CANADIAN THESES

THÈSES CANADIENNES

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

Canada

National Library of Canada
Bibliothèque nationale du Canada

Canadian Theses Division
Division des thèses canadiennes

Ottawa, Canada
K1A 0N4

0-315-24828-9

PERMISSION TO MICROFILM — AUTORISATION DE MICROFILMER

• Please print or type — Écrire en lettres moulées ou dactylographier

Full Name of Author — Nom complet de l'auteur

SAMUEL OWUSU BAAH

Date of Birth — Date de naissance
27TH FEBRUARY, 1952.

Country of Birth — Lieu de naissance
GHANA

Permanent Address — Résidence fixe
C/O REV. A. KWAA, PRESBY BOYS' SECONDARY SCHOOL, BOX 98, LEGON, ACCRA. GHANA. WEST AFRICA

Title of Thesis — Titre de la thèse

PRICING EFFICIENCY IN THE ALBERTA HOG INDUSTRY.

University — Université
UNIVERSITY OF ALBERTA

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée
MASTER OF SCIENCE (AGRICULTURAL ECONOMICS)

Year this degree conferred — Année d'obtention de ce grade
1984

Name of Supervisor — Nom du directeur de thèse
DR. M H HAWKINS

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

~~30 JUNE, 1984~~

Date
6TH JULY, 1984

Signature

THE UNIVERSITY OF ALBERTA

PRICING EFFICIENCY IN THE ALBERTA HOG INDUSTRY

by

SAMUEL OWUSU BAAH

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

AGRICULTURAL ECONOMICS

DEPARTMENT OF RURAL ECONOMY

EDMONTON, ALBERTA

FALL 1984

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR SAMUEL OWUSU BAAH

TITLE OF THESIS PRICING EFFICIENCY IN THE ALBERTA HOG INDUSTRY

DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED FALL 1984

Permission is hereby granted to THE UNIVERSITY OF ALBERTA LIBRARY to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

(SIGNED) .....

PERMANENT ADDRESS:

c/o REV. AUGUSTUS KWAA

PRESBY BOYS' SECONDARY SCHOOL

P. O. BOX 98, LEGON-ACCRA, GHANA.

DATED 15th JUNE, 1984

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled PRICING EFFICIENCY IN THE ALBERTA HOG INDUSTRY submitted by SAMUEL OWUSU BAAH in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL ECONOMICS.

.....

Supervisor

.....

.....

.....

Date 15th June, 1984

ABSTRACT

This study has attempted to assess the success of the Alberta Pork Producers' Marketing Board in its efforts to achieve pricing efficiency in the Alberta hog industry.

The pricing efficiency concept was analysed through the use of graphical illustrations and empirical methods. Two empirical methods were applied. The first was the Box-Jenkins Procedure which was used to study the impact of policy changes initiated by the Alberta Pork Board during the period from January, 1964 to December, 1983. The second method was the utilization of the concept of Granger causality to study the lead-lag relationship between the Edmonton hog market, the Toronto hog market and an average of seven mid-western United States markets.

The choice of the alternative market areas was to help determine how rapid and effective was the information flow between the Edmonton hog market and the other markets of comparison. Effective information flow is important in achieving pricing efficiency.

The conclusions drawn from this study were three. First, none of the policies initiated by the Pork Board had any significant impact on pricing levels. Secondly, analysis from the lead-lag structure showed that pricing efficiency levels improved immediately after the formation of the Pork Board itself. Thirdly, the Alberta hog market was found to have isolated itself from the alternative markets. This is an indication that the Pork Board has had some control over

the local supply and demand conditions of hogs.

ACKNOWLEDGEMENTS

The author is grateful to the many individuals who have contributed their time towards the completion of this study.

My special thanks go to Dr. M.H. Hawkins and Mr. W.L. Adamowicz for their suggestions, directions and understanding. The personal interest of these two professors in this study provided a wonderful learning experience for me. I would like to thank Mr. Greg Whalley of the Alberta Pork Board for his cooperation in my efforts to seek information.

I am also very grateful to fellow graduate students, Mike McEvoy, Rodney Dlugos and Greg Smith, who provided the necessary editorial comments and suggestions.

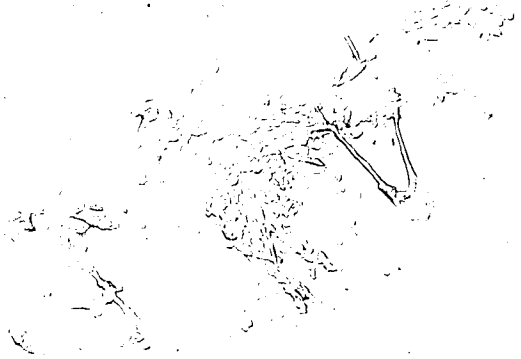
My sincere thanks go to Jim Copeland, C.A. Shier, and Judy Warren for their assistance and advice in my computer work. My sincere thanks also go to Ms. Lynn Gaetz who stayed late at night to type this thesis, and to Holly Horvath for her assistance in typing some of my papers on the type-writer for me.

Finally, my gratitude is extended to all the smiling faces in the Department of Rural Economy, especially Mr. Reginald Norby, for their continued support and encouragement.

This work is dedicated, with love, to my wife Margaret Amonoo and my daughter Emily Owusu Baah, for their encouragement and moral support. The following provided the financial support for my studies in Canada and I owe them

tons of gratitude for that. They are: my sister Mrs. Beatrice Kwaa, my brother-in-law Reverend Augustus Kwaa and my mother Mrs. Juliana Owusu Baah.

Table of Contents



List of Tables

List of Figures

I. OVERVIEW

A. INTRODUCTION

The hog industry in Alberta is an important segment in the province's agriculture. The province is the third major producer of hogs in Canada, next to Ontario and Quebec .(Table 1-1).

Manning estimated in 1965 that some 40,000 producers in Alberta sold 1,634,000 hogs with a market value of $77 million. This value represented nearly 12 per cent of total cash farm receipts in the province. A further $91 million was the estimated value added to the hogs through assembly, processing, and distribution during the same period. In all, the total retail value in 1965 amounted to about $168 million.[1] Although Alberta still remains the third major producer of hogs in Canada, the number of producers, presently estimated at about 6,350, is below the 1965 level.[2]

The major consumption areas for pork in Canada are Ontario, Quebec and British Columbia. Alberta has traditionally been a surplus production region, with production exceeding consumption. The province's surplus pork has mainly been divided between British Columbia and the Pacific North Western United States, with some shipments

---

[1] Travis Manning, *Performance of the Hog Marketing System in Alberta.* (Edmonton: U. of A., Dept. of Extension, 1967) p.1.
[2] Suzanne Zwarun, "A Pork Barrel Conspiracy". *Maclean's News Magazine.* (January 30, 1984) p. 39.

TABLE 1-1

HOG NUMBERS, MARKETING AND FARM CASH RECEIPTS BY PROVINCE, 1980

	Number On Farm (000)	Commercial Marketings (000)	Farm Cash Hog Receipts	Percent of Total Farm Receipts
Newfoundland	n.a.		n.a.	n.a.
P.E.I.	101.5		20.0	14.1
Nova Scotia	110.0	462.3	21.7	10.7
New Brunswick	61.0		10.2	6.6
Quebec	3,150.0	4,819.2	487.9	21.8
Ontario	3,155.0	4,090.1	470.8	10.7
Manitoba	826.3	1,152.4	115.2	8.2
Saskatchewan	625.0	605.6	76.1	2.4
Alberta	1,280.0	1,758.6	171.4	5.3
B.C.	245.0	262.8	32.3	4.3
East	6,577.5	9,371.6	1,010.6	14.1
West	2,976.3	3,779.4	395.0	4.6
Canada	9,553.8	13,151.0	1,405.6	8.9

Sources: Statistics Canada, Farm Cash Receipts, Catalogue No. 21-201, Annual Statistics Canada, Livestock and Animal Products Statistics, Catalogue No. 23-203, Annual.

to eastern Canada.[3]

The efficiency in the industry or a lack of it has been of concern to the many people employed in the industry, as well as to consumers. Elements of concern include ". . . the concentration of market power in food retailing, the system for establishing basic hog prices, competitive practices in hog procurement, and marketing charges which resulted in different prices for the same quality of hogs."[4]

B. SITUATION

The Alberta Pork Producers' Marketing Board (APPMB) was established in October of 1969, to institute a method of central selling and to allocate pigs for competitive bidding. The mandate of the Board was to improve the operational and pricing efficiency in the hog industry.

Prior to the formation of the board in 1969, there was increasing concern over pricing procedures in the hog market.[5] Only about 10 to 12 per cent of the province's hogs were consigned to the stockyards in Alberta. Of the hogs consigned to the three Alberta stockyards in Calgary, Edmonton and Lethbridge, slightly more than one half were sold on the livestock exchange; the rest were sold by private treaty elsewhere (Table 1-2). This 5 to 6 per cent sold on the livestock exchange established the market price

---

[3] Travis Manning, *op. cit.* p. 3.
[4] Manning, *op. cit.* p. 1.
[5] M.H. Hawkins, et al, *Development and Operation of the Alberta Hog Producers' Marketing Board.* (Edmonton: U. of A.) p. 1.

TABLE 1-2

SLAUGHTER HOGS CONSIGNED TO TERMINAL STOCKYARDS IN ALBERTA, 1965

CONSIGNMENT TYPE	TERMINAL STOCKYARD			
	CALGARY	EDMONTON	LETHBRIDGE	TOTAL
	Number of hogs			
Through Bill...	45,347	48,553	15,419	109,319
Sale....	53,505	53,414	38,013	144,932
Total....	98,852	101,967	53,432	254,251

Sources: Canada Department of Agriculture, Production & Marketing Branch, Calgary. Annual Livestock Market Report, 1965, (Calgary: 1966), Edmonton Annual Livestock Market Report, 1965, (Edmonton: 1966), Lethbridge Annual Livestock Market Report, 1965, (Lethbridge: 1966).

for hogs.[4]

The Board, since its inception, has had continued challenges. In order to meet these situations, several developments and policies have been instituted by the Board. Among them are:

1. the involvement of the board in the domestic and foreign markets, with its first contract signed with the Japanese in May, 1973;
2. formation of the Producers' Hog Indemnity Fund in July, 1973, to replace the higher private insurance costs to producers;
3. informative activities through provision of the *Hog Journal* and the producer toll free code-a-phone service;
4. institution of court action against the packing plants for price fixing activities;
5. price pooling system to reduce any price variability;
6. the establishment of a teletype to aid in the marketing of hogs under the system of advance buyer bidding.

Table 1-3 gives in-depth information regarding some of the Board's development and policy changes since it has been in existence.

C. OBJECTIVES

The objectives of this study are:

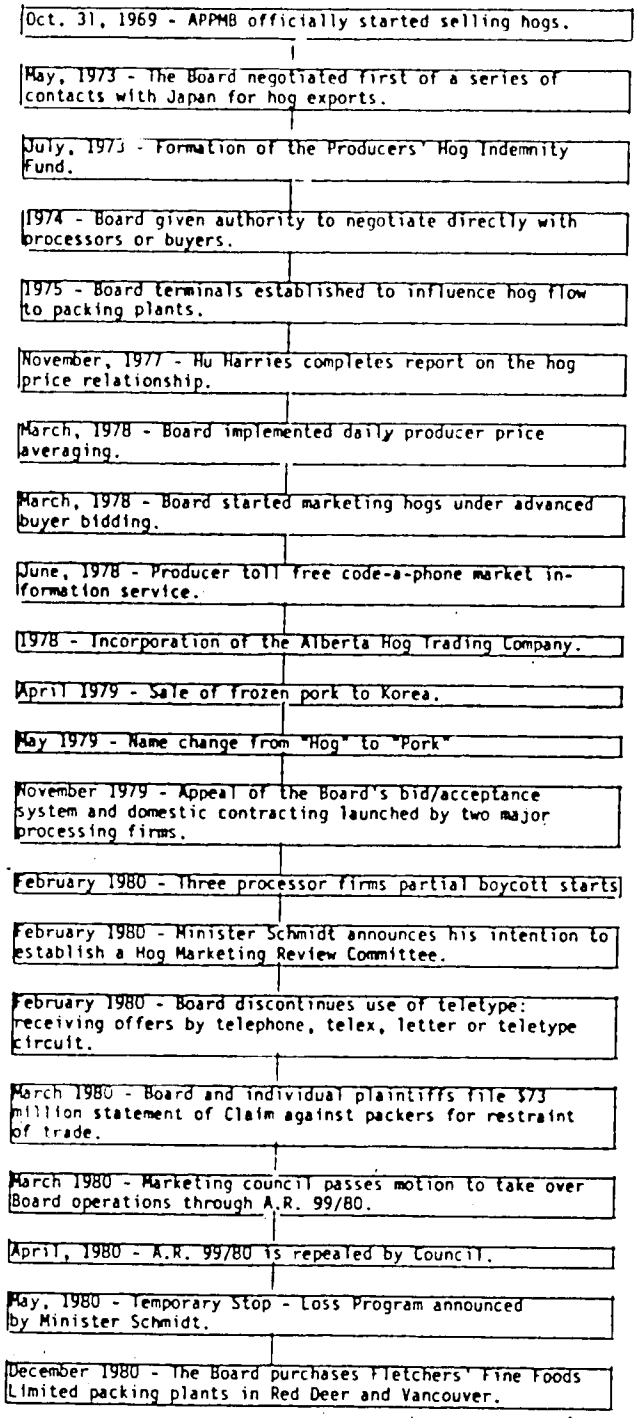
1. to examine the impact of major Board policy changes on pricing efficiency in the marketplace;

---

[4] Manning, *op. cit.* p. 6.

TABLE 1-3

SELECTED POLICY CHANGES BY THE APPMB BETWEEN 1969 AND 1980



Source: Alberta Pork Producers' Marketing Board, Alberta Hog Journal. Edmonton, Alberta. Various issues 1977-1980. Title changed to Western Hog Journal summer of 1979. M. Hawkins, et al. Development and Operator of the Alberta Hog Producers Marketing Board, Rural Sociology Bulletin 12 (Edmonton, University of Alberta, March 1977)

2. to determine whether the Board has improved pricing efficiency in the pig marketing system for Alberta
3. to study the lead-lag structure of the markets under study and
4. to study the movement of the price spread between the Edmonton hog market and the other markets of comparison.

D. METHODOLOGY

In this study, weekly average slaughter hog prices in Canada and in the United States were analysed for the period January 1, 1964 to December 31, 1983. Differences between the weekly average prices of the following market regions were examined: Edmonton, Toronto and an average of 7 major United States Midwestern markets.

This study is an extension of the earlier work of Leavitt at the University of Alberta, Department of Rural Economy, in 1981. In his study, Leavitt used the simple correlation models and regression models in order to examine the market performance of the Alberta Pork Producers' Marketing Board. This study however, will attempt to further analyse pricing efficiency, through the utilization of somewhat newer concepts, the Autoregressive Integrated Moving Average and the Granger Causality Model.

The Box-Jenkins Procedure is one type of the Autoregressive Integrated Moving Average (ARIMA) model. This procedure will be used to:

1. analyse the pre- and post-formation periods of the APPMB

in order to determine the success of the Pork Board;

2. assess the effectiveness of the policy changes of the Board in achieving pricing efficiency in the hog industry.

The Granger causality model will further be used to study the lead-lag structure of prices for the markets during the various time periods considered. Finally, a graphical illustration will be presented to show the movement of the price spreads between the markets under study.

E. HYPOTHESIS

My hypothesis is that the formation of the APPMB has not increased pricing efficiency in the Alberta hog market. To test this hypothesis, I will study the period January 1, 1964 to October 31, 1969, the period prior to the formation of the Marketing Board and the period November 1, 1969 to December 31, 1983, the period since the formation of the Marketing Board.

F. LIMITATIONS OF THE STUDY

The results of this study are likely to be influenced by the market structure of the Alberta hog industry. While producers of hogs face a competitive market structure, the situation appears different if one considers the structure of the pork processing industry. The packing plant industry for pork in Alberta is highly concentrated, which may

provide incentives for interdependence.

Reschenthaler's study of 1980 showed a degree of price leadership in the packers' patterns of purchases. Price leadership exists when a firm or a group of firms in an industry, usually by their market power, set prices for all other smaller firms in the industry to follow. This is an element of oligopoly. Two larger packers were found to have usually bid lowest for their hog requirements.[7] It is possible that these two larger packers waited for the other three smaller packers to complete their purchases before going in to bid on the residual hogs at lower prices. More on market structure will be discussed in the next chapter.

G. FORMAT

Organization of subsequent chapters will be in the following order. In chapter 2 the literature dealing with pricing efficiency will be reviewed. To give the reader a feel of market power and how it may be used to influence prices, the same chapter will review the theory of market structure, conduct and performance, which are important considerations in market power and price fixing. Chapter 3 will contain an analysis of the methodology and methods of the Box-Jenkins Procedure and the Granger Causality. In Chapter 4, the interpretations and results of the study will be reported. Chapter 5 will contain the conclusions and

---

[7] G.B. Reschenthaler, "An Analysis of the Competitiveness of the Pork Industry in Alberta". Paper presented to the Hog Marketing Review Committee, Edmonton, June 24, 1980.

recommendations, based on the results of the study.

II. SOME THEORETICAL CONCEPTS OF OLIGOPOLY, MARKET PERFORMANCE AND PRICING EFFICIENCY

A. INTRODUCTION

This chapter will contain a theoretical discussion of oligopoly behaviour and pricing. The theoretical discussion will be utilized in order to attempt to determine how close the pork industry in Alberta comes to the oligopoly structure.

The chapter will also contain additional aspects of market performance. In this regard, it will review literature and empirical results with respect to pricing efficiency.

B. THEORY ON OLIGOPOLY BEHAVIOUR AND PRICING

There are several competing hypothesis of oligopoly with varied sets of assumptions. Among the assumptions, one particular assumption (that is, sufficiently small number of sellers) unifies nearly all the models. The small number of sellers in the market causes the firms to recognize their interdependence.[8] The mirror side of oligopoly is oligopsony, where there are a relatively small number of buyers.

The Chamberlin small-group case, also referred to as monopolistic competition, may be modified to cover the oligopolistic case more explicitly. Chamberlin assumes the

---

[8]J.V. Koch, *Industrial Organization and Prices.* (New Jersey: Prentice Hall, 1974), p. 268.

firms' products to be differentiated. Differentiation enables the firms to revise their prices, making pure profits possible. Pure profits attract new firms into the industry. In the long run, all firms in industry make normal profits. The entry of new firms into the industry may however, be infrequent in an oligopolistic market. Barriers to entry are the characteristics of most oligopolistic markets.'

A common model of oligopoly exhibits a kinked demand curve. The kinked demand curve causes the marginal revenue curve to be discontinuous, creating "stickiness" in pricing and quantity within some range. It is this stickiness in pricing and quantity that enables the kinked demand curve and the discontinuous marginal revenue cost theory to be applied to the rigidity in oligopoly pricing.

Stigler disagrees with the kinked curve and argues that ". . . nominal price quotations may be stable although the prices at which sales are taking place fluctuate often and widely."[10] Stigler lists a number of factors that may affect the length of the discontinuity as follows: the number of firms in the industry, the relative size of the firms, the differences among rivals' products, the extent of collusion, and the number of buyers.

In his conclusions, Stigler argues that ". . . neither price experiences would lead oligopolists to believe in the

---

' Koch, *op. cit.* p.270.

[10] George Stigler, "The Kinky Oligopoly Demand Curve and Rigid Prices", *Journal of Political Economy.* (Volume 55, 1947), p. 241.

existence of a kink nor the pattern of changes of price quotations that the theory leads us to believe."[11] Stigler's conclusions are based on a study of some United States manufacturing companies in 1947.

In a reply to Stigler's findings, Efroymson writes that ". . . the fact that oligopolistic demand curves were proven, . . . to be unkinked does not mean that they are never or infrequently kinked."[12] The kink may be circumvented by a habit of price leadership or quasi or overt agreement. Price leadership and covert or overt collusion are therefore indications of the "belief" in the kink in demand. It is for this reason that rivals in the industry establish customs to iron it out.[13] Heflebower agrees with the arguments of Efroymson.[14]

The bottom line in oligopoly theory is that firms in the industry recognize their interdependence. This interdependence may encourage the firms to collude, either formally or informally, to fix prices to their advantage.

C. MARKET STRUCTURE AND CONDUCT

Market structure are the characteristics of organization in the market influencing strategically the nature of competition and pricing. Market conduct is the

---

[11] *Ibid.* p. 447.
[12] C.W. Efroymson, "The Kinked Oligopoly Curve Reconsidered", *Quarterly Journal of Economics.* (Harvard: Volume 69, 1955), p. 124-125.
[13] Efroymson, *op. cit.* p. 128.
[14] R. Hefflebower, "Stability in Oligopoly", *The Manchester School.* (29, 1961).

behaviour followed in adopting or adjusting, through the market, what firms buy or sell. Both structure and conduct are related to performance to determine market power of a firm.

Caves summarizes the main elements of market structure as: the degree of concentration, the degree of product differentiation, existence of barriers to entry, growth rate of market demand, price elasticity of market demand, and the ratio of fixed to variable costs in the short run. The first three elements are pointed out as the most important.[15]

Rhodes lists the elements of market structure as: the number and relative size of sellers and buyers, the degree of product differentiation, and the degree of difficulty of entry and exit of buyers and sellers.[16]

Bain gives two distinguishable but interrelated phases of market conduct. Firstly, the character of interseller relationships and coordination (whether firms act independently or interdependently) and secondly, principles and methods which firms observe in arriving at decisions and actions (whether individually or collectively).[17]

---

[15] Richard Caves, *American Industry: Structure, Conduct, Performance, 2nd Ed.* (New Jersey: Prentice Hall, 1967), p. 16.
[16] V. James Rhodes, *The Agricultural Marketing System, 2nd Ed.* (New York: John Wiley and Sons, 1983), p. 22.
[17] Joe Bain, *Industrial Organization.* (New York: John Wiley, 1966), p. 267.

D. EVALUATION OF MARKET PERFORMANCE

Economists have several views on market performance criteria. Low states that there are two general approaches that struggle for supremacy in establishing and judging market performance. The first is the Neo-orthodox approach which uses resource allocation as the basis for satisfaction. The second is the Traditionalist approach which uses criteria such as: product variation, market growth, and innovation.[18]

Caves advances a macro approach and considers factors such as income distribution, full employment and price stability, progress, research and innovation.[19] In this regard, the economy must be efficient in the employment of resources, fully employed to avoid waste in production factors, progressive in raising quality and variety of goods, and equitable in rewarding productive efforts.[20] Bain looks at three criteria: the degree of efficiency attained, the relation of price to cost as indicated by investment profits, and the size of sales promotion cost.[21] Scherer considers the criteria to be allocative efficiency of resource use, equity of income distribution, progressiveness and macro economic stability.[22]

Appraisal of performance is an indicator and measure of general material welfare. What performance criterion is most

---

[18] Richard Low, *Modern Economic Organization.* (Homewood: Richard Irwin Inc., 1970), p. 295.
[19] Caves, *op. cit.* p. 98-100.
[20] Caves, *op. cit.* p. 96-97.
[21] Bain, *op. cit.* p. 341.
[22] Scherer, *op. cit.* p. 459.

important depends therefore on value judgements. In marketing, performance criteria affect the physical or operational performance and the establishment of prices and values. One thing though is certain in economic theory. When measuring pricing performance in an oligopoly market, prices are easily distorted by lack of competition.

Discussion so far of market structure, conduct and performance is intended to expose the reader to how oligopolists work in attempting to distort competitive pricing, which is an essential element in pricing efficiency. Later in the chapter, a case of oligopoly behaviour in the Alberta hog industry will be presented in order to show how the structure of the industry has created an atmosphere which encourages price distortions.

E. THEORETICAL CONCEPTS OF PRICING EFFICIENCY

Williams and Stout summarize price functions as: allocating resources in production and marketing, allocating goods and services among consumers, balancing supply and demand forces, and producing and allocating income payments among the recipients.[23] For prices to achieve these functions, pricing information must be accurately and rapidly transmitted to the buyers and sellers in the market place. Handling of the information itself requires other inputs like capital and labor. Pricing efficiency, therefore, must also consider the costs associated in

---

[23] Willard Williams and Thomas Stout, *Economics of Livestock Meat Industry.* (New York: Macmillan, 1964), p. 123.

providing the accuracy and rapidity of the required information.[24]

According to Kohls, pricing efficiency is achieved if prices fully reflect consumer preferences, direct resources from lower to higher valued uses, and coordinate the buying and selling activities of farmers, marketing firms and consumers.[25]

In evaluating pricing performance, Williams and Stout advocate the perfect market model as close to perfection in pricing efficiency. The perfect market is the market characterized by many sellers and buyers, equal access to information by all participants in the market and homogeneous products, making it difficult for one seller or buyer to manipulate prices. Characteristics of prices in the perfect market are summarized as:

1. perfect prices among geographically separated markets, with price differences among the markets equal to the cost of transporting the commodity from one market to the other;
2. perfect prices in time, making any price differences through time be equal to the costs of storage or transfer from one period of time to another; and
3. perfect prices among forms of a commodity; that is, the costs of transforming a commodity from one form or grade to another must be equal to the price differences among

---

[24] *Ibid.* p. 122.

[25] Richard Kohls and David Downey, *Marketing of Agricultural Products, 4th Ed.* (New York: Macmillan, 1978), p. 11.

the forms and grades.[26]

The concept of pricing efficiency may sometimes be sacrificed for operational efficiency. The problem then becomes one of determining how much operational efficiency must be allowed. Williams and Stout think of some sort of compromise between the two concepts. They argue that:

> While the adequacy and effectiveness of prices and pricing usually are improved through increasing the number . . . of firms, . . . cost in terms of physical efficiency of achieving these conditions might be prohibitive. An acceptable compromise, . . . sometimes is selected as a standard of reference or comparison for evaluating the level or nature of performance actually observed.[27]

Warrack integrates operational and pricing efficiency and suggests that ". . . public marketing policy must focus on both operational and pricing efficiency. If a trade-off relationship exists, . . . marketing efficiency can be maximized by equalizing the gain in one component with the opportunity-cost loss in the other component."[28]

Tomek and Robinson relate efficient pricing with perfect competition as well. They see the competitive norm as one criteria for judging performance of the pricing mechanism. Any manipulation of prices or deviation from the competitive ideal creates inefficiencies. Such pricing aberrations may appear in the nature of price adjustments, in the variability of prices and in the level or prices.[29]

---

[26] Williams and Stout, *op. cit.* p. 124.
[27] Williams and Stout, *op. cit.* p. 125.
[28] Warrack, *op. cit.* p. 21.
[29] William Tomek and Kenneth Robinson, *Agricultural Products Prices, 2nd Ed.* (Ithaca: Cornell University, 1982), p. 225-226.

Evaluation of pricing efficiency has a welfare norm which may lead to problems. A price discovery mechanism that may clear the market may not in itself be efficient if it leads to production surpluses and lower producer prices.[30] In view of the welfare connotation in pricing efficiency, judgement may be made difficult.

F. REVIEW OF SELECTED EMPIRICAL STUDIES

Several studies have been done on pricing efficiency in both the United States and Canada. This author will however restrict the review to studies done on pricing efficiency in the meat industry.

Leavitt's study of 1981 failed to come to any specific conclusion, vis-a-vis pricing efficiency. His differencing model showed improvement in pricing efficiency in the Alberta hog market. However, another model, using supply variables as a measurement device, indicated lack of pricing efficiency. He concludes that ". . . a firm conclusion concerning pricing efficiency could not be made because of mixed evidence on improved pricing efficiency."[31] A critique of Leavitt's work will be provided in the next chapter.

In studying the lead-lag structure of slaughter hog prices between four major Canadian cities and the United States midwest in 1982, Beaton and Pearson found market information to be rapidly communicated between their study

---

[30] Tomek and Robinson, *op. cit.* p. 226.
[31] Steven Leavitt, *Market Performance of the Alberta Pork Producers Marketing Board.* (Edmonton: U. of A., M.Sc. Thesis), p. 184.

markets.[32] Their study concluded that Canadian markets have higher cross correlation among themselves than with the markets of the United States. Beaton and Pearson attribute this to the institutional trade barriers between the two countries.[33] Within Canada, the study found the Toronto and Winnipeg markets to be more correspondent with zero lag adjustments between themselves and the United States markets. The Saskatoon and Edmonton markets however lagged one period with the other markets.[34] While the model used in this study is appropriate for time series analysis, the observation period did not include the period since the purchase of the Fletcher's Packing Plant by the APPMB. The packing plant was purchased in December, 1980 to increase competition in the buying patterns of the packing plants.

A study by Faminow in 1981 analysed the lead-lag structure of two wholesale beef price quotes in the United States. Although specific markets are not mentioned per se, the results of the study may be applied to the purpose here. Faminow concluded in his study that the Yellow Sheet prices led the Meat Sheet prices, indicating that prices quoted in the former may respond to changing market conditions more expediently than the latter.[35]

---

[32] Norman Beaton and Charles Pearson, *Lead-Lag Structure of Slaughter Hog Prices Between U.S. Midwest and Four Major Canadian Markets Utilizing Univariate Residual Cross-Correation Technique.* (Presented to American Ag. Econ. Ass., Utah Univ., 1982), p. 8.

[33] Beaton and Pearson, *op. cit.* p. 8.

[34] Beaton and Pearson, *op. cit.* p. 8.

[35] M.D. Faminow, "Analysis of the Lead-Lag Structure of Two Wholesale Beef Price Quotes Using Residual Cross-Correlation", *North Central Journal of Agricultural*

A study in 1980 by Bessler and Haugh used univariate residual cross-correlation analysis to study the leads and lags among prices of turkey products, as quoted in the Producers' Price Current -- a most widely used source of information in the United States.[36] This particular study used the Box-Jenkins filtering procedure to remove time series properties. Their findings showed ". . . no consistent lead-lag pattern from parts prices to whole bird prices or from whole bird to parts prices."[37] While breast prices led whole bird prices, other parts -- notably, tail and wing -- seemed to follow whole bird prices.[38] This pattern of prices may be due to the differences in demand elasticities between the various parts of the bird.

Miller also used univariate residual cross-correlation analysis to study beef price changes at the retail, wholesale, and farm levels in the United States. His conclusions were that farm level price changes were reflected in wholesale level price changes within a week, but wholesale level price changes were not reflected in the retail level price changes for three weeks.[39] However, it takes time to transform a live beef animal into beef cuts at the retail level, and considering the time factor, Miller

---

[35](cont'd) *Economics.* (July 1981), p. 94.
[36] David Bessler and Lee Schrader, "Measuring Leads and Lags Among Prices: Turkey Products", *Agricultural Economics Research.* (3, Volume 32, July 1980), p. 1.
[37] Bessler and Schrader, *op. cit.* p. 6.
[38] Bessler and Schrader, *op. cit.* p. 6.
[39] Stephen Miller, "Univariate Residual Cross-Correlation Analysis: An Application to Beef Prices", *North Central Journal of Agricultural Economics.* (1, July 1979), p. 145.

concluded ". . . the current price discovery mechanisms in the beef marketing system provide fairly rapid price adjustments between the farm, wholesale, and retail levels."[40]

The hog industry was the subject of study by Gupta and [illegible] n West Germany. Autocorrelation and filter rules were used by the two analysts to study three markets. In their conclusion, they argued that the three markets studied were efficient at least, in the time period analysed.[41]

Prior to the establishment of the Alberta Pork Producers' Marketing Board (APPMB), some studies were done on the market performance in Alberta's hog industry. Manning, in his 1967 study, identified the major problem in Alberta's hog marketing system to be prices paid to producers.[42] In his recommendation, Manning suggested a meat marketing program ". . . to purchase from producers, pay an initial price based on minimum quality, have slaughtering and processing done on a custom basis, and act as the sole seller of pork or red meat to retail buyers."[43]

Lockhart's 1967 study also identified the pricing problem in the Alberta hog industry. "The major problem in hog marketing is the performance of the marketing system. This problem is related to the establishment of the actual sale price which is comprised of a base price less transportation, selling fees, and commissions plus possible

---

[40] Miller, *op. cit.* p. 145.
[41] Gupta and Mueller, *op. cit.* p. 350.
[42] Manning, *op. cit.* p. 23.
[43] Manning, *op. cit.* p. 25.

procurement allowances."[44] A Lack of sufficient accurate data on market conditions, and the absence of proper ways to disseminate pricing information between markets were seen as some of the causes for pricing inadequacies.[45]

Ulrich in his study of beef industry prices found competitive bidding to result in higher producer prices.[46] Such competition in the market place is possible if all participants in the market have equal access to pricing information, with the information presumably disseminated effectively and quickly to both sellers and buyers.

Andersen used the correlation coefficient to study price fluctuations in the Alberta hog industry in 1971. Results of his study showed, among other things, little dependency of western hog prices on eastern markets. Furthermore, pricing systems in Canadian markets failed to use price information from other markets.[47] At the same time, Andersen concluded that pricing efficiency has improved marginally since the establishment of the Alberta Pork Producers' Marketing Board.[48] It is the view of this author that the existence of the board, at the time of Andersen's study, was too short to have had any significant

---

[44] W. James Lockhart, *Alberta Hog Market, Conduct and Performance*. (Edmonton: U. of A., Dept. of Rural Economy, M.Sc. Thesis, 1967), p. 61.
[45] Lockhart, *op. cit.* p. 62.
[46] Martin Ulrich, "Price Differentials Between Selected Channels of Marketing", *Canadian Journal of Agricultural Economics*. (Volume 12, 13, 1964 & 1965), p. 66.
[47] Richard S. Andersen, *"Daily Hog Price and Supply Analysis", (Edmonton: U. of A., Dept. of Rural Economy, M.Sc. Thesis, 1971), p. 107.*
[48] Andersen, *op. cit.* p. 109.

impact on pricing efficiency. A critique of the model used in this study will be given in the next chapter.

G. THE ALBERTA HOG INDUSTRY: A CASE STUDY IN MARKET BEHAVIOUR

There are reasons to believe that the packers in Alberta developed oligopsonistic tactics to fix lower producer prices. This is evident in the recent court decision handed down by the Court of Queen's Bench on three Alberta packers. "In a statement of facts that the convicted companies admitted was true, the Crown Prosecutor . . . said that plant managers of the three companies held meetings, usually at hotels, to discuss the price range at which hogs would be purchased."[‘’] The court's decision followed an admission by Burns Food Limited, Gainers Limited, and Eschen Canada Incorporated to conspiring to lessen competition in the purchase of hogs in Alberta. The other three packers -- Canada Packers, Intercontinental and Fletchers, which has been bought by the marketing board, are still challenging the law suit brought against them by APPMB.

Price fixing is an agreement between firms to buy or sell at a pre-determined price. This activity is made possible by the structure of the industry and by the nature of the product involved in the price fixing agreement.

The packing industry in Alberta is concentrated with a sufficiently small numbers of firms involved. It is an

---

‘’ Suzanne Zwarun, *op. cit.* p. 39.

oligopsonistic structure. This is confirmed by the Hog Marketing Review Committee in its report of January, 1981.[50] Hogs are a homogeneous product and are not subject to grading. Economists in industrial organization agree that these two factors provide the incentive to fix prices in order to achieve stability, protect profits and to avoid any potential price warfare.

Information provided by the Alberta Pork Producers' Marketing Board also suggests a form of market sharing by the four major meat processing plants in Alberta between 1972 and 1976 (Tables 2-1, 2-2, 2-3). Market sharing is another element of oligopsony. It is possible that the relatively smaller packers feared retaliation from their larger rivals and so avoided any moves to increase their volume purchases. The Board contends that the market sharing scenario broke down after 1978, probably due to the Board's introduction of domestic contracting and selling system changes.[51] The possible collusion of the larger firms is also evident in a personal letter sent to the Minister of Agriculture in 1978, by the President of the Grande Prairie Packers. An excerpt of the letter read:

> Prior to July, 1977, our firm experienced some difficulty in obtaining the necessary supply of hogs for slaughter, which is unusual since the immediate area produces more than my slaughter requirement. I experienced situations where Edmonton packers paid much more for F.O.B. Grande Prairie hogs than they

---

[50] *Hog Marketing Review Committee.* A Report Presented to Alberta Ministry of Agriculture Based on a Study Conducted by the Committee Appointed by the Minister of Agriculture, 1981.

[51] Leavitt, *op. cit.* p. 38.

TABLE 2-1

Market Shares and Volume Purchased Among the Four Largest Packing Firms in Alberta (1972)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PACKER A												
Market Share %	24.45	24.43	25.80	25.89	25.76	25.87	25.71	24.97	24.88	25.34	25.27	26.90
Volume Purchased	38,141	35.712	42.677	42,771	45,180	41,273	35,418	34,793	28,596	30,475	32.435	27, 40
PACKER B												
Market Share %	17.37	17.02	18.59	17.53	17.76	17.14	17.58	16.02	17.24	17.04	16.90	16.33
Volume Purchased	27,101	24,897	30,765	28,979	31,154	27,358	24,487	23,205	19,821	20,492	21,693	16,712
PACKER C												
Market Share %	23.88	24.28	23.64	23.98	24.13	23.31	23.01	23.26	22.78	22.56	23.00	23.79
Volume Purchased	37,253	35,494	39,118	39,632	42,325	37,202	31,704	33,518	26,177	27,129	29,527	24,358
PACKER D												
Market Share %	9.22	9.78	9.81	10.09	9.59	9.67	9.25	10.23	9.51	9.56	9.64	8.62
Volume Purchased	14,388	14,300	16,237	16,672	16,823	15,425	12,747	14,251	10,934	11,501	12,376	8,827

Source: Information provided by Greg Whalley, Alberta Pork Producers' Marketing Board, Edmonton, June 1980. (Mimeographed.)

TABLE 2-2

Market Shares and Volume Purchased Among the Four Largest Packing Firms in Alberta (1974)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PACKER A												
Market Share %	28.91	27.62	25.95	29.16	26.75	N.A.	N.A.	25.75	27.63	27.16	25.04	24.67
Volume Purchased	41,052	39,494	34,643	43,911	35,280	N.A.	N.A.	32,051	29,677	29,642	26,434	21,663
PACKER B												
Market Share %	14.34	16.31	17.29	17.28	18.24	N.A.	N.A.	15.63	15.12	16.97	17.71	16.83
Volume Purchased	20,362	23,061	23,081	25,556	24,065	N.A.	N.A.	19,455	16,237	18,528	18,698	14,780
PACKER C.												
Market Share %	26.93	25.44	26.75	23.67	24.66	N.A.	N.A.	28.27	29.90	28.84	27.84	28.03
Volume Purchased	38,238	36,373	35,707	35,628	32,525	N.A.	N.A.	35,190	32,112	31,486	29,391	24,618
PACKER D												
Market Share %	9.05	7.69	9.15	8.83	6.82	N.A.	N.A.	5.35	6.02	6.53	7.11	8.30
Volume Purchased	12,843	10,989	12,216	13,291	8,994	N.A.	N.A.	6,656	6,470	7,129	7,512	7,287

Source: Information provided by Greg Whalley, Alberta Pork Producers' Marketing Board, Edmonton, 20 March 1981. (Mimeographed.)

TABLE 2-3

Market Shares and Volume Purchased Among the Four Largest Packing Firms in Alberta (1976)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PACKER A												
Market Share %	27.27	27.30	26.72	27.69	27.69	27.17	25.64	28.50	28.93	27.42	26.68	28.14
Volume Purchased	21,495	19,029	22,734	20,710	20,018	19,345	16,742	20,476	19,757	17,718	20,809	19,527
PACKER B												
Market Share %	11.07	8.01	7.67	10.38	10.61	10.86	11.16	8.04	6.34	7.88	9.51	10.31
Volume Purchased	8,727	5,585	6,522	7,766	7,810	8,386	7,288	5,776	4,329	5,093	7,416	7,030
PACKER C												
Market Share %	30.67	32.04	33.04	30.75	30.76	31.07	30.82	32.63	31.51	33.47	32.28	30.34
Volume Purchased	24,172	22,332	28,110	22,999	22,664	24,000	20,118	23,445	21,522	21,633	25,176	21,057
PACKER D												
Market Share %	9.33	9.83	12.35	10.56	8.48	9.81	9.71	9.88	10.81	9.97	9.80	9.16
Volume Purchased	7,350	6,853	10,512	7,898	6,246	7,575	6,342	7,102	7,384	6,441	7,640	6,359

Source: Information provided by Greg Whalley, Alberta Pork Producers' Marketing Board, Edmonton, 20 March 1981. (Mimeographed.)

> paid for Edmonton area hogs, and then these Edmonton packers had to pay transport costs to Edmonton. This situation was certainly not a reflection of any quality differential between Edmonton and Grande Prairie hogs. It is my view that such a phenomenon occurs to ensure that there is industry unanimity -- that is, we all toe the line drawn by the largest of our peer groups. Apparently, my firm must not grow, and certainly must not participate in the Edmonton market.[52]

A number of recommendations were presented by the Hog Marketing Review Committee to break the oligopsonistic structure of the packers. Among the recommendations, the committee ". . . recognizes that proper functioning of the industry can only occur if such features as barriers to entry, price fixing, market share allocations and predatory pricing are discouraged."[53]

H. SUMMARY

From the evidence so far presented, it becomes apparent that the Alberta hog industry has an oligopolistic market structure. The small number of firms in the packing industry, the concentration of the packing plants, and the nature of the product under consideration have contributed to such imperfections. The oligopsonistic structure of the meat packing industry would appear to make it compatible with the theoretical concept of oligopoly behaviour and pricing.

Concerns with the market for pigs, prior to 1969, led to the formation of the Alberta Pork Producers' Marketing

---

[52] Reschenthaler, *op. cit.* p. 30-31.
[53] Hog Marketing Review Committee, *op. cit.*

Board. The board, to ensure that hog marketing was orderly and efficient, used a teletype system known as a Dutch auction. Sale prices were displayed on the teletype in a descending order by the board. The buyers on their part had to punch a button on their own teletypes when they thought the price was right for them. In 1980, the board claimed to have had evidence of tampering with the electronic gadget by the packers. This led the board to launch a court action against the packing plants.

In its court statement, the board claimed that plant managers from the packing plants held meetings to discuss a price range for hog purchases -- usually 50 cents or less. As indicated earlier, three of the packers have already pleaded guilty to the charges and have been fined accordingly. These factors; that is, the formation of the Marketing Board along with the subsequent legal actions have led to the need for this study. The study seeks to measure the success of the marketing board in its efforts to improve pricing efficiency in the Alberta hog industry.

III. METHODOLOGY

A. INTRODUCTION

This chapter will present the data source for the study and develop a critical evaluation of past research in this area. The chapter will also develop the theory of Autoregressive Integrated Moving Average (ARIMA) and the Granger Causality models which were used in this particular study. The latter part of the chapter will further develop a model to be used to assess pricing efficiency in the Alberta hog industry.

B. DATA SOURCES

Data used for this study were collected from the Canada Livestock and Meat Trade Report. The report is published by the Market Information Service Department of Agriculture Canada, and provides the average weekly prices of hogs for all the markets under study. The observation period is January 1, 1964 to December 31, 1983.

Prices for Canadian hogs are quoted on slaughtered dressed carcass weights of 100 pounds. United States prices are quoted on live hogs. To convert the United States live hog prices to their Canadian equivalents, a conversion factor of .78 was used.[54] A further adjustment was made to account for the exchange rate differentials between the two

---

[54] Conversion Factor supplied by Mr. Greg Whally of the Alberta Pork Producers' Marketing Board in a telephone conversation. Conversion is done as follows:
U.S. Price / .78 x Exchange Rate.

countries. The exchange rate quotations used were obtained from the Weekly Financial Statistics published by the Bank of Canada.

C. METHODOLOGICAL CRITIQUE

In his study of pricing efficiency in the Alberta hog industry in 1981, Leavitt used correlation coefficients, coefficients of determination, and differencing models.[55] Together, the three models are an integral part of the Ordinary Least Squares Method (OLS).

Leavitt's work is commendable for being the first major study of the Alberta pork industry since the inception of the Pork Marketing Board. His study considered, among other things, the impact of major policy changes initiated by the Board in its attempt to improve operational and pricing efficiency in the market place.

The problem with his work however, revolves around the utilization of the OLS models. Results obtained from correlation coefficient models may be misleading. A high correlation may imply an efficient market, leading the analyst to conclude an efficient dissemination of information. But correlation coefficients do not in any way establish causality between variables. Pierce and Haugh have argued that ". . . high correlation among variates does not in any necessary sense establish that they are causally related. Variables may be functionally related, yet be

---

[55] Leavitt, *op. cit.* p.

uncorrelated, and . . . they may be correlated yet not causally related."[56]

Coefficient of determination models may establish causality. However, results from this model may be misleading as well, if applied to time series analysis. Ordinary Least Squares (OLS) assumes no correlation between the random terms. This condition is not met in time series analysis, since economic conditions are such that present economic values are affected by previous values. For example, the price of hogs this week is likely to be influenced by hog prices a week or two earlier. If such is the case, then the use of OLS could bias the standard errors of the parameter estimates.

If the structure of serial dependence is known, Generalized Least Squares (GLS) may be used for the estimation.[57] However, the structure of serial dependence is hardly ever known *a priori*. Serial dependence is a measure of the influence of past values on the present values.

Furthermore, Leavitt's model 4, using price differencing, is defective. Depending on whether Ptj>Ptk or vice versa, the B1 coefficient could be a negative or a positive value, where Ptj is the price in the original market (Edmonton) and Ptk is the price in the comparative market (Toronto or the United States). Leavitt stated his

---

[56] D.A. Pierce and L.D. Haugh, "Causality in Temporal Systems", *Journal of Econometrics*. p. 265.
[57] C.W. Ostrom, *Time Series Analysis: Regression Techniques*. Sage University Paper Series on Quantitative Applications in Social Sciences, 07-009.

model 4 as follows:

$$(Ptj-Ptk)=Bo + B1Stj$$

and imposed a negative value on the B1 coefficient. Representing (Ptj-Ptk) by D, what Leavitt was testing was a change in D with respect to a change in hog supply levels in the original market, Stj. If Ptj>Ptk, an increase in Stj will result in the fall in Ptj and generally in D, making B1 a negative value. However, if Ptj<Ptk, an increase in Stj will lead to a decrease in Ptj but an increase in the overall D. In this regard, the B1 coefficient will become a positive value.

Problems involved in the use of the OLS for time series have led some analysts to consider the use of the ARIMA model. The Box-Jenkins technique is used to examine an interrupted time series analysis. Interrupted time series analysis is a way of assessing the impact of a discrete interventaion on an economic process. The intervention divides the economic process into two periods -- the preintervention and the postintervention. In its simplest form, the null hypothesis would be: The intervention had no impact on the time series.

Econometrically,

$$Ho : bpre - bpost = 0$$

where,

bpre = the preintervention series level,

bpost = the postintervention series level.

The model itself may be stated as follows:

Yt = Nt + It

where,

Yt = the t(*th*) observation of the time series,

Nt = the "noise" component,

It = the "intervention" component.

The intervention impact could be obscured by trend, seasonality and random errors, the first two being common in agriculture. The use of the ARIMA model does account for these types of noise; that is, the trend and seasonal movement in the data. "If the model does not account for these types of noise, the analysis will be confounded"[58]

In the Box-Jenkins application utilized in this study, the interventions are policy changes of the APPMB in its attempt to improve pricing efficiency. The interventions studied were divided into six time periods as follows:

January 1, 1964 - October 31, 1969: the pre-formation period of the Alberta Pork Producers' Marketing Board (APPMB);

November 1, 1969 - April 1, 1975: the period from the inception of the APPMB to the board's purchase of Assembly Yards;

April 2, 1975 - March 12, 1978: purchase of assembly yards to the introduction of the producer bid program;

March 13, 1978 - March 15, 1980: the period from the

---

[58] D. McDowall, et al, *Interrupted Time Series Analysis: Quantitative Applications in the Social Sciences.* Sage University Papers, P. 14.

introduction of the bid acceptance to the period of provincial government intervention in the operations of APPMB;

March 16, 1980 - December 31, 1980: the period from the government intervention to the replacement of the teletype marketing system with the sealed bids system;

January 1, 1981 - December 31, 1983: the start of the sealed bid marketing system and the purchase of Fletchers plant to the end of the observation period.

These periods were compared in order to assess the impact of individual policy interventions by the APPMB on pricing efficiency.

D. DISCUSSION OF THE ARIMA MODEL

An ARIMA model has three structural parameters, p, d, and q, generally written as ARIMA (p, d, q). The parameter p indicates the number of autoregressive relationships. Autoregression denotes a measure of relation between the current time series observation and a portion of a previous observation. For example,

$$Yt = \delta_1 yt-1 + at,$$

where,

Yt = current time series,

yt-1 = one previous time series,

δ_1 = parameter to be estimated that is assigning weight to coefficient of i prior entry,

at = current random term.

The random factor is a representation of variations that may be observed in the time series. The error term has the usual assumptions of zero mean, zero covariance, constant variance, and normal distribution. An autoregressive model in which current time series is related to one most recent entry is represented by AR(1). In much the same way, if the current series is related to two most recent entries, the model is represented by AR(2), and so on.

The parameter q is the number of moving average relationships, and usually abbreviated as an MA model. An MA(1) model is interpreted as a series where the present time series is composed of a portion of the most recent random error, and MA(2) is a time series composed of two portions of the most recent random errors. For example,

$$Wt = at - \theta_1 at-1$$

where,

Wt = the current time series,

at-1 = one previous random shock,

θ_1 = parameter to be estimated,

at = current random term as given earlier.

The parameter d represents the number of differences needed to convert an original data to a stationary time series. Stationarity involves getting drifting and/or trending data to fluctuate noisily about a zero mean, with a common variance. Differencing involves subtracting the first observation from the second, the second from the third, and so on. When a series is differenced, it is referred to as

"integrated". An integrated model may be stated as:

$$Yt - Yt-1 = at$$

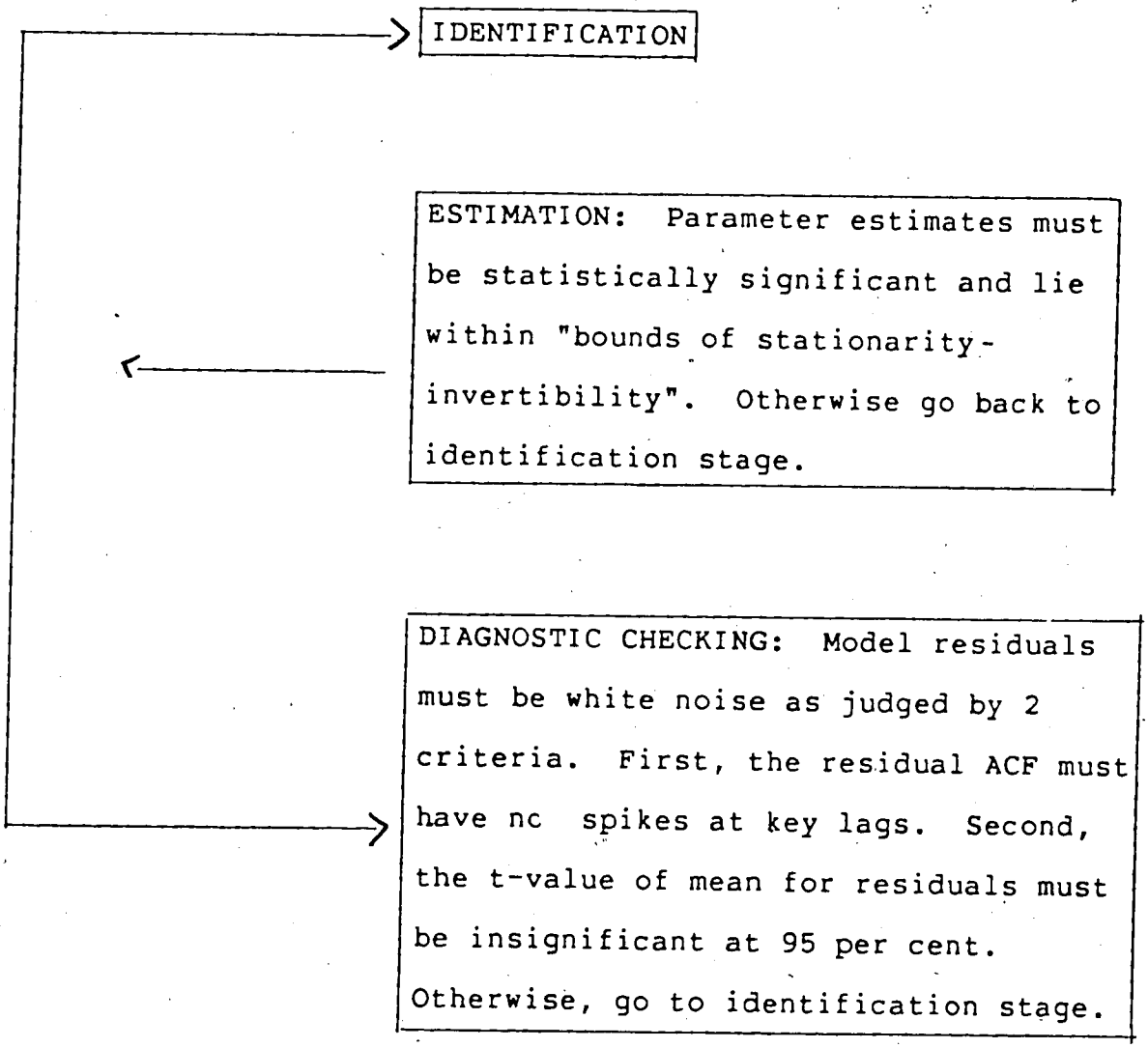
The above equation represents a first order differencing with the parameter d equal to 1. Higher order of differencing may be used if necessary. In such a case, d is greater than 1. Combinations of all three models above yield the ARIMA (p, d, q) model. For example, ARIMA (1, 1, 1) is a series where present time series have been differenced once, and has both first order autoregressive and moving average relationship. Such a model is called a mixed ARIMA (p, d, q).

There are basically three stages involved in ARIMA model building: identification, estimation and diagnostic checking (Fig. 3-1). An important requirement in this model building is the stationarity of the raw data. When the data trend or drift the coefficient estimates will be confounded. If the data are observed to be non-stationary, they must be differenced.

The identification stage helps to identify stationarity. At this stage, the autocorrelation function (ACF) has to taper down to zero readily. The essence of this is that the most recent lags have more impact on present time series, but that these impacts decrease exponentially with time. Any contrary behaviour of the ACF means that the data are non-stationary and must be differenced. If the first differencing proves to be inadequate, higher levels of differencing are used. In most cases however, a first

FIGURE 3-1

STAGES IN THE ARIMA MODEL BUILDING



differencing is enough.

The autocorrelation function is a measure of correlation or relationship between time series (lag-0) and its first lag (lag-1). Mathematically, ACF may be defined as:[5]

ACF(k) = Covariance (YtYt+k) / Variance(Yt)

where,

= number of lags,

Yt = Yt - Y(that is, observed value minus the mean)

Yt+k = Yt+k -Y(that is, observed value minus the mean)

Generally, ACF(k) is a correlation coefficient between time series (lag-0) and (lag-k). The ACF is an output of the BMDP statistical software package (See Fig. 3-3). Lags shown in the ACF output are bounded by parentheses which indicate a 95 percent level of significance. If the value of a lag lies outside the parentheses, it is said to be a spike. Relatively larger values of such lags are described as "significant spikes". A significant spike at the first lag of the ACF indicates ACF(1); that is, current time series is influenced by portion of a previous time series. Spikes at the first two lags indicate ACF(2). Here, current time series is influenced by portions of two previous time series.

---

[5] McDowall, et. al., *op. cit.* p. 24.

Another important measure of autoregressive models is the Partial Autocorrelation Function (PACF). The PACF is related to the ACF in measuring the strength of relationship between time periods after intermediate lags have been controlled. For example, for k=2

$$PACF(2) = ACF(2) - \{ACF(1)\}^2 \; / \; 1-\{ACF(1)\}^2$$

where k is the number of lags. The PACF is also an output of the BMDP package (Fig. 3-4). The importance of the PACF arises from the difficulties in trying to determine the parameter p from the ACF alone. Usually an ARIMA (2, 0, 0) has a slower rate of decay in its ACF than an ARIMA (1, 0, 0) process. For that matter, successive lags of the PACF are expected to be zero for ARIMA (2, 0, 0) process (recall the PACF and ACF relationship).[40] Since the PACF tapers down readily to zero for AR greater than one, its output is a model form for autoregression. On the other hand, ACF output tapers down readily to zero for a moving average model making the ACF output to be used as representation for moving average models.

The identification stage involves identifying the model that best represents the series; that is, to determine the serial dependence, if any, for the autoregression and moving average. For example, an ARIMA (0, 1, 2) model means there are two significant spikes in the ACF at the first two lags

---

[40] *Ibid.*, p. 41.

after a first order differencing and it is represented by the equation:

$$Wt = at - \theta_1 at-1 - \theta_2 at-2,$$

where,

Wt = present time series,

at-1 = one previous random term,

at-2 = two previous random term,

at = present random term with all the usual assumptions,

θ_1 , θ_2 = the parameters to be estimated.

An ARIMA (2, 1, 0) on the other hand shows there are two significant spikes in the PACF at the first two lags after differencing and it is represented by the equation:

$$Yt = at + \delta_1 Yt-1 + \delta_2 Yt-2$$

where,

Yt = present time series,

Yt-1 = one previous time series,

Yt-2 = two previous time series,

at = present random term with all the usual assumptions,

δ_1 , δ_2 = the parameters to be estimated.

Discussions so far of the ARIMA (p, d, q) have not considered the problem of seasonality. Seasonality may be defined as a periodic behaviour in the time series. For example, in considering pork prices it may be possible to observe higher prices during Easter when demand for ham is traditionally high. Such seasonal occurences do show up in

the ACF and PACF, both dying out from seasonal lag to seasonal lag and exhibiting significant spikes as follows:

ACF(12).....ACF(24)

or

PACF(12).....PACF(24)

When this happens, the present time series is not only related to most recent lags, but also to lags twelve months earlier. Such seasonal considerations appear obvious when considering monthly average data. In this study, average weekly data are used and seasonality is ignored.

The ARIMA model works on the principle of parsimony. This means that the analyst selects the ACF or the PACF that has the least number of significant spikes as representation for estimation. For example, if the ACF has one spike and the PACF has two or three, the ACF is considered the preferred model since it involves estimating only one parameter, instead of two or three.

The next stage in the model building is estimation. Estimation involves the unknown coefficient estimates. For the autoregression, the coefficients, also known as the parameters, must lie within the "bounds of stationarity". In other words, the value of the parameter(s) estimated must be less than unity in absolute terms; that is,

$$-1 < \delta_1 < +1$$

$$\delta_1 + \delta_2 < +1$$

$$\delta_2 - \delta_1 < +1$$

For the moving average model, the parameter(s) must also lie

within the "bounds of invertibility", identical to the bounds of stationarity; that is,

$$-1 < \theta_1 < +1$$

$$\theta_1 + \theta_2 < +1$$

$$\theta_2 - \theta_1 < +1$$

If these conditions are not met; for example, if the parameter(s) value is more than unity, subsequent distant lags will seem to have more impact on present time series, making the series non-stationary. In practice, economic conditions are such that more recent disturbances have more impact on present time series than distant disturbances. Also, all parameters at the estimation stage must be statistically significant at a chosen level of significance, usually 95 per cent. If for any reason these conditions are not met, the model building goes back to the identification stage.

Assuming all conditions in the identification and estimation stages are met, the next stage is diagnostic checking. This stage helps to judge whether the model residuals are white noise. That is, the autocorrelation of the residuals must not be different from zero at 95 percent level of significance. Two criteria are used for such judgment. Firstly, the residual autocorrelation function must have no spikes at key lags. Secondly, the t-value of the mean (against zero) must be insignificant at the 95 per cent level of significance. If these two conditions are not met, the model does not fit properly. The procedure then

goes back to the identification stage for the proper choice of the model.

When estimation is done and the results have passed diagnostic checking, the intervention component is added to the equation and its value estimated. Using the example of the equation for the moving average given earlier, the equation may be extended as follows:

$$Wt = I_{100} - \theta_1 at-1 - \theta_2 at-2 + at$$

where,

I_{100}= the intervention at the one-hundredth period and the rest of the equations are as before.

If, in this example, the value of I_{100} is found to be a negative, the interpretation is that the impact of the interruption had a negative effect on the series, and vice versa during the one-hundredth observation time. All parameters here must be significant as well.

E. DISCUSSION OF THE GRANGER CAUSALITY

The Box-Jenkins procedure is an initial step of filtering for the Granger causality model. In defining pricing efficiency, it was stated that any price difference between two markets must tend to zero as more information becomes available. In this regard, it may be realistic to state that a consistent lead-lag relationship between prices of two markets suggests that the leading market has access to superior information. Alternatively, any instantaneous

relationship between the two markets may suggest that both markets have equal access to pricing information. It is as well possible for prices of two markets to lead each other. This situation is referred to as feedback. Granger causality is a concept used to study a lead-lag structure. For example, if Edmonton hog prices are found to lead Toronto or U.S. prices, then Edmonton prices can be said to "cause" Toronto and United States prices. However, if Edmonton, Toronto and U.S. prices are found to be significantly correlated at a zero lag, then there is an instantaneous causality, and Edmonton prices may be said to adjust quickly to prices of the comparative markets.

Univariate residual cross-correlation analysis is one way of ordering variables in the Granger causality concept. This particular analysis was chosen over the others for this study because of the argument by Bessler and Brandt that this analysis does a better job in removing autocorrelation.[1] Univariate residual analysis involves calculating cross correlation coefficients between residuals. The residuals are generated from each series, for example, the Edmonton price data being considered in this study. The residuals are the difference between the observed and predicted values of the original time series. It is these residuals that are cross-correlated between the various series at positive and negative lags.

---

[1] Bessler and Brandt, *op. cit.*

The estimated residuals are first tested for randomness. To accept the model as fit for the purpose, the residuals tested must be insignificant at a chosen level of significance. The test usually applied is the Q-statistic test. The Q-statistic is simply an overall deviations of a series from the random series. Any large values of the Q is an indication of remaining autocorrelation. If such is the case, the model is said to be poor for fit. Table 3-2 shows the results of the Q-statistic for the three markets under study at the various time periods. The results show that except for the Toronto price series during the period 2nd April, 1975 to 12th March, 1978, all models fit for application to the study.

An F-statistic is computed to determine the significance of the lags after cross-correlating the residuals. In its simplest form, Granger causality studies the relationship between current Xt and past values of Yt. A cross-correlation of this nature which is also significantly different from zero implies some predictive power, and so causality. A significant positive lag between Xt and Yt+1 indicates a lag of the Y series. On the other hand, a significant negative lag between the two series indicates a lead for the Y series.

In brief, the models developed here are used first to study changes in the time series, if any, and their magnitude. Secondly, the statistical association of pork prices in Edmonton, Toronto and the United States are

considered. This was done by considering the relationship between estimated residuals of Edmonton prices and estimated residuals of Toronto and the United States prices. Also residuals of Toronto prices and residuals of United States prices were considered.

Representing Edmonton prices as variable Y and Toronto prices as variable X for example:

1) Y may cause X;
2) X may cause Y;
3) there may be instant causality between Y and X; and
4) there may not be any relationship between Y and X.

Causality is said to exist if there is any relationship between residuals of Y and residuals of X. This discussion goes for the Toronto and United States price relationship as well.

F. MODEL BUILDING

MODEL 1: For Edmonton prices, the raw data was found to be non-stationary at the identification stage. Figure 3-2 shows the raw Edmonton data before differencing. The ACF of the data does not taper down to zero readily. The data was therefore differenced by one order. Figures 3-3 and 3-4 show the differenced series for the Edmonton prices. It was found that the ACF (Fig 3-3) has a significant spike at lag-1 but the spike does not taper readily to zero at the second lag.

On the other hand, the PACF (Fig 3-4) has a significant spike at lag-1 and the spike tapers readily to zero at the second lag. This led to the choice of the autoregressive model as representation for the series. The model was stated as follows:

$$Yt = at + \delta_1 Yt-1$$

where,

Yt = present time series,

Yt-1 = one previous time series,

δ_1 = the parameter to be estimated,

at = present random term, with zero mean, zero covariance, constant variance, and normal distribution.

The equation was estimated and both conditions of invertibility and significant parameters were met. In Figure 3-5, the parameter value was found to be (0.2535) with a significant t-ratio of (8.45). The diagnostic checking also showed the residual autocorrelation function to be white noise with no significant spikes(Fig. 3-6). Again in Figure 3-6, the t-value of mean for the residual is insignificant while the serial autocorrelation of the residual had no significant spikes at key lags. The model was therefore accepted as a good fit and the intervention component was added to the equation.

The above model considered the whole period of observation for the Edmonton price data. The details of the selected models, for each time period considered, in the

Figure 3-2

RAW EDMONTON PRICE DATA BEFORE DIFFERENCING THE SERIES
(JANUARY 1,1964 - DECEMBER 31,1983)

ACF VARIABLE IS EDP /

NUMBER OF OBSERVATIONS	=	1044
MEAN OF THE (DIFFERENCED) SERIES	=	47 4163
STANDARD ERROR OF THE MEAN	=	0.6121
T-VALUE OF MEAN (AGAINST ZERO)	=	77 4676

AUTOCORRELATIONS

1- 12	1.0	.99	.98	.98	.97	.96	.95	.95	.94	.94	.93	.92
ST.E.	.03	.05	.07	.08	.09	.10	.11	.12	.12	.13	.14	.14
13- 24	.92	.91	.90	.90	.89	.88	.88	.87	.86	.86	.85	.85
ST.E	.15	.15	.16	.16	.17	.17	.18	.18	.19	.19	.19	.20
25- 36	.84	.84	.83	.83	.82	.82	.81	.81	.81	.80	.80	.80
ST.E.	.20	.20	.21	.21	.21	.22	.22	.22	.22	.23	.23	.23

PLOT OF AUTOCORRELATIONS

```
                -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG   CORR.  +----+----+----+----+----+----+----+----+----+----+----+
                                          I
  1   0.995                           +   IX+XXXXXXXXXXXXXXXXXXXXX
  2   0.989                          +    IXX+XXXXXXXXXXXXXXXXXXXXX
  3   0.982                          +    IXX+XXXXXXXXXXXXXXXXXXXXX
  4   0.975                         +     IXXX+XXXXXXXXXXXXXXXXXXX
  5   0.968                         +     IXXX+XXXXXXXXXXXXXXXXXXX
  6   0.961                        +      IXXXX+XXXXXXXXXXXXXXXXXX
  7   0.954                        +      IXXXX+XXXXXXXXXXXXXXXXXX
  8   0.948                       +       IXXXXX+XXXXXXXXXXXXXXXXX
  9   0.942                       +       IXXXXX+XXXXXXXXXXXXXXXXX
 10   0.935                       +       IXXXXX+XXXXXXXXXXXXXXXXX
 11   0.929                      +        IXXXXXX+XXXXXXXXXXXXXXXX
 12   0.922                      +        IXXXXXX+XXXXXXXXXXXXXXXX
 13   0.916                      +        IXXXXXX+XXXXXXXXXXXXXXXX
 14   0.909                     +         IXXXXXXX+XXXXXXXXXXXXXXX
 15   0.903                     +         IXXXXXXX+XXXXXXXXXXXXXXX
 16   0.895                     +         IXXXXXXX+XXXXXXXXXXXXXXX
 17   0.888                     +         IXXXXXXX+XXXXXXXXXXXXXXX
 18   0.882                     +         IXXXXXXX+XXXXXXXXXXXXXXX
 19   0.876                    +          IXXXXXXXX+XXXXXXXXXXXXXX
 20   0.869                    +          IXXXXXXXX+XXXXXXXXXXXXXX
 21   0.864                    +          IXXXXXXXX+XXXXXXXXXXXXXX
 22   0.859                    +          IXXXXXXXX+XXXXXXXXXXXXXX
 23   0.853                    +          IXXXXXXXX+XXXXXXXXXXXXXX
 24   0.848                   +           IXXXXXXXXX+XXXXXXXXXXXXX
 25   0.842                   +           IXXXXXXXXX+XXXXXXXXXXXXX
 26   0.837                   +           IXXXXXXXXX+XXXXXXXXXXXXX
 27   0.832                   +           IXXXXXXXXX+XXXXXXXXXXXXX
 28   0.828                   +           IXXXXXXXXX+XXXXXXXXXXXXX
 29   0.823                   +           IXXXXXXXXX+XXXXXXXXXXXXX
 30   0.819                  +            IXXXXXXXXXX+XXXXXXXXXXXX
```

Figure 3-3

EDMONTON PRICE DATA AFTER DIFFERENCING SHOWING THE AUTOCORRELATION FUNCTION

(JANUARY 1,1964 - DECEMBER 31,1983)

```
  ACF        VARIABLE IS EDF
             DFORDER IS 1
             MAXLAG IS 24 /

NUMBER OF OBSERVATIONS                    =        1043
MEAN OF THE (DIFFERENCED) SERIES          =      0 0368
STANDARD ERROR OF THE MEAN                =      0 0519
T-VALUE OF MEAN (AGAINST ZERO)            =      0 7087

AUTOCORRELATIONS

 1- 12     .25   .07   03   04   0 0  -.07  -.06  - 06   05   06  - 04  -.06
 ST E.     .03   03    03   03   .03   .03   .03    03   .03   03    03   .03

13- 24    -.04   .08   05   0 0  -.10  -.09   .03  - 06  -.03   03    01   02
 ST E.     .03   03    03   03   .03   .03   03     03    03   .03   03   .03

PLOT OF AUTOCORRELATIONS

                -1.0 -0 8 -0 6 -0.4 -0.2  0 0  0 2  0 4  0 6  0.8  1.0
LAG    CORR  +----+----+----+----+----+----+----+----+----+----+----+

                                          I
  1    0 253                          + IX+XXXX
  2    0.070                          + IYX
  3    0.033                          + IX+
  4    0 039                          + IX+
  5   -0.001                          + I +
  6   -0 070                          XXI +
  7   -0 061                          XXI +
  8   -0 059                          +XI +
  9    0.048                          + IX+
 10    0.061                          + IYX
 11   -0 039                          +XI +
 12   -0 058                          +XI +
 13   -0.039                          +XI +
 14    0 081                          + IXX
 15    0 052                          + IX+
 16    0.004                          + I +
 17   -0.096                          XXI +
 18   -0.085                          XXI +
 19    0.026                          + IX+
 20   -0.065                          XXI +
 21   -0.033                          +XI +
 22    0.029                          + IX+
 23    0.015                          + I +
 24    0.018                          + I +
```

Figure 3-4

EDMONTON PRICE DATA AFTER DIFFERENCING SHOWING THE PARTIAL AUTOCORRELATION FUNCTION (JANUARY 1,1964 - DECEMBER 31,1983)

```
   PACF      VARIABLE IS EDP.
             DFORDER IS 1
             MAXLAG IS 24

NUMBER OF OBSERVATIONS                =          1,443
MEAN OF THE (DIFFERENCED) SERIES =          0.0366
STANDARD ERROR OF THE MEAN       =          0.0519
T-VALUE OF MEAN (AGAINST ZERO)             0.7057

PARTIAL AUTOCORRELATIONS

  1- 12     .25  .01  .01  .03 -.02 -.07 -.03 -.04  .08  .04 -.07 -.04
  ST.E.     .03  .03  .03  .03  .03  .03  .03  .03  .03  .03  .03  .03

 13- 24    -.02  .10  .03 -.01 -.11 -.06  .05 -.07  .03  .06 -.03 -.02
  ST.E.     .03  .03  .03  .03  .03  .03  .03  .03  .03  .03  .03  .03

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+

  1    0.253                        +    I    +
  2    0.007                        +    I    +
  3    0.014                        +    I    +
  4    0.029                        +    I    +
  5   -0.019                        +    I    +
  6   -0.072                        +   XI    +
  7   -0.028                        +   XI    +
  8   -0.036                        +   XI    +
  9    0.082                        +    IX   +
 10    0.042                        +    IX   +
 11   -0.070                        +   XI    +
 12   -0.043                        +   XI    +
 13   -0.024                        +   XI    +
 14    0.098                        +    IXX  +
 15    0.025                        +    IX   +
 16   -0.008                        +    I    +
 17   -0.107                        +   XI    +
 18   -0.061                        +   XI    +
 19    0.053                        +    IX   +
 20   -0.069                        +   XI    +
 21    0.029                        +    IX   +
 22    0.065                        +    IXX  +
 23   -0.032                        +   XI    +
 24   -0.019                        +    I    +
```

FIGURE 3-5

ESTIMATED COEFFICIENT FOR THE DIFFERENCED EDMONTON PRICE DATA (JANUARY 1,1964 - DECEMBER 31,1983)

```
   ESTIMATION RESIDUAL IS REDP.
              MAXLAG IS 24./

ESTIMATION BY CONDITIONAL LEAST SQUARES METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.1000E-04


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- EDP
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME      DIFFERENCES
                                          1
EDP         RANDOM             1-1044   (1-B  )

PARAMETER VARIABLE   TYPE  FACTOR  ORDER ESTIMATE      ST. ERR.  T-RATIO
      1   EDP          AR       1      1   0.2534       0.0300     8.44

RESIDUAL SUM OF SQUARES  =      2742.666016
DEGREES OF FREEDOM       =              1041
RESIDUAL MEAN SQUARE     =         2.634645

ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN 0.1000E-04


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- EDP
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME      DIFFERENCES
                                          1
EDP         RANDOM             1-1044   (1-B  )

PARAMETER VARIABLE   TYPE  FACTOR  ORDER ESTIMATE      ST. ERR.  T-RATIO
      1   EDP          AR       1      1   0.2535       0.0300     8.45

RESIDUAL SUM OF SQUARES  =      2742.668457 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =              1041
RESIDUAL MEAN SQUARE     =         2.634647
```

FIGURE 3-6

RESIDUAL AUTOCORRELATION FUNCTION FOR
DIFFERENCED EDMONTON PRICE DATA
(JANUARY 1,1964 - DECEMBER 31,1983)

ACF VARIABLE IS REDP /

NUMBER OF OBSERVATIONS	=	1044
MEAN OF THE (DIFFERENCED) SERIES	=	0.0278
STANDARD ERROR OF THE MEAN	=	0.0502
T-VALUE OF MEAN (AGAINST ZERO)	=	0.5543

AUTOCORRELATIONS

1- 12	0.0	0.0	.01	.04	.01	-.06	-.03	-.06	.05	.07	-.04	-.05
ST.E.	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
13- 24	-.05	.09	.04	.02	-.09	-.06	.07	-.07	-.03	.04	0.0	.02
ST.E.	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
25- 36	-.01	-.07	-.04	-.02	.01	.02	-.02	-.04	.03	0.0	-.10	0.0
ST.E.	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03

PLOT OF AUTOCORRELATIONS

LAG	CORR.	-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0
		I
1	-0.002	+ I +
2	0.002	+ I +
3	0.007	+ I +
4	0.036	+ IX+
5	0.009	+ I +
6	-0.062	XXI +
7	-0.034	+XI +
8	-0.064	XXI +
9	0.054	+ IX+
10	0.066	+ IXX
11	-0.045	+XI +
12	-0.046	+XI +
13	-0.051	+XI +
14	0.089	+ IXX
15	0.037	+ IX+
16	0.016	+ I +
17	-0.088	XXI +
18	-0.078	XXI +
19	0.071	+ IXX
20	-0.071	XXI +
21	-0.028	+XI +
22	0.037	+ IX+
23	0.004	+ I +
24	0.024	+ IX+
25	-0.013	+ I +
26	-0.071	XXI +
27	-0.037	+XI +
28	-0.020	+XI +
29	0.005	+ I +
30	0.019	+ I +
31	-0.021	+XI +
32	-0.038	+XI +

TABLE 3-1

DETAILS OF SELECTED ARIMA FILTERS FOR THE THREE MARKETS AS AT THE VARIOUS TIME PERIODS
(JANUARY 1, 1964 - DECEMBER 31, 1983)

Time Period[3]	EDP[2]	TNP[2]	USP[2]
1	$(1-.356B)Y_t=a_t$	$(1-.266B)Y_t=a_t$	$(1-.155B)Y_t=a_t$
2	$Y_t=(1+.107B+.129B^2)a_t$	$Y_t=(1+.343B)a_t$	$(1-.352B)Y_t=a_t$
3	$Y_t=a_t$	$Y_t=(1+.112B)a_t$	$(1-.372B)Y_{1t}=a_t$
4	$(1-.392B)Y_t=a_t$	$Y_t=a_t$	$Y_t=(1+.16B+.28B^2)a_t$
5	$Y_t=a_t$	$Y_t=a_t$	$Y_t=a_t$
6	$Y_t=(1+.511B)a_t$	$Y_t=a_t$	$Y_t=(1-.361B)a_t$

[1] U.S. prices are an average of 7 midwest hog market prices.

[2] Y_t is the first difference of the series, a_t is a random error term and B is the backshift operator.

[3] Time period 1 is January 1, 1964 to October 31, 1969. Time period 2 is November 1, 1969 to April 1, 1975. Time period 3 is April 2, 1975 to March 12, 1978. Time period 4 is March 14, 1978 to March 15, 1980. Time period 5 is March 16, 1980 to December 31, 1980. Time period 6 is January 1, 1981 to December 31, 1983.

TABLE 3-2

COMPUTED Q-STATISTIC FOR EDMONTON, TORONTO AND THE 7 U.S. AVERAGE MARKETS (JANUARY 1, 1964 - DECEMBER 31, 1983)

PERIOD	EDMONTON	TORONTO	U.S. AVERAGE
JANUARY 1, 1964-OCTOBER 31, 1969	15.03	25.03	19.06
NOVEMBER 1, 1969-APRIL 1, 1975	18.95	24.31	15.36
APRIL 2, 1975-MARCH 12, 1978	20.07	45.64*	10.50
MARCH 13, 1978-MARCH 15, 1980	11.14	25.87	13.09
MARCH 16, 1980-DECEMBER 31, 1980	19.93	18.03	11.57
JANUARY 1, 1981-DECEMBER 31, 1983	14.81	11.47	7.55

* The only significant value at 99 per cent with 14 degrees of freedom

various markets, appear in Table 3-1.[62]

G. SUMMARY

The chapter has discussed the models used in this study. It also explained how the different models for the different time periods in the various markets were arrived at in studying the pricing efficiency concept in the Alberta hog industry. The results of the tests are presented in the next chapter.

---

[62] For more detailed discussion of ARIMA and Granger Causality, refer to D. McDowall et. al. *op. cit.* and Haugh and Box, *op. cit.*

IV. RESULTS AND INTERPRETATIONS OF THE EMPIRICAL ANALYSIS

A. INTRODUCTION

This chapter will contain the results from the intervention analysis. It contains the results of the lead-lag structure of the markets as well. In addition, the chapter contains graphical illustrations of the price differentials between Edmonton-Toronto, Edmonton-United States, and Toronto-United States markets.

B. RESULTS OF THE INTERVENTION ANALYSIS

Table 4-1 contains the results of the intervention analysis for the Edmonton market and for the Edmonton-Toronto, Edmonton-United States and Toronto-United States markets. The results show that none of the policy changes initiated by the Pork Board had any significant impact on pork prices in Edmonton. The Board's policy changes did not show any significant closure of the Edmonton-Toronto price spread.

However, the results do show that the price difference between the Canadian markets and the United States markets closed in favour of Canada during the period November 1, 1969 to April 1, 1975. This is the period immediately after the formation of the Alberta Pork Producers' Marketing Board in Alberta. The implication for the significant intervention value between the Edmonton and United States price spread is that, the formation of the Pork Board improved the pricing

TABLE 4-1

RESULTS OF THE IMPACTS IN THE MARKETS UNDER STUDY
(JANUARY 1, 1964-DECEMBER 31, 1983)

TIME PERIOD	EDMONTON	EDMONTON-TORONTO	EDMONTON-U.S.	TORONTO-U.S.
A	-0.81 (-0.78)	-0.48 (-0.58)	2.82* (2.96)	3.48* (2.48)
B	-0.80 (-0.44)	1.15 (0.91)	-0.74 (-0.34)	-1.18 (-0.54)
C	-1.68 (-0.76)	0.37 (0.24)	-3.37 (-1.27)	2.42 (0.84)
D	-2.36 (-1.41)	-1.10 (-0.74)	-1.28 (-0.34)	-1.50 (-0.44)
E	-0.39 (-0.23)	-1.05 (-0.68)	-0.30 (-0.07)	0.53 (0.13)

t-Values in brackets
* Significant at 95 per cent
A Compares Pre- and Post-Intervention 1
B Compares Interventions 1 and 2
C Compares Interventions 2 and 3
D Compares Interventions 3 and 4
E Compares Interventions 4 and 5

levels in the Alberta hog industry. This inference however must be made with caution, especially with an even larger significant impact between the Toronto and the United States markets during the same time period. The period prior to 1976 was generally a period of surplus hog supply in the United States. The surpluses led to a downward pressure on hog prices in that country, and may have closed the price spread in favour of Canada. The price trend has however been reversed since 1976, in favour of the United States.[3]

C. LEAD-LAG STRUCTURE ANALYSIS

Table 4-2 contains the results of the lead-lag structure for the three markets under study.

EDMONTON: Before the formation of the Alberta Pork Producers' Marketing Board in 1969, Edmonton prices lagged Toronto prices and United States prices by one period. At the same time, there were instantaneous price adjustments between Edmonton and the two markets. This is possible because price adjustments occurring completely within the week are considered to be instantaneous.

From November 1, 1969 to April 1, 1975, there was a feedback of pricing information between Edmonton and the other two markets of comparison. Feedback is a situation where two series lead each other. The feedback in this case is an indication of how Edmonton hog prices were important during this time period. This period corresponds with the

---

[3] Personal conversation with Greg Whalley of the APPMB, April 1984.

TABLE 4-2

CALCULATED F STATISTICS FOR WEEKLY SLAUGHTER HOG PRICES BETWEEN SEVEN U.S. MARKETS COMBINED AND THE TWO CANADIAN MARKETS (JANUARY 1, 1964 - DECEMBER 31, 1983)

	NEGATIVE LAGS a	INSTANTANEOUS RELATIONSHIP b	POSITIVE LAGS c
JANUARY 1, 1964-OCTOBER 31, 1969			
EDMONTON - TORONTO	16.05*	105.25*	5.17
EDMONTON - U.S.	15.46*	10.08*	5.17
TORONTO - U.S.	12.67*	23.86*	0.82
NOVEMBER 1, 1969-APRIL 1, 1975			
EDMONTON - TORONTO	19.94*	92.51*	8.19*
EDMONTON - U.S.	9.88*	10.33*	7.70*
TORONTO - U.S.	16.93*	10.56*	3.33
APRIL 2, 1975-MARCH 12, 1978			
EDMONTON - TORONTO	8.03*	131.46*	1.05
EDMONTON - U.S.	4.92	8.57*	0.24
TORONTO - U.S.	4.20	2.18	0.86
MARCH 13, 1978-MARCH 15, 1980			
EDMONTON - TORONTO	3.77	79.92*	2.96
EDMONTON - U.S.	6.46	9.18*	0.52
TORONTO - U.S.	2.99	4.80	0.88
MARCH 16, 1980-DECEMBER 31, 1980			
EDMONTON - TORONTO	19.16*	16.48*	0.56
EDMONTON - U.S.	6.03	3.66	1.96
TORONTO - U.S.	1.48	16.91*	1.34
JANUARY 1, 1981-DECEMBER 31, 1983			
EDMONTON - TORONTO	30.59*	91.38*	4.78
EDMONTON - U.S.	10.87*	0.02	19.07*
TORONTO - U.S.	7.51*	1.08	10.07*

* Significant at 99 per cent
a Calculated from the first negative cross-correlation
b Calculated from zero cross-correlation
c Calculated from the first positive cross-correlation

formation of the Pork Marketing Board until the purchase of the assembly yards. The significant zero lags between Edmonton and the other markets imply that market information was rapidly and efficiently communicated between Edmonton and the two markets.

The temporal structure changed during the next time period. Between April 2, 1975 and March 12, 1978, there were instantaneous price relationship between Edmonton and the other markets but Edmonton prices lagged Toronto prices by one period. This time period runs from the time that the Pork Board purchased the assembly yards until the time when the board introduced the producer bid acceptance. The instantaneous relationship between Edmonton and the other markets continued up to the end of the third time period; that is, March 15, 1980.

The time period from March 16, 1980 until December 31, 1980, was the period of government intervention in the operations of the APPMB. It was also the first time that information flow between the Edmonton and the United States markets was found to be inadequate. There was no instantaneous relationship between the Edmonton and the United States markets during this time period. However, the instantaneous relationship between Edmonton and Toronto markets continued.

Between January 1, 1981 and December 31, 1983, Edmonton prices still had an instantaneous relationship with Toronto prices but lagged Toronto prices by one period. Information

flow failed to improve between Edmonton and the United States markets. However, the Edmonton and the United States prices showed evidence of feedback. The lead-lag structure during this time period may suggest that either market alternatively had access to superior information or used available information more effectively than the other.

The overall analysis illustrates that pricing efficiency levels were high in the Alberta hog industry immediately after the formation of the Pork Board. The high efficiency levels have however declined since April, 1975, although decline in some time periods was more pronounced than in others.

The statistical results reported in Table 4-2 also show that the Edmonton hog market has been isolated from the alternative markets since the inception of the Pork Board. This observation is based on the fewer significant values between Edmonton prices and the prices of the alternative markets since April, 1975.

TORONTO: During the observation period studied, Toronto prices were found to have mostly lagged the United States prices but led Edmonton prices. Evidence of feedback was observed for the Toronto-United States markets during the period January 1, 1981 to December 31, 1983. The lack of instantaneous relationship during this same time period suggest that the Toronto and the United States markets were not closely related. During two of the six time periods studied there was no relationship at all between the Toronto

and the United States markets. These two periods ran from April 2, 1975 to March 15, 1980. The implication is that United States price changes were not reflected in Toronto price changes during the two time periods.

The results also indicate a larger cross-correlation between Toronto and Edmonton prices. The implication here is that there is a more rapid adjustment of prices within the two Canadian markets than with the United States markets (See table 4-3). This result confirms the finding of Beaton and Pearson in their study of some selected Canadian markets and seven United States market average.[4] Besides, there was consistent instantaneous relationship between Toronto and Edmonton markets during the twenty year period. This would imply that information existing between the two markets are used equally effectively by the markets concerned.

SEVEN UNITED STATES MARKET AVERAGE: The results show that United States prices generally led Canadian prices. However, there was a lesser integration with the Canadian markets prices. This is evident by the smaller values of the cross-correlations between the United States and the Canadian markets.

Between the two countries, Edmonton prices were more integrated with the United States prices than the Toronto prices were with the United States prices. This indicates that market information was communicated more often between Edmonton and the United States markets than between Toronto

---

[4] Beaton and Pearson, *op. cit.* p. 8

TABLE 4-3

ESTIMATED CROSS-CORRELATION BETWEEN WHITE NOISE RESIDUALS OF HOG PRICES FOR EDMONTON TORONTO AND SEVEN U.S. AVERAGE (JANUARY 1, 1964 - DECEMBER 31, 1983)

	-1a	0b	1c
JANUARY 1, 1964-OCTOBER 31, 1969			
EDMONTON - TORONTO	0.225	0.509*	0.13
EDMONTON - U.S.	0.221	0.18	0.13
TORONTO - U.S.	0.201	0.271	0.052
NOVEMBER 1, 1969-APRIL 1, 1975			
EDMONTON - TORONTO	0.257	0.497*	0.168
EDMONTON - U.S.	0.184	0.188	0.163
TORONTO - U.S.	0.238	0.19	0.108
APRIL 2, 1975-MARCH 12, 1978			
EDMONTON - TORONTO	0.224	0.681*	0.083
EDMONTON - U.S.	0.177	0.231	0.04
TORONTO - U.S.	0.164	0.119	0.075
MARCH 13, 1978-MARCH 15, 1980			
EDMONTON - TORONTO	0.188	0.661*	0.167
EDMONTON - U.S.	0.243	0.286	0.071
TORONTO - U.S.	0.168	0.211	0.092
MARCH 16, 1980-DECEMBER 31, 1980			
EDMONTON - TORONTO	0.574	0.545*	-0.119
EDMONTON - U.S.	0.366	0.293	-0.219
TORONTO - U.S.	0.191	0.55	-0.182
JANUARY 1, 1981-DECEMBER 31, 1983			
EDMONTON - TORONTO	0.406	0.609*	0.173
EDMONTON - U.S.	0.256	0.010	0.331
TORONTO - U.S.	0.215	0.083	-0.247

* Note: These stand high among values in each category
a Negative Lags
b Lag zero cross-correlations
c Positive Lags

and the United States markets. This observation is based on the finding that for four out of six time periods, Edmonton prices had instantaneous relationship with the United States prices. On the other hand, the instantaneous relationship occurred three out of six time periods between Toronto and the United States markets.

There was no instantaneous relationship between the United States prices and Edmonton prices from March 16, 1980 to December 31, 1980. The government intervention during this period resulted in a lower level of information flow between the United States markets and Edmonton market.

There was a feedback between the United States markets and the Canadian markets from January 1, 1981 to December 31, 1983. However, the lack of instantaneous causality between the markets suggests that the Canadian markets and the United States markets were not closely related during this time period.

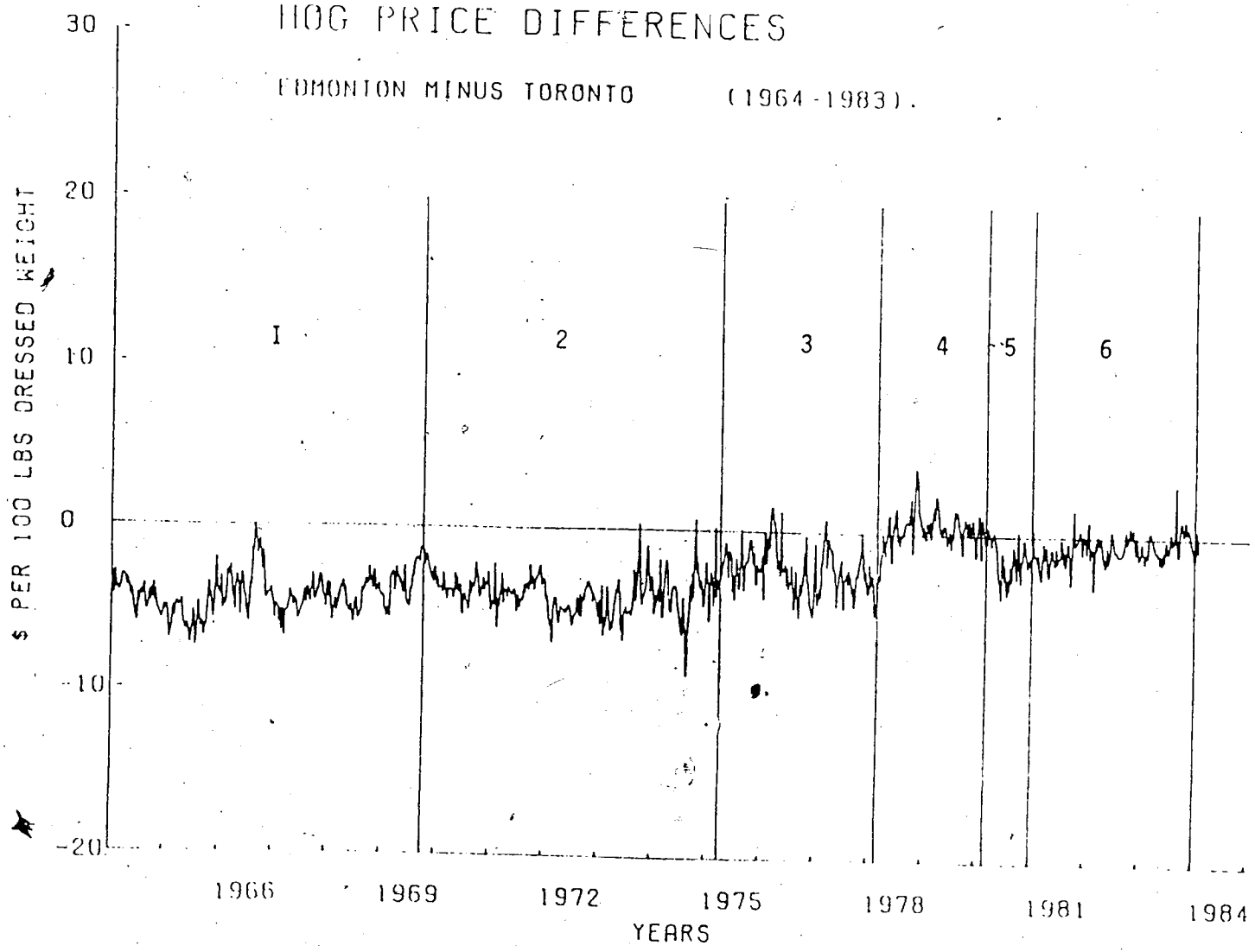
D. GRAPHICAL ILLUSTRATIONS OF THE PRICE MOVEMENTS

Figures 4-1, 4-2 and 4-3 show the price fluctuations between the study markets for the whole observation period. To give a clearer picture, the graphs are broken down into the six time periods studied.

EDMONTON-TORONTO PRICES

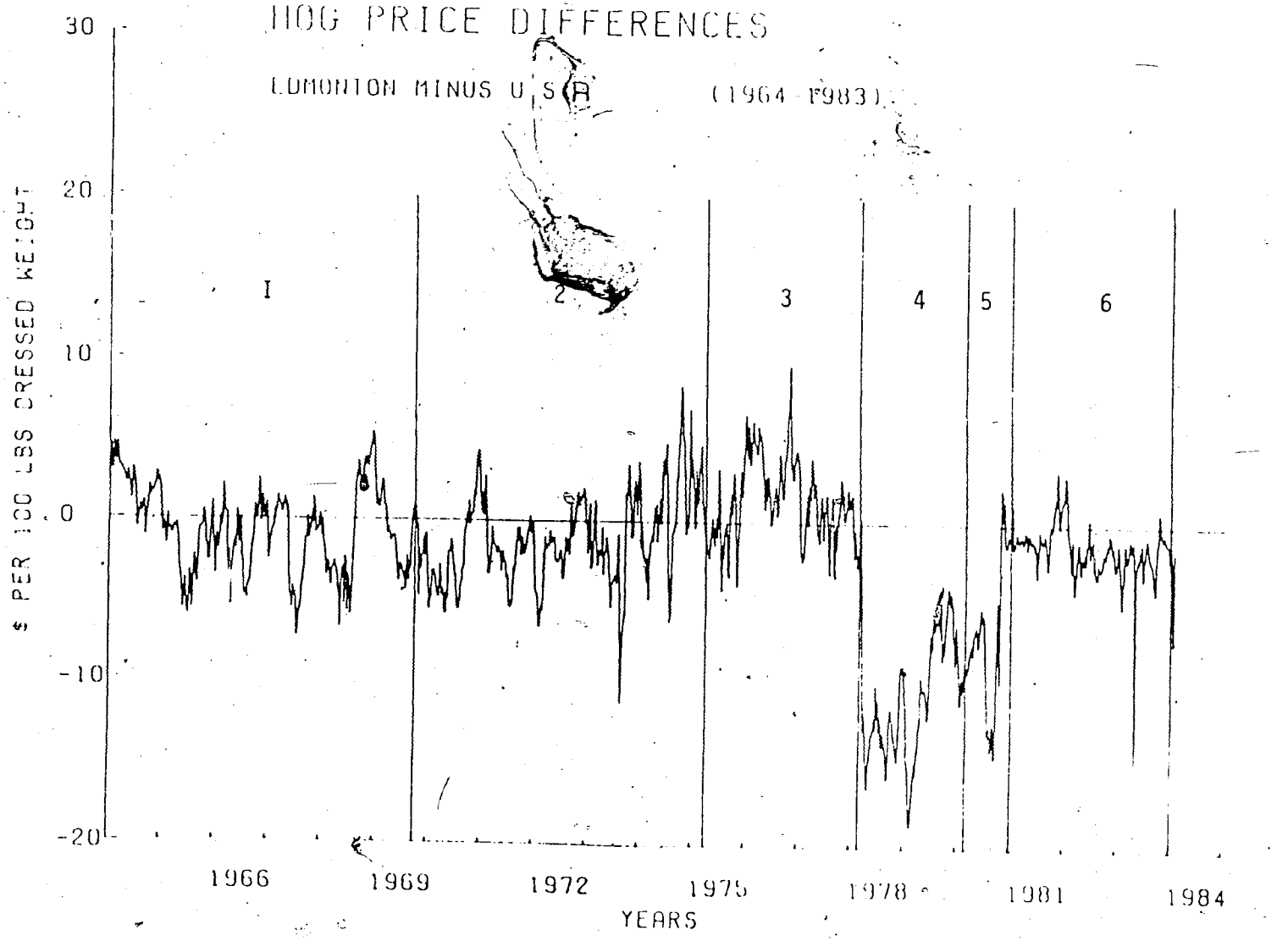
The price difference between these two markets has normally been to the advantage of Toronto; that is, Toronto

FIGURE 4-1



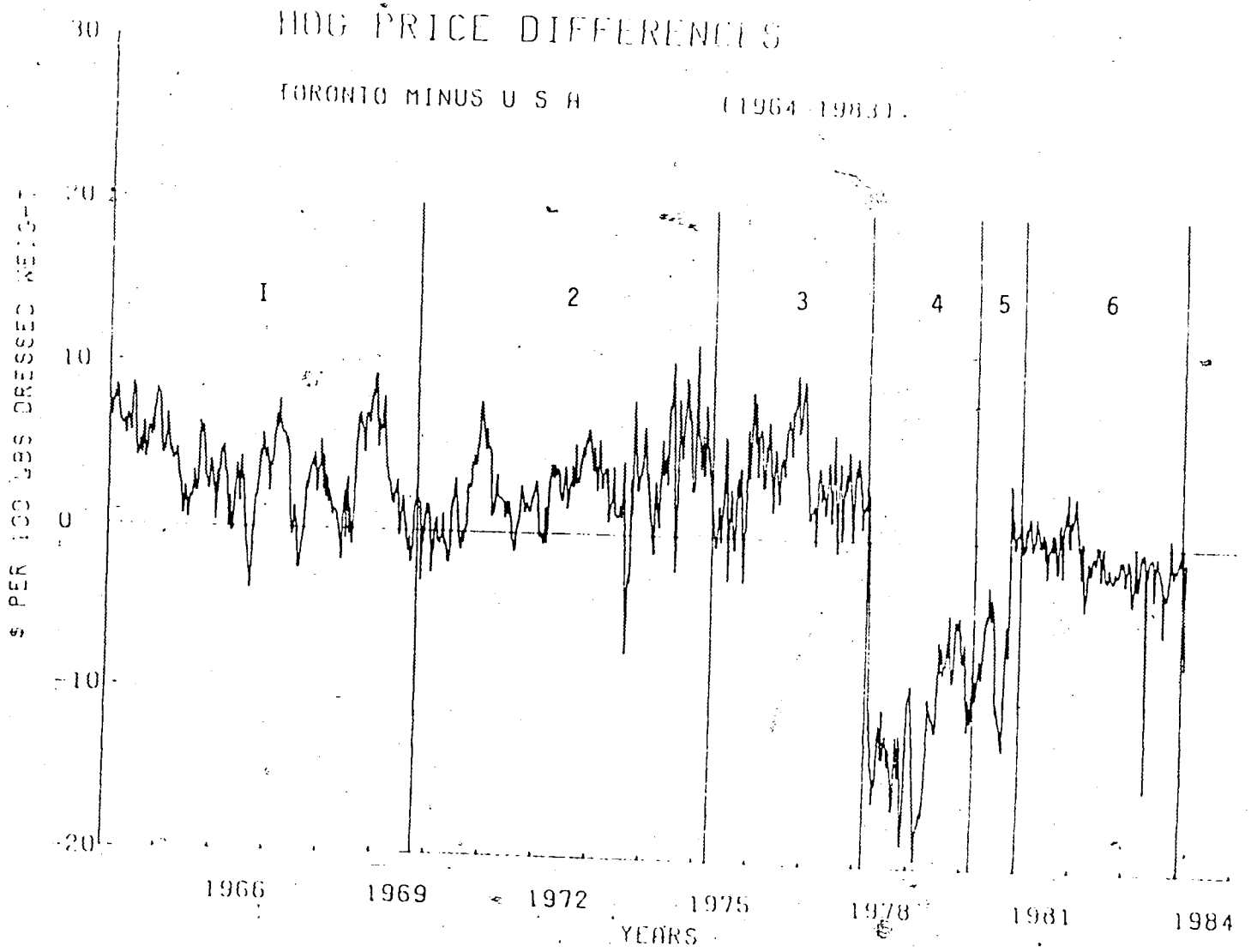
SOURCE: GRAPH DRAWN FROM DATA COLLECTED IN THE CANADA LIVESTOCK AND MEAT TRADE REPORT (1964-1983).

FIGURE 4-2



SOURCE: GRAPH DRAWN FROM DATA COLLECTED IN THE CANADA LIVESTOCK AND MEAT TRADE REPORT (1964-1983).

FIGURE 4-3



SOURCE: GRAPH DRAWN FROM DATA COLLECTED IN THE CANADA LIVEST CK AND MEAT TRADE REPORT (1964-1983).

prices have usually been higher than Edmonton prices (Figure 4-1). Before 1972, the difference between these markets fluctuated noisily around a mean of about four cents, with Toronto prices higher than Edmonton prices. Toronto prices during this period were generally higher than Edmonton prices by about 2 to 8 cents per hundred pound weight.

Since 1972, the variations have been wider. Furthermore, the movements have shown cycles since 1972, although some are more pronounced than others. Between 1973 and 1975, the difference trended upwards and then drifted down between 1975 and 1977. Between 1977 and 1979, the difference fluctuated around a zero mean but mostly in favour of Edmonton. By mid-1980 however, this price difference widened against Edmonton but has since closed in favour of Edmonton.

Generally, the price spread between the two markets kept narrowing in favour of Edmonton. The most obvious period of narrowing was during the fourth time period; that is, from the time when the Pork Board introduced the bid acceptance procedure. However, the intervention by the government in the operations of the APPMB, resulted in a price spread against Edmonton. The spread has however been narrowing again for Edmonton since 1981.

EDMONTON-UNITED STATES MARKETS AVERAGE

The difference in these two markets fluctuated around a zero mean until 1972, with United States prices often higher

than Edmonton prices (Figure 4-2).

Unlike the Edmonton-Toronto price difference, the introduction of the producer bid acceptance failed to close the price gap between these two markets. Instead, the gap widened at the expense of the Edmonton market and continued into the fifth period when the government intervened in the operations of the APPMB.

Edmonton prices picked up between 1972 and 1977 with the price gap mostly in favour of Edmonton. Between 1977 and 1980 however, the United States prices were high enough to have widened the difference to as much as 20 cents at some periods. The situation changed in favour of Edmonton during some periods in 1980 and 1981. Generally, the United States prices led the Edmonton prices, except during the third time period when the Edmonton prices were higher than the United States prices.

TORONTO-UNITED STATES MARKETS AVERAGE

The Toronto-United States price difference followed a similar behaviour as the Edmonton-United States price difference (Figure 4-3).

Fluctuations in these markets were mostly steady in favour of Toronto, up until 1972. Between 1972 and 1977, the difference widened to the advantage of Toronto. This situation changed between 1977 and 1980 when United States prices picked up and exceeded Toronto prices by up to 20 cents. Toronto prices picked up in early 1980, but have

since been losing ground.

E. SUMMARY

The empirical work in this chapter has had two objectives. The first was the usage of the Box-Jenkins Procedure to assess the impacts, if any, of the policy interventions initiated by the Alberta Pork Producers' Marketing Board. The second was to use Univariate Residual Cross-Correlation Analysis to study the lead-lag relationship of pork prices for Edmonton, Toronto, and an average of seven United States cities in the mid-west.

Conclusions and recommendations based on the empirical results will be given in the next chapter.

V. SUMMARY OF EMPIRICAL RESULTS, CONCLUSIONS AND RECOMMENDATIONS

A. RESULTS CONCERNING GRAPHICAL ILLUSTRATIONS

1. The graphical results show that since about 1972, the variability in the spreads between the markets under study has increased. This widening was even more obvious for the price gaps between the Canadian markets and the United States markets.
2. Between the Canadian markets, the results show that the price gap between the Edmonton hog market and the Toronto hog market has generally become smaller. This agrees with the empirical finding that the two markets have higher zero lag adjustments, indicating a more efficient information flow.
3. The spread between the Edmonton and the Toronto prices has followed a 2 year cyclical pattern since 1972. Between the Canadian and the United States markets however, there appears to be a 3 to 5 year cyclical pattern during the same time period.

B. RESULTS CONCERNING PRICING EFFICIENCY

1. The study of the intervention analysis showed that the policies initiated by the Alberta Pork Board, and which were considered in this study, had little significant impact on pricing levels. With regards to the price gaps between the Edmonton hog market and the other markets of

comparison, the ARIMA model showed that the formation of the Pork Board itself helped to close the price gap between Edmonton prices and the United States prices. This period coincided, however, with lower United States hog prices due to supply levels and conclusions from these results must therefore be made with caution.

2. The lead-lag structure brought out results which indicated that the formation of the Alberta Pork Board improved information flows between the Edmonton hog market and the alternative markets. This is an indication of improved pricing efficiency, and rejects the null hypothesis that the formation of the Board did not increase pricing efficiency in the Alberta hog industry.

3. The pricing efficiency levels attained with the inception of the Pork Board have declined since April 1975. The loss in efficiency was relatively higher during the provincial government's intervention in the operations of the Pork Board. For the first time during this period, there was little relationship between the Edmonton prices and the United States prices. Information flows between the two markets had not improved as at the end of 1983.

4. The Canadian markets had the greatest correspondence, with zero lag adjustments between each other. Information flows between Edmonton and Toronto markets were more efficient. Between Canada and the United

States, Edmonton prices performed better with the United States prices in terms of information flows between the markets.

5. There were relatively lower zero lag adjustments between the Canadian market prices and the United States market prices. This was an expected finding given the institutional barriers and uncertainties in planning exports between the two countries.

6. The United States hog prices generally led the Canadian hog prices. This result confirmed the study by Hawkins et. al. that hog prices in Canada are tied to the United States hog price levels.[5]

7. There were fewer significant cross-correlation values between Edmonton prices and prices of the other markets as at December, 1983. This result indicates that the Edmonton hog market has isolated itself from the alternative markets. This statistical result clarifies the fact that relatively fewer hogs are actually transported from Alberta to the Toronto or the United States markets. Before the formation of the APPMB, Edmonton hog prices were priced at Toronto hog prices "less freight". Edmonton prices were tied to that of Toronto. Furthermore, there were relatively more hogs that were sent to the Toronto market. Since the formation of the Pork Board however, the Board has been

---

[5] M. Hawkins, et. al., *North American Hog-Pork Study.* A project for the Economics Branch of the Canada Department of Agriculture, p. 3.

able to take control of supply and demand conditions affecting the local hog market. Alberta hog prices therefore may be said to be responding to local conditions. Locally, this is of advantage to hog producers in Alberta. Basically, the Pork Board is concerned with seeking "reasonable" prices for its members. If prices in the United States markets are higher, the Board ships some pigs into that market. The Board is not obliged to ship pigs to the United States. Internationally however, the isolation may be injurious to the Alberta hog industry in terms of foreign competition.

Before drawing conclusions from the above findings, it may be appropriate to briefly restate, at this point, the concept of pricing efficiency. Accurate and rapid information flow between two markets that deal in the same commodity is an important prerequisite in pricing efficiency. It is only when information is accurately and rapidly disseminated to the players in the market that no single individual or group of individuals can manipulate prices. If for any reason there are price differences between any two selling points, after transport costs are considered, such a difference must give room to arbitrage to eventually even out the prices. In other words, the basis for pricing efficiency involves achieving the highest available price for the producers of a commodity and seeking lower prices for consumers. Pricing efficiency is therefore

said to exist if prices reflect and coordinate the buying and selling activities of the farmers, marketing firms, and of consumers.

C. CONCLUDING REMARKS

Subject to any limitations of this study, the empirical analysis has led to the following conclusions:

1. that pricing efficiency gains in the Alberta hog industry, after the formation of the Alberta Pork Board, were short-lived;
2. that the provincial government's intervention in the operations of the Pork Board had an adverse effect on the Alberta hog industry and contributed to the loss of pricing efficiency gains;
3. that depending on how one looks at the performance of the Alberta Pork Board, conclusions may be mixed. Locally, Edmonton hog prices reflect Toronto hog prices and information flows between the two markets are efficient. This indicates pricing efficiency and rejects the null hypothesis that the formation of the Pork Board has not increased pricing efficiency. Internationally however, the empirical results indicate that the United States hog prices do not reflect in the Edmonton hog prices. Information flow between these two markets is inefficient. Therefore there is pricing inefficiency at the international scene and confirms the null hypothesis. A number of factors may account for this

inefficiency. These include: tariffs, currency exchange rate between Canada and the United States, health regulations, and so on.[6] These factors make export planning between the two countries unstable and difficult;

4. that the price margins between the Edmonton and Toronto hog prices have narrowed considerably since the formation of the APPMB;
5. that the Alberta hog market is presently isolated from the Ontario and the United States midwestern hog markets.

D. RECOMMENDATIONS

1. It is recommended that the provincial government allow the Board the freedom to operate without any further interruptions.
2. More cooperation is needed between the Ministry of Agriculture and the Marketing Board in achieving "reasonable" prices for the hog producers of Alberta. At present, the Alberta hog industry has lost some markets for its live hogs which were shipped to two packing plants on the west coast of the United States. Both plants closed down in March, 1984.[7] The Pork Board is therefore faced with the problem of transporting live pigs to longer distances in the United States. The

---

[6] Hawkins, et. al., *op. cit.*
[7] Personal conversation with Greg Whalley of APPMB, March 9, 1984.

potential higher transport costs facing the industry could hamper the Board's efforts to improve pricing efficiency.

3. Since it is difficult for the Pork Board to break the oligopsonistic structure of the packing plants, the Combines Investigations Authorities may have to intervene. The authorities could, for example, restrict market shares of the packers and the retailers of fresh pork.

E. RECOMMENDATIONS FOR FUTURE RESEARCH

1. It is recommended that a further intervention analysis be done to study the long term impact of the purchase of the Fletcher's Packing Plant on pricing efficiency.
2. Future research may have to include the Saskatoon hog market as an alternative market. The study by Beaton and Pearson found information flow between this market and the United States markets to be more efficient than between Edmonton and the United States markets.[‡‡] Considering that this market has smaller sales volume of pigs than Edmonton, this is a surprising result. If afuture study still finds the Saskatoon hog market to be doing relatively better than Edmonton, then some pricing policies of the Saskatchewan Hog Marketing Commission may have to be suggested to the Alberta Pork Board.
3. A future study may also consider the use of daily hog

---

‡‡ Beaton and Pearson, *op. cit.* p. 9.

prices to determine how many days within the week that prices lag or lead each other between the Edmonton market and other alternative markets.

BIBLIOGRAPHY

Agriculture Canada. Food and Agriculture Marketing Branch. *Livestock Market Review*. Ottawa: 1961-1980.

Agriculture Canada. Marketing Services Division. *Canada Livestock and Meat Trade Report*. Ottawa: 1964-1983.

Andersen, Richard S. "An Economic Analysis of Daily Hog Price Fluctuations and Supply Response." M.Sc. Thesis, University of Alberta, 1971.

Bain, Joe, S. *Industrial Organization*. New York: John Wiley and Sons, Inc., 1966.

Beaton, N. and Pearson, C. "Lead-Lag Structure of Slaughter Hog Prices Between U.S. Mid-west and Four Major Canadian Markets Utilizing Univariate Residual Cross-Correlation Technique." Winnipeg, Manitoba, 1982. (Mimeographed).

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

Bessler, D. and Schrader, L. "Measuring Leads and Lags Among Prices: Turkey Products." *Agricultural Economics Research 3*. Vol. 32, July 1980.

Box, G.E.P. and Tiao, G.C. "Intervention Analysis with Applications to Economic and Environmental Problems." *Journal of the American Statistical Asscia*tion. Vol. 70, No. 34, March 1975.

Caves, Richard. *American Industry: Structure, Conduct, Performance*. Englewood Cliffs, New Jersey: Prentice

Hall, Inc., 1967.

Efroymson, C.W. "The Kinked Oligopoly Curve Reconsidered." *Quarterly Journal of Economics.* Vol. 69, 1955.

Faminow, M.D. "Analysis of the Lead-Lag Structure of Two Wholesale Beef Price Quotes Using Residual Cross-Correlation." *North Central Journal of Agricultural Economics 3(2).* July 1981.

Fredeen, Howard. *The Competitive Position of the Canadian Pork Industry.* Lacombe, Alberta: Agriculture Canada Research Station, 1977.

Gupta, S. and Mueller, R. "Intertemporal Pricing Efficiency in Agricultural Markets: The Case of Slaughter Hogs in West Germany." *European Review of Agricultural Economics 9.* No. 025-040, 1982.

Harries, Hu and Associates Ltd. "Price Relationships in the Alberta Hog Market." *Study commissioned by the Minister of Agriculture, Government of Alberta.* Honorable M. Moore, Edmonton. October 1977.

Haugh, Larry D. and Box, G.E.P. "Identification of Dynamic Regression (Distributed Lag) Models Connecting Two Time Series." *Journal of the American Statistical Association.* Vol. 72, No. 357, March 1977.

Hawkins, M.H., Bennett, R. and Boswell, A. "North American Hog-Pork Study." Project for the Economics Branch of the Canada Department of Agriculture, Ottawa, 1972.

Hawkins, M.H., Dawson, J.L. and Geldard, G. *Development and Operation of the Alberta Hog Producers' Marketing Board.*

Rural Sociology Bulletin 12, Edmonton: University of Alberta, March 1977.

Hog Marketing Review Committee. A Report Presente[illegible] the Alberta Ministry of Agriculture Based on Stud[illegible] by the Committee Appointed by the Alberta [illegible] of Agriculture, 1981.

Heflebower, R. "Stability in Oligopoly." *The Manchester School.* Vol. 29, 1961.

Koch, James V. *Industrial Organization and Prices.* Englewood Cliffs, New Jersey: Prentice Hall, Inc. 1974.

Kohls, Richard and Downey, David. *Marketing of Agricultural Products, 4th Ed.* N[illegible] York, N.Y.: Macmillan, 1978.

Koutsoyiannis, A. [illegible] *of Econometrics.* London: The MacMillan Press Li[illegible] 1978.

Leavitt, Steven S. "Market Performance of the Alberta Pork Producers' Marketing Board." M.Sc. Thesis, University of Alberta, 1981.

Ljung, G. M. and G.E.P.Box. "On a Measure of Lack of Fit in Time Series Models." *Biometrika 65(1978):* p. 297-303.

Lockhart, James W. "Alberta Hog Market, Conduct and Performance." M.Sc. Thesis, University of Alberta, 1967.

Low, Richard E. *Modern Economic Organization.* Homewood, Illinois: Irwin, Inc., 1970.

Manning, Travis. *Performance of the Hog Marketing System in Alberta.* Agricultural Economics Research Bulletin 4, Edmonton: University of Alberta, July 1967.

McDowall, D., McCleary, R., Meidinger, E. and Hay, R.A.

Interrupted Time Series Analysis: Quantitative Applications in the Social Sciences. Publication from Sage University.

Miller, Stephen E. "Univariate Residual Cross-Correlation Analysis: An Application to Beef Prices." *North Central Journal of Agricultural Economics 1.* 1979.

Ostrum, C.W. *Time Series Analysis: Regression Techniques.* Sage University Paper Series on Quantitative Applications in Social Sciences, 07-009.

Pierce, D.A. and Haugh, L.D. "Causality in Temporal Systems." *Journal of Econometrics.* Vol. 5, 1977.

Reschenthatler, G.B. "An Analysis of the Competitiveness of the Pork Industry in Alberta." Presented to the Hog Marketing Review Committee, Edmonton, 24 June, 1980. (Mimeographed).

Stigler, George. "The Kinky Oligopoly Demand Curve and Rigid Prices." *Journal of Political Economy.* Vol 55, 1947.

Tomek, W. and Robinson, K. *Agricultural Product Prices.* Ithaca, New York: Cornell University, 1982.

Ulrich, Martin. "Price Differentials Between Selected Channels of Marketing." *Canadian Journal of Agricultural Economics.* Vol. 11, 1963 and Vols. 12 and 13, 1964 and 1965.

Warrack, Allan. "A Conceptual Framework for Analysis of Marketing Efficiency." *Canadian Journal of Agricultural Economics.* Vol. 20, No. 3, Noveber 1972.

Whalley, Greg. Alberta Pork Producers' Marketing Board,

Edmonton. Information provided June 1980 and March 1981. (Mimeographed).

Whalley, Greg. Alberta Pork Producers' Marketing Board. Personal Conversation, Edmonton, March 1984.

Whalley, Greg. Alberta Pork Producers' Marketing Board, Edmonton. Personal Interview, 30 April, 1984.

Williams, W. amd Stout, T. *Economics of Livestock Meat Industry*. New York, N.Y.: Macmillan, 1964.

Zwarun, Suzanne. "A Pork Barrel Conspiracy." *Maclean's News Magazine*. January 30, 1984.