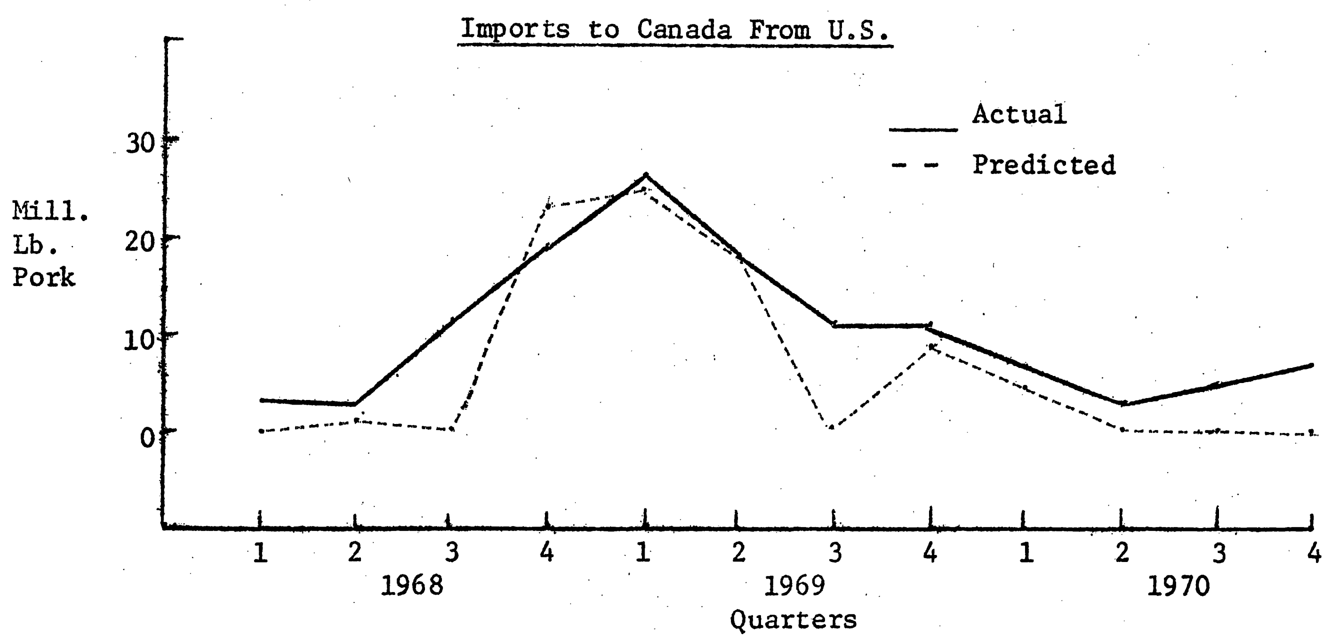


Figure 4

CANADA - U.S. TRADE



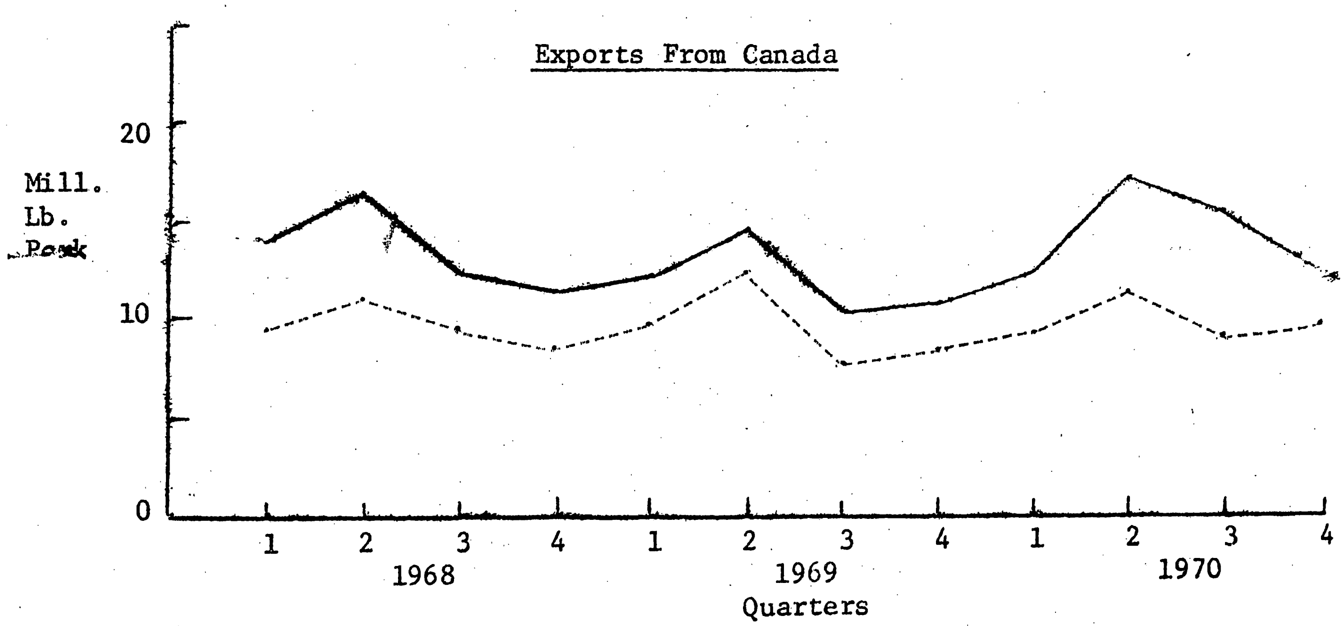


Figure 5

HOG SLAUGHTER

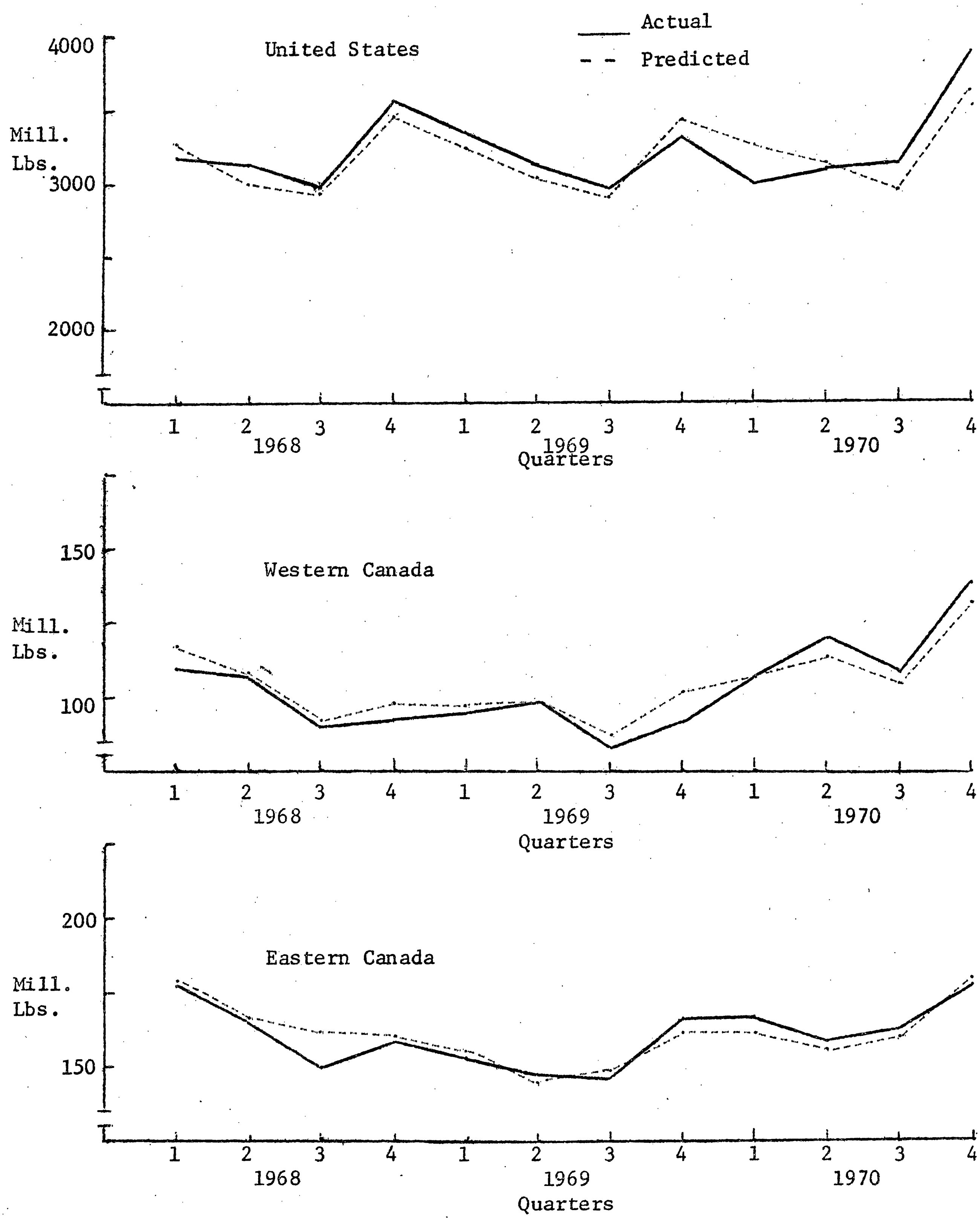
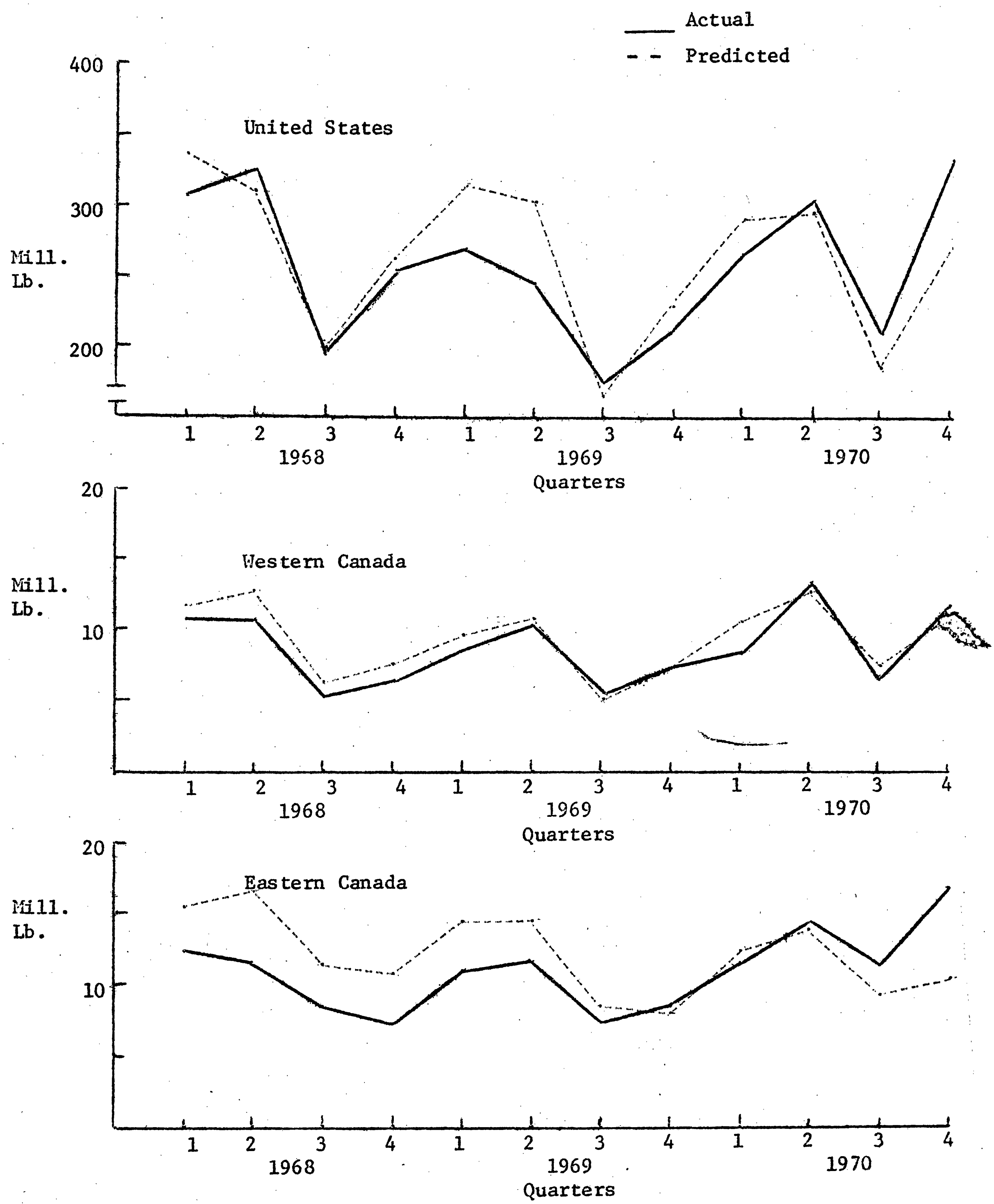


Figure 6

COLD STORAGE STOCKS OF PORK



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