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THE UNIVERSITY OF ALBERTA

Lead-Lag Price Relationships in the Beef and Pork Sectors

by

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A THESIS

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Abstract

The objective of this study was to evaluate the pricing efficiency of the marketing channels for the beef and pork sectors in Canada. The study employed the concept of Granger causality along with univariate residual cross correlation analysis in order to assess the nature of lead-lag price relationships in the Canadian beef and pork sectors. The direction of price change within the channel along with the time lag involved has implications for pricing efficiency.

From derived demand theory, it was expected that retail prices would lead both wholesale and farmgate prices and that wholesale prices would lead farmgate prices for both beef and pork. The autocorrelation in each price series was filtered using an ARIMA model. The result of this filtering process was a set of residuals or innovations that were free of serial correlation. The residuals of each series were then used in the cross correlation procedure rather than the original data. Cross correlations were calculated for three and five lags in both positive and negative directions. This offered an opportunity to determine which series led the other and whether or not there was feedback or bidirectional causality..

The results indicated that farmgate prices led retail prices by about three weeks for both beef and pork. This was contrary to the expected results and may have been the result of cost plus pricing on the part of wholesalers and retailers. The live market is the only visible market in both the beef and pork channels, therefore it is hypothesized that firms further along the channels may have based their prices on a "cost plus" type of approach.

These results suggest that generally the pricing efficiency of the channels could be improved, since a theoretically price efficient channel should transmitt price changes instantly. If price information is not relayed quickly the result could be the inefficient use of resources in the production, and distribution of beef and pork The results also suggest that since the live market may be the principle point of price discovery for the entire channel and therefore any changes made at this level could have far reaching effects.

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There are a number of people to whom I am deeply indebted for the help and encouragement they provided over the course of this study. Dr. Murray Hawkins, my supervisor and friend, I thank for all his assistance, and for keeping things in perspective. Reg Norby very ably obtained funding and data for this project and to him I owe many thanks. To the other members of my committee, Dr. M. L. Lerohl, Wiktor Adamowicz, and Dr. G. Reschenthaler I say thank-you, especially to Wiktor for his help with some of the statistical and computing problems.

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I. Introduction

A. Importance of the Study

This study deals with the red meat industry in Canada. In particular it focuses on price relationships in the fresh meat marketing channel for beef and pork. Together these two commoditites account for 23 percent of the consumer's budget for food consumed at home, while the sale of slaughter cattle and hogs constitutes approximately 19 percent of farm cash receipts.[1]

Concern has been expressed at the producer level of these sectors about the relationship between farmgate prices for live cattle and hogs, and the prices at higher levels of the marketing channel. One aspect of the relationship that has been of interest is the time lag that exists between a price change at one level and the subsequent price changes, if any, at other levels. The length of time for price changes to be transmitted along the marketing channel has implications for the pricing efficiency of the channel. Pricing efficiency refers to the "accuracy, rapidity, and effectiveness with which marketing information is developed and disseminated."[2] Price is a major component of market information, therefore the speed with which its influence is felt at other levels of the marketing channel is an aspect of pricing efficiency. Information on the lead-lag relationship between price changes at different levels of the marketing channel, for beef and pork, would provide more knowledge about the pricing efficiency associated with the marketing of these products, and may provide some indication of whether or not the marketing mechanism is working adequately, at least with respect to time.

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[1]Agriculture Canada Handbook of Food Expenditures, Prices and Consumption, Marketing and Economics Branch (Pub. No.81/5 Dec. 1981) p. 89
[2]Willard F. Williams, Thomas T. Stout, *Economics of the Livestock-Meat Industry* (The MacMillan Company, New York) p. 122

B. Problem

The problem dealt with in this study centered on the need for information. No information existed on the lead-lag relationship between prices at the farmgate, wholesale, and retail levels of the marketing channel for beef and pork in Canada.

C. Objectives

The main objective was to determine the time lag that existed between price changes at one level of the marketing chain and price changes at other levels.

D. Hypotheses

The hypotheses of this study were:

1. Retail prices for beef lead farmgate prices for live cattle.
2. Wholesale prices for beef lead farmgate prices for live cattle.
3. Retail prices lead wholesale prices for beef.
4. Retail prices for pork lead farmgate prices for hogs.
5. Wholesale prices for pork lead farmgate prices for hogs.
6. Retail prices lead wholesale prices for pork.

On a week to week basis one would expect that the very short run supply curve for these products is likely very inelastic and that the determinants of supply do not shift this curve in this short time horizon. The very short run demand curve however, is likely subject to shift as the determinants of demand (such as the price of compliments and substitutes) change. Therefore, since primary demand exists at the retail level the shift of the demand curve and subsequent change in price would take place at the retail level first. The derived demand which exists at the farmgate would shift later, Therefore, the retail price should lead the farmgate price; the retail price should lead the wholesale price; and the wholesale price should lead the farmgate price.

E. Data

Data for this study consisted of weekly price information obtained at three levels of the fresh meat marketing channel for beef and pork. Farmgate prices for live hogs (index 100) were recorded for Edmonton and Toronto, while the prices of A1 and A2 steers were used to represent farmgate prices for live cattle. This information was obtained from I.P. Sharp and included the years 1979 through 1982.

Edmonton was the only center for which wholesale data was obtained. This consisted of the weekly procurement prices for beef and pork provided by an Edmonton retail chain from May of 1981 to December of 1982.

Retail prices for beef and pork were recorded in five cities which included Vancouver, Edmonton, Calgary, Toronto, and Montreal. For all centers, except Toronto, the period of analysis covered four years, from 1979 to 1982. In Toronto a price war among retailers prevented the collection of retail prices for the first quarter of 1982.

F. Limitations of the Study

One of the limtations of this study was that it focused on only one market channel. Analysis of the fresh meat marketing channel did not take into consideration those volumes of beef and pork that were consumed through the hotel, restaurant, and institutional trade.

Also, the approach was restricted to treating the beef and pork marketing channels separately. In other words there was no analysis of the impact that beef and pork prices had on one another. The analysis was only concerned with price relationships within each marketing channel.

G. Format of the Study

Following the Introduction (Chapter I), Chapter II provides a review of related literature. A description of each marketing channel and a disscussion on data and methodology make up Chapters III and IV respectively, followed by the analysis of results in Chapter V.

Finally Chapter VI is a review of the study and also includes recommendations for further inquiry.

II. Review of Related Literature

A. Lead-Lag Price Relationships

Analyzing lead-lag relationships between two time ordered variables has been of increasing interest to agricultural economists. Most economic relationships are influenced not only by events in the current time period but also by events that have happened in the past. Much of the earlier work done in this area followed the traditional econometric approach of first establishing a model based on "a priori" reasoning. For example Richard King analyzed the temporal behavior of beef price spreads using first difference and polynomial distibuted lag models. [3] His paper examined the relationships between various levels of the beef marketing chain from October 1973 to September 1975 in the U. S.

The conclusion that King reached was that farm and carcass values move together instantaneously whereas retail prices are influenced by carcass values "for as many as five previous weeks." However as King noted, the results may have been biased due to serial correlation in the time series.

Much of the recent work done on lead-lag relationships in agricultural economics is based on the concept of Granger causality. "That is, a time ordered variable X may be said to lead or cause a second time ordered variable Y if Y may be better predicted with the use of the history of X than without, with all other information (including the history of Y) being used in either case. [4]

One of the first papers in agricultural economics based on Granger causality also employed the techniques of Box and Jenkins.[5] In this paper Stephen Miller used such analysis to assess the lead-lag relationships between retail, wholesale and farm level beef prices.

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[3]Richard A. King, "Transmission of Week-to-Week Changes in Choice Beef Prices Between Farm, Carcass, and Retail Levels", (A contributed paper read at the annual meeting of the American Agricultural Economics Association, Pennsylvania State University, August 16, 1976)
[4]Stephen E. Miller, "Univariate Residual Cross Correlation Analysis: An Application to Beef Prices" North Central Journal of Agricultural Economics 1(1979): 141-46
[5]G. E. P. Box and G. M. Jenkins, *Time Series Analysis Forecasting and Control,* San Fransisco: Hc' :n-Day Inc., 1970.

The Box-Jenkins technique was developed to forecast future values of a time series. In order to do this the researcher must first establish the relationship between the current value of the variable and its past. This method involves the assumption that the time series was generated by a stochastic process and therefore the relationship between the current term and its past can be specified in autoregressive and/or moving average forms. Once the specification has been made and the parameters estimated, the model can then be used to predict future values of the time series.

The application of this technique in analyzing lead-lag relationships is not to forecast but rather to use the model to remove the serial correlation inherent in each time series. In other words, the model is used to filter out the autocorrelation in each series leaving only the residuals or innovations. If these residuals are not autocorrelated then they are referred to as white noise terms. It is these white noise terms from each of the two series that are cross correlated. This procedure is called univariate residual cross correlation analysis.

To implement univariate cross correlation analysis the above procedure is applied to each time series of interest. With the residuals of each series being white noise terms, calculation of the cross correlations between the residuals are made. Different lags are used in these calculations to determine the lead-lag relation between the two time series. One of the advantages of this technique "is that any autocorrelation in the original time series (which may lead) to over estimation of the significance of the cross correlations" is obviated by using the residuals instead of the original series.[6]

The results of this method, when applied to the retail, wholesale, and farm level beef prices for January 1974 to June 1978 (U.S.), indicated "that farm prices (led) wholesale prices by about one week, and in turn; wholesale prices (led) retail prices by about three weeks."[7]

Univariate residual cross correlation analysis has been used in a number of articles most of which give a brief discussion on Granger causality and the Box-Jenkins technique for modeling time series.

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[6]Ibid
[7]Ibid

Bessler and Schrader used such an approach to investigate the lead-lag relationship between two egg price reporting agencies. [8] The motivation for this work came from the fact that the two reporting agencies based their price quotations on different information sets. One agency based its quotations on information from a thinly traded cash market as well as nonprice information and market reporters' judgements. The second agency used only the cash market to establish egg price quotations.

Both price quotation series consisted of twice weekly observations. Each series was modeled as a second order autoregressive process. From the autoregressive models a series of residuals were generated and then cross correlated. The results of these cross correlations showed that the first agency's price quotations led the second by one to two periods. Recall that the first agency based its price quotations only on the thinly traded market, where as the second agency used additional information. This led the authors to the conclusion that the additional information was actually misleading and that in spite of the cash market being thinly traded it represented the real equilibrium price and thus provided the most accurate information.

A comparison of two price reporting agencies was also made by Faminow, who analyzed the lead-lag structure of two wholesale beef price quotes using univariate residual cross correlation analysis. [9] In his discussion on Granger causality Faminow noted that there were two general methods for conducting causal analysis; one was univariate residual cross correlation analysis and the other was a method proposed by Sims. [10] In this second method Sims suggested using an "ad hoc" filter to remove the autocorrelation from the economic time series. Specifically he recommended using $(1-0.75B)^2$ as a filter to whiten the time series.

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[8]David A. Bessler, Lee F. Schrader, "Relationship Between Two Price Quotes for Eggs." (American Journal of Agricultural Economics Vol. 62 1980): 766-71

[9]M.D. Faminow, "Analysis of the Lead-Lag Structure of Two Wholesale Beef Price Quotes Using Residual Cross Correlation."North Central Journal of Agricultural Economics 3 (July 1981): 89-94

[10]See C.A. Sims, "Money Income, and Causality." American Economic Review Vol. 62(1972), 542-52

Faminow noted the following attributes of univariate residual cross correlation analysis when compared to Sims' method:

1. "First, cross correlation analysis rather than regression analysis is used to measure causality.
2. Second, seperate filters are used for X and Y in contrast with Sims' method of applying one common filter.
3. Third, the filters are empirically determined as opposed to applying ad hoc filters" [11]

Faminow also pointed out some interesting methodological considerations when using univariate residual cross correlation analysis. In particular he noted that the technique, which is used to measure causality between two variables, depends entirely upon empirical evidence and not on economic theory. It is the actual data which is allowed to suggest the nature of the causal relationship and not a priori reasoning. He suggested that a more appropriate term to describe the relationship between two variables as determined through empirical analysis only, might be "time ordered association". The question of causality, he felt, should be reserved for theoretical consideration.

The application of the technique, by Faminow, consisted of modeling the time series properties of "The Meat Sheet" and "The Yellow Sheet" price quotations for wholesale beef prices. It was discovered that after applying first difference filters to both series, neither could be distinguished from a white noise series. Therefore the cross correlation function was calculated. The results indicated that "The Yellow Sheet" led "The Meat Sheet" by one or two periods. The author concluded that the former price reporting agency responded "to changing market conditions more expediently than" the other.

Bessler and Schrader, who investigated lead-lag price relationships for turkey products, raised some of the issues discussed earlier. [12] They noted that economic theory is often not

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[11]M.D. Faminow, "Analysis of the Lead-Lag Structure of Two Wolesale Beef Price Quotes Using Residual Cross Correlation." North Central Journal of Agricultural Economics 3 (July 1981): 89-94

[12]D.A. Bessler, L.F. Schrader, "Measuring Leads and Lags Among Prices: Turkey Products." Agricultural Economics Research 32(July 1980): 1-7

explicit on the dynamic relationship between two variables and that where competing theories about the relationship exist policy analysts may have difficulty recommending the appropriate measures. Univariate residual cross correlation analysis, they said, might offer some assistance in choosing the best theory since it offers a more empirical approach.

The empirical work by Bessler and Schrader was conducted with the use of a fifth order integrated moving average process that was used to model each of the eight time series under consideration. After analyzing various lead-lag relationships they concluded that the results were in keeping with their prior expectations which were that wholesale prices led farmgate prices. The prior expectations were based on the theory that demand at the farmgate is derived from the retail and wholesale levels.

Bessler and Brandt investigated lead-lag relationships in the livestock sector using three different approaches to test for Granger causality.[13] The first two approaches both involved prefiltering the data to remove autocorrelation. Univariate residual cross correlation analysis and Sims' general filter were the two prefiltering methods used. The third technique used was one developed by Geweke who directly utilized ordinary least squares to test for causality between two time series.

Seven separate time series were analyzed which involved data from the beef and pork sectors of the U.S. from 1963 to 1980. Comparisons were made between the three approaches for assessing lead-lag relationships. One of the conclusions reached was that Sims' general filter was inadequate since autocorrelation was still evident, as indicated by the autocorrelation function, after prefiltering had been carried out. Another conclusion reached was that no distinction could be made between which of the two remaining methods was better. Univariate residual cross correlation analysis and Geweke's direct method both provided the same results.

The motivation [illegible] dy conducted by Beaton and Pearson came from a concern for pricing efficiency. One [illegible] for examining pricing efficiency is to determine the time

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[13]D.A. Bessler, J.A. Brand[illegible] Causality and Inference: An Application to Livestock Markets" Purdue Universit[illegible] [illegible]tural Experiment Station, West Layfayette, Indiana, Research Bulletin 972 June 19[illegible]

period for pricing information to be communicated among markets." [14]

Univariate residual cross correlation analysis was used by Beaton and Pearson to analyze the lead-lag structure of slaughter hog prices between the United States and Canada. U.S. data consisted of the aggregation of seven midwest markets and the Canadian price series included slaughter hog prices in Toronto, Winnipeg, Saskatoon, and Edmonton.

The findings indicated that Toronto and Winnipeg were correlated at zero lag which suggested that pricing information is transmitted instantaneously between the two markets. Also, both of these markets were correlated at zero lag with the seven U.S. markets. Saskatoon and Edmonton prices showed the highest correlation with the other markets when lagged by one period, indicating that these markets were slower to adjust to the changing North American market for slaughter hogs.

The analyses of lead-lag relationships between time series discussed in this section have raised the concepts of causality and prefiltering. In particular, Granger causality and univariate residual cross correlation analysis have been discussed. These two concepts will be revisited in Chapter IV where their applicability to the study of lead-lag price relationships in the beef and pork marketing channels in Canada will be discussed.

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[14] N.J. Beaton, C.L. Pearson, "Lead-Lag Structure of Slaughter Hog Prices Between United States Midwest and Four Major Canadian Markets Utilizing the Univariate Residual Cross Correlation Technique" (Paper presented, American Agricultural Economics Association and Western Agricultural Economics Annual Meeting, Utah State University, August 1-4, 1982)

III. The Pork and Beef Systems

A. Introduction

The purpose of this chapter is to provide a brief description of the beef and pork systems from an operational and pricing perspective. The production and processing of each commodity will be dealt with separately, while the discussion on retailing will pertain to both since most retail enterprises market both beef and pork through a single department.

B. Production - The Beef System

Beef production includes those activities involved in raising the animal to slaughter weight and can be divided into two phases: the feeder cattle phase, and the slaughter cattle phase.

The term feeder cattle refers to animals that are mature enough for fattening, a process which usually begins after one year of age. However not all animals are introduced to fattening rations at the earliest possible date since there are several factors which the producer must consider. Feed costs, interest rates, and market prospects rank among the more important issues on which judgements must be made. Hence the phase of feeder cattle production, like other economic time horizons, is related more to an act of decision making than to an actual period of time.

The raising of feeder animals normally begins on a cow-calf operation, which is characterized by a relatively large marginally productive land base. The size of these operations varies considerably, especially with respect to region. Table 3.1 shows the average size of the national and provincial cow-calf operations for 1971, 76, and 81.

Generally the figures reach a peak before showing a decline. Table 3.2 provides a more detailed account of this trend in terms of national and provincial cow herd totals. The distribution of the national herd is shown in Appendix A.

Table 3.1 Average Cow Herd Size 1971, 76, 81

Year	B.C.	Alta	Sask	Man	Ont	Que	Can
1971	36.3	54.7	41.9	35.9	14.8	24.3	33.9
1976	47.6	54.8	40.6	37.9	16.9	34.5	37.1
1981	35.4	46.0	34.1	32.4	16.3	14.5	30.8

Source: 1971,1976,1981 Census, Statistics Canada

Table 3.2 Beef Cow Herd Numbers '000 Head, 1971-80

Year	B.C.	Alta	Sask	Man	West	Ont	Que	Mar	East	Canada
1971	184.3	1270.2	1027.7	384.2	2866.4	434.7	163.9	49.2	647.8	3514.2
1972	198.0	1364.0	1079.0	406.0	3047.0	465.0	177.0	50.4	692.4	3739.4
1973	211.0	1509.0	1174.0	447.0	3341.0	485.0	192.0	51.6	728.6	4069.6
1974	227.0	1660.0	1270.0	500.0	3658.0	530.0	235.0	61.5	826.5	4484.5
1975	235.0	1692.0	1304.0	516.0	3747.0	535.0	250.0	68.0	853.0	4600.0
1976	223.0	1590.0	1215.0	491.0	3519.0	510.0	246.0	70.7	826.7	4345.7
1977	230.0	1555.0	1173.0	485.0	3443.0	480.0	240.0	67.6	787.6	4230.6
1978	230.5	1425.0	1065.0	435.0	3155.5	430.0	225.0	63.3	718.3	3873.8
1979	230.0	1440.0	1005.0	400.0	3075.0	395.0	210.0	55.0	660.0	3735.0
1980	242.0	1515.0	1045.0	410.0	3212.0	425.0	220.0	58.5	703.5	3915.5

Dawson, Dau, and Associates Ltd.,*Impact of Government Programs on the Regional Location of Meat Production in Canada* P. 23

The trends indicate the cyclical nature of beef production. The much studied "beef cycle" begins with low cow herd numbers which are accompanied by relatively high prices. High prices provide an incentive for producers to increase the amount of beef supplied to the market, however they cannot do this instantaneously due to the biological traits of the animal. To increase supply it is necessary to retain females for breeding purposes, an act which further accentuates the already short s[illegible] of beef available to the consumer. From the time the female is born to the time her progeny is ready for slaughter a minimum of three and a half years will have passed.

Eventually the quantity of beef available to the consumer increases as the offspring of previously retained females are slaughtered. These increased quantities of beef exert downward pressure on prices. As prices decline producers liquidate their cow herds which exerts even more downward pressure on prices and causes further liquidation. Until this abundance of beef is consumed the price remains low, inevitably however, the oversupply is diminished and once again prices begin to rise. The cow herd has then returned to a relatively small size and the cycle repeats itself. Typically these cycles have a duration of approximately ten years.[15]

With the distribution of cow-calf operations concentrated in the West and the high production of corn in Ontario along with low freight rates for Western grain, a West to East movement of feeder cattle takes place. The movement of feeder cattle to the U.S. has been relatively large at times, however the reverse has not occurred during the 1970's due to Canadian import restrictions based on health standards.

Once the decision has been made to sell feeder cattle the owner has three main marketing alternatives:

1. A direct sale can be negotiated between the producer and purchaser.
2. The producer can sell his cattle through a local country auction.
3. The producer may elect to consign his cattle to an agent operating in a terminal market.

Once the animals are within the slaughter cattle phase of beef production they are introduced to high energy rations.[16] The length of the feeding period ranges from approximately 90 to 120 days and depends among other things on climate,initial weight of the feeder animal, the animal's feed-meat conversion ratio.

Regionally, the distribution of cattle feeding is effected most by the availability of feed. Mentioned earlier was the fact that Ontario produces an abundance of corn. This, coupled with discriminatory freight rates on grain shippments from Western Canada, has made Ontario

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[15]Charles Gracey, "The Cattle Cycle" (A publication of the Canadian Cattlemen's Association, Printed by Public Press, March, 1981).

[16]Roy Kennedy and Malcolm Churches, eds., Canada's Agricultural Systems 4th ed. (Department of Agricultural Economics MacDonald Campus of McGill University, Ste. Anne de Bellevue, Quebec, 1981).

an important producer of slaughter cattle. Evidence of this appears in Table 3.3 which provides a breakdown of slaughter cattle production across Canada based on the origin of marketings of A, B, and C grade cattle.

Like the feeder cattle producer the seller of fat cattle has three market alternatives when selling to packing companies: direct sales, consignment of stock to a terminal market, or marketing through a local country auction. When electing to market his cattle through a direct sale the producer can do so either on a live weight or rail grade basis.

The relative importance of these three alternatives has changed over the last decade with direct sales now being the method by which the majority of fat cattle are traded. The popularity of this option has risen mostly at the expense of terminal markets which now serve a limited role in slaughter cattle transactions. The main force behind the increase in direct sales has been the proliferation of custom feedlots. Large modern feedlots with many customers provide an efficient link between the seller and packer buyer. Packing companies can send buyers to the feedlots where they can view a large number of cattle at once and make offers. The owner, in this situation, is under less pressure since a refusal of the bid does not mean transporting the cattle back from an auction.

C. Production - The Pork System

The production of pork, unlike beef, is not land extensive. It is, however, strongly tied to feed grain price and availability. Approximately seventy percent of the cost of hog production is made up of feed costs.[17] In Ontario the main ingredient in the feed ration is corn, where as in the West it is barley. Quebec producers use approximately equivalent amounts of each. Evidence of the close relation between hog production and feed grains is the concept of the hog-barley ratio. This refers to the "number of bushels of number one feed barley that are equal in value to one hundred pounds of Index 100 live hog, on the basis of Winnepeg prices."[18] This ratio is an important market statistic.

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[17]Agriculture Canada "The Canadian Pork Industry" August 1977.
[18] Ibid p. 5

Table 3.3 Provincial Shares of A, B, & C Marketings, 1971-80[1]

Year	B.C.	Alta	Sask	Man	West	Ont	Que	Mar	East
1971	1	41	15	09	66	32	1	1	34
1972	1	41	16	09	67	31	1	1	33
1973	2	42	14	09	67	31	*	1	33
1974	2	43	14	09	67	32	*	1	33
1975	2	45	14	09	68	30	*	1	32
1976	2	45	12	90	69	30	*	1	31
1977	2	45	10	90	67	31	1	1	33
1978	2	45	09	10	65	33	1	1	35
1979	2	46	08	09	64	34	1	1	36
1971	2	45	08	08	63	34	2	1	37

[1]Provincial shares expressed as a percentage of national total.
Dawson, Dau, and Associates Ltd., *Impact of Government Programs on the Regional Location of Meat Production in Canada* P. 38

The nature of the hog production unit has changed over the last decade so that now most operations raise the hog through all stages of its life. This is called a "farrow to finish" operation which refers to the integration of farrowing and feeding enterprises into one unit. Tables 3.4 and 3.5 indicate the size of operations regionally in terms of ranges.

Like beef production, hog production is characterized by cycles which have a duration of approximately 36 months. The hog cycle is of the same basic nature as the beef cycle however it is mitigated by the hog's short gestation period and ablility to give birth to several offspring at once. This makes the supply response to a price change more rapid than is the case for beef. However, in the early seventies the barriers to entry into hog production were quite low since the cost of capital was also low. Movement of producers into and out of the industry served to intensify the severity of the cycles. However, in the latter part of the decade high start up costs tempered this somewhat.

The hog cycle is not confined to Canada, but is a North American and world phenomenon. The Canadian pork situation is tied very closely to American hog production,

Table 3.4 Proportion of Hogs on Farms by Given Size Stratum, 1976[1]

No.	B.C.	Alta	Sask	Man	Ont	Que	Mar
1-122	23.5	29.9	39.7	17.0	24.0	10.6	20.5
123-272	11.1	16.1	19.3	17.2	20.9	11.4	13.2
273-527	11.0	16.3	13.7	18.7	25.0	17.6	19.6
528 +	54.4	37.7	27.3	47.1	30.1	60.4	46.7

Dawson, Dau, and Associates Ltd.,*Impact of Government Programs on the Regional Location of Meat Production in Canada* P. 11

Table 3.5 Proportion of Sows on Farms by Given Size Stratum, 1976[1]

No.	B.C.	Alta	Sask	Man	Ont	Que	Mar
1-32	30.5	46.4	57.5	31.9	39.7	26.5	38.6
33-47	02.9	08.6	08.6	09.8	11.8	09.0	09.4
48-62	08.6	07.4	07.4	08.5	12.0	11.0	09.8
63 +	58.0	37.6	26.5	49.8	36.5	53.5	42.2

Dawson, Dau, and Associates Ltd.,*Impact of Government Programs on the Regional Location of Meat Production in Canada* P. 11

with Canada contributing about ten percent to the North American total.[19]

The domestic distribution of hog production changed during the nineteen seventies. Table 3.8 shows the declining share of the West and the increasing share of Quebec.

Various factors have influenced this trend, including government policies. The Western Grain Stabilization Act and the Canadian Feed Grains policy likely had some impact on Western pork production, however, rising grain prices during the seventies probably had the most influence. Since many operations are mixed grain and livestock enterprises, higher grain

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[19]Larry Martin, "Economic Intervention and Regulation in the Beef and Pork Sectors", Economic Council of Canada Technical Report No. E/11. p.5

Table 3.6 Provincial Shares of Hog Production, 1971-80[1]

Year	B.C.	Alta	Sask	Man	West	Ont	Que	Mar	East
1971	1	20	12	13	46	31	19	4	54
1972	1	20	12	13	46	31	20	3	54
1973	1	19	12	14	46	30	21	4	55
1974	1	18	11	13	43	30	25	3	58
1975	1	16	08	11	36	31	29	4	64
1976	1	14	07	11	33	33	30	4	67
1977	1	14	07	10	32	32	32	4	68
1978	1	13	06	09	29	33	34	4	71
1979	1	13	06	09	29	34	34	4	72
1971	2	12	06	09	29	32	36	4	72

[1]Provincial shares expressed as a percentage of national total
Dawson, Dau, and Associates Ltd.,*Impact of Government Programs on the Regional Location of Meat Production in Canada* P. 4

prices create an incentive for producers to sell their grain rather than feed it to livestock. The situation has been further effected by the Crow Rate and the Feed Freight Assistance Act. In 1977, as a result of these programs, it was cheaper to ship 800 lbs. of grain from Western Canada to Eastern Canada than it was to ship 160 lbs. of dressed pork. [20]

In Quebec, feed manufacturers have taken advantage of the low cost of transporting grain. Such low costs have provided them with the opportunity to take advantage of the absence of a supply management scheme in the Quebec hog industry. The result has been backward integration on the part of these feed companies into the production stage through contractual arrangements with farmers. This too has contributed to Quebec's increased share of national production.

The marketing of hogs by producers is facilitated, in most provinces, by a marketing board. Alberta, Saskatchewan, Manitoba and Ontario all had operative marketing boards for most of the seventies. These boards did not act to restrict hog production in any way, but rather assumed the role of central selling agencies. Their aim is to improve the efficiency with

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[20]Agriculture Canada "The Canadian Pork Industry" August 1977

. which the exchange of hogs between producer and packer takes place.

D. Processing - The Beef System

After the live animal has been sold to the packing company it is immediately shipped to the processing plant where it is slaughtered. The average carcass yield for steers is 57 percent, which means that a steer weighing 1000 pounds live will yield a carcass weighing 570 lbs. [21] The carcass is then allowed to age either as swinging beef, in the form of sides, or as boxed beef. The process of "boxing beef" involves breaking the side down into five main parts called primals, these include: the short hip or round, the steak piece, short loin, rib, and the square cut chuck with shank. Each piece is then either vacum packed in special bags or placed in a film lined cardboard box with carbon dioxide pellets, the former method being the most popular.[22]

There are several advantages to boxed beef which include, better sanitation, less, shrinkage, and transportation economies from the shippment of less fat and bone. However, the adoption of this technique on the part of packers depends on how acceptable the process is to retailers. Some retail chains in the country have gone totally to boxed beef however the majority still prefer to receive the product in swinging form. Therefore this is how packers market most of their beef.

The grading of carcass beef is done in the plant by a federal meat inspector. The Canadian grading system for beef is divided into five categories and is based on maturity, quality, and meat yield. By far the majority of the animals slaughtered are those in maturity class one (youthful) although the proportion changes with the stages of the beef cycle. In 1976 61.5 percent of the animals slaughtered graded A1 or A2. [23]

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[21]Agricultural Economics Research Council of Canada, "The Montreal - Alberta Beef System - How it Works" Ottawa, Ontario 1977. p. 115
[22]Ibid p. 17
[23]Patrick M. Moncreif, "Beef Retailing in Canada" Agricultural Economics Research Council of Canada 1978 p.7

Locationally, packing plants are tied to the areas of live fat cattle production. The regional distribution of all cattle slaughtered in inspected establishments is presented in Table 3.10. Note the large shares of Alberta and Ontario.

Alberta slaughters more beef than it consumes whereas Quebec experiences the opposite situation. The result of this imbalance has been a West to East flow of carcass beef. Practically all the beef moving from Alberta to Quebec goes to the Montreal market. The interdependence of these two areas is evident considering that 60 to 65 percent of Quebec's deficit comes from Alberta and approximately 40 percent of Alberta's kill goes to Quebec.[24]

Due to the large production surplus of beef most Alberta beef packing plants only perform the primary functions of the processing industry. They are oriented to a "kill and ship" mode of operation as opposed to "full line" processing which involves processing various cuts and by-products for final use. This type of operation is more common in Eastern Canada.[25]

In most markets in Canada packing companies perform both processing and wholesaling functions. The one important exception to this is the Montreal market where wholesale facilities exist apart from those of the processing segment. These wholesale facilities are either independently owned, branches of packing companies, or retail affiliates. They receive the carcasses from Western Canada and provide storage and distribution services to the Quebec retailers.

The price determination mechanism for the exchange of beef between the processor and retailer is of an "offer and acceptance" nature. Typically, the retail meat buyer is contacted by the processor late in the week with offers for the coming week. These prices are recorded by the retailer who can then compare the processors' offers and chose the one most acceptable. This exchange of product is facilitated in the Alberta - Montreal system by meat brokers. These middlemen take offers from Alberta packers and bids from Montreal wholesalers and

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[24]Agricultural Economics Research Council of Canada, "The Montreal - Alberta Beef System - How it Works" Ottawa, Ontario 1977. p. 57
[25]Ibid 92.

Table 3.7 Provincial Shares of Cattle Slaughtered in Inspected Establishments 1971-80[1]

Year	B.C.	Alta	Sask	Man	West	Ont	Que	Mar	East
1971	1	36	6	15	59	33	7	1	41
1972	1	39	6	15	61	32	6	1	39
1973	1	39	6	15	61	32	6	1	39
1974	1	38	6	15	60	33	6	1	40
1975	1	41	5	15	62	31	6	2	38
1976	1	42	5	15	63	29	7	2	37
1977	1	42	6	14	63	28	7	1	37
1978	2	40	7	12	61	32	6	2	39
1979	2	43	6	11	61	31	6	2	39
1980	2	41	6	10	59	32	7	1	41

Provincial shares expressed as a percentage of national total
[1]Dawson, Dau, and Associates Ltd.,*Impact of Government Programs on the Regional Location of Meat Production in Canada* P. 139

Provincial shares expressed as a percentage of national total
then negotiate settlements. For their services they receive a flate rate commission from the seller [26]

E. Processing - The Pork System

Upon reaching a settlement with the marketing board, or producer in the case of Quebec, the packing company immediately moves the hogs to slaughter facilities. The carcass yield of a hog is considerably greater than a steer being aproximately 77 percent of the live weight. Unlike beef, however, the pork carcass does not improve with age, therefore it is chilled and cut into primal pieces immediately after slaughter and shipped to the retailer all within three to four days.

Almost all fresh pork is sold in the form of primal cuts. These include the ham, loin, belly, shoulder, and side ribs.[27] These chilled cuts are wrapped in peach paper and boxed before being sent by refrigerated truck to the retailer. Some pork is shipped under controlled

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[26]Ibid 63
[27]Food Prices Review Board "Pork Pricing" August, 1974

atmosphere conditions. This is similar to one of the alternatives used in the handling of boxed beef where the cuts are placed in a film-lined cardboard box with carbon dioxide pellants as a coolant.

The relatively short period for which pork stays fresh leads to further processing such as curing, smoking and packaging. It is only about 37 percent of the pork carcass that is sold as fresh meat. The loin and rib primals are usually sold fresh with the ham, shoulder and belly primals most often being further processed.

To facilitate the exchange of pork between the producer and packer a grading system relating fat cover to carcass value was instituted in 1968 .[28] It was last amended in 1978 and is carried out by Agriculture Canada graders. The grading system consists of a matrix with eleven weight categories and seventeen backfat categories. It is based on index numbers with a premium paid to hogs over index 100 and a discount on those below.

The trend in packing plant operations has been toward single species processing units. The location of these units has changed over the last ten years for the reasons discussed earlier - namely a change in the location of hog production. Numerous plant closures and consolidations have taken place in the West with expansion occurring in Eastern Canada especially Quebec.

The shipping patterns for pork have changed as well. In the early seventies there was movement from West to East. However as the Quebec hog industry grew this trend reversed itself, and a new development, the exportation of pork from Quebec to the U.S., began to occur. In spite of the decline in hog production experienced in Alberta that province has remained in a production surplus position. In terms of the domestic market it was estimated, in 1979, that approximately 30 percent of Alberta's production went to B.C., 7.8 percent to the East, 9.5 percent to Japan and only 0.7 percent to the U.S. [29]

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[28]Agriculture Canada "The Canadian Pork Industry" August, 1977. p. 4

[29]Foodwest Resource Consultants "Pork Industry in the Alberta Economy" Prepared for: Alberta Pork Producers Marketing Board, Edmonton, Alberta, March, 1980.

The exchange of pork between the processing sector and the retail segment takes place in much the same manner as that for beef. The main reason for this similarity is that firms involved in the processing of beef usually have the same interest in pork. As mentioned earlier, in the case of beef, the retailer records price offers from the processors and places an order for various cuts of fresh and processed pork on the basis of the most acceptable offer.

F. Retail

Since the sale of fresh beef and pork has increasingly taken place through large super market chain shores, most of which can be said about the retailing of one product can be said of another - therefore, the discussion on the retailing of these two products is grouped into one section.

The product that has the most utility added to it in terms of time, place, and form within the retail segment, is beef. This is especially so if it is received in swinging form, since it must undergo further changes before it is offered to the consumer. If it arrives at the retail outlet in boxed form, less breakdown is necessary, however, the primals must still be processed into retail cuts which may number as many as thirty-six. After the beef is cut and wrapped it is offered as fresh product in meat display cases with a shelf life of at most four days. It accounts for approximately 40 percent of meat department sales. [30]

Throughout the seventies the per capita consumption of beef showed some variability by rising to a maximum of 51.35 kg in 1976 before dropping to 39.78 in 1980. [31] This can be partially explained by a similar trend in real disposable income coupled with an opposite movement in real beef prices. Depending on the estimation technique used, income elasticity for beef ranges from .4867 to .5534, with price elasticity ranging from -.723 to -.767 [32]

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[30]Patrick M. Moncreif, "Beef Retailing in Canada" Agricultural Economics Research Council of Canada 1978 p.7

[31]Agriculture Canada, Handbook of Food Expenditures, Prices and Consumption, Marketing and Economics Branch (Publication No. 81/5 December 1981) p. 197

[32]Agriculture Canada, "Food and Agriculture Regional Model II Retail Demand", Policy, Planning and Economics Branch, Ottawa, Ontario, March 1980 p.8

The utility added to pork at the retail level is not as great as beef since fresh pork is delivered to the retail outlet already broken into primal cuts, and also because much of the pork sold at retail, such as ham and bacon, has been completely processed at the packing house level. Like beef, pork is offered to the consuming public through meat display cases and comprises approximately 20 percent of retail meat sales [33]

The consumption of pork over the last decade has shown considerable fluctuation, however, substantial increases occurred near the end of the seventies with per capita consumption reaching 29.7 kg in 1979 and 32.3 in 1980. [34] In spite of declining real personal income in this period pork consumption rose due to significant reductions in real price. This is supported by elasticity estimates which suggest the demand for pork is more sensitive to price than income. The range for income elasticity is .2501 to .2574 and for price -.9358 to -.9547. [35]

Food retailing in Canada is characterized by large multi-department outlets which may be part of a corporate chain, a voluntary group, or independent organization. In 1978 the size of corporate retail chain super markets ranged in size from 10,000 to 50,000 square feet of which approximately 15% was meat department selling area. [36]

These large retail outlets are a powerful force in the marketing chain for meat. From a national perspective six buying offices were responsible for purchasing beef for 1,020 stores in 1978, accounting for "about 57 percent of the average weekly Canadian slaughter". [37] In a survey of Canada's 32 largest markets which included all major food retail organizations, the four largest firms held 51.0 percent of the market share At the local level, concentration ratios can be particularly high. In Western Canada the four firm concentration ratio ranged from

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[33]Patrick M. Moncreif, "Beef Retailing in Canada" Agricultural Economics Research Council of Canada 1978 p.46
[34]Agriculture Canada, Handbook of Food Expenditures, Prices and Consumption, Marketing and Economics Branch (Publication No. 81/5 December 1981) p. 197,
[35]Agriculture Canada, "Food and Agriculture Regional Model II Retail Demand", Policy, Planning and Economics Branch, Ottawa, Ontario, March 1980 p.8
[36]Patrick M. Moncreif, "Beef Retailing in Canada" Agricultural Economics Research Council of Canada 1978 p.46
[37]Ibid p.15

77.4 percent in Winnipeg to 96.6 in Regina.[31]

The purpose of this chapter was to provide a description of the workings of the beef and pork marketing channels, from the farmgate to the consumer. The production process is carried out by many relatively small farm firms. Volumes of live animals are then shipped to packing houses which usually also fulfill the role of wholesalers. This wholesale level consists of relatively few firms which procure live cattle and hogs, and in turn market fresh beef and pork to retailers. At the retail level these volumes of beef and pork are broken down into cuts made available to the consumer. The retail level is also relatively highly concentrated.

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[31]GROCERY GUIDE March 1982

IV. Methodology

A. Data

The data used in this study consisted of weekly price observations at the farmgate, wholesale, and retail levels of the fresh meat marketing channel for beef and pork. The period of analysis covered the period 1979 to 1982 inclusive.

The farmgate prices were obtained from I.P. SHARP and for beef included the live weight prices of A1 and A2 steers in Calgary and Toronto.[39] Hog prices included index 100 prices for Edmonton and Toronto.

Wholesale prices for beef and pork were restricted to Edmonton and were obtained through a co-operating retail chain. Although wholesale prices for other areas in Canada could have been obtained through secondary sources it was decided, after comparison of primary and secondary data, that only the primary data should be used. Secondary data on wholesale prices is usually obtained through price lists published by processors. These prices appear to be the "starting points" of price negotiation between wholesalers and retailers with the result usually being lower prices paid by retailers for volume buying and other discounts.

The wholesale price data was limited to the period May 1981 to December 1982. The cuts for which prices were recorded during this period are shown in Appendix B.

Retail prices for beef and pork were recorded in Vancouver, Edmonton, Calgary, Toronto and Montreal. The collection of the prices was sponsored by the BIC and APPMB.[40] In all cities, except Toronto, prices were obtained by individuals visiting as many as six stores per week and recording the prices of selected cuts as they appeared in the meat display cases. In Toronto, retail price information was provided through the Ambler pricing service. A price war in Toronto during the first quarter of 1982 prevented the acquisition of data for that period. The retail cuts for which prices were obtained are shown in Appendix A as are the

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[39]I.P. Sharp information service, Alberta Agriculture
[40]BIC and APPMB stand for Beef Information Centre and Alberta Pork Producers' Marketing Board respectively.

retail chains visited in each city.

The main objective of this study was to assess the lead-lag relationships between price series at different levels of the marketing channel. The technique used to carry out this investigation was univariate residual cross correlation analysis. This technique is one method used to infer causality between two variables. Causality is a concept that scholars have had difficulty testing for, however Granger has developed a definition that allows for the empirical testing of causality between variables.

B. Granger Causality

Granger defined causality by first stating the following two rules:

1. The future cannot cause the past. Strict causality can occur only with the past causing the present or future.
2. It is sensible to discuss causality only for a group of stochastic processes. It is not possible to detect causality between two deterministic processes. [41]

Observing these two rules Granger asserted that one variable causes another if the first variable can be better predicted using not only its own past values but also the past values of the other variable. In other words if X is better predicted by $P_x(X_{t-j}, Y_{t-j})$ than by $P_x(X_{t-j})$ where t is the time period and j refers to the number of lags, then Y causes X in the Granger sense.

The type of causality described above is considered unidirectional, that is, causality running from Y to X, however, Granger also discussed the possibility of feedback or bi-directional causality. This occurs when X_{t+1} is better-predicted using Y_{t+1} In this case, $P(X_{t+1} | X_{t-j}, Y_{t+1}, Y_{t-j})$ is the optimal predictor of X_{t+1} rather than $P(X_{t+1} | X_{t-j}, Y_{t-j})$ [42]

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[41]C.W.J. Granger and Paul Newbold, Forecasting Economic Time Series (Academic Press Inc., New York 1977) p. 224

[42]M.D. Faminow, "Analysis of the Lead-Lag Structure of Two Wholesale Beef Price Quotes Using Residual Cross Correlation" North Central Journal of Agricultural Economics 3 (July 1981): p.91

In the bivariate example, with an information set consisting of X and Y, Granger's definition allows for the empirical testing of causality between the two variables. The following four possible relationships may exist between X and Y.

1. X causes Y.
2. Y causes X.
3. X and Y cause each other - feed back, bi - directional.
4. No relationship. [43]

In this study X and Y represent price series at different levels of the marketng channel, therefore an attempt to determine the causal ordering of these price series was made.

C. The Role of the Box-Jenkins Technique

Granger's definition allows for empirical testing of causal ordering between variables, however, there are at least three ways to do this. Unvariate residual cross correlation analysis was chosen over the technique proposed by Sims and also the direct method developed by Geweke. In the case of the former technique, the work by Bessler and Schrader, which compared the three alternatives, indicated that Sims' general filter may not always remove the autocorrelation from the time series and therefore may not provide the strongest inference. [44] Gewekes direct method provided results consistent with univariate residual cross correlation analysis and so it was decided that due to the computing facilities available, the latter technique would be used.

Using univariate residual cross correlation analysis to infer the causal ordering of variables, ultimately involves calculating cross correlation coefficients between the variables. However, because the data are time series in nature, there exists the possibility that autocorrelation is inherent in each. Autocorrelation, if it exists, would lead to an

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[43]Robert V. Bishop, "The Construction and Use of Causality Tests" Agricultural Economics Research/Vol.31, No. 4, October 1979

[44]D.A. Bessler, J.A. Brandt, "Causality and Inference: An Application to Livestock Markets" Purdue University, Agricultural Experiment Station, West Layfayette, Indiana, Research Bulletin 972 June 1982

"overestimation of the signficance of the cross correlations".[45]

The problem of autocorrelation refers to the influence past values of the time series have on the current value. For example, today's retail price for beef may be partially explained by the price yesterday or the day before. If this source of explanation of the current retail price is not taken into consideration before testing other potential sources of explanation, such as past farm prices, then the explanatory power of these other sources could be accorded undue importance. Therefore, the autocorrelation inherent in each time series must be dealt with before the series are cross correlated.

Univariate residual cross correlation analysis attempts to remove autocorrelation by applying a filter to each series. The filters used in this technique are derived from the Box Jenkins approach to time series forecasting. In this approach the focus is a single time series for which a model is constructed to predict future values of the time series. This forecasting procedure is predicated on the assumption that the behavior of the time series is characterized by a pattern that can be modeled. This pattern or time series property is also referred to as autocorrelation. A model of autocorrelation constructed to forecast future values of a time series can also be used as a filter to remove the autocorrelation present in the existing time series. It is this filtering role that the procedure of Box and Jenkins plays in univariate residual cross correlation analysis.

Much of the methodology of the Box-Jenkins approach to forecasting is embodied in univariate residual cross correlation analysis and therefore both have similar data requirements. One important requirement is that the time series be stationary. This means that the series (which may also be called the process since it is assumed to be stochastic) is characterized by a joint probability distribution that is invariant with respect to time. This property is defined in equation 4.1.

$$p(Xt, \ldots, Xt+k) = p(Xt+m, \ldots, Xt+k+m) \qquad (4.1)$$

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[45]Stephen E. Miller, "Univariate Residual Cross Correlation Analysis: An Application to Beef Prices" North Central Journal of Agricultural Economics 1(1979): 141-46 p. 142

This equation implies that the expected value of observation X is the same. Therefore a stationary process will always show on affinity for a mean value.

The problem most frequently encountered with respect to economic time series is that they are often not stationary. This situation can usually be remedied by transforming the data either through differencing or log transformations, into a series that is stationary. The term "integrated" is used to describe a data series that has been differenced.(footnote on invertibility)

Time series models constructed on the basis of the BoxJenkins technique may consist of autoregressive terms, moving average terms or both. An autoregressive model approximates the time series properties of the data using the current disturbance term and past observations. Equation (4.2) is the simplest form of an autoregressive process:

$$X_t = \phi_1 X_{t-1} + \delta + u_t \quad (4.2)$$

where X_t is the current observation; X_{t-1} is last period's observation δ is a fixed parameter, and U_t is the current distrubance term which is randomly distributed with mean zero and variance σ^2 This model is called an AR (1) process.

A moving average model approximates the time series properties of the data using current, and past disturbance terms. The simplest moving average model is (4.3):

$$X_t = \mu + u_t - \theta_1 u_{t-1} \quad (4.3)$$

where X_t is the current observation; X_{t-1} is last period's disturbance term; μ is a fixed parameter: and U_t is the current disturbance term, this is called an MA (1) process. All disturbance terms in a moving average process are assumed to be randomly distributed with mean zero and variance σ^2. Such random disturbances are also referred to as white noise.

Finally, the last type of model that my be used to describe the autocorrelation in a time series is one that has both autogressive and moving average terms. The simplest form of an autoregressive moving average (ARMA) model is (4.4).

$$X_t = \phi_1 X_{t-1} + \delta \ u_t - \theta_1 u_{t-1} \quad (4.4)$$

The terms have the same meaning as in (4.2) and (4.3). This model is used to achieve parisomony. This means that the ARMA approximation of the process involves estimating fewer parameters than would be the case if the process were modeled as either a pure autoregressive or pure moving average process.[46]

As mentioned earlier, data that have been transformed are referred to as "integrated", hence an ARMA model using differenced data is called an autoregressive integrated moving average (ARIMA). Similarly, a pure autoregressive or moving average model that uses differenced data is abbreviated ARI or IMA respectively.[47]

D. Choosing the Filter

Before a model can be estimated and used as a filter in univariate residual cross correlation analysis the data must be stationary. Inspection of the autocorrelation function can usually indicate whether some transformation should be made. Once the researcher is satisfied that the data are stationary, work can proceed on the selection of a model.

The first step involves inspection of the estimated autocorrelation (AC) and partial autocorrelation(PAC) functions of the data series. The aim of this inspection is to identify a pattern in these functions which could be approximated by some ARMA process of order p and q. In other words, a comparison is made between the estimated autocorrelation and partial autocorrelation functions and those generated by various theoretical ARMA processes.[48] On this basis, a tentative model is established and preliminary estimates of the p and q parameters are made from the sample autocorrelations. These preliminary estimates are then used as the starting values in an iterative search for the maximum liklihood estimates of the parameters.

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[46] Charles R. Nelson, Applied Time Series Analysis for Managerial Forecasting (Holden-Day Inc., San Francisco 1973) ch.3.

[47] The standard notation used to specifically describe a model involves the letters p, d, q, where p is the number of autoregressive terms, d, the degree of differencing, and q, the number of moving average terms. Therefore, an ARIMA (p, d, q) with three autoregressive terms, and two moving average terms that uses data that has been differenced would be denoted as ARIMA (3, 1, 2).

[48] Charles R. Nelson, Applied Time Series Analysis for Managerial Forecasting (Holden-Day Inc., San Francisco 1973) p. 89

Once the maximum liklihood estimates have been determined they are used to compute predicted values of the sample time series. The difference between the predicted value and the observed value is the residual. Diagnostic checks of the residual series are made to determine whether they are white noise.

Recall that the purpose of the Box-Jenkins technique is to model the autocorrelation present in the time series, hence, if this is accomplished the autocorrelation will be explained. Any unexplained variation will be captured by the disturbance term or residual. Therefore, if the autocorrelation is explained by the model the remaining unexplained portion - the residual - should contain no autocorrelation. This means the residual series generated by the model should be indistinguishable from a white noise series. Theoretically, if no autocorrelation exists the sample autocorrelation function of the residuals would be zero. The following statistic suggested by Box and Pierce can be used to test the smallness of the sample autocorrelations of the residual series.

$$Q_m = T \sum_{j=1}^{k} (r_j)^2 \quad (4.5)$$

where T is the number of residuals in the series and r_j^2 is the correlation coefficient at lags. The Q statistic is approximately chi square distributed with (k-p-q) degrees of freedom.[49] If the tests reveals that the autocorrelation function of the residuals is significantly different from zero a restructuring of the ARMA (p,q) model must take place. This restructuring continues until the residual series is white noise.

E. Testing for Causality

In testing for causality the procedure for modelling the time series properties of a data series is carried out for each series of interest. For example, testing for causality between farmgate and retail prices requires both the farmgate and retail prices to be approximated with ARMA models. From each series a set of white noise residuals is generated. It is the white noise residuals from each series that are cross correlated. The ARMA model for each series works as

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[49]Charles R. Nelson, Applied Time Series Analysis for Managerial Forecasting (Holden-Day Inc., San Francisco 1973) p. 115

a filter, removing the autocorrelation, leaving only the new information or "innovation" associated with each observed value.

Measuring the lead lag relationship between the two series therefore, involves cross correlating the residuals at positive and negative lags. The model for the two time series of interest, whether they be pure autoregressive pure moving average, or autoregressive moving average can be represented by:

$$u_t = F(B)X$$
$$v_t = G(B)Y$$

where F (B) and G (B) are infinite polynomials in the lag operator B for Y_t and X_t respectively and V_t and U_t represents the white noise residuals for each series. The theoretical cross correlation between v_t and u_t at lag k may be written as:

$$\rho uv(k) = E(u_{t-k}v_t)/[E(u_t^2)E(v_t^2)]^{.5} \quad (4.8)$$

Puv(k) is a theoretical statistic that can be estimated using ruv(k). Therefore the estimated cross correlation at lag (k) would be calculated using:

$$r_k = ruv(k) = \Sigma u_{t-k}v_t/[\Sigma u_t^2 \Sigma v_t^2]^{.5} \quad (4.9)$$

The U statistic is used to determine the signficance of r at lag k and hence the lead-lag relationship between the two series. It is from this test that causality between the two series is determined.

The U statistics used are:

$$U_m = n \sum_{k=1}^{m} (r_k)^2$$

$$U_m = n \sum_{k=-1}^{-m} (r_k)^2$$

$$U_m = n \sum_{k=-m}^{m} (r_k)^2$$

where n is the number of observations and k is the number of lags, -m k m. The statistic "U. is used to test the null hypothesis that X_t does not lead Y_t. U_{-m} tests the null hypothesis that Y_t does not lead X_t, and U_{2m+1} is used for a summary test of independence". [50]

This chapter has discussed the approach that was used to infer lead-lag price relationships in the beef and pork sectors. The problem of autocorrelation, which can bias the results, can be dealt with by adapting time series forecasting models to work as filters of time series properties. Specifically, the Box-Jenkins approach can be used to create these filters which are either autoregressive, moving averages or both. These models or filters are also known as ARMA processes. The residuals that are left after the application of the filters can be cross correlated and the concept of Granger causality used to assess the lead-lag relationship between the series. This procedure is carried out in the next chapter.

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[50]M.D. Faminow, "Analysis of the Lead-Lag Structure of Two Wolesale Beef Price Quotes Using Residual Cross Correlation." North Central Journal of Agricultural Economics 3 (July 1981): p. 91

V. Analysis of Results

This chapter examines the application of the Univariate Residual Cross Correlation technique and the use of Granger causality to infer lead-lag relationships in the pork and beef sectors. First the ARIMA technique is briefly reviewed, followed by a summary of the filters used in this study to remove the time series properties of the data. The discussion then turns to the analysis of the cross correlation functions that were generated and the subsequent calculation of the U statistics. Finally the results are interpreted and summarized in the last section.

A. ARIMA Models

As discussed in Chapter Four, the first step in determining the lead lag relationship when testing for causality using the ARIMA technique is to determine the appropriate filter for each time series. This can be accomplished first of all by inspection of the autocorrelation function and partial autocorrelation functions of each series.

The autocorrelation function for a series shows the strength of the linear relationship between observations at various lags. Since the term autocorrelation refers to correlation between obervations within the same time series the values of the autocorrelation function range between -1 and +1.

Similarly the partial autocorrelation function shows the strength of the linear relationship between observations at various lags when the intervening lags are controlled. For example, the relationship between the first observation and the fifth as measured by the autocorrelation function also includes the influence of the second, third, and fourth observation. The partial autocorrelation function controls these influences and measures the relationship accordingly.

By inspection of these functions the researcher makes a conjecture on the model that will best remove the autocorrelation present in the series. Table 5.1 provides some guidance when choosing the most appropriate filter. Note that when there are spikes at (q) lags in the autocorrelation function the process is likely a moving average process of order (q). When there are spikes at (p) lags in the partial autocorrelation function then the process is likely an autoregressive scheme of order (p). Finally the process may be of a mixed autoregressive moving average nature if the autocorrelation function tapers off and the partial autocorrelation function exhibits an irregular pattern.

Once the autocorrelation and partial autocorrelation functions have been inspected and on the basis of Table 5.1 a possible model is put forth, the parameters of the model are estimated. The estimation of the models in this study was done with a computing package called SPSS. [51] To meet the criteria of an adequate model for the data at hand the results of the estimation procedure must yield the following:

1. t values of the coefficients which are significant,
2. the conditions of stationarity and invertibilty must be satisfied which means the coefficients must be less than one; and
3. the innovations or residuals must approximate white noise as determined by the calculation of the Q statistic.

Tables 5.2 and 5.3 provide a summary of the models or filters used on each time series in this study. Column one of each table lists the series under study. Column two shows the filters applied to each time series with the corresponding t ratios under each coefficient. The degrees of freedom for the calculation of the Q statistic are shown in column three with the estimates of the Q statistics appearing in column four.

One of the criteria for model adequacy is a calculated Q statistic that is low relative to the Chi Square value for a predetermined level of significance. At the 1 percent level of significance the Chi Square values for 16, 17 and 18 degrees of freedom are 32.0, 33.4 and 34.8 respectively. [52]

In Tables 5.2 and 5.3 none of the estimated Q statistics exceed their critical values, therefore, the residuals or innovations from each filtered series cannot be distinguished from white noise. In other words any autocorrelation in the series has been removed at, least to the

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[51]SPSS - Statisitcal Package for the Social Sciences
[52] A. Koutsoyiannis, Theory of Econometrics, 2nd ed.

TABLE 5.1 CHARACTERISTIC BEHAVIOR OF AUTOCORRELATIONS AND PARTIAL AUTOCORRELATIONS FOR THREE CLASSES OF PROCESSES

CLASS OF PROCESS	*AUTOCORRELATIONS*	*PARTIAL AUTOCORRELATIONS*
MOVING AVERAGE	SPIKES AT LAGS 1 THROUGH q, THEN CUT OFF	TAIL OFF
AUTOREGRESSIVE	TAIL OFF ACCORDING TO $\rho_j = \phi_1\rho_{j-1} + \dots + \phi_p\rho_{j-p}$	SPIKES AT LAGS 1 THROUGH q, THEN CUT OFF
MIXED AUTOREGRESSIVE-MOVING AVERAGE	IRREGULAR PATTERN AT LAGS 1 THROUGH q, THEN TAIL OFF ACCORDING TO $\rho_j \quad \phi_1\rho_{j-1} + \dots + \phi_p\rho_{j-p}$	TAIL OFF

Source: Charles R. Nelson; Applied Time Series Analysis for Managerial Forecasting (Holden-Day Inc., San Fransico, 1973) P. 89

TABLE 5.2 ESTIMATED FILTERS FOR THE PORK SECTOR

SERIES	FILTER	D.F.	Q STAT.
VANCOUVER RETAIL PORK	$X_t=(1-.569B)U_t$ (9.9)	17	18.93
CALGARY RETAIL PORK	$(1+.290B+.298B^2)X_t = U_t$ (-4.4) (-4.4)	16	19.75
EDMONTON RETAIL PORK	$X_t=(1-.374B)U_t$ (5.7)	17	14.22
TORONTO RETAIL PORK	$X_t=(1-.272B)U_t$ (3.5)	17	11.82
MONTREAL RETAIL PORK	$X_t(1-.286B)U_t$ (4.2)	17	25.66
ALTA FARMGATE HOG	$X_t=(1+.500B)U_t$ (-8.3)	17	13.17
ONT FARMGATE HOG	$X_t=(1+.211B)U_t$ (-3.1)	17	14.88
EDMONTON WHOLESALE PORK	$X_t=(1-.226B)U_t$ (2.0)	17	12.76

TABLE 5.3 ESTIMATED FILTERS FOR THE BEEF SECTOR

SERIES	FILTER	D F	Q STAT.
VANCOUVER RETAIL BEEF	$X_t=(1-.502B)U_t$ (8.4)	17	8.97
CALGARY RETAIL BEEF	$X_t(1-.307B)U_t$ (4.7)	17	11.55
EDMONTON RETAIL BEEF	$X_t=(1-.430B)U_t$ (6.8)	17	11.35
TORONTO RETAIL BEEF	$(1-.874B)X_t = (1-1.03B)U_t$ (53.4) (27.9)	16	31.45
MONTREAL RETAIL BEEF	$X_t=(1+.489B)U_t$ (7.9)	17	29.70
ALTA FARMGATE STEER	$X_t= U_t$	18	16.00
ONT FARMGATE STEER	$(1-.975B)X_t= (1-1.01B)U_t$ (50.2) (55.1)	16	17.85
EDMONTON WHOLESALE BEEF	$X_t=(1-.612B)U_t$ (7.0)	17	4.87

extent that it cannot be distinguished from a random time series.

Another criteria mentioned earlier was the that all coefficients be significant. This requirement was satisfied as indicated in Tables 5.2 and 5.3, column two. Shown below each coefficient is the t ratio. In all cases the t ratios have values greater than two, therefore, all coefficients were considered significant.

The final criterion for model adequacy is the requirement that the coefficients not have a value greater than or equal to plus or minus one. This requirement was violated in two instances both involving beef prices from Toronto. For "Toronto Beef Retail" and "Toronto beefFarmgate" the coefficients on the moving average terms exceed one. In Chapter IV the discussion on ARIMA modeling mentioned that the original use of ARIMA models was for time series forecasting. In forecasting a time series the requirement that the coefficients be less than the absolute value of one is a necessity since a model in violation of this rule would yield a forecast best described as explosive. However, when ARIMA models are not being used for forecasting but rather as filters of autocorrelation, violation of this rule is less serious. The sole purpose of modeling in the latter instance is to create a filter to remove serial correlation. If this can be accomplished by filters with coefficients greater than one and the innovatic cannot be distinguished from white noise then the model is acceptable.

B. Cross Correlations

Completion of the modeling process and subsequent filtering of the autocorrelation resulted in a corresponding set of residuals or innovations for each time series. The lead-lag relationship between the various time series was then assessed by cross correlating the residuals of each series. Because these residuals are not autocorrelated the resulting cross correlations provided unbiased estimates of the lead-lag relationships between the original time series of interest.

One of the main objectives of this study was to assess the lead-lag relationship between prices at different levels of the marketing channel for beef and pork. Using the ARIMA methodolgy along with Granger's definition on causality an assessment of these relationships was made.

For example, one lead-lag relationship studied within the pork marketing channel was the relationship between farm level prices and retail prices. The residuals from each price series were cross correlated at a predetermined number of lags in both negative and positive directions as well as at zero lag. The number of lags for which cross correlations are calculated should be determined, as Bessler and Schrader point out, "according to one's prior expectations on leads or lags." [53]

As discussed in Chapter One, economic theory suggests that causality should run from the retail level to the farmgate, however, theory does not suggest how long this should take. Therefore, the U statistics discussed in Chapter IV were calculated at three and five lags in either direction. There was no particular reason for selecting three and five lags however, it was felt that by calculating two U statistics in each direction for each set of cross correlations, one may be able to determine the time dimension involved in the lead lag relationship.

Figure 5.1 is an example of output showing the cross correlation function between the Vancouver retail price for pork and the Alberta farmgate price for hogs. The r values at negative lags measure the relationship between current values of Vancouver retail prices for pork and past values of the Alberta farmgate price for hogs. In other words the null hypothesis that the farmgate price does not lead the retail price is subject to acceptance or rejection. Similarly the reverse is true at positive lags of the cross correlation function. The null hypothesis that the retail price does not lead the farm price is being tested. At zero lags the null hypothesis that there is instantaneous causality is being tested. If the value at the zero lag is at least twice its standard it is considered significant and therefore an instantaneous relationship exists.

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[53]David A. Bessler, Lee F. Schrader "Measuring Leads and Lagvs Amoung Turkey Products, AGRICULTURAL ECONOMICS RESEARCH / Vol. 32, No. 3, July 1980

Table 5.3 Cross Correlations for Pork and Beef Price Relationships at Zero Lag[1]

RELATIONSHIPS	CROSS CORRELATIONS
Vancouver Retail Pork/Alta Farmgate Hog	.007
Calgary Retail Pork/Alta Farmgate Hog	.108
Edmonton Retail Pork/Alta Farmgate Hog	.121
Toronto Retail Pork/Ont Farmgate Hog	.002
Montreal Retail Pork/Ont Farmgate Hog	.112
Edmonton Retail Pork/Edmonton Wholesale Pork	.124
Edmonton wholesale Pork/Alta Farmgate Hog	.064
Vancouver Retail Beef/Alta Farmgate Steer	.046
Calgary Retail Beef/Alta Farmgate Steer	.149*
Edmonton Retail Beef/Alta Farmgate Steer	.194*
Toronto Retail Beef/Ont Farmgate Steer	.045
Montreal Retail Beef/Alta Farmgate Steer	.006
Edmonton Retail Beef/Edmonton Wholesale Beef	.317*
Edmonton Wholesale Beef/Alta Farmgate Steer	.230*

[1]The cross correlations at zero lag for the relationships above are considered significant if they are at least twice their standard error.

Table 5.4 Haugh's U Statistic - Testing for Causality in the Pork Marketing Channel[1]

Retail Prices	Lags	Alta Farm Price		Ont Farm Price		Edmonton Wholesale Price	
		As Cause	As Effect	As Cause	As Effect	As Cause	As Effect
Vancouver	3	11.57*	0.93	-	-	-	
	5	30.31*	1.79	-	-	-	
Calgary	3	10.21	2.87	-	-	-	
	5	16.51*	4.58	-	-	-	
Edmonton	3	20.58*	5.33	-	-	1.21	6.59
	5	29.65	5.38	-	-	4.62	7.13
Toronto	3	-	-	14.38*	0.93	-	
	5	-	-	18.28*	8.78	-	
Montreal	3	-	-	19.13*	3.08	-	
	5	-	-	23.77*	6.27	-	
Alta Farm Price	3	-	-	-	-	5.67	2.95
Alta Farm Price	5	-	-	-	-	5.82	3.25

[1]Significant values are denoted with an asterisk. The calculated U statistic is larger than the critical Chi squared value at the 1% v level. $X^2(3) = 11.34$ $X^2(5) = 15.09$.

Table 5.5 Haugh's U Statistic - Testing for Causality in the Beef Marketing Channel[1]

Retail Prices	Lags	Alta Farm Price		Ont Farm Price		Edmonton Wholesale Price	
		As Cause	As Effect	As Cause	As Effect	As Cause	As Effect
Vancouver	3	42.43*	4.92	-	-	-	
	5	46.32*	5.81	-	-	-	
Calgary	3	36.74*	3.41	-	-	-	
	5	41.3[illegible]	3.64	-	-	-	
Edmonton	3	26.5[illegible]	5.41	-	-	2.31	4.15
	5	27.67	5.67	-	-	2.32	9.66
Toronto	3	-	-	21.88*	4.13	-	
	5	-	-	22.66*	10.49	-	
Montreal	3	11.35*	14.03*	-	-	-	
	5	13.46*	16.97*	-	-	-	
Alta Farm Price	3	-	-	-	-	0.78	6.11
Alta Farm Price	5	-	-	-	-	2.07	9.32

[1]Significant values are denoted with an asterisk. The calculated U statistic is larger than the critical Chi squared value at the 1% v level. $\chi^2(3) = 11.34$ XSUP2>(5) = 15.09.

Figure V.1 Cross Correlation Between Vancouver Retail Pork (C1) and Alberta Farmgate Hog (C6)

```
CCF - CORRELATES        C1(T) AND        C6(T+K)

            -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
              +----+----+----+----+----+----+----+----+----+----+
 -5    0.202                           XXXXXX
 -4    0.223                           XXXXXXX
 -3    0.121                           XXXX
 -2    0.072                           XXX
 -1    0.190                           XXXXXX
  0    0.007                           X
  1   -0.002                           X
  2    0.054                           XXX
  3   -0.021                          XX
  4   -0.007                           X
  5    0.064                           XXX
```

C. Pork Sector Results

As described in Chapter IV, Haugh's U statistic is calculated as follows:

$$U_m = n \sum_{k=-m}^{m} (r_k)^2$$

The U statistic is approximately chi square distributed with m degrees of freedom. Therefore at a given level of significance a researcher can determine whether or not the calculated U statistic is significantly different from zero and hence the direction of causality if it exists. In this study the chosen level of significance was 1%. Since the number of lags in either direction was 3 and 5 (and therefore the degrees of freedom) the critical values were 11.34 and 15.09 respectively. The values marked with an asterisck in Tables 5.4 and 5.5 indicate U statistics greater than the critical value.

A comparison of the expected results and the actual findings will be carried out for the pork sector first. In regard to the expected relationship between farm and retail prices it was hypothesized that the latter would lead the former. A review of Table 5.3 indicates that in the farm-retail relationships studied no instantaneous causality existed since none of the zero lag correlation coefficients exceeded twice their standard error. However Table 5.4, which contains U statistics calculated at positive and negative lags, indicates that in all cases farm prices led retail prices. This was true for all relationships at both 3 and 5 lags with the exception of the Calgary Retail Pork-Alta Farmgate Hog cross correlation function which showed no significant relation at three lags, however did have a significant U statiste at five lags.

In terms of economic theory these results would mean that consumer demand was actually stable and that the change in price was due to either a shifting farmgate supply function or a shifting derived farmgate demand curve. The latter explanation seems more plausible since, as mentioned earlier, the supply function should be relatively stable on a week to week basis. However the demand curve at the farmgate, even though derived from the retail level, was likely subject to influences at the wholesale level. The demand at the farmgate is expressed by the wholesaler or packing house. This demand, on a week to week basis, was probably determined to a large extent on wholesalers expectations of what the price would settle at between retailers and themselves. Since anticipation may have been involved the live price would, in part be be a function of wholesalers expectations, the determination of the price at higher levels of the marketing channel may then have followed.

Alternatively, it may have been the case that the live price was used in the price discovery process for the entire channel, and that prices at the wholesale and retail levels were determined by "marking up" the live price. If this had occurred it would mean that market information had gotten back to the live market and caused a price change at that level. Then as quantities of pork moved through the channel and the mark-up rules were applied price changes occurred at the wholesale level and then the retail level.

The hypothesized relationship between farmgate and wholesale prices in Edmonton was that Wholesale prices were expected to lead those at the Farmgate. The farmgate-wholesale price relationship in the pork sector as indicated in Table 5.3 was not significant at zero lag, therefore no instantaneous relationship was apparent. In Table 5.4 none of the U statistics for this relationship were in excess of their critical value which may tempt one to conclude that there was no relationship at all. However visual inspection of the cross correlation function suggests that some type of relationship did exist since some of the individual r values were twice their standard error. Based on this criteria it would seem that one-way causality running from the wholesale level to the farmgate existed in the Edmonton pork market. This unfortunatly does not support the argument just discussed, that is, farmgate prices were determined before wholesale prices as the result of packers anticipating the outcome of their dealings with retailers, however it is in keeping with the expected outcome. It was decided that since the results of the farm-retail relationships were the same for all five cities under study, the argument given for that outcome would be accepted, and therefore the expected results of the farm-wholesale relationship, in spite of being supported by the data, would be set aside. The main reason for this was that the wholesale data was limited to 81 observations and also limited to one [illegible]. Perhaps a greater sample size would bring out results consistent with the accepted argument.

Also it should be noted that drawing a conclusion on the individual r values in a cross correlation function raises the question of inference and the U statistic. It was just mentioned that the Wholesale series consisted of only 81 observations compared to the 208 obtained for the other series. Had the number of observations for the Wholesale series been greater perhaps the U statistics would have been significant. However individual r values can also be misleading. In these situations, as Pierce noted, "judgement frequently need(s) to be excersised." [54] Ususally a combination of the U statistic and individual r values are used to assess lead-lag relationships.

The relationship between Wholesale and Retail prices was expected to be one where Retail prices led those at the Wholesale level. This was supported by Table 5.3 in so far as there was no apparent instantaneous causality, however Table 5.4 has no U statistics that exceed their critical value, and so it appears there was no relationship. As before inspection of the cross correlation function suggests there may have been causality inherent in this relationship based on the size of some of the individual r values. There were r values at both positve and negative lags that exceeded their standard error twofold. In other words it appears wholesale prices led retail prices part of the time and retail prices led wholesale prices at other times. Concern was expressed earlier over the limitations on the wholesale data and it seems the same reservations apply here as well. The results do not agree with the expected relationship set out in Chapter One nor do they agree with the revisions just made involving the argument given for the farmgate-retail relationship. Based on this revised expectation between farmgate and retail prices it seems more likely that retail prices would respond to wholesale prices determined earlier.

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[54]David A. Pierce, "Relationships- and Lack Thereof- Between Economic Time Series, with Special Reference to Money and Interest Rates", Journal of the American Statistical Association 72 (1977)

D. Beef Sector Results

The hypotheses put forth regarding price relationships in the beef sector were similar to those for pork. First of all it was expected that Retail prices would lead Farmgate prices. The first indication that this was not the case for all beef price relationships studied were the results pertaining to the beef sector in Table 5.3. Two of the five farm-retail relationships studied exhibited instantaneous causality. These were the Calgary Retail Beef - Alta Farmgate Steer and Edmonton Retail Beef - Alta Farmgate Steer relationships. The results of the calculation of the U satistics in Table 5.4 were also contrary to the expected results. Four of the five relationships, including the two that exhibited instantaneous causality, had U statistics that indicated that farm prices led retail prices. The exception to this trend was the outcome of the cross correlation function between the Montreal retail price for beef and the Alberta farmgate price. In this case, at three lags there was evidence of feedback. However at five lags the retail price was leading the farmgate price.

In spite of the instantaneous causality in Calgary and Edmonton and the results in Montreal, where it appears retail prices did indeed lead farmgate prices, the same argument put forth for the pork sector is now put forth for the beef sector. That is, that farmgate prices changed first due to a shifting farmgate demand curve which shifted because of wholesalers expectations of a change in the wholesale price, retailers in turn reacted to the live price when negotiating with wholesalers.

The farm-wholesale price relationship differed from that of the pork sector in that the farm price showed an instantaneous relationship with the wholesale price as indicated in table 5.3. Also it appeared that the farm price was leading the wholesale price. Even though the U statistics in Table 5.5 for the farm-wholesale price relationship are not significant, the individual r values in the cross correlation function suggest that farm prices led wholesale prices. This result is consistent with the reasoning behind the farm-retail outcome however it does not agree with the expected result of the farm-wholesale relationship outlined in Chapter One. It was concluded that for the same reasons farm prices led retail prices the results pertaining to the farm-wholesale relationship were acceptable.

Finally the last relationship to be analyzed in the beef sector is that between the wholesale and retail levels. The expected outcome of this relationship, as outlined in Chapter One, was for retail prices to lead those at the wholesale level. The results, as indicated by the individual r values in the cross correlation function conform to the expected outcome mentioned above, however conflict with the logic used to explain the lead-lag relationship between farm and retail prices. As discussed in the section dealing with pork prices, the wholesale data was limited and could be the reason that these conflicting results arose.

E. Horizontal Relationships

Although the scope of this study was originally intended to include only the vertical price relationships in the beef and pork sectors there was an opportunity to digress and investigate horizontal relationships as well. It was expected that price adjustments between markets on a horizontal basis would take place fairly rapidly, likely in one or two weeks, therefore no U statistics were calculated, only the individual r values were used to assess relationships.

In the pork sector lead-lag relationships between retail prices were investigated, as well as the relationship between the two farmgate price series. At the retail level the three Western cities, Vancouver, Calgary, and Edmonton, were instantaneously related. The Toronto price series tended to lead each of the Western cities by one week as well as show a relatively strong instantaneous relationship with each. The Toronto-Montreal retail price relationship appeared to be instantaneous as well. Finally the lead-lag relationship between the Alberta and Ontario farm price for hogs showed the strongest correlation at zero and negative one lags, therefore there was an instantaneous relation in addition to the Ontario price leading the Alberta price by one week.

In the beef sector, Calgary and Edmonton retail prices appear to have been instantly related. These two centers in turn showed an instant relation to Vancouver in addition to leading Vancouver by one week. These same two cities also led Toronto by one period and showed no significant relation to Montreal. The Toronto-Montreal calculations showed Toronto leading Montreal by one week. Ontario farm prices for beef showed a strong relation to Alberta farm prices at zero and negative one lags suggesting that the two series were instantly related in addition to Ontario leading Alberta by one week. The results are generally as expected except for the two Alberta cities' relationship with both Toronto and Montreal. Toronto is a very large market and is usually seen as the price leader in the beef sector. It did seem to lead the Montreal price, however, given its size and importance it was not expected that Calgary and Edmonton would lead this market. It was also unexpected that Calgary and Edmonton did not show any significant relationship to the Montreal market since, as mentioned in Chapter Three, a large percentage of Alberta beef goes to Montreal.

To summarize the results, the findings suggest that farmgate prices led retail prices by about three weeks since the most U statistics were significant at three lags. The wholesale price relationships were not clear, perhaps because of the limited number of observations. The horizontal lead-lag analysis provided the expected results, showing that most markets lead or lag others by about one week. The price leader for pork was Toronto at the retail level and Ontario at the farmgate level. The beef sector relationships were similar in that the time lags were about one week, however the price leader as suggested by the data was the western region which was unexpected. Also, it was anticipated that the western region and the Montreal market would be related, but the cross correlation functions showed no significant relationship.

VI. Conclusions and Recomendations

A. Conclusions

The main objective of this study was to determine the lead-lag structure of the price relationships within the beef and pork marketing channels in Canada. This objective was set out in light of the problem that there was a lack of information regarding the time dimension involved for price changes at one level of the marketing channel to reach other levels and also the level at which the change occurred first. It was suggested in Chapter One that this type of information may be useful in the study of pricing efficiency. Recall that pricing efficiency refers to the "accuracy, rapidity, and effectiveness with which market information is developed and disseminated."[55] Price is a component of market information and since time is of concern with respect to market information, the lead-lag structure of price change in the marketing channel should provide some basis to comment on pricing efficiency. Initially the scope of this study was to include only the vertical aspects of lead-lag relationships in the beef and pork sectors, however the data at hand also provided an opportunity to assess the lead-lag relationships from a horizontal perspective as well. In the following paragraghs the results of both the vertical and horizontal lead-lag relationships will be summarized.

The results of the investigation regarding lead-lag relationships in the market channels for beef and pork yielded similar results in that both market channels were characterized by lead-lag relationships where the farm price led the retail price. These results were contrary to the expected results put forth in Chapter One. It was expected that the retail price would lead the farm price since the farmgate supply curve is usually seen as inelastic and stable on a week to week basis. The impetus for change, it was thought, would come from a shifting retail demand curve that shifted on a week to week basis due to factors such as changes in the price of substitutes. The demand curve, it was reasoned would shift at the retail level first causing a price change there, then the derived demand curve at the farmgate would shift after some time

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[55] W.F. Williams and T.T. Stout *Economics of the Livestock-Meat Industry.* MacMillan Company, New York. p. 122

lag. The results of the ARIMA modeling and subsequent use of the Granger definition for inferring causality revealed that the farmgate price led the retail price in both the beef and pork sectors. The explanation offered for this outcome was that the impetus for change must have come from the farmgate either due to a shifting farmgate supply function or a shifting farmgate demand function. It was conluded that the shifting demand curve offered a more plausible explantation. The primary demand for both commodities exists at the retail level therefore the demand at the farmgate is a derived demand. For this to shift at the farmgate it seems necessary that a shift take place at the retail level first. There is however an influence that intervenes between the retail and farmgate levels and that is the wholesale segment of the marketing channel. It was reasoned that wholesalers' expectations of the price settlement that would be reached between themselves and retailers had an impact on the farmgate price. This impact on the farmgate price occurred first then was followed by the settlement of the wholesale price as negotiated by wholesalers and retailers. Wholesalers anticipating a change in the price they would receive from retailers may have brought about a change in the farmgate price. The change in the farmgate price may have influenced the outcome of wholesale-retail negotiations. Finally the price change would show up at the retail level in the way of either increased or decreased prices for beef and pork offered to the consumer.

A slight variation of this argument that could explain the results is that perhaps wholesalers and retailers follow mark-up rules based on the live price. The live price appears to be the most visible price in the market channel and therefore could be the basis for price determination at other levels.

Results regarding wholesale price relationsh to other levels of the marketing channel for both beef and pork were unexpected and conflicting. In some cases the results conformed to the hypothesis in Chapter One and in other cases were consistent with the argument presented above regarding the farm-retail price relationships. Since the evidence with respect to the farm-retail lead-lag relationships strongly suggests that the farm price led the retail price, acceptance of the argument for why this was the case has an impact on what one would expect regarding wholesale price relationships. Given the argument above one would expect the wholesale price to follow the farmgate price and to lead the retail price. In the pork sector the wholesale price led the farmgate price and had a feedback relationship to retail prices. In the beef sector the farm price led the wholesale price, thus conforming to the new expectations, however the retail price led the wholesale price which is in conflict with new the expectations.

One fact to take into consideration when dealing with the outcome of the wholesale price relationship analysis is that the conclusions drawn regarding these relationships were done solely on the individual r values in the respective cross correlation functions. This was done since none of the U statistics for these relationships were significant. This was the main reason it was suggested that a greater number of observations for the wholesale price series be obtained with the hope of coming to a clearer conclusion. As a final word on the wholesale situation the only conclusion reached was that no clear direction could be ascertained with regard to the lead-lag relationship, however the new hypotheses are that:

1. Farm prices lead wholesale prices, and
2. Wholesale prices lead retail prices..

The horizontal relationships, that is those relationships between markets at the same level of the marketing chain, seemed easier to reach conclusions on. The leads or lags in these situations were not expected to be greater than one or two weeks, and as the cross correlation functions showed, the individual r values were usually quite pronounced at these lags and the zero lag. The investigation for horizontal relationships could only be carried out for the retail and farm levels since there was no more than one wholesale series.

In the pork sector the conclusion reached was that, at the farmgate level the Ontario price led the Alberta price. Given the findings from the vertical perspective this would mean that, in the pork sector the Ontario farmgate price leads all others.

On the beef side the results of the lead-lag investigation indicated that, at the retail level, the Western region was playing a leadership role. Vancouver,Calgary and Edmonton were all strongly related at zero lag, thus showing an instantaneous relationship, and each in turn tended to lead Toronto. The Toronto retail price showed a significant relationship to the Montreal price by leading that market by about one week. At the farmgate level the Ontario price series led Alberta prices by one week as well. One unexpected result was the lack of any significant relationship between the Western retail markets and the Montreal market. As pointed out in Chapter Three approximately forty percent of the cattle slaughtered in Alberta are shipped to Montreal, therefore it seemed likely that there would be some relationship between retail price changes in these two regions. This result remains largely unexplained

One of the concerns expressed in Chapter Five was the use of the U statistic and individual r values to infer causality or lead-lag relationships. The concern focused mainly on the fact that none of the wholesale price relationships, for either commodity, resulted in significant U statistics, yet some individual r values from the cross correlation functions were at least twice their standard error. In these situations conclusions were based on the r values, however lack of significant U statistics in spite of high r values may be reason alone to set aside the wholesale results due lack of strong enough inference.

The main finding of this study is that farm prices led retail prices for both pork and beef over the period 1979 - 82 by about three weeks. As a standard of comparison Miller found that in the U. S., farmgate steer prices led retail beef prices by the same amount of time. [56] As more evidence accumulates further comparisons can be carried out and evaluations can be made. However, an efficient market channel should reflect the price changes instantaneously, the fact that it takes two to three weeks for beef and pork to move through the channel is no reason for price change to take that long as well. The only indication of an instantaneous relationship between price changes at the farmgate and retail levels was for the beef sector in Calgary and Edmonton.

The only conclusion to be reached with respect to wholesale price relationships is that, given the results of the farm-retail situation for both commodities, the hypotheses regarding wholesale price relationships have been altered so that now it is expected that

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[56] Stephen E. Miller, "Univariate Residual Cross Correlation Analysis: An Application to Beef Prices", North Central Journal of Agricultural Economics 1 (1979) P. 146

1. the farm price will lead the wholesale price and
2. the wholesale price will lead the retail price.

From the horizontal perspective it was concluded that price changes at the retail level were led by Toronto for pork and the western cities for beef, and that the lags were no more than one week. There was also evidence of instantaneous relationships for most series analyzed. Similar results occurred with respect to the farmgate relationships. Hog and Steer prices changed in Ontario first then the following week in Alberta. These relationships also showed strong instantaneous causality.

The results of the [illegible] estigation, at least for the farmgate series, are fairly consistent with the results [illegible] which have indicated that prices in the east lead the west at very short lags.

The implications these findings have for those concerned with the beef and pork sectors is that the live market could be used as an indicator of what will happen in the retail market. This may have a practical application for the consumer who is trying to keep food expenditures within a predetermined budget. For the producer and policy maker the results provide evidence that the pricing efficiency of the two channels could be improved by reducing the time lag involved for price changes to be transmitted through the channels. The information flow from one level to the other should result in price changes that occur within the week. If this is not the case production, consumption and distribution decisions are based on noncurrent information and consequently may result in an inefficient use of resources in carrying out the activities associated with the beef and pork sectors. The results also seem to indicate the importance of the live markets in the determination of price throughout the marketing channels. As the market to which wholesalers and retailers look for price information any change in the structure of these markets could have far reaching effects.

B. Recomendations

It is recommended that the study of these relationships continue using the retail data collected by the Canadian Cattlemen's Association and the Alberta Pork Producer's Marketing Board. The use of this data in calculating a composite retail price series along with price data from other levels can provide additional updated information on lead-lag relationships, which may even provide a basis for policy makers to render decisions on matters regarding the structure and performance of these sectors.

Since lags do exist in the marketing channels for beef and pork it is suggested that these be taken into consideration when price spreads or margins are calculated. Since it takes approximately two weeks for these products to move from the farmgate to the consumer, the appropriate procedure when calculating the price spread would be to lag the farmgate price by two weeks.

Also, further inquiry into wholesale price relationships and testing of the hypotheses offered by this study should add to the information on pricing efficiency. Additional information on the institutional variables at work in the market channel would also be very useful to explain the outcome of the statistical results. The actual pricing policies of wholesalers and retailers are difficult to obtain due to the personal nature of competition at these levels of the marketing channels. This information is usually considered confidential and thus actual prices are not available for study. If this type of information were available it would provide a much better basis for assessing pricing efficiency and for making possible improvements.

The statistical procedures used in this study can also be modified to analyze the lead-lag relationships in the beef and pork sectors. One alternative is Geweke's OLS approach to inferring lead-lag relationships. It may be useful to compare the techniques to further substantiate or criticize the results found using the univariate residual cross correlation approach.

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Table B.1 Wholesale Pork Cuts and Factor Weights for Edmonton

RETAIL CUT	FACTOR WEIGHT
HAM	21.9
LOIN	17.5
BELLY	11.8
RIBS	2.8
PICNIC	9.52
BUTT	8.1

Table B.2 RETAIL PORK CUTS AND FACTOR WEIGHTS FOR VANCOUVER CALGARY, AND EDMONTON

RETAIL CUT	FACTOR WEIGHT
PORK CHOPS CENTRE	.08
PORK CHOPS RIB	.039
PORK TENDERLOIN	.006
PORK LOIN ROAST	.031
BOSTON BUTT	.062
SPARERIBS	.028
PICNIC SMOKED	.095
HAM RTS	.099
GROUND PORK	.016
PORK HOCKS	.028
PIGS FEET	.008
BACON UNSLICED	.008
BACON SWIFT	.05
BACON M.L.	.05
BACON SCHNEIDERS	.018
HAM SWIFT	.05
HAM M.L.	.05
HAM SCHNEIDERS	.02

Table B.3 Retail Pork Cuts and Factor Weights for Toronto

RETAIL CUT	FACTOR WEIGHT
PORK CHOPS CENTRE	.08
PORK CHOPS RIB	.039
PORK TENDERLOIN	.006
PORK LOIN ROAST	.031
BOSTON BUTT	.062
SPARERIBS	.028
HAM RTS	.099
PORK HOCKS	.028
PIGS FEET	.008
BACON SWIFT	.053
BACON M.L.	.053
BACON SCHNEIDERS	.02
HAM SWIFT	.06
HAM M.L.	.06

Table B.4 Retail Pork Cuts and Factor Weights for Montreal

RETAIL CUT	FACTOR WEIGHT
PORK CHOPS CENTRE	.08
PORK CHOPS RIB	.039
PORK TENDERLOIN	.006
PORK LOIN ROAST	.031
BOSTON BUTT	.062
SPARERIBS	.028
PICNIC SMOKED	.111
HAM RTS	.099
PORK HOCKS	.028
PIGS FEET	.008
BACON UNSLICED	.008
BACON SWIFT	.05
BACON M.L.	.05
BACON SCHNEIDERS	.018
HAM SWIFT	.05
HAM M.L.	.05
HAM SCHNEIDERS	.02

Table B.5 Retail Beef Cuts and Factor Weights for Vancouver, Calgary, and Edmonton

RETAIL CUT	FACTOR WEIGHT
SIRLION STK	.045
PORTERHOUSE	.02
T-BONE	.025
WING	.02
FLANK STK.	.005
ANDING RIB ROAST	.06
SIRLOIN TIP ROAST	.035
RUMP ROAST	.05
ROUND INSIDE	.071
XRIB ROAST	.06
BLADE ROAST BONE REMOVED	.06
SHOULDER ROAST	.026
POINT BRISKET	.035
PLATE BRISKET	.035
SHORT RIBS	.046
SHANK CENTER	.012
STEWING BEEF	.05
GROUND BEEF REG.	.05
GROUND BEEF MED.	.025
GROUND BEEF LEAN	.025

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