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UNIVERSITY OF ALBERTA

HOG GRADING, GENETIC PROGRESS, AND U.S.-CANADIAN TRADE IN PORK

BY

JO ANN CMOLUCH SANDHU

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

IN

AGRICULTURAL ECONOMICS

DEPARTMENT OF RURAL ECONOMY

EDMONTON, ALBERTA

SPRING 1992

ISBN 0-315-73197-4

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Jo Ann Cmoluch Sandhu

TITLE OF THESIS: Hog Grading, Genetic Progress, and U.S.-Canadian Trade in Pork

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: Spring 1992

11429 - 78th Avenue
Edmonton, Alberta
T6G 0N2

DATED: April 24, 1992

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read and recommend tc the Faculty of Graduate Studies and Research for acceptance, a thesis entitled HOG GRADING, GENETIC PROGRESS, AND U.S.-CANADIAN TRADE IN PORK submitted by JO ANN CMOLUCH SANDHU in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL ECONOMICS.

Dr. M. M. Veeman

Dr. J. S. Eales

Dr. B. Wilkinson

Date: April 7 1992

To mom, for keeping her faith
in an awkward little girl.

Abstract

Since 1979, export of hogs and pork from Canada to the United States have increased while imports from the United States have decreased. It is argued in this study that this change in trade patterns resulted from differences in grading systems and their use in the U.S. and Canada that allowed Canadian hog producers to breed hogs which yield superior carcasses at a reduced cost. Consumer preferences for pork in Canada and the United States are examined. Lean meat content in the carcass is identified as the primary factor affecting consumer perceptions of quality in pork. Grading systems are recognized as effective market institutions in articulating consumer preferences to producers. The grading systems in Canada and the U.S. are compared and their relative usefulness in guiding producer decisions in genetic selection for lean carcasses is assessed. The genetic and economic effect on hog production of marketing on a liveweight basis versus marketing on a graded basis are also examined. The relative efficiency of genetic selection for lean meat when marketing on a liveweight basis is calculated to be 12.83 per cent as opposed to marketing on a carcass merit basis where efficiency would essentially be 100 per cent.

A theoretical framework of assessing the effects of such improvements in technology on trade is delineated and is seen to be consistent with patterns of trade in hogs and pork between the U.S. and Canada in recent years. A model of trade that encompasses technological change, developed by Edwards and Freebairn (1984), is used to estimate the welfare benefits of trade in pork between Canada and the U.S. from 1970 to 1989. Basic assumptions that are invoked in this estimation are that genetic selection for lean in carcasses was the same in both countries from 1970 to 1979 but the differences in grading institutions arising from marketing on a liveweight basis and the lack of guidance from the grading system in the U.S. resulted in diminished selection for leanness in the U.S. from 1980 to 1989. The estimates from the model suggest that producers and consumers received almost equal relative

welfare benefits from genetic-related cost reductions in hog production from 1970 to 1979. From 1980 to 1989, relative consumer benefits decreased and relative producer benefits increased in Canada and declined in the United States. It is concluded that genetic advance in the production of hogs has been fostered by the marketing institution of the grading system that has transmitted consumer preferences for pork to producers, that this influence has contributed to the increased exportation of pork to the U.S. from Canada from 1979 to 1989 and that the apparent decline in genetic advance in the U.S has been detrimental to the competitive position of U.S. hog producers vis à vis Canadian hog producers.

Acknowledgements

I would like to thank Dr. Michelle Veeman for her patience, foresight, and guidance in pulling the pieces of this thesis together. I am sincerely grateful for her efforts. I would also like to thank Professors J. Eales and B. Wilkinson for their valuable comments.

Thanks to the staff of Rural Economy for making the department a pleasant place to study. In particular, sincere thanks goes to Barb Johnson for her assistance in researching this thesis and for allowing me to monopolize library materials longer than I should have. I would also like to give special recognition to Wendy Williamson for not letting me get lost in the system after so many years.

I would also like to express my special thanks to Dr. Linda Chase-Wilde for initially focusing my interest on this topic and for her warm friendship and encouragement.

To my colleagues at Alberta Agriculture, thanks for putting up with my not always amiable disposition and for the encouragement to finish this work. In particular, I would like to acknowledge both Chuck Sterling and David Walker for giving me the latitude in my job which was necessary to complete this thesis.

Finally, a big thank you to Gurmit for giving me the motivation, support and affection to get this thing done and for making the whole process a lot more interesting.

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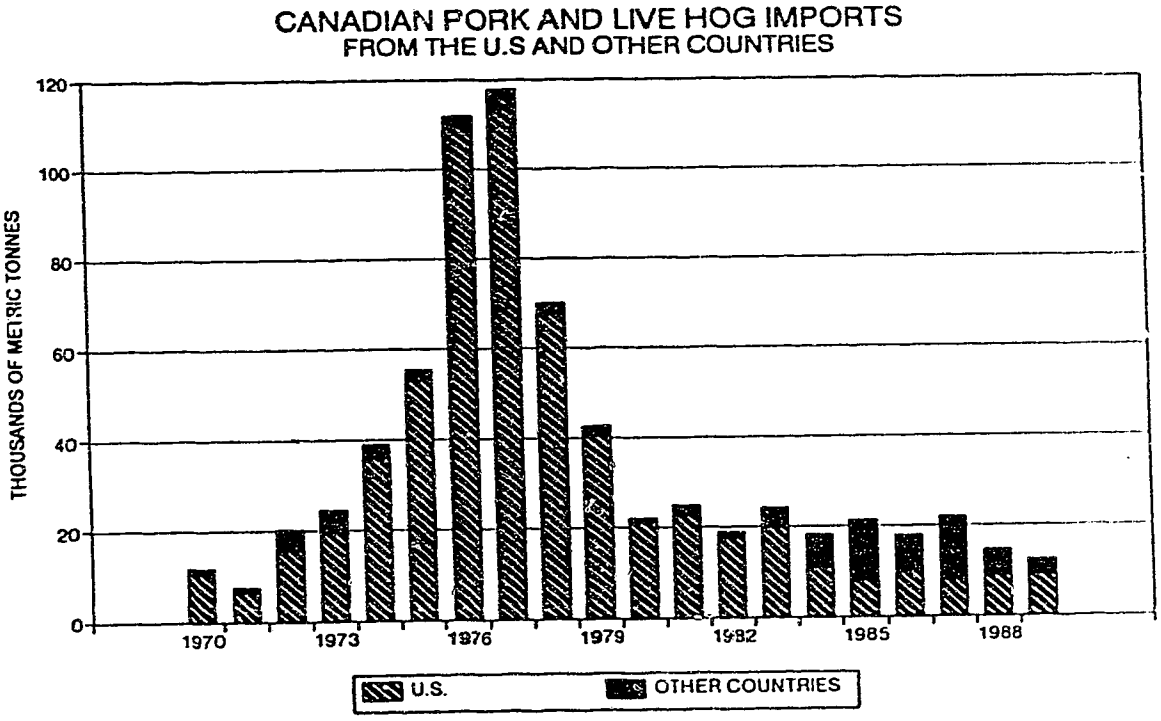
Chapter 1

During the nineteen eighties, the historical pattern of trade in hogs and pork products between Canada and the United States changed. Canada is now a relatively large net exporter of live hogs and pork products to the United States. Previously, Canada had been a net importer of pork products from the United States (Figures 1.1, 1.2 and 1.3, p. 2).

Various explanations have been offered for this change in trade patterns. One serious and contentious explanation has been argued by representatives of the United States hog industry. These accuse Canadian federal and provincial governments of unfairly subsidising the production and export of hogs to the detriment of the hog industry in the United States. Complaints by hog industry lobby groups in the United States led to hearings by the United States International Trade Commission (ITC) and the Commerce Department. These resulted in the implementation of countervailing tariffs on imports of Canadian hogs in May 1985. Deposit rates on U.S. imports of Canadian hogs in U.S. currency on a liveweight basis were applied at levels of $0.0439 per pound from April 1985 to January 1989, $0.0216 from January 1989 to April 1991, zero from April 1991 to June 1991, $0.0449 from June 1991 to October 1991 and are presently $0.0932 per pound. Final determinations of the levels of subsidization after administrative reviews by the U.S. Commerce Department set countervailing duties to be applied retroactively at $0.0216 per pound from April 1985 to April 1986, zero from April 1986 to April 1988, $0.0449 per pound from April 1988 to April 1989 and $0.0932 per pound from April 1989 to April 1990.

A countervailing duty of $0.036 per pound was applied by the United States to imports of Canadian pork products in July 1989. Rulings by both the bilateral trade panel established under the free trade agreement and the GATT panel formed to rule on the matter indicated that the procedures used by the ITC in determining injury to the US hog

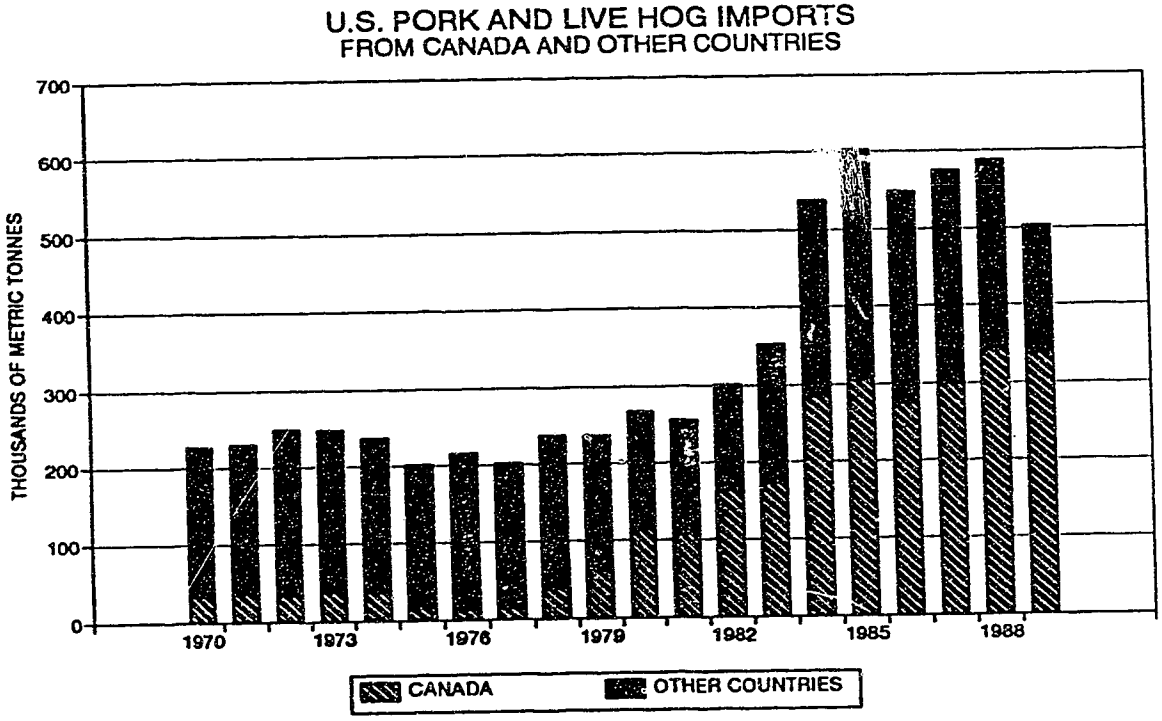
Figure 1.1



*LIVE HOG IMPORTS CONVERTED TO CARCASS EQUIVALENT WEIGHTS USING ANNUAL AVERAGE CARCASS WEIGHTS OF THE IMPORTING COUNTRY

Statistics Canada, *Livestock and Animal Products Statistics*, Catalogue No. 23-203.

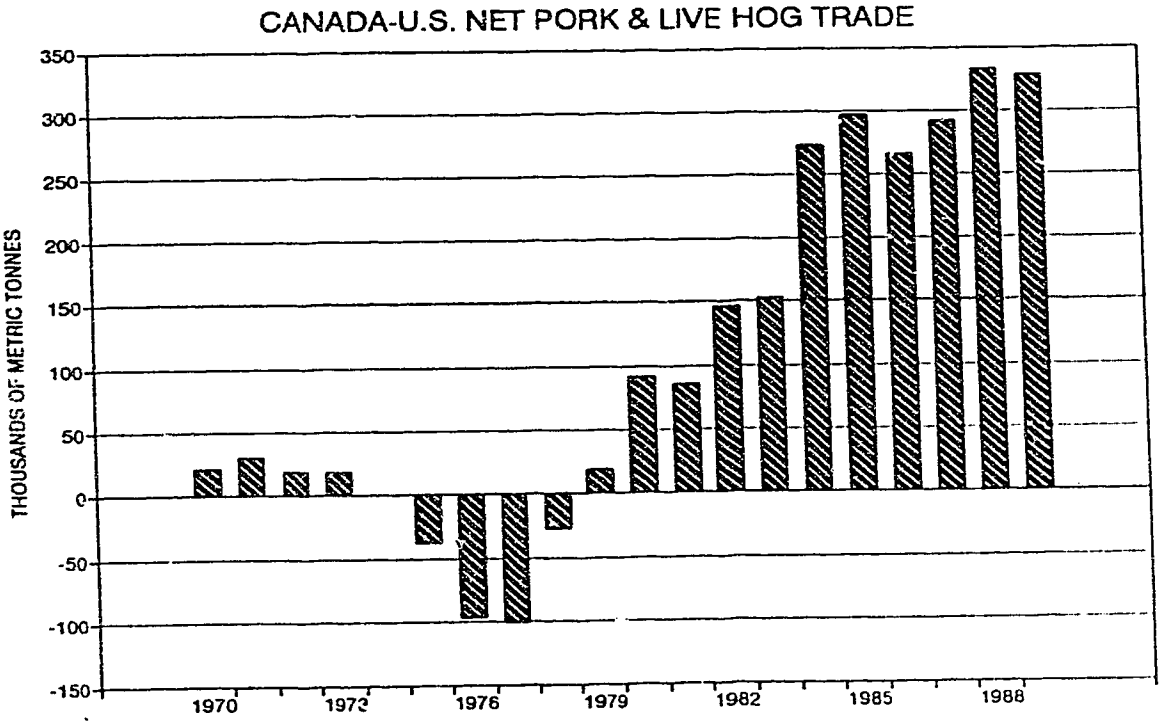
Figure 1.2



*LIVE HOG IMPORTS CONVERTED TO CARCASS EQUIVALENT WEIGHTS USING ANNUAL AVERAGE CARCASS WEIGHTS OF THE IMPORTING COUNTRY

USDA, *Agricultural Statistics*.

Figure 1.3



*LIVE HOG IMPORTS CONVERTED TO CARCASS EQUIVALENT WEIGHTS USING ANNUAL AVERAGE CARCASS WEIGHTS OF THE IMPORTING COUNTRY

Statistics Canada, *Livestock and Animal Products Statistics*, Catalogue No. 23-203.
USDA, *Agricultural Statistics*.

industry caused by imports of pork from Canada exaggerated the degree of subsidization and used erroneous data. A U.S. challenge to the bilateral trade panel ruling on Canadian pork imports did not succeed and the countervail tariff on pork was removed in 1991.

Some light on whether different levels of subsidy in Canada, relative to the U.S. may have been the source of increased levels of Canadian hog and pork exports to the U.S. is given by data from the Organization for Economic Co-operation and Development (OECD). The OECD (1989) estimated final Producer Subsidy Equivalents (PSE) for pigmeat production in Canada at 7, 4, and 6 per cent for 1984, 1985, and 1986, respectively. While in the United States, for the same years, OECD estimates of PSE for pigmeat production were 6, 7, and 8 per cent respectively. For two of the these three years, the United States is estimated to have subsidized pigmeat production relatively more than Canada. The PSE estimates for pork production in Canada for 1987 and 1988 were projected to be 10 and 14 per cent, while the U.S. PSE was projected to remain at 8 per cent. In view of the data on relative levels of subsidization, it does not appear that these were responsible for the increasing levels of U.S. imports of Canadian pork that date from the early 1980's.

During the period from 1970 to 1979, when Canada was a net importer of pigs and pork from the United States, Canadian tariffs on fresh pork imports were 60 cents per pound in 1970, 65 cents in 1971 and 50 cents from 1972 to 1979. United States tariffs (in U.S. currency) on fresh pork imports for 1970 were 8 cents per pound in 1970, 7 cents per pound in 1971 and 5 cents per pound from 1972 to 1979. In neither country has fresh pork imports been subject to tariffs since 1980. The estimates of relative subsidy levels cited above indicate that pork production was at times subsidized as much in the U.S. as in Canada. During periods when subsidization in Canada was estimated to be greater than in the U.S., countervailing duties were applied to Canadian

imports. If tariffs and government subsidization were the predominant factors affecting trade of pork between the United States and Canada, the United States should have been a large net exporter of pork and hogs to Canada from 1980 to 1989 rather than a growing net importer. It follows that other factors must have caused the changes in trade patterns observed during the 1980's.

Some of the submissions by Canadian lobby groups to the ITC hearings argued that the production of hogs in Canada has evolved differently and that Canadian hogs and pork products can be differentiated from those produced in the United States. These arguments were largely ignored or dismissed as unsubstantiated in the ITC hearings. This issue is in essence the topic of this thesis.

1.1 Problem Definition

The primary problem in supporting the argument that Canadian hogs are a somewhat different, i.e. differentiated, product from U.S. hogs is that it is difficult to measure the extent of differentiation in terms of quality differences between hogs produced in Canada and the United States. However, changes in costs of production due to changes in measurable carcass characteristics can be estimated and give an indication of the relative competitive positions of the two industries in question. Further, an important consideration is determining who benefits and by how much from any progressive increase in production efficiency and carcass quality.

1.2 Thesis Objective

The primary hypothesis of this study is that market structures including market institutions or infrastructure directly influence the efficiency of an industry in selecting and improving those livestock that yield products that are most suited to consumer preferences. This study will develop a model of the North American hog industry in the context of the interaction of market structures on genetic selection and the resulting relative efficiency of hog production and quality in

Canada and the United States. Genetic selection is a technology which develops only under continuous selection pressure from one generation to the next. The genetic make-up of a population provides the primary material with which producers can combine other inputs in order to minimize their costs to produce a product of the highest potential market value, and thereby maximize their net return. Incomplete or incorrect signals of the relative value of genetic traits impair producers' ability to select the genetic traits that would yield products with the characteristics valued by consumers.

This thesis examines the argument that the Canadian hog industry has bred a population of genetically superior hogs because of the development of a compulsory grading system which financially rewards those producers that raise hogs with characteristics most suited to the preferences of consumers.

An estimate of who benefits from genetic selection for leanness within existing market institutions in the United States and Canadian pork industries is of interest to both industry participants and policy makers. The complex market interactions of consumer preferences with marketing systems, and the response of hog producers in their production decisions with regard to genetic selection can result in a change in comparative advantage in hog production in different countries. The characteristics of consumers and producers in the North American pork market will therefore be defined. The interaction between market participants through marketing systems will then be discussed. The linkages between consumer preferences how these preferences can be articulated through existing market systems and how they are interpreted by producers to modify their production behaviour and genetic selection programs will also be discussed.

The welfare benefits and losses due to relative progress in genetic selection is a primary concern in this study. Measures of the accuracy with which producers interpret market signals with regard to

consumer preferences are applied to give measures of the relative welfare gains and losses for consumers and producers and of the industry as a whole.

1.3 Thesis Outline

In the second chapter of this thesis, the evolution of consumer preferences for meat and, more specifically pork, is discussed. The purpose of this chapter is to assess the genetic traits that are most valued by consumers in the pork that they eat. The issue of whether market structures accurately articulate consumer preferences to the producer is addressed following the argument that markets can fail to articulate consumer preferences to producers because adequate institutions do not exist to facilitate the flow of information.

The third chapter outlines the basic market systems that exist in hog industries in Canada and the United States. The progress of each industry in producing a population of hogs which yield carcasses that are preferred by consumers will be discussed. The genetic technology of the hog industries in the United States and Canada has developed under the influence of marketing structures that have different methods and systems of estimating value or quality. The Canadian marketing system has adopted a universally applied system of grading carcass quality and value estimation. Relatively few US hogs are sold on the basis of objectively measured carcass merit. Most are sold on a liveweight basis, which is subject to many factors which can affect prices (Van Arsdall and Nelson, 1984).

The fourth chapter delineates with the concept of genetic selection as a technology that is accumulated over time. It is argued that this is driven by the economic objective of minimizing costs of production, while maximizing the value of the product. In this chapter, a bio-economic hog production model is introduced. The results of this predict the behaviour of producers in both countries given the differences in market structures.

In the fifth chapter, elements of trade theory are used to construct a model to provide an understanding of changes in trade patterns resulting from accumulated technological differences. This theoretical trade model is be related to the performance of the pork industries in United States and Canada and to the resulting welfare gains or losses to producers and consumers in both countries.

The sixth chapter outlines the estimation of the welfare benefits from trade induced by the development of technology through genetic selection for Canadian and U.S. pork producers and consumers. The estimated reduction in the costs of producing pork by genetically selecting for leaner carcasses is the basis of these calculations.

The seventh chapter gives a summary of the results and a discussion of the implications of these results. The more complicated issue of the welfare gain by consumers from enhanced quality of pork products and the welfare gain by pork producers from strengthened consumer preferences for pork is also discussed.

Chapter 2

In this chapter, the primary focus is on consumers' purchasing patterns for pork and other meats and their associated demand behaviour. Since an understanding of the economic implications of changing consumer values is the basis of analysis in this study, reviews of recent studies of the demand structure for pork and then lard are first discussed. Changes in the general attitude of government and consumers towards health and nutrition along with the reasons for changes in consumer preferences for pork products are discussed. Finally, the problem of consumer articulation of preferences will be discussed in the context of the North American hog industry.

2.1 The Demand for Pork in Canada and the United States

From the evidence in this chapter, it is concluded that the structure of demand has changed over time because of changes in consumer preferences. These changes in attitude are reflected in altered consumer buying patterns. Transformations in the structure of demand for pork can be empirically analyzed by observing changes in consumption patterns with respect to changes in relative prices and real incomes over time.

2.1.1 Trends in North American Pork Consumption

The following section examines pork and beef and poultry consumption trends in the United States and Canada. The tables below present per capita consumption on a carcass basis rather than on a retail basis.

In the United States, since 1963, total per capita consumption of pork, beef and poultry has grown steadily (Table 2.1). In terms of individual meats, beef holds the largest market share of meat consumption, although its relative market share has weakened steadily since 1976 (Table 2.2). Poultry meat consumption expanded nearly 126 percent from 1960 to 1989, to almost rival the market share of beef. Per capita pork consumption remained fairly constant since 1963, however the relative market share of pork declined.

Meat consumption patterns in Canada have been somewhat different from those in the United States. Since 1963, total per capita consumption of pork, beef and poultry on a carcass basis steadily increased from 71 kilograms in 1963 to reach of nearly 96 kilograms in 1976 (Table 2.3). However, Canadian per capita consumption of pork, beef and poultry continued to lag U.S. consumption levels by about 15 to 20 kilograms per annum. Canadian poultry consumption was on average about ten kilograms less than in the United States, beef consumption was on average about eight kilograms less, while pork consumption was on average only one to two kilograms less for most of the past three decades. Poultry consumption grew from less than 15 kilograms per capita in the 1960's to about 28 kilograms by the late 1980's. Per capita consumption of beef increased to a peak level over 51 kilograms per capita in 1976 and has since declined to about 38 kilograms in the late 1980's.

Until 1975, the relative share of per capita poultry consumption was greater in Canada than in the United States (Tables 2.2 and 2.4). Since then, the relative market share of poultry has been slightly less in Canada than in the United States. In Canada, the relative market share of beef peaked in 1976 at nearly 54 percent and declined to a current level of less than 40 percent. Canadians have consistently consumed relatively more beef than consumers in the United States since the early 1970's. The relative market shares of pork remained stable in Canada since the early sixties, but have declined in the United States.

To summarize, consumers in the United States appear to have substituted poultry for beef and, to a limited degree, pork in their diets. In Canada, consumers appear to have primarily substituted poultry for beef with pork consumption remaining relatively stable in their diets.

and Poultry Carcasses(KG. PER ANNUM)

YEAR	PORK	BEEF	POULTRY	TOTAL
1960	35.54	38.88	15.49	89.91
1961	34.00	40.14	16.99	91.13
1962	34.31	40.59	16.82	91.72
1963	34.91	43.06	17.16	95.13
1964	34.90	45.85	17.60	98.35
1965	30.91	45.81	18.67	95.39
1966	30.20	47.98	19.83	98.01
1967	33.01	49.05	20.56	102.62
1968	33.71	50.37	20.38	104.46
1969	32.64	50.69	21.26	104.59
1970	33.18	51.88	22.08	107.14
1971	35.90	51.46	22.22	109.58
1972	32.35	52.54	23.15	108.04
1973	28.93	49.45	22.34	100.72
1974	31.17	52.47	22.59	106.23
1975	25.34	54.05	22.19	101.58
1976	26.79	57.92	23.66	108.37
1977	27.64	56.16	24.28	108.08
1978	27.60	53.57	25.49	106.66
1979	31.49	47.89	27.62	107.00
1980	33.55	46.92	27.67	108.14
1981	31.97	47.33	28.46	107.76
1982	28.65	47.16	29.08	104.89
1983	30.09	48.03	29.62	107.74
1984	29.89	47.94	30.48	108.31
1985	30.07	48.39	31.88	110.34
1986	28.42	48.78	32.97	110.17
1987	28.56	46.97	35.61	111.14
1988	30.50	46.50	36.80	113.80
1989	30.21	44.32	38.96	113.49

USDA, *Livestock and Poultry Situation and Outlook*, LPS-39, January 1990.

YEAR	PORK	BEEF	POULTRY
1960	39.53	43.24	17.23
1961	37.31	44.05	18.64
1962	37.41	44.25	18.34
1963	36.70	45.26	18.04
1964	35.49	46.62	17.90
1965	32.40	48.02	19.57
1966	30.81	48.95	20.23
1967	32.17	47.80	20.04
1968	32.27	48.22	19.51
1969	31.21	48.47	20.33
1970	30.97	48.42	20.61
1971	32.76	46.96	20.28
1972	29.94	48.63	21.43
1973	28.72	49.10	22.18
1974	29.34	49.39	21.27
1975	24.95	53.21	21.84
1976	24.72	53.45	21.83
1977	25.57	51.96	22.46
1978	25.88	50.23	23.90
1979	29.43	44.76	25.81
1980	31.02	43.39	25.59
1981	29.67	43.92	26.41
1982	27.31	44.96	27.72
1983	27.93	44.58	27.49
1984	27.60	44.26	28.14
1985	27.25	43.86	28.89
1986	25.80	44.28	29.93
1987	25.70	42.26	32.04
1988	26.80	40.86	32.34
1989	26.62	39.05	34.33

USDA, *Livestock and Poultry Situation and Outlook*, LPS-39, January 1990.

1960	25.08	31.39	12.61	69.08
1961	24.27	31.21	14.24	69.72
1962	22.59	31.43	14.06	68.08
1963	23.00	33.48	14.79	71.27
1964	23.59	35.61	15.65	74.85
1965	22.32	35.70	16.33	74.35
1966	21.59	37.42	17.83	76.84
1967	24.36	37.01	18.55	79.92
1968	24.31	39.33	18.01	81.65
1969	23.54	39.19	19.41	82.14
1970	25.95	38.96	20.41	85.32
1971	29.98	39.55	19.96	89.49
1972	27.66	41.97	20.61	90.24
1973	26.13	41.62	21.24	88.99
1974	27.15	42.96	20.60	90.71
1975	21.97	46.38	19.05	87.40
1976	24.12	51.35	20.27	95.74
1977	24.19	49.01	20.62	93.82
1978	26.19	45.75	21.38	93.32
1979	29.05	39.90	22.89	91.84
1980	31.30	39.53	22.70	93.53
1981	30.10	40.59	22.48	93.27
1982	27.84	40.45	22.62	90.91
1983	28.64	40.09	22.91	91.64
1984	27.89	38.30	23.70	89.89
1985	28.50	38.73	25.06	92.35
1986	27.94	39.51	26.21	93.66
1987	27.93	38.15	27.64	93.72
1988	29.28	38.29	28.35	95.92
1989	29.34	37.55	27.69	94.58

Statistics Canada, *Apparent per Capita Consumption in Canada*, Cat. No. 32-230

TABLE 2.4 Canadian Relative Apparent per Capita Consumption of Pork, Beef and Poultry Carcasses (PERCENT OF TOTAL)

YEAR	PORK	BEEF	POULTRY
1960	36.31	45.44	18.25
1961	34.81	44.76	20.42
1962	33.18	46.17	20.65
1963	32.27	46.98	20.75
1964	31.52	47.58	20.91
1965	30.02	48.02	21.96
1966	28.10	48.70	23.20
1967	30.48	46.31	23.21
1968	29.77	48.17	22.06
1969	28.66	47.71	23.63
1970	30.41	45.66	23.92
1971	33.50	44.19	22.30
1972	30.65	46.51	22.84
1973	29.36	46.77	23.87
1974	29.93	47.36	22.71
1975	25.14	53.07	21.80
1976	25.19	53.63	21.17
1977	25.78	52.24	21.98
1978	28.06	49.02	22.91
1979	31.63	43.45	24.92
1980	33.47	42.26	24.27
1981	32.27	43.63	24.10
1982	30.62	44.49	24.88
1983	31.25	43.75	25.00
1984	31.03	42.61	26.37
1985	30.86	42.00	27.14
1986	29.83	42.18	27.98
1987	29.80	40.71	29.49
1988	30.53	39.92	29.56
1989	31.02	39.70	29.28

Statistics Canada, *Apparent per Capita Consumption in Canada*, Cat. No. 32-230

2.1.2 Price Effects on Pork Consumption

From 1960 to 1989, nominal retail prices for poultry in the United States more than doubled from $0.81 to $2.05 U.S. per kilogram (Table 2.5). In the same period, both beef and pork prices increased by about 330 percent. Beef prices increased from $1.77 to $5.94 U.S. per kilogram and pork prices increased from $1.23 to $4.03 U.S. per kilogram. In the United States, poultry meat has been the cheapest meat obtainable by consumers, while beef has been the most expensive meat.

U.S. consumer price indices show that real prices for beef, pork and poultry declined steadily from 1960 to 1989 (Table 2.6). Average annual real prices of beef appear to be less volatile than those for chicken and pork. Prices for beef peaked in 1973 and have declined since then. Real prices of poultry in the U.S. declined dramatically from 1960 to 1989. This downward trend was briefly interrupted by a resurgence of prices in 1973, but resumed in subsequent years. Average annual real prices of pork in the U.S. were the most volatile from 1960 to 1989, with prices tending to decrease from their peak in 1975.

Statistics Canada no longer publishes estimated nominal average retail prices for pork, beef and poultry on a carcass basis. However, approximate values of pork, beef and poultry carcasses at the retail level in Table 2.7 are derived by summing average retail prices for meat cuts from Agriculture Canada's 1986 estimates of family food expenditures survey weighted by their estimated average percentage in a carcass. Statistics Canada's retail price indices for pork, beef and poultry are then applied to the 1986 nominal retail price estimates to obtain estimates of nominal retail prices on a carcass basis. In the case of poultry, nominal retail prices for chicken and turkey are weighted by their relative per capita consumption estimates.

Estimated average nominal retail prices for pork, beef and poultry in Canada also increased steadily from 1960 to 1989 (Table 2.7). Poultry prices increased from $0.86 to $3.70 per kilogram, a 430 per cent

increase, while beef prices increased from $1.11 to $5.91 per kilogram, a 530 per cent increase; pork prices increased from $1.30 to $6.15, a 470 per cent increase.

As in the United States, poultry has been the cheapest meat available to Canadian consumers. From 1980 to 1989, poultry prices in Canada were about 60 percent of the price levels of both beef and pork. In contrast, poultry meats in the U.S. were one third the cost of beef and about forty per cent the cost of pork.

One difference between meat prices in Canadian and United States is that pork in Canada tends to be relatively more costly than beef, the reverse of the situation in the United States. However, this relationship is changing since from 1960 to 1969, Canadian pork prices were on average 25 per cent higher than beef, while from 1980 to 1989, pork prices were on average 1.5 per cent higher. In the United States, pork prices were on average 25 per cent lower than beef prices from 1960 to 1969 and 30 percent lower on average from 1980 to 1989.

In Canada, real prices of poultry declined from 1960 to 1989, but not nearly as much as in the United States. Real prices for beef in Canada increased from 1960 to 1979 and subsequently declined. The real price of pork in Canada increased from 1960 to peak in 1973 and generally decreased from 1973 to 1989.

The relative changes in the real prices of beef and pork to poultry in Canada have been far less than in the United States. Young (1987) hypothesized that Canadian meat prices have been supported by the restrictions of supply of poultry meat to the market.

TABLE 2.5 United States Nominal Retail Prices for Pork, Beef and Poultry ($U.S. PER KG.) and Consumer Price Index (BASE YEAR 1985=100)

YEAR	PORK	BEEF	POULTRY	C.P.I.
1960	1.23	1.77	0.81	27.53
1961	1.29	1.73	0.73	27.81
1962	1.30	1.80	0.77	28.13
1963	1.25	1.73	0.76	28.45
1964	1.23	1.68	0.74	28.84
1965	1.44	1.80	0.77	29.32
1966	1.62	1.86	0.81	30.16
1967	1.47	1.86	0.76	31.03
1968	1.47	1.95	0.78	32.35
1969	1.62	2.17	0.83	34.09
1970	1.71	2.24	0.82	36.09
1971	1.54	2.38	0.83	37.67
1972	1.82	2.61	0.84	38.89
1973	2.41	3.13	1.17	41.31
1974	2.38	3.22	1.11	45.85
1975	2.97	3.41	1.23	50.04
1976	2.95	3.26	1.18	52.90
1977	2.74	3.27	1.19	56.31
1978	3.16	4.00	1.31	60.63
1979	3.18	4.98	1.38	67.46
1980	3.07	5.23	1.45	76.58
1981	3.36	5.25	1.51	84.50
1982	3.87	5.34	1.48	89.72
1983	3.74	5.24	1.50	92.59
1984	3.57	5.27	1.66	96.55
1985	3.57	5.12	1.64	100.00
1986	3.93	5.08	1.76	101.90
1987	4.15	5.34	1.74	105.57
1988	4.04	5.61	1.86	109.92
1989	4.03	5.94	2.05	115.18

USDA, *Agricultural Statistics Handbook*
USDA, *Livestock and Poultry Situation and Outlook*

TABLE 2.6 United States Real Price Indices for Pork, Beef and Poultry (BASE YEAR 1985=100)

YEAR	PORK	BEEF	POULTRY
1960	125.32	125.25	179.44
1961	129.63	121.22	160.34
1962	129.04	124.85	167.54
1963	122.81	118.63	163.09
1964	119.63	114.04	157.35
1965	137.28	120.23	159.52
1966	150.20	120.32	163.49
1967	132.48	117.21	148.92
1968	127.45	117.87	147.26
1969	133.29	124.35	147.76
1970	132.39	121.14	138.79
1971	114.39	123.36	133.71
1972	131.27	131.22	131.19
1973	163.16	147.88	173.15
1974	145.15	137.19	148.05
1975	166.05	132.99	149.98
1976	156.35	120.43	136.01
1977	136.37	113.30	128.59
1978	146.20	128.98	131.78
1979	131.84	144.22	124.33
1980	112.37	133.39	115.13
1981	111.34	121.44	108.60
1982	120.68	116.21	100.49
1983	113.20	110.55	98.57
1984	103.57	106.69	104.58
1985	100.00	100.00	100.00
1986	108.07	97.33	105.57
1987	110.16	98.76	100.37
1988	102.98	99.62	103.38
1989	98.02	100.75	108.40

USDA, *Agricultural Statistics Handbook*
USDA, *Livestock and Meat Statistics*

TABLE 2.7 Canadian Nominal Retail Prices for Pork, Beef and Poultry ($CAN. PER K.G.) and Consumer Price Index (BASE YEAR 1985=100)

YEAR	PORK	BEEF	POULTRY	C.P.I.
1960	1.30	1.11	0.86	24.72
1961	1.42	1.10	0.81	24.87
1962	1.45	1.21	0.82	25.20
1963	1.45	1.17	0.84	25.66
1964	1.42	1.13	0.80	26.14
1965	1.60	1.18	0.82	26.77
1966	1.84	1.30	0.88	27.71
1967	1.67	1.37	0.85	28.75
1968	1.65	1.39	0.85	29.89
1969	1.84	1.50	0.87	31.25
1970	1.81	1.55	0.85	32.29
1971	1.55	1.59	0.86	33.22
1972	1.87	1.74	0.98	34.79
1973	2.38	2.10	1.29	37.50
1974	2.41	2.31	1.47	41.56
1975	3.10	2.19	1.59	46.04
1976	3.22	2.05	1.64	49.48
1977	3.16	2.18	1.65	53.44
1978	3.64	3.19	1.89	58.22
1979	3.71	4.19	2.14	63.54
1980	3.68	4.55	2.24	70.00
1981	4.23	4.67	2.60	78.65
1982	4.92	4.64	2.72	87.19
1983	4.93	4.68	2.80	92.19
1984	4.91	4.98	2.98	96.25
1985	5.03	5.11	2.94	100.00
1986	5.84	5.23	3.18	104.17
1987	6.36	5.70	3.35	108.75
1988	6.05	5.79	3.38	113.13
1989	6.15	5.91	3.70	118.75

Statistics Canada, *Consumer Prices and Price Indexes*, Cat. 62-010
Statistics Canada, *Family Food Expenditure Survey*, 1986

TABLE 2.8 Canadian Real Price Indices for Pork, Beef and Poultry (BASE YEAR 1985=100)

YEAR	PORK	BEEF	POULTRY
1960	104.37	87.62	118.12
1961	113.19	86.73	110.78
1962	115.04	93.93	110.36
1963	112.98	89.40	110.72
1964	108.65	84.97	104.71
1965	118.34	86.40	104.41
1966	132.23	91.70	107.87
1967	115.17	93.15	100.77
1968	109.94	91.13	96.86
1969	117.50	94.18	94.94
1970	111.40	93.99	89.22
1971	92.75	93.56	87.69
1972	106.96	97.73	95.80
1973	126.16	109.44	117.23
1974	115.62	108.88	120.00
1975	133.69	93.11	117.62
1976	129.61	81.10	112.79
1977	117.48	79.88	104.87
1978	124.49	107.23	110.58
1979	115.86	129.18	114.75
1980	104.33	127.31	108.83
1981	106.84	116.22	112.52
1982	112.18	104.21	106.00
1983	106.28	99.25	103.48
1984	101.28	101.33	105.37
1985	100.00	100.00	100.00
1986	111.48	98.10	103.64
1987	116.29	102.52	104.74
1988	106.36	100.09	101.64
1989	102.98	97.42	106.10

Statistics Canada, *Consumer Prices and Price Indexes*, Cat. 62-010

2.1.3 Structure of Demand for Pork

Recent estimates of own price elasticity of demand for pork in the U.S. are similar to those reported by Canadian studies. Curtin et al. (1987) estimated the own price elasticity for pork in Canada to be -0.745 which was higher than the own price elasticity that was estimated for beef. Hahn (1988) reports a significant value of -0.784 and a study by Huang (1985) referred to by Curtin et al. (1987) estimated a value of -0.73. Hayenga et al. compiled a summary of the estimates of the relevant demand parameters for pork conducted in the United States from 1953 to 1981. A trend of declining estimates of retail price elasticity of demand for pork over time becomes apparent with high estimates ranging around -0.90 before 1965 and ranging around -0.85 from 1965 to 1981.

Cross price elasticities estimated for pork vary significantly between studies. Beef has traditionally been the primary substitute for pork in the U.S., however chicken has been shown in recent studies as a significant competitor for pork. The estimated cross price elasticities of pork with respect to prices of beef were reported as ranging from .17 to .55 (Hayenga et al., 1985, Appendix Table 1). Hahn (1988) estimated a significant cross price elasticity of pork with respect to beef prices of 0.437. Those estimated by Young (1987), ranged from 0.1950 to 0.2617. There is an estimate by Curtin et al.(1987) of 0.40 for Canada.

Most estimates of the cross price elasticity of demand for pork with respect to prices of chicken for Canada are small and not significant. Curtin et al. (1987) reported a calculated value of 0.15 using the formula for want-independent commodities developed by Frisch (1959). Recent U.S. studies have shown a significant substitution effect of chicken for pork although this was not found to be significant in the estimations by Hahn (1988).

Young (1985) argued that the economic factors important in determining the structure of demand for meat are disposable incomes,

rates of saving, prices and relative changes of prices of commodities and services. From 1951 to 1985, real per capita disposable income increased by two and one half times, while the proportion of income expended for food consumed at home declined from 20.6 per cent to 10.4 per cent of disposable income. The proportion of income spent on durable goods remained relatively constant, while expenditures on services and other commodities and savings have all increased.

Young (1985) noted that income distribution had changed in part due to the increase in the number single parent homes, which tend to have lower per capita incomes and less opportunity to eat out. This group's income levels and eating patterns may be counterbalanced by the increase in the number of childless singles and couples, who tend to eat out more frequently. "The change in relative proportions of groups with different consumption habits in the total population has an impact on demand" (Young, p. 14).

Curtin et al. (1987) estimated a demand system for food commodities in Canada using data from 1973 to 1985. A double log functional form was used to estimate income, own price and cross price elasticities of demand for beef, pork, chicken, lamb, turkey and fish prices. The cross price elasticity of beef prices on pork consumption was estimated at 0.25, while a negative but insignificant cross price elasticity was estimated for chicken prices on pork consumption.

The income elasticities of demand for pork estimated with time series data by Curtin et al. (1987) were between .24 and .30. Theoret (1986) analyzed data based on the 1982 Family Food Expenditure survey and estimated an income elasticity for pork of 0.072 . The estimated coefficient of the time variable was not significant indicating a somewhat stable consumer preferences for pork in Canada. The analysis by Chen and Veeman (1991) of meat consumption in Canada based on a dynamic almost ideal demand system indicated a shift in the intercept in terms of expenditure share equations for beef and chicken during the mid

1970's. These suggested a shift in preferences away from beef and toward chicken; a minor nonsignificant shift was seen for pork.

Martin and Goddard (1987) examined trends in meat consumption in the United States from 1960 to 1985 with reference to real income, prices and consumption levels of pork, beef and chicken. They observed that real expenditures on pork increased from the mid-sixties to the mid-seventies as real incomes increased. After the recession of the late seventies, when pork consumption declined with decreasing real incomes, the trend of expanding consumption with increasing real income did not re-establish itself in the eighties. From this evidence, Martin and Goddard inferred that there has been a real decline in the demand for pork in the United States during the eighties. "Consumers are willing to pay less in real terms for a given quantity of pork than they were previously" (Martin and Goddard, p. 51). They surmised that this was largely due to the substitution in the diet of cheaper protein sources such as chicken and, to a lesser degree, non-meat protein sources for both beef and pork.

The effects of changing income distributions were attributed by Hahn (1988) as partially explaining the decline in the demand for red meats in the United States. In estimating demand parameters for meats by using a statistical device, a Moment Generating Function, to correct for changes in income distribution, Hahn concluded that income distribution had a significant affect on the demand for meats, although none of the individual income distribution parameters were found to be significant. Hahn observed that, since the early nineteen sixties, both per capita income and the unemployment rate increased at the same relative rate. In studying demand patterns between 1960 and 1984, Hahn (1988) found that, in the late nineteen seventies, when mean real per capita income diverged from the median real per capita income, meat demand was negatively affected by the tendency for income distribution to become increasingly skewed toward the higher income segment of the population.

Hayenga et al. (1985, p.109) indicated that pork consumers had been often characterized as being "blue collar" because of the low and sometimes negative estimates of income elasticities reported by many studies in the early 1960's. However, studies based on data from the 1960's and 1970's reported significant positive income elasticities of demand for pork ranging between 0.30 to 0.85 (Hayenga et al., p. 110). Estimates were generally lower than those for beef. Hahn (1988) computed the income elasticities for pork and concluded that none were significantly different from zero based on U.S. data for the period 1960 to 1984. This estimate is close to that of 0.072 by Curtin et al. (1987) for pork in Canada. Young's (1987) estimates of the income elasticity for pork lie between 0.21 and 0.39 and are similar to estimates from older Canadian studies (Johnson and Hassan, 1976 and 1979).

In comparing the estimates of price and income elasticities for pork in Canada obtained by Young (1987) and Curtin (1987), with those estimated by Hassan and Johnson (1976) and (1979), it appears that the nature of demand for pork has changed over time. First, the decline in the estimates of own price elasticity indicate that consumers have become less responsive to changes in pork prices. The lower estimates of income elasticity reported by Young (1987) and Curtin et al. (1987) as compared to the study by Hassan and Johnson (1979), also indicate a decline in the income sensitivity to changes in income on the demand for pork. The earlier estimates of the cross-price elasticities for pork with respect to beef prices are higher than the more recent estimates. Low cross price elasticity estimates for pork with respect to prices of other meats suggest that other meats have continued to have an insignificant effect on pork consumption in Canada.

Moschini and Meilke (1989) tested for structural change in meat demand in the United States from 1968 to 1987. Own price, cross price and expenditure elasticities were derived for beef, pork and chicken at the beginning and end of the period studied from a time-varying version

of the almost ideal demand system (AIDS) model. The null hypothesis of no structural change was rejected with the change estimated to have occurred between 1975 and 1976. Two sets of coefficients were computed; one set were computed based on the means of the budget shares over the entire sample. The other set were calculated at the means of the budget shares before and after structural change. The results are given in Table 2.9.

Estimates by Moschini and Meilke (1989) of own price elasticity of demand for pork decreased from -1.015 to -0.839 after structural change. The cross price elasticity of pork for beef prices was estimated to be

TABLE 2.9 Estimates of U.S. Meat Demand Elasticities 1968 to 1987

	PRICE OF			
ELASTICITY OF	BEEF	PORK	CHICKEN	EXPENDITURE
BEFORE STRUCTURAL CHANGE:				
BEEF	-0.983	-0.004	-0.124	1.220
	(0.068)	(0.038)	(0.016)	(0.083)
PORK	0.087	-1.015	-0.047	1.041
	(0.119)	(0.075)	(0.029)	(0.148)
CHICKEN	-0.161	-0.086	0.090	0.238
	(0.147)	(0.092)	(0.061)	(0.200)
AFTER STRUCTURAL CHANGE:				
BEEF	-1.050	-0.078	-0.129	1.1394
	(0.064)	(0.041)	(0.018)	(0.093)
PORK	0.134	-0.839	-0.093	0.853
	(0.101)	(0.072)	(0.032)	(0.153)
CHICKEN	-0.017	-0.068	-0.104	0.211
	(0.114)	(0.084)	(0.072)	(0.172)

Moschini and Meilke (1989)

positive before and after structural change with pork consumption becoming more elastic with respect to beef prices after structural change. The expenditure elasticity of pork before the structural change was estimated to be 1.041, after the structural change, this became more inelastic at 0.853.

Reynolds and Goddard (1991) followed the same estimation procedure as Moschini and Meilke (1989) for the same period using Canadian data. Structural change in meat demand was found have occurred over a longer period of time, from 1975 to 1984. The results are summarized in Table 2.10.

TABLE 2.10 Estimates of Canadian Meat Demand Elasticities 1968 to 1987

	PRICE OF			
ELASTICITY OF	BEEF	PORK	CHICKEN	EXPENDITURE
BEFORE STRUCTURAL CHANGE:				
BEEF	-1.0482	-0.1020	-0.1150	1.2652
	(0.0599)	(0.0497)	(0.0226)	(0.0740)
PORK	0.1176	-0.8088	-0.0673	0.7585
	(0.0881)	(0.0793)	(0.0347)	(0.1119)
CHICKEN	-0.1406	-0.0948	0.1139	0.3493
	(0.1406)	(0.1254)	(0.1432)	(0.1673)
AFTER STRUCTURAL CHANGE:				
BEEF	-0.7359	-0.2646	-0.1356	1.1361
	(0.0981)	(0.0877)	(0.0420)	(0.0995)
PORK	-0.3860	-0.6756	-0.0774	1.1391
	(0.1288)	(0.1243)	(0.0529)	(0.1356)
CHICKEN	0.0055	0.1459	-0.3342	0.1829
	(0.1366)	(0.1211)	(0.1272)	(0.1442)

Reynolds and Goddard (1991)

Several significant features were noted by Reynolds and Goddard (1991) from their estimates of elasticity before and after structural change. The estimated own price elasticity of demand for beef became less elastic; the cross price elasticities for beef and pork indicate that these meats have become significant complements; and the own price elasticity for chicken became significant after structural change. The estimate of the expenditure elasticity for beef was lower but continued to suggest that this is a luxury good. The expenditure elasticity for pork was found to have changed after structural change with estimates from 0.7585 to 1.1391. Tests of bias in structural change indicated that chicken was becoming increasingly favoured over beef from 1975 to 1984.

2.2 The Demand for Pigfat and Lard

The consumer demand for pigfat in a hog carcass represents the combined demand from two distinct markets. The first market can be defined as the demand for fat content in a cut of pork while the other is the demand for a raw material to be processed into lard.

Because of its subjective nature, the demand for quality characteristics in pork, particularly fat content, is difficult to directly and empirically analyze. The relative change in consumption and demand for processed pigfat or lard as a food in Canada and the United States can provide a partial indication of demand for pigfat. Changing patterns of consumption of lean pork cuts, such as ham, relative to pork products with high fat content, such as side bacon is also an indirect indication of changing consumer quality preferences for pork with regard to fat content.

2.2.1 Lard Consumption

Per capita consumption of fats and oils in the United States increased over the period between 1960 and 1987, with marginal declines in 1988 and 1989 (Table 2.11). In Canada, per capita consumption of fats and oils increased marginally until 1974; consumption then levelled and

showed some tendency to decline in 1988 and 1989. Per capita consumption of fats and oils in the United States has been consistently higher by some 33 to 50 per cent than in Canada since 1968.

Both in Canada and the United States, consumption patterns within the fats and oils group have changed considerably. Saturated fats of animal origin, such as butter and lard, are increasingly being substituted for unsaturated fats of plant origin. Lard consumption in the United States declined from 3.5 kilograms per capita in 1960 to about 0.8 kilograms per capita in the late 1980's.

From the limited data available, Canadian consumption of lard appears to have declined slowly from the period 1960 to 1979, paralleling patterns in the United States. Canadian lard consumption tended to be one half to one kilogram per capita higher than in the United States during this period. Canadian imports of lard decreased from a peak in 1979 of 19.2 thousand tonnes to 6.6 thousand tonnes in 1988. Lard exports have increased since 1983 from 413 tonnes to two thousand tonnes in 1989.

It is probable that the per capita consumption of lard in Canada is at least as low as the per capita consumption in the United States for a number of reasons. Other food consumption patterns in Canada and the United States do closely parallel each other. Total per capita consumption of fats and oils is lower in Canada than in the United States. Canadian pork producers have significantly reduced the fat content of carcasses. Lard imports have declined while exports have increased.

Total production of lard in the United States declined rapidly from 1,122 thousand tonnes in 1963 to 459 thousand tonnes in 1975, to 384 thousand tonnes in 1989 (USDAa). Lard production in the United States during the 1960's was approximately 25 per cent of pork production by weight and varied between 10 to 20 per cent of pork production in the 1980's. United States exports have declined from an

TABLE 2.11 Fats and Oils per Capita Consumption (KILOGRAMS)

	CANADA		UNITED STATES	
	LARD	OTHER EDIBLE FATS AND OILS	LARD	OTHER EDIBLE FATS AND OILS
1960	3.27	17.10	3.45	17.05
1961	3.81	16.19	3.49	16.97
1962	3.63	16.83	3.22	17.51
1963	3.40	17.24	2.90	18.10
1964	3.40	17.19	2.86	18.73
1965	3.36	16.64	2.90	18.78
1966	3.13	18.37	2.49	20.05
1967	3.54	18.23	2.45	19.96
1968	3.54	18.64	2.54	20.68
1969	n/a	18.92	2.31	21.23
1970	n/a	18.64	2.13	21.91
1971	n/a	18.64	1.95	21.73
1972	n/a	19.64	1.72	22.91
1973	n/a	21.39	1.54	23.09
1974	n/a	22.08	1.45	22.68
1975	n/a	19.91	1.36	22.36
1976	n/a	20.42	1.22	23.68
1977	n/a	20.35	1.04	23.05
1978	2.89	20.12	1.00	23.81
1979	3.02	19.69	1.13	24.50
1980	n/a	19.69	1.18	24.81
1981	n/a	20.79	1.13	24.95
1982	n/a	20.62	1.13	25.27
1983	n/a	21.52	0.95	26.40
1984	n/a	20.82	0.95	25.68
1985	n/a	21.49	0.82	28.26
1986	n/a	21.52	0.77	28.35
1987	n/a	20.45	0.82	27.39
1988	n/a	18.29	0.77	27.40
1989	n/a	17.28	0.82	26.71

Statistics Canada, *Apparent per Capita Food Consumption*, Cat.No. 32-230.
USDA, *Agricultural Statistics*.

average of over 500 million lbs. in the early 1960's to less than 100 million lbs. in the 1980's (USDAa).

2.2.2 Lard Prices

The price of lard has declined appreciably but is highly variable. According to USDA statistics, in 1975 the un-indexed average wholesale price of loose tanks of lard in Chicago was at a high of 30.9 cents/lb., whereas in 1986, it declined to 13.7 cents/lb (USDAb). Hayenga et al. (1985) pointed out that wholesale prices of unprocessed pork fat versus lean pork had declined to a ratio of 1:5, reflecting the decreasing value of pork fat. Since pork and lard are produced jointly, an important consideration in lard supply is the potential change over time of the relative impact of increasing supplies of lard stimulated by high pork prices and increased pork production and vice versa. In other words, the short-run supply of lard to the market depends on increases or decreases in the demand for pork. Since lard production can be decreased relative to pork production through genetic selection, the long-run supply of lard is not entirely dependent on changes of the supply and demand for pork.

2.2.3 The Presence of Fat in Retail Cuts

Primal cuts from hog carcasses tend to have similar proportional sizes. In general, the size of the hams in a carcass is proportional to the size of the loins, bellies and butts. Side bacon is produced from the belly of the animal. Side bacon and ham are processed using similar techniques. The carcass is cut into primal parts, such as loins, butts and hams. These parts can be then deboned, shaved of excess fat, pumped or mixed with a pickling solution, smoked, perhaps sliced, and finally packaged and shipped. The primary difference between a ham, which may or may not be deboned, and side bacon is fat content. Side bacon has a high fat content, generally being 80 to 85 per cent fat, while ham is relatively low in fat, which usually contains less than 15 per cent fat.

Since the relative supply of side bacon to ham is fixed, shifts in

the demand for either commodity will be reflected in a change in the relative value of the two commodities. If the demand for side bacon has shifted downward because of its high fat content, while the demand for ham has remained the same or increased, then one would expect the price of bacon to decline relative to ham. During the early 1960's in the United States, the average wholesale price of hams relative to side bacon was about 15 per cent higher, while in the late 1980's hams are almost double the price of side bacon (USDAb).

2.3 Food Consumption Trends

In order to understand the market structure for any commodity, it is important to understand the factors which affect the supply and demand for the commodity. The quality of a commodity can be an important factor influencing consumers' choices. Quality perceptions are personal and subjective, but consumers as a group can be influenced by external forces, such as mass advertising and education, which attempt to shape or change consumer perceptions of commodities or products. Information from research into how human nutrition affects human health can also shape consumers' perceptions of the quality of a commodity or commodity group. For example, there have been widely published reports on the benefits of oat fibre and the differences between saturated and unsaturated fat intake on cholesterol levels.

2.3.1 Consumer Preferences for Pork Quality

Most consumers are able to distinguish products from one another through differences in quality attributes, and to assign value according to the desirability of the various characteristics of the products (Lancaster, 1966). In this section it is argued that the primary quality characteristic which consumers use to distinguish the relative values of meat, is fat content. Young (1987) categorized the factors that are likely to affect meat demand as either economic, demographic or health related changes.

2.3.2 Consumer Lifestyles and Purchasing Patterns

Kline (1986) of the National Pork Producers Council (NPPC) concluded that household preferences for pre-processed and packaged convenience foods in ready to serve portions are increasing in the United States. It was suggested that with more than half of U.S. women working outside the home, there is less time to prepare food at home, which increases the demand for convenience foods. Young (1987) noted that the participation rate of women in the Canadian work force doubled from 24.9 per cent in 1956 to 51.7 per cent in 1981 (Young, p. 15). Since the overall labour force participation rate expanded in this period, there was an increase of per capita family incomes. In two income families, there is more discretionary income to eat out.

Kline (1986) also suggested that increased mechanization had reduced the need for high calorie intake necessary to support manual labour. Consumers' increasing tastes for new and exotic foods were also noted as a consumption factor.

2.3.3 Retailing Patterns

Kempster (1988) noted that the catering and restaurant industries have gained an increased share of the consumer's food budget. In order to maintain competitiveness, many caterers and restaurateurs have incorporated more "low cost raw materials", such as "cheap lean meat" into their products. Purchasing leaner meats has allowed firms to avoid additional processing and labour costs involved in trimming and disposing of excess fat to obtain the quality control specifications. Further, firms have recognized that the fat trimmed from meat becomes relatively valueless, even though it has been paid for by the firm. Kempster contended that these types of changes in buying criteria may be altering the structure of the demand for meat by increasing its price elasticity.

2.3.4 Population Demographics

Young (1987) noted that the demographic factors which affect the age distribution of the population are fertility and mortality rates. The median age of the Canadian population had increased from 26 years in 1970's to 29.6 years in 1981 because of lower mortality rates and fertility rates. Kline (1986) contended that sophisticated birth control methods and increasing concerns of the "population bomb" had reduced the size of U.S. families. The aging of the population reduces the number of individuals who require higher energy diets. Young (1987) also suggested that the population growth rate may have decreased because immigration rates had been curtailed in recent years.

2.3.5 Health Considerations

Numerous widely publicized medical studies indicate that consumption of large quantities of saturated fats can lead to higher blood cholesterol levels and increase the risk of diseases associated with this condition. A 1977 report to the United States Senate by a Select Committee on Nutrition and Human Needs outlined the results of its investigation into food consumption patterns and how these related to the health of the population of the United States. A set of long term dietary goals for the United States was suggested for implementation. This report found that the increase in the proportion of fat and cholesterol in the American diet was associated with disease patterns involving high rates of ischemic heart disease, certain forms of cancer, diabetes and obesity(p. 3). These diseases were the major causes of death and disability in the United States. Food consumption patterns were viewed as unplanned and characterized as "a happenstance related to our affluence, the productivity of our farmers and the activities of our food industry."(Hegsted, p. 3)

The Committee determined that consumers' "personal dietary preferences" were not fixed but influenced by the environment in which people lived. "People learn the patterns of their diet not only from the

family and its socio-cultural background, but from what is available in the marketplace and what is promoted both formally through advertising and informally through general availability in schools, restaurants, supermarkets, work places, airports and so forth" (Winkoff, p. 5). It was argued that government activity or inactivity can determine how economic forces interact (p. 5). The Select Committee concluded that unhealthy food consumption patterns persisted because the progress of health and nutrition education was impeded by the inundation of mass advertising of fatty and sugary foods, cigarettes and alcohol.

The report recommendations were as follows: to increase the health and nutrition education of students and institutional food workers, to label food products more thoroughly and to support research into improving processing, preparation methods and human nutrition. Finally it was suggested that "The Department of Agriculture and Department of Health, Education and Welfare form a joint committee to periodically consider the implications of nutritional health concerns on agriculture policy"(p. 65). The problem of how to induce agricultural industries into producing nutritionally sound foods was left unresolved. Kline (1986) suggested that for health and aesthetic reasons, adults prefer to be much leaner than they have been in the past. This trend was not considered a transitory fad since ninety per cent of consumers expressed specific concerns about fat in their diet.

The results of many taste panel studies consistently indicate that the meat of lean carcasses is not as juicy and tender as the meat of fatter carcasses. However, Kempster (1988) showed that when butchers generally believed that the cuts from lean carcasses were too lean, the majority of consumer panellists felt that fat content was about right. Kempster (1988) added that excess fat could not entirely be removed by trimming, since the chemical composition of the meat and fat tissue in fatty carcasses contain more lipid than is found in the carcasses of leaner animals.

Kline (1986) reported that the results of an National Pork Producers Council consumer survey indicated that half of the respondents felt that although pork had become leaner, it still had too much fat, was high in cholesterol and was not good for you. Eighty per cent of the consumers surveyed reported that they used fresh pork; of those, eighty per cent reported wanting leaner pork, while over half indicated that they would consume more pork if it was less fatty.

In summary, the estimates of the demand parameters for pork derived from U.S. and Canadian data support the conclusion that since demographic, consumer behaviour patterns and health concerns of both populations are similar, it is probable that the fundamental demand characteristics for a primary food commodity, such as pork, may also be similar. One can also infer that shifts in trade patterns between Canada and the United States are not due to differences in basic consumer preferences between the two countries. Measured elasticities of demand may differ due to differences in the quality characteristics of pork available to consumers in both countries. Shifts in trade patterns between these two countries are more likely related to the differences in supply and characteristics of the market for pork and hogs in Canada and the United States.

2.4 Consumer Preference Articulation within Markets

The processes by which taste changes are expressed is known as "preference articulation". There are market inefficiencies in continuing to produce products which are becoming less acceptable to consumers because of changing tastes and increased choices among products and services. If this is the case, it follows that market mechanisms as well as political processes can also be improved in order to respond more effectively to consumers' preferences. "Thus it is useful to think of the effectiveness of the political processes as a mechanism for articulating preferences about the rules of the market, property rights

and the like and as a means for directly expressing preferences in regard to specific outputs"(Shaffer, p. 225).

Shaffer noted that, historically, a significant amount of the research of the 1960's on consumer preferences was oriented toward the business school concept of effective merchandising. This approach represented the minority opinion of the National Commission on Food Marketing of the United States in 1966. They advocated private brands over compulsory grades and standards. Private brands were believed to induce higher quality control standards and if these standards were not maintained then brands would lose their relative value. The minority also believed that selling costs and product development are an indication of high levels of competition. The majority opinion of the Commission held the opposing view that compulsory grades and standards improved the information flow to market participants and were more responsive to consumer preferences.

2.4.1 Market Performance

Shaffer recognized that "The political articulation of preferences requires knowledge about relevant dimensions or characteristics of performance"(p. 232). In doing so, "An important task for agriculture economists is the definition of important outcomes of the food system and the design of performance indicators" (Shaffer, p.232). He went on to state that one of the most important outcomes of performance is market efficiency, which is defined as "producing the mix of products most consistent with consumer preferences as expressed through the market at the least cost, given the opportunity set (Shaffer, p. 233). If this concept is applied to the U.S. hog industry, its primary goal should be to breed and produce the leanest hogs possible. This objective, as it will be shown in other sections, can satisfy the performance requirements of consumer preferences and while achieving lower costs of production of lean carcasses.

Consumers primarily articulate their preferences by their decisions to "buy" or "not to buy". A problem arises for the seller, when the decision is "not to buy", since the seller receives little or no information of what would have been preferred by the consumer. "Markets articulate preferences effectively only to the extent that prices summarize the relevant information"(Shaffer, p.236). It follows that a market is imperfect when critical information is not available to any or all of the participants.

2.4.1 Market Information

Shaffer illustrated the role played by information by referring to a study conducted by Hirshman (1970) on the impact of quality deterioration. Hirshman studied the following market scenario: a firm, producing a product which is consistent with consumer preferences, is doing well. Inexplicably, the quality of the product deteriorates. If the firm is unable to identify the cause of the resulting reduction in sales, then it will simply go out of business without understanding why. If the firm has "loyal or inert customers" then the seller may have enough time to recover from the problem. Hirshman introduced an added complexity, where customers go from firm to firm without gaining any satisfaction. This situation may give customers enough incentive to organize and complain in order to improve the system. "When price does not carry the information alternative, information systems are required"(Shaffer, p. 236).

In this chapter, the development of hog market institutions in Canada and the United States are outlined. The effects that these institutions have on pork production is then discussed.

3.1 The Development of the Canadian Hog Grading System

In 1981, Gordon Bowman explained to the National Pork Producers Council (NPPC) Conference on Pork Value that the development of a hog carcass grading system in Canada had both an explicit objective and an implicit ulterior purpose. The objective motive was to "provide a basis for producers and packer to arrive at a settlement based on relative value" (Bowman, 1981). This basis of comparison is obtained through the use of "definitive categories or indices". The ulterior purpose of the grading system was to provide incentives for the improvement of the quality of the product being marketed. Bowman listed the desirable qualities of a grading system as being simple to understand, cheap to administer, objective with the minimum of opinion, fair to all market participants, accurate in describing value differences, inclusive in measuring all important factors and providing incentives for improvements.

Bowman (1981) outlined the development of the Canadian hog industry and the national grading system. Prior to 1914, the Canadian hog industry was described as primarily a domestically based industry which served regional needs. Between 1914 and 1918, Canada captured a significant share of the British market for hogs, which was subsequently lost to the Danes, who produced a cheaper and better quality product than the Canadian industry. Between 1921 and 1922, after two all-industry national conferences, a policy was adopted to expend efforts in developing an industry oriented towards capturing a share of the British market. This would be accomplished through the development of a national breed improvement program and the development of a National Grading System.

The system of live hog grading, used from 1922 to 1934, differentiated between butcher, bacon, and choice bacon types with small differences in price. A number of hog carcass grading systems have been used since 1934, the first of which favoured long, lean, white carcasses. Carcass grading became universally used in 1940, coinciding with a period of increased exports to Britain. After World War II, exports to Britain dwindled to almost nothing after 1951, but this decline was offset by the emergence of the U.S. as the major export market for Canadian hogs. Because the carcass grading system in Canada was oriented to the production of a Wiltshire side for the British market, it was at odds with market realities from 1946 to 1968 since it did not emphasize the production of hams and loins, which were more valued in the North American market.

In 1969, a grading system was implemented in all provincially and federally inspected slaughter facilities by which hog carcasses would be indexed and their relative values determined for payments to producers through their provincial marketing boards. The carcass indexing system was based on a carcass weight measurement and two backfat depth measurements at the maximum shoulder and maximum loin of the split carcass. A grid of fixed indices of price differentials was developed for all combinations of carcass weight and backfat measurements. The optimal weight of carcasses under this grading system was between 160 to 169 lbs. from 1969 to 1977. A number of revisions have been made to refine the grading system. The first revision, in 1978, set the optimal weight category at between 180 to 189 lbs.(Canada Gazette, 1979). This twenty pound increase in the optimal carcass weight range appears to have been unacceptable or unattainable to the industry participants and within a year the optimal weight range was dropped to between 170 to 179 lbs (Canada Gazette, 1979). In March of 1982, the measurement of back fat thickness was revised to include a single measurement at the point of maximum thickness of the lumbar region of the split carcass, while

the indices of price differentials remained the same (Canada Gazette, 1982). In 1985, the Canadian government sought to recover some of the costs of grading by instituting a charge of 9 cents per carcass graded (Canada Gazette, 1985).

In 1986, hog carcass grading in Canada was revised to allow the use of an electronic probe, capable of measuring not only backfat thickness but muscle depth as well. The orientation of the latest grading system is to estimate lean yield instead of the yield of trimmed wholesale cuts. This is accomplished by a single measurement of backfat and loin depth in millimetres at a specific location on the carcass along with the measurement of carcass weight. The number of weight categories was reduced from 11 to 10 and weight became expressed in terms of kilograms instead of pounds. The optimal weight category was

TABLE 3.1 Canadian Hog Carcass Grading Grid, 1991

YIELD CLASS		1	2	3	4	5	6	7
WT. CLASS	CARCASS WEIGHT (KG.)	ESTIMATED PER CENT LEAN YIELD						
		> 53.59	52.0- 53.59	50.4- 51.99	48.8- 50.39	47.2- 48.79	45.6- 47.19	< 45.6
1	40- 64.99	80	80	80	80	80	80	80
2	65- 69.99	100	96	92	88	85	83	80
3	70- 74.99	110	107	104	102	100	96	90
4	75- 79.99	114	112	109	107	104	100	96
5	80- 84.99	114	112	109	107	104	100	96
6	85- 89.99	112	110	108	105	101	97	94
7	90- 94.99	107	104	100	96	92	88	82
8	95- 99.99	101	97	93	89	82	82	82
9	100 +	81	81	81	81	81	81	81

Agriculture Canada, Livestock Section.

Gazette, 1986). Carcasses that are lighter than the optimal weight category are penalized slightly more than carcasses which are heavier than optimal. The penalties become progressively more severe as carcass weights deviate further from the optimal weight category. Further revisions have been made to the national grid and were adopted by most provinces in early 1991. Alberta adopted a modified grid which penalizes lighter weight carcasses to suit its specialized marketing concerns. The national grid is shown in Table 3.1.

3.1.2 The Effects of the Canadian Hog Grading System

Fredeen (1984) published an analysis of the effect of the Canadian hog grading system on changes in the characteristics of commercial hog carcasses produced in Canada. Changes in numbers slaughtered, average carcass weight and index performance were analyzed for the period 1969 to 1982.

The annual numbers of hogs slaughtered declined from 1971 to 1976, surged between 1976 to 1979, and declined slightly from 1979 to 1982. Between 1977 and 1978, average carcass weight jumped from approximately 74 kg. to over 77 kg., a 6.5 percent increase in carcass weight. These changes were accompanied by a 30 percent improvement in carcass indexing based on the 1968 version of the grading system and a reduction of carcass backfat thickness of approximately 10 percent in all weight classes.

Fredeen (1982) suggested that these trends in carcass characteristics resulted from a number of factors. "The increase in carcass weight derived directly from the marketing decisions made by individual producers as they attempted to increase the frequency of weight classes which optimized indexing potential. Such decisions tended to improve the average index, but it is clear that the primary component of index improvement was the steady reduction in carcass fat. Changes in management (e.g. restricted feeding,[and] separation of sexes during the

feeding period) undoubtedly made some contribution to the 10 per cent reduction of fat. However, the prolonged and remarkably linear time trends for both index and fat are more logically explained in terms of progressive genetic change."(Fredeen, 1982)

The progressive genetic change which occurred in the Canadian herd could be explained as resulting from a number of causes: record of performance (ROP) testing of boars, the growth of a number of large private breeding units since 1969, the increased use of artificial insemination (AI) and the decline in the numbers of herds in Canada. However, Fredeen (1984) believed that the use of ROP tested boars was not extensive enough to produce the results evident in the Canadian herd. Nor were the private breeding companies large enough in the initial stages of the genetic evolution of the Canadian herd to have contributed the linear improvement. The use of AI was a relatively new phenomenon and the numbers of breeding stock and market hogs produced through the use of AI had not been extensive.

The reduction of herd numbers in Canada was considered by Fredeen to have been an overwhelmingly cause of the improvement of the carcass quality of Canadian hogs. Fredeen argued that in view of the 64 percent reduction in the number of farms reporting hogs between 1966 and 1981, "it is highly probable that the majority of herds which failed to survive were those characterized by inferior carcass merit" (Fredeen, 1984). Van Arsdall and Nelson (1985) attributed the decline in herd numbers in the U.S. to the exploitation of scale efficiencies; the quality of hog carcasses was not considered as a factor in determining the survival of the production unit, although lager units are concluded to produce hogs of higher quality.

The effects of the decrease in fat achieved from 1969 to 1982 represented a reduction of fat trim equivalent to 0.96 kg. per carcass or "the yield of trimmed retail product from the total 1982 slaughter in Canada was approximately 13 million kg greater than would have been

obtained from the same number of pigs in the 1968 vintage"(Fredeen, 1984).

3.2 The U.S. Hog Industry

The U.S. hog industry has evolved a complex of production and market systems which to attempt to supply that large consumer market with plentiful, inexpensive and high quality pork products. In order to achieve economic efficiencies, the hog industry has undergone physical and institutional restructuring over time. This has, in some cases, required the relocation of production and processing activities to minimize transportation costs, the exploitation of economies of scale in the production and processing sectors, the development of innovative management techniques and genetic selection for higher quality and more productive breed lines. The relative success of these changes within the hog industry can be measured by the ability of hog producers to compete for market share with producers of close substitutes of pork, such as beef and chicken, and with foreign producers of pork.

One feature in the late seventies that continued through the eighties was the chronic overcapacity of slaughter and processing plants. Many plants require more hogs to process than are supplied to the market by U.S. hog producers. Therefore, U.S. plants are often forced to accept poor quality hogs for delivery without being able to discount them in order to keep their slaughter lines moving for a whole shift. Simultaneously, the relative size of the U.S. hog industry has had periods of either stagnation or contraction. Many pork industry commentators in the U.S. have also acknowledged that the quality of pork products is highly variable and improvements have been slow. It appears that the pork processing industry has not been able to obtain enough supplies of cheap, high quality hogs to process and supply to their wholesale and retail customers at prices competitive with producers of close substitutes of pork and foreign suppliers of pork products. These features seem to be a major cause of the transformation of the United

States from being a net exporter of hogs and pork products to a net importer.

The Canadian and European hog industries have been in a state of expansion during the same time period as the U.S. has become a net hog importer. The production and market structures of Canada and the United States will be compared in order to assess the hypothesis that there is an on-going form of market failure in the U.S. hog industry.

3.2.1 U.S. Hog Industry Production Characteristics

Because of locational efficiencies of production, United States hog production is centred in the region around the state of Iowa, in "the Corn Belt", which is the major corn producing region of the United States. Generally, hog rations in the United States are based on corn supplemented by a protein source, usually soybean meal (Van Arsdall and Nelson, 1984). A secondary region of production is located inland, parallel to the Southeast coast of the United States (Hayenga et al., 1985). Hayenga et al. (1985) also report that most hog slaughter and pork processing facilities are located in the same regions as hog production (p. 5). Locational efficiencies of hog production in the United States are achieved by minimizing the costs of transporting feed and live animals which are bulky and difficult to handle (Van Arsdall and Nelson, 1984).

Van Arsdall and Nelson (1984) as well as Rhodes and Grimes (1985) found that hog production in the United States has undergone changes which attempt to exploit scale efficiencies such that the size of production units is increasing, while the numbers of producers are decreasing. Van Arsdall and Nelson (1984) analyzed and compared the effects of size of operation on efficiency of physical production and economic performance on Illinois farms from the beginning of 1980 to the end of 1983. The sizes of operation were categorized by production levels ranging from under 200 head per year to over 5000 head per year, with a few large scale operations producing nearly 15,000 head per year.

Despite wide variability of productivity and efficiency due to the individual nature of hog operations, all physical performance measures studied, except for pounds produced per litter, improved with the size of operation (p. 32). Purchasing and marketing efficiency were found to also improve with size of operation, again with large variability. Prices per hundred pounds of hog liveweight produced increased, while costs per ton of feed purchased declined as the size of operation increased (p. 34). The largest producers were found to receive an average of $2.00 per hundred weight premium for their hogs. Van Arsdall and Nelson (1984) explained that large scale hog producers achieved these price efficiencies and premiums because they tended to market hogs at lighter weights, while "factors such as higher prices paid for breeding stock, direct selling to packers, and more hogs priced according to grade and yield suggest that larger operations produce better quality slaughter hogs and are able to cut costs in marketing compared to smaller operations" (p. 37). Economic performance measures also indicated that large producers were more efficient. Costs of feed per hundred pounds of liveweight hog produced declined with size of operation, while returns per hundred dollars of feed fed and returns net of feed costs increased (p. 38).

The findings of Van Arsdall and Nelson (1984) suggest that the size of U.S. hog farms will likely continue to increase in order to exploit scale economies and reduce costs of production. Therefore, assuming relative prices will decrease with declines in the costs of production, the economic incentive for many small producers to continue operations will decline as scale efficiencies are exploited by others (p. 40). Since large scale producers tend to market their hogs on a grade and weight basis and the number of large scale farms are increasing in the U.S., Van Arsdall and Nelson (1984) expected that the proportion of market hogs sold on a carcass merit basis would also increase.

3.2.2 U.S. Assembly and Processing Plant Characteristics

Scale efficiencies within the intermediate market sector, which includes assemblers and purchasers of hogs, slaughter and processing plants and wholesalers and retailer of pork products, have also been pursued.

Hayenga et al. (1985) described the development of slaughter hog marketing systems from the turn of the century, when producers shipped their hogs by rail to major packing centres or terminals to be sold through commission agents. With the advent of improved transportation and roads, hog producers were able to ship directly to packers or choose between different terminals.

Direct marketing caused some controversy because of the argument that it interfered with or hindered the competitive price discovery processes which had existed earlier (Hayenga et al., p. 53). In 1925, 80 per cent of hogs were marketed through terminal markets while by 1980 only 13.5 per cent of hogs were marketed through terminals and 76.6 per cent of hogs were purchased directly by packers. A direct result of this development was that the number of terminal markets declined in the U.S. from 80 in 1900 to 28 in 1980. Hayenga et al. (1985) also noted that intermediate hog buyers do not typically appraise hogs on sight, but purchase lots of hogs based on the quality of past purchases of hogs from that particular producer (p. 55).

Sarhan and Albanos (1985) documented the main structures of the U.S. livestock processing industry. They found that the current system for marketing hogs was dominated by direct marketing. Producers negotiate with and ship hogs directly to packers who, in turn, wholesale pork products directly to retail outlets. Packing plants have increased in size but diminished in number in the United States resulting in fewer buyers. The numbers of branch houses and travelling purchasers and sales men have also declined. Sarhan and Albanos commented that there appeared to be an increased "willingness of buyers and sellers to accept the

practice of sales at any price, provided that their rivals used the same system. This type of practice has led to the evolution of formula pricing which relies on the prices reported by government and private reporting services" (p.1). Federal and State inspection of plants was found to be primarily concerned with the safety and wholesomeness of the products produced. According to 1981 and 1982 figures, at least 95% of hog slaughter took place in federally inspected plants (p.3).

3.2.3 Liveweight Selling

Liveweight pricing involves visually appraising individual or groups of hogs and offering a price based on the weight of the live hog at the time of ownership transfer (Hayenga et al., p.59). There are variations of this system based on sorting hogs into lots of similar weights and expected grades, and the practice of offers based on a given liveweight category with pre-stated discounts for light and heavy weights.

Live weight marketing of hogs offers the advantage of instantly determining market values of hogs; thus the producer receives payment for his hogs almost immediately. There are, nevertheless, a number of disadvantages in marketing hogs on a liveweight basis. Liveweight selling prices represent a poor index of the relative value of an individual hog with respect to quality. Inaccuracies in estimating the relative value of a hog can make the marketing system inequitable to both buyers and sellers. For instance, because of competition among buyers, the inability to accurately evaluate individual hogs in a lot may lead to averaged bids where superior hogs are underpriced or inferior hogs are overpriced. A further complication can occur when buyers "offer different prices for loads of hogs varying in quality, but quality differences reflected in prices offered are often masked by changes in other market factors such as available supply of hogs and wholesale market prices"(Hayenga et al., p. 60).

Hayenga et al. (1985) were critical of producers who chose to market their hogs on a liveweight basis. "Producers who choose the visual method because they think they can fool the buyer into paying more than their hogs are worth, often do not realize that buyers who consistently overprice hogs are not likely to keep their jobs very long"(p. 60). They noted that most buyers receive daily cutout reports on all hogs they purchased in order to help improve their bidding skills and buyers use information on carcass quality of individual producers to adjust prices offered in the future. Sale based on carcass merit, or a grade and weight pricing method determined by measurements of backfat thickness and carcass weight, was considered by Hayenga et al. (1985) to be a better alternative to liveweight selling, since producers receive prices which more accurately reflect quality characteristics (p. 61).

The major points of contention with regard to the issue of "to grade or not to grade" along with the other issue of "to standardize or not to standardize" can be summarized as follows. Although producers would receive "reliable production signals", if they sold their hogs on the basis of carcass merit, there is the perception that the system has performed not too badly as it is, while the costs of grading would reduce returns. Even so, the additional cost of adopting a policy of grading all hogs marketed would only involve the extra paperwork necessary in providing the information to producers, since the majority of processors already grade the hogs they process for accounting purposes. The use of a standardized grading system would help overcome the mistrust that producers have of processors. However, many market participants believe that it is more important to retain the market characteristics of flexibility and non-regulation of the industry (Hayenga et al., p. 62).

3.4 The Development of U.S. Grading Systems

Hayenga et al. (1985) listed the functions of grading systems, in particular, the USDA grades. Grading systems, based on either live or

carcass merit, have been developed to enable market participants to discern the relative value of hogs according to a scale of weight and quality measurements. Marketing a hog on a graded basis provides information to the producer on traits most desirable to packers. This information can be used by the producer to optimize production decisions such as choice of breeding programs and weights at marketing. The use of electronic marketing services also necessitates the use of a grading system. Grades form the basis of reporting market prices by reporters and news services, which are the primary sources of information for most market participants (p. 57).

The basis of value of a hog carcass used in most American grading systems is the yield of the four trimmed wholesale primal cuts, trimmed lean, fat, skin, bones and feet multiplied by their respective market values. This type of grading system is expected to provide producers with information on the relative value of hogs in the wholesale market.

There is a federal government carcass merit grading system and a large number of privately developed systems in use in the U.S. that are intended to equitably evaluate market hogs. A noted flexibility in the U.S. pork processing industry is that processors are able to set their grading systems according to their product specializations. For example, Hayenga et al.(1985) suggested that sausage makers may be willing to pay higher prices for heavier hogs(p. 60).

One disadvantage to different processors of using a variety of grading systems is that these systems can be complicated and make comparisons of bids by processors difficult. Hayenga et al. (1985) commented that this has led to a distrust of packers by producers, mainly because producers are unsure of the relative value of the hogs they market and fear lower than expected returns when marketing on a carcass merit basis.

3.4.1 The USDA Grading System

The voluntary USDA grading system that was in effect from 1951 to 1984, with slight revisions in 1968, graded animals accordi g to the expected percentage yield of the four trimmed wholesale cuts ie. loins, hams, picnics and butts. From a measurement of backfat thickness and either a carcass length or weight measurement, a carcass was graded U.S. #1 if the expected yield of the four lean cuts was 53 percent or better of total live weight. A U.S. #2 carcass would yield between 50 to 52.9 percent as the four lean cuts, while a #3 carcass would yield 47 to 49.9 percent and a U.S. #4 would yield less than 47 percent as lean cuts (Hayenga et al., 1985 p. 58). This system was believed to be effective in reducing the amount of fat in hog carcasses until the late seventies, when nearly all the carcasses produced graded either U.S. #1 or #2 (Crom, 1981). However, Grisdale et al. (1984) found that the USDA grading system was accounting for only 34 per cent of the variability of carcass value on the basis of a percentage yield of the four lean cuts in the early eighties.

Because the USDA grading system was unable to effectively differentiate between differences in the percentage yield in four lean cuts of carcasses, this system was revised in 1984. The revised system still employs a backfat measurement but instead of using a weight or length measurement, the grader is required to make a subjective appraisal of the degree of muscling in the carcass. A scale of three is used, where a 1 score is for heavily muscled, a score of 2 is for moderate muscling and a score of 3 is applied to a carcass with thin muscling. A grade of U.S. #1 is assessed to a carcass which is expected to yield at least 60.4 percent of the four lean primal cuts. If a carcass has less than 1.00 inch (last rib) backfat thickness and is moderately muscled, or if a carcass has a backfat thickness of less than 1.24 inches and is heavily muscled, then both will be graded U.S. #1.

A U.S. #2 grade is applied to any carcass with an expected yield of between 57.4 and 60.3 per cent of the four lean primal cuts. "Animals

with average estimated backfat thickness over the last rib and average muscling, less than average estimated backfat thickness over the last rib and thin muscling or greater than average backfat thickness over the last rib and thick muscling will qualify for this grade"(USDA, Dec. 14 1984).

The U.S. #3 grade is applied to those carcasses expected to yield between 54.4 to 57.3 per cent of the four lean primal cuts and a carcass yielding less than 54.4 per cent cuts warrants a grade of U.S. #4.

The 1984 revision of the USDA hog grading system is a simplification of the previous system in the sense that only one objective measurement is taken of the hog carcass, that is, the last rib backfat thickness. However, this system also represents a simple upward shift of the definition of the relative value of carcasses based on yield. For instance, a carcass that yields 53 percent of the four lean, primal cuts under the old system would have graded USDA #1, while under the revised system this carcass is graded as U.S. #4. It appears that the objective of the USDA grading system continues to be the estimation of differences in the value according to yield of trimmed wholesale primal cuts rather than the direct identification of leanness as a quality characteristic.

The redefinition of a U.S. #1 carcass is believed to allow processors to discriminate between carcass quality characteristics more effectively than the older system. However, the lower standards of the previous grading system appear to have alienated many producers from marketing hogs on a carcass merit basis and a positive response by producers toward the new more stringent grading system could not be expected (Rhodes and Grimes, 1985).

3.4.2 Difficulties with Grading Systems based on Yield of Primal Cuts

Fortin et al. (1981) in a large Canadian study using over 3,800 carcasses, found that, depending on the location of measurement, from 60 to 70 percent of the variation of commercial trimmed carcass value was

accounted for by a ruler measurement of backfat thickness. Fortin also found that there were slight improvements in the estimation of carcass value when two backfat carcass measurements were used. The residual standard error in the estimation of carcass value decreased significantly when a carcass weight measurement was included. Using the same data set, Martin et al. (1981) found that a carcass weight measurement marginally improved the estimation of carcass value based on commercially trimmed lean cuts. Grisdale et al. (1984) found that in a sample of 185 carcasses, depending on the location of the ruler measurement of backfat thickness, from 73 to 79 per cent of the variability of carcass value was accounted for by these two measurements.

A number of inconsistencies can occur over time when using a system based on the value of commercially trimmed lean cuts. Fortin et al.(1981) demonstrated that ruler measurements of fat thickness at the edge of the split carcass produced larger residual standard errors and did not account for as much of the variation in carcass value as comparable measurements using ultrasonic equipment.

Further, if a carcass grading system is developed under the assumption that the relative value or relative amounts of wholesale cuts does not change, but in reality they do change, then the grading system must constantly be revised in order to reflect these changes. Constant revision of this type of grading system would be inconsistent with attempts by hog producers to institute long term breeding programs for optimal growth patterns. If, for example, the demand for hams increases one year, causing producers to alter their breeding programs accordingly, and in the next year, loins become the most desired product, producers would again have to alter their programs. A lack of continuity in market structure is likely to prevent producers from progressing in terms of providing consumers with the product that they consistently want, which appears to be lean meat.

Fortin et al. (1981) found that although backfat measurements were adequate in determining the value of trimmed wholesale cuts, they were less efficient in determining lean yield. Grisdale et al. (1984) determined that the percentage of lean in a carcass only accounted for 44 per cent of the variation in carcass value based on yields of wholesale cuts. It appears that the value of commercially trimmed wholesale cuts is not strongly associated with the determination of the value of a carcass based on lean content. This phenomenon can be explained in the following way: the yield of trimmed commercial wholesale cuts includes lean, bone and untrimmable fat, both intra- and inter-muscular fat; all of these can vary from carcass to carcass. Yield estimates are used to determine the relative value of a carcass, without differentiating between carcasses that are high in lean, bone or un-trimmable fat content. Therefore, the value of the wholesale cuts does not necessarily reflect the value to the consumer of the resulting retail cuts, if consumers want the leanest cuts possible.

A grading system that is based solely on a combination of a carcass weight or length measurement, with one or more backfat measurements, provides the producer with a narrow band of market information on which to base production decisions. Producers may tend to identify the optimal breeding strategy as minimizing backfat thickness, not necessarily minimizing the overall fatness of the carcass or the weight of the skeletal structure of the animal. Jones and Haworth (1983) found that measurement of lean depth between the 3rd and 4th last rib on a carcass using an electronic probe reduced the standard residual error in the estimation of the proportion of lean in the carcass. They surmised that "lean depth could therefore be valuable in commercial grading of pork carcasses as it probably has identified some of the differences in muscle:bone ratio among pigs which are not explained by carcass weight" (Jones & Haworth, 1983).

3.4.3 Proposed Changes to the Current U.S. Grading System

In 1986, the NPPC proposed a system of grading based on a grid which would relate the measurement of hog carcass weight on one axis and compare this to last rib fat thickness measurements on the other axis. The proposal was similar to some later versions of the Canadian hog grading system. In each back fat thickness category, the heavier the carcass, the less the producer would receive for it on a per pound basis. Lighter than average, lean carcasses would be assigned premiums to the base market prices while heavy, fat carcasses would be discounted. The average carcass was described as being between 169-175 lbs. with 1 inch backfat thickness at the last rib location. If muscling was considered too thin, a 1.5 per cent discount would be assigned and a 1.5 per cent premium would be assigned for thick muscling.

The 1987 revision of the NPPC proposal deleted the carcass weight category between 205-212 lbs and added two fat thickness carcass measurement categories of 0.6 inches and 1.4 inches. The distribution of weight categories was changed slightly; the average carcass would be expected to have 1.1 inches of fat in the 167-173 weight category. The most critical change was that a carcass in the optimal weight range category, in this case between 167-173 lbs., with 0.6 inches back fat thickness, would receive the largest premium. Heavier and lighter carcasses would receive proportionately less in each fat thickness category, although the lighter carcasses would be penalized more than heavier carcasses. The proposed grading system would provide a one per cent premium if the carcass has heavy muscling and a one per cent deduction if the carcass is poorly muscled.

The 1987 NPPC proposed grading program was expected to be a useful guide to producers' breeding and marketing decisions, since ideally processors require moderately heavy carcasses to achieve plant efficiencies. However, both the USDA and NPPC grading systems represent compromises, since they use the yield of wholesale cuts as the basis of carcass value and not the actual lean content of the carcasses. The NPPC

grading system is based on work by Grisdale et al.(1984) and Hayenga et al. (1985b) both of which are based on a relatively small number of carcasses. The estimates of the accuracy of backfat measurements in predicting carcass value from these studies are puzzling, since they are less variable than those of other studies with larger samples ie. Fortin et al. (1981) and Jones and Haworth (1983).

R. G. Wells (1986), a vice president of a major U.S. packer, Geo. A. Hormel and Co., reported to pork producers in 1986 that Hormel's house grading system was much more generous in rewarding carcasses of the ideal weight and minimal backfat than either the USDA or the NPPC grading systems. Wells indicated 5 to 6 percent premium for carcasses with a backfat measurement of less than .8 inches for the same carcasses graded under the NPPC system. Fatter carcasses were penalized, but not as severely as the NPPC grading system. Wells explained that Hormel was willing to pay premiums for high quality carcasses because their branded pork product lines are increasingly marketed boneless and trimmed of excess fat.

3.5 Inconsistencies in U.S. Hog Markets

The standard definition of a perfectly competitive market, where the interaction of supply and demand determine the equilibrium market price of a commodity, involves the assumptions that the many buyers and sellers participating in the market possess perfect information, that the commodity being produced is homogeneous and that entry and exit from the market is costless in the long run (Henderson and Quandt, p. 136). The requirements for workable competition include the requirement that differences in quality characteristics of economic value are objectively measured and premiums or discounts are equitably assessed. This presumes that neither buyer nor seller has the power to influence or alter the appraisal of quality.

The assumption of a perfectly competitive unregulated hog market would require, amongst other things, that the hogs produced and offered

to the market be homogeneous in the quality characteristics of economic value. Market hogs would be homogeneous if they had the same relative amounts of fat and muscle in their carcasses, they were equally resistant to stress, had identical costs of production and were indistinguishable on the basis of gender. These conditions are unlikely to be met because of biological mechanisms, which depend on the genetic variation of characteristics of individuals within a population to ensure the survival of the species. Therefore, in order for any hog market to be efficient, it is necessary for some institutional mechanism to recognize variation in market characteristics and assign or facilitate assignment of appropriate premiums and discounts, which, respectively, reward producers of high quality hogs and penalize returns for poor quality hogs.

The U.S. hog industry has consistently followed the policy that the best method of determining the value of hogs is through the forces of free and unregulated market operations under the assumption that conditions for a perfectly competitive market exists. Although there have been attempts to distinguish quality characteristics, there has not been a unified effort to develop and use a universal grading system which directly reflects consumer perceptions of carcass value.

The inadequacy of the USDA grading system to distinguish between the individual merits and faults of carcasses is shown by the biased statistics it generates. For instance, in 1981, over 70 per cent of the hogs graded by the USDA grading system were U.S. #1 and over 24 per cent of the hogs graded were U.S. #2, with the other five per cent of hog carcasses graded in the U.S #3 and #4 categories. It follows that the marketing system could have been expected to assign premiums to nearly 95 per cent of the carcasses graded that year (Crom, 1981), a feature that obviously could not apply.

Producers have the option of marketing their hogs on either a liveweight basis or on the basis of carcass quality and the U.S. carcass

grading systems have not been used extensively. Generally, between ten and twenty per cent of hogs marketed in the U.S. are reported to be sold on a carcass merit basis. Many U.S. producers have expressed doubts about the economic benefits of shipping on the basis of carcass merit or do not trust packers to grade carcasses equitably (Van Arsdall and Nelson, 1984). There have also been many concerns expressed by packers over a lack of progress by U.S. hog producers in reducing the fat content of carcasses (Hayenga et al, 1985).

The relative value of pork in the U.S. is declining with respect to other protein sources. Consumers have cheaper alternatives that are easier to prepare, while processors incur extra costs in trimming off excess fat found on carcasses in order to make retail cuts more acceptable to consumers. Van Arsdall and Nelson (1984) reported that approximately 11 percent of hogs were marketed on the basis of carcass merit and that producers tended to ship on carcass merit basis primarily to test the existing market situation (1984, page 58). Hayenga et al.(1985) reported that, in a 1981 survey conducted by the National Pork Producers Council, "71 percent of pork producers consider the monetary incentives to produce lean heavy muscled pigs to be fair or poor".

Many U.S. hog industry commentators have suggested that individual U.S. producers who sell on a liveweight basis are not fully informed of the true relative value of the carcasses of the hogs they produce nor are they consistently compensated for the extra efforts required in producing leaner hogs. Therefore, the U.S. industry can be described as failing to recognize and respond to consumer preferences. The Canadian hog industry, on the other hand, has attempted to achieve this performance goal by instituting a nationally administered grading standard. All processors must purchase their hogs through provincial marketing boards on the basis of the established grading system; thus most Canadian producers receive consistent compensation and information

on their relative progress in achieving the industry performance goal of producing leaner pigs.

3.3.2 The Politics of Market Structures

Since it appears that the U.S. hog industry is failing to fully respond to consumer preferences, there may be an imbalance of power within the market institutions of the U.S.hog industry. The infrastructure of political influence and control of market information, along with the principal groups and their domains of influence are described in this section.

Primary hog producers appear to have most political influence in determining the fundamental market structure of the industry. Producers have and do exercise the right of refusal in marketing their hogs on a carcass merit basis. They have also been successful in lobbying the U.S. government for tariffs on Canadian live hogs and in lobbying state governments for non-tariff barriers based on health restrictions on Canadian live hogs. The other major factor which producers have almost complete control over is the timing of marketing, weight and quality at marketing of hogs offered to the market.

Meat packers and processors do not appear to have had as much influence over the structure of the U.S. hog market through political processes. They have been unsuccessful recently in lobbying for tariffs on processed pork from Canada, while U.S. tariffs on live hogs from Canada have increased their purchasing costs. Meat packers and processors do hold and exercise influence on pricing and pricing structures for live hogs and processed pork, both of which are reported to be mistrusted by hog producers (Rhodes and Grimes, 1985). Processors also have a considerable amount of control of quality aspects such as the amount of added water, salt, nitrate and nitrite levels in pickling processes and the degree of fat trimmed.

Retailers are the primary receptors and conduits of information on consumer preferences in the marketing system. Retailers are in constant

and direct contact with consumers and therefore they receive the most accurate information of consumer expectations of quality. If consumers refuse to buy a product offered for sale at a retail outlet because of poor quality, a retailer can lower prices or discontinue stocking that product. Alternatively, retailers can find another supplier of the product in hopes of recapturing consumer interest. Retailers of pork usually have in-store or central facilities to cut and trim meat products. If the amount of trimming required to maintain the quality standard of the chain is excessive, the cost of this wastage must be absorbed by either the supplier, in offering a discount on the product or by the consumer, in paying a higher price for the product. The outcome would depend on the relative market power of suppliers to consumers.

Similar conditions may develop if consumer quality expectations increase, but are not responded to by producers. Consumers are unable to effectively communicate their dissatisfaction with pork products being offered for sale other than by not purchasing the product. Alternatively, a consumer may choose to take the time needed to trim excess fat from the purchased product, and the recollection of this exercise may have a negative impact on future purchasing decisions. Following Hirshman's (1970) analysis, if the US hog industry is viewed as a firm, such a firm would be expected to decline and provide market opportunities for more consumer responsive firms (industries) such as the Danish or Canadian hog industries. An expected outcome is rising imports of higher quality pork products to satisfy particular consumers' preferences and relative declines in prices for domestic product as consumers substitute other meats and imported products for domestic pork.

The U.S. hog industry has not effectively responded to consumer preferences because most hogs are marketed on a liveweight basis with inadequate price differentiation between fat and lean animals. Further,

when the USDA grading system is used, it does not objectively and directly identify lean content in hog carcasses. Therefore, most U.S. producers have had neither critical information nor economic incentives in order to respond to consumer preferences for leaner pork.

Chapter 4

In this chapter, the process of genetic selection as a form of accumulation of biological technology is discussed. First, it is necessary to define some of the pertinent mechanisms which allow genetic selection to occur. Initially, the terminology used in the field of animal genetics will be defined. This is followed by a brief summary of the fundamentals of animal genetics and their application to animal breeding, in particular, to swine.

4.1 The Theory of Genetic Selection

There are three main areas involved in the study and application of animal genetics: Mendelian genetics, population genetics and quantitative genetics (Van Vleck, 1987).

4.1.1 Mendelian Genetics

The principles of Mendelian Genetics are generally used when studying qualitative characteristics which are simply inherited, such as eye and coat colour. They describe the mechanism of inter-generational transmission of genetic material or "the laws of particulate inheritance". The first principle is the law of segregation which states that genes, which are units of inheritance, occur in pairs within an individual. Mendel's second law applies to the principle of independent segregation, which states that separate gene pairs which control separate characteristics will assort independently. The Mendelian laws of particulate inheritance insure that there is an equal probability of each progeny inheriting one of a pair of genes from each parent irrespective of other inherited genes, which may effect the same or different physical characteristics.

The chromosomes found in the nuclei of each somatic cell of an animal are made up of series of nucleotides in specific combinations and locations, which not only govern the outward physical characteristics, but more importantly, govern the complicated bio-chemical processes which occur within cells and the organs which they constitute. Because

all individuals have a high probability of inheriting a unique genotype, one can only make assumptions of an individual's genotype based on knowledge of relatives' characteristics and those which the individual itself displays. Further, since not all the characteristics of the genes which an individual has inherited are expressed, the study of genetics and an individual's genotype must be centred around the terms, potential and probable. One allele of a gene pair may be completely dominated by the other allele, or they may co-dominate. Also, one pair of genes can effect more than one characteristic or interact with other genes to produce still other physical characteristics.

4.1.2 Population Genetics

The study of population genetics involves the determination of why certain genes, as expressed by distinct physical characteristics, occur at certain frequencies within a population. It also is the study of why gene frequencies vary in a population over time (Van Vleck, p.2).

4.1.3 Quantitative Genetics

Quantitative genetics is the study of animal traits which are not qualitative or simply inherited. Quantitative traits are usually ones which are measured, for example rate of gain, backfat thickness, or rate and persistence of lactation. Besides the study of genetic variability in a population, the study of quantitative genetics seeks to explain differences between animals which are due to differences in the environments in which the animals are raised (Van Vleck, page 227). A phenotypic characteristic of an animal, for instance, rate of gain, is determined by its genetic potential, which it has inherited from its parents, as well as environmental factors, such as the quality of animal's housing and diet. The phenotypic traits of an animal can be influenced both by its genotype (inherited genetic potential) and its environment. A phenotypic trait may be disproportionately influenced by either of these two forces.

Therefore, much of the study of quantitative characteristics in domestic animals has centred been around the determination of genetic potential and the relative influence of genetic potential and the environment. This is of significant economic importance, since efficiency in selecting the best breeding stock from within a population is dependent on an understanding of how quantitative traits are expressed and how they interact with and influence other traits.

The principles of quantitative genetics can be illustrated by using a statistical model of a population.

4.2 Natural Selection

Natural genetic selection was first explained by Darwin and Wallace as a process by which nature ensures that a living species can improve its ability to survive in a hostile environment. It is a mechanism by which the variation of individuals within a species results in some individuals being fitter than others in a given environment. The fitter individuals will have an increased survival rate and, therefore an increased chance of reproducing. The other individuals, less fit to survive in an environment, have reduced chances of reproducing. The genetic factors which make individuals more fit will be inherited by the next generation. Conversely, the frequency of genetic factors which render an individual less fit to survive, will diminish within a population.

4.3 Artificial Selection

The term heritability is a calculated ratio of genetic variance to the total (phenotypic) variance found within a population. Usually expressed as a percentage, this measure estimates the degree of resemblance that can be expected between an off-spring and its parent. Generally the higher the measured heritability of a trait, the easier and quicker will be the progress of increasing or decreasing the phenotypic expression of the trait within a population through selection pressure.

Domestic animals have been subjected to an artificial selection process through controlled breeding such that human criteria of desirable characteristics have superseded those necessary for survival in the wild. Many farm animals, for instance domestic chickens, have so been so altered by animal husbandry practices that they are no longer viable in the wild. The loss of natural viability has been compensated for by man with the creation of artificial environments, such as barns. Nutritional standards have been increased to allow for high growth rates by the use of measured rations of formulated feed specific to the animal's particular needs at a particular stage of growth. The present system of breeding animals in modern agriculture stresses the accumulation of economically important production characteristics.

4.4 The Selection Index

The use of a selection index is a method by which an animal production industry can acquire or develop genetic technology. The acquisition of genetic technology by an industry can involve the importation of animals or gametes of animals, which are the result of generations of selection for desirable production characteristics. With the development of biotechnology transfer, the forms of technology that can be purchased are as diverse as purebred seed stock, crossbred gilts for commercial production, frozen sperm and embryos or pieces of isolated DNA which yield specific phenotypic characteristics when incorporated into an animal's genetic make-up. Genetic technology can also be developed through the long process of traditional genetic selection techniques, or as is expected in the future, more quickly with biosynthesis methods such as recombinant DNA procedures.

4.4.1 Estimating the Efficiency of Artificial Selection

Smith (1983) formulated a method for determining the degree of efficiency of selection when the economic weights assigned to genetic traits are do not reflect realistic economic values. He describes the

aggregate breeding value of an animal (H) as a linear function of the genetic value of individual traits weighted by their economic value.

$$H = a_1g_1 + a_2g_2 + \ldots\ldots a_ng_n \qquad (1)$$

where g_n is the genetic value of a trait and a_n is the economic value of the trait. Aggregate breeding value is estimated by the partial regression of H on g. Since it is difficult to know the genetic value of any particular trait, a selection index is used. The selection index is a linear function of phenotypic observations (x_n) of traits for an individual where the observations are standardized and expressed as standard deviations as below:

$$H = b_1x_1 + b_2x_2 + \ldots\ldots b_nx_n \qquad (2)$$

where b_n are the weights for the selection index. They are determined by the equation:

$$Pb = Ga \qquad (3)$$

where P is an n * n matrix of the phenotypic covariences of the individual traits, G is an n * n matrix of the genetic covariences of individual traits and b and a are single column vectors of the index and economic weights. The weights for the selection index (b) are calculated by a simple manipulation of equation 3 to:

$$b = P'Ga \qquad (4)$$

The breeding value of superior individuals is defined by the equation:

$$\#H = ir_{HI}\sigma_H \qquad (5)$$

where i is defined as the standardized selection differential, r_{HI} is the correlation of H and I and σ_H^2 is the variance of H. If the economic weights are defined erroneously by a vector defined as a^*, the index coefficients can be defined by a vector, b^* and by a selection index, I^* will result. The genetic superiority of an individual can be termed $\#H^*$ and can be estimated by the formula, $ir_{HI^*}\sigma_H$. The relative efficiency of selection is calculated by dividing $\#H^* = ir_{HI^*}\sigma_H$ by $\#H=ir_{HI}\sigma_H$. This relationship reduces to the relative difference in the correlation of H

and I and H and I'. With further mathematical manipulation, a matrix formulation for the estimation of efficiency of selection, E is defined as:

$$E = a'GP^{-1}Ga(a''GP^{-1}Ga a'GP^{-1}Ga)^{-1/2} \qquad (6)$$

Taking into consideration a two-trait selection index, Smith calculated the efficiency of selection for cases where the heritabilities of the traits were equal, higher or lower than each other; where the traits were positively or negatively correlated or independent; and for various degrees of error in weighting one trait to another.

The results of interest to this study are the ones that reflect the relationship between lean and fat growth rates. Bereskin (1987) estimated the genetic and phenotypic correlations of a number of traits in various breeds of hogs, two of which were average backfat thickness and lean muscle area. The relative heritability of average backfat thickness of 0.480 was more than twice that for lean muscle area which was 0.218. The genetic correlation between these traits was highly negative at -0.650, while the phenotypic correlation was positive at .213. Assuming that lean muscle is worth four times as much as fat and that marketing a hog on a liveweight basis results in the erroneous conclusion that fat and lean have equal value, equations of Smith's model estimates the efficiency of selection of lean hogs as approximately 12.83 per cent. It appears that the assumption that fat and lean muscle in pork are of equal value leads to the use of selection indices that result in breeding programs being less than thirteen per cent efficient in genetically selecting for fast growing hogs with lean carcasses. Nearly ninety per cent of hogs in the U.S. are marketed on a liveweight basis which can lead producers to the assumption that fat and lean have the same value. It is assumed in this study that the efficiency of selection for leanness is about ten to twenty per cent of

that in Canada where the carcass grading system correctly weights the relative values of lean and fat content.

4.5 Genetic Selection in Hog Populations

There are three main components of swine herd performance which are of economic importance. These are: reproductive efficiency; post weaning feedlot performance; and carcass merit. Reproductive traits involve a highly complex interaction of genetic information. It is therefore difficult to select for one particular reproductive trait, since other reproductive traits can be negatively effected. There is, however, a positive epistatic effect on reproductive efficiency associated with crossbreeding two unrelated lines which have superior reproductive traits already.

Feedlot performance and carcass quality do not appear to be effected by crossbreeding as are reproductive traits. According to Fredeen (1982): "traits comprising feedlot performance and carcass merit have moderate to high heritability. They show no measurable heterosis (apart from the hybrid response associated with preweaning growth rate) but do respond to direct selection". Pigs having superior feedlot performance measurements are rapid growing and efficient converters of feed. Carcass merit, which is essentially the reduction of the proportion of fat in a finished animal, enables further economisation of feed, since the growth of fat tissue requires seven times the amount of energy per pound of gain as does the growth of lean tissue.

There have been numerous studies of the use of a simple selection index for lean muscle growth as compared to total growth rate. Fredeen (1982) reported: "Ten generations of selection for more rapid [total] gain increased growth rate but also increased the fatness of carcass. Selection against fat improved carcass merit but growth rate was reduced. In both cases, the economic gains obtained for the trait under selection were offset by unfavourable results for the other trait and there was no meaningful improvement of net economic merit. In contrast,

10th generation averaging approximately 30% higher than the unselected control population. Higher carcass value associated with improved lean content contributed 1/3 of this economic gain. One third was contributed by the reduction of labour and feed costs provided by more rapid feedlot gains. The remaining third came from a reduction in feed requirements, a trait that was not under direct selection". The greater the selection pressure for a particular trait, the more rapid the rate of improvement of the population for that trait.

The Canadian swine industry has used, in one form or another, a nation wide, government administered indexed grading system, based on weight of carcass and the relative proportion of fat in the carcass since 1934. Effective genetic selection for these criteria became possible when back fat probes were introduced to make on-farm selection of breeding stock with optimal carcass fat levels economical. Fredeen (1982) attributes the evolution of a carcass merit system as having provided large economic incentives to follow breeding programs which minimize the fat content of swine carcasses. Since 1968, the numbers of commercially produced hog carcasses grading above the initial base index of 100, has improved at a rate of 2% annually (Fredeen, 1982). The production of fat relative to lean has declined steadily and the Canadian swine industry can be recognized as having accumulated the technology of producing lean fast growing hogs over the past twenty years.

4.6 The Economic Effects of Genetic Selection

Tess (1981) developed a bioeconomic model which simulated the effects of genetic change on life cycle production efficiency in swine herds. The deterministic model was produced from a compilation of individual studies which measured the effects of genetic change in biological and economic efficiency of swine production. The objective was to produce a model which would account for the positive and negative

of the production cycle. For instance, selection pressure which reduces the fat content of a sow's body may have a negative effect on lactation potential and reduce maternal value. The model was able to assess the importance of selecting for certain economically important traits over others and the interaction of changes in genetic traits within a selection index. Since the proportion of fat in a carcass increases as a pig increases in weight, the model assumes that market pigs are raised to a standard liveweight to yield a 95 kilogram carcass in order to avoid biases in the estimations of the model that would be associated with raising pigs to various market weights.

Tess (1981) listed as economically important the following genetic traits: age at puberty, conception rate, number born alive, preweaning viability, milk potential, percent fat at 95 kg empty body weight, growth rate, fat growth rate and lean growth rate. The first five traits are typically described as maternal traits with low heritability. The last four traits are considered growth performance traits and are generally described as highly heritable.

Tess (1981) approached the construction of the model by attempting to account as accurately as possible for the biological and economic inputs needed to sustain a predetermined level of performance (p. 15). In Tess's model, the calories required and the costs associated in the production cycle are dependent on the genetic levels of economically important performance traits. Tess assumes that feed is not a limiting factor in the production cycle. The base level performance parameters represented in his model are of modern crossbred hogs raised in a midwestern United States farrow-to-finish operation.

The interaction of genetic changes on phenotypic traits in the production cycle were accounted for in five subroutines of the model. The Gilt subroutine accounts for the changes in performance relating to raising gilts to breeding age. The Gestation and Lactation subroutines

account for the periods from conception to farrowing and from farrowing through to the weaning and rebreeding. The Weaner and Grower subroutines simulate the weaner and the grower-finisher phases of pig growth.

All the subroutines account for changes in feed requirements, mortality rates, breeding efficiency and culling rates, as well as space, management and heating costs due to independent changes in genetic traits. In order to account for various production goals, four different definitions of efficiency were used. Biological improvements in efficiency were measured as reductions in metabolizable energy in megacalories required per kilogram of lean carcass weight marketed and required per kilogram of empty body weight marketed. Improvements in economic efficiency were measured as reductions in the cost of producing one hundred kilograms of lean carcass and cost reductions of producing one hundred kilograms of live weight.

Tess (1983b, 1986) points out that reductions in metabolizable energy and costs in producing lean carcass represent improvements of the real value of pork carcasses. In contrast, reductions in the metabolizable energy required to produce empty body weight or in the cost of producing live weight represent improvements in pork production in markets which do not effectively differentiate between lean and fat market hogs.

Within the bio-economic model, the seven economically important genetic traits were simulated as improving independently within the bio-economic model by incremental percentages of their individual standard deviations from the mean levels of the base population. The effects of these improvements on production were measured in terms of the four definitions of efficiency. The estimated differences in cost of production as fat content is reduced are given in Table 4.1. These estimates are used later in this study to estimate relative year to year changes in the costs of producing lean carcasses in Canada and the

United States from 1970 to 1989 due to relative changes in the fat content of hog carcasses in each country.

TABLE 4.1 Simulated Economic Efficiency for Changes in Percent Fat at 95 KG. Empty Body Weight

PERCENT CHANGE IN CARCASS FAT	$U.S. PER 100 KG. OF CARCASS LEAN	$U.S. PER 100 KG. OF LIVEWEIGHT
0	169.14	87.89
-5	165.46	88.17
-10	162.15	88.56
-20	155.92	89.33
-30	150.12	90.01
-40	144.84	90.73

Tess (1981, p. 117)

The basic assumption of the current study is that hog producers in the United States limited their efforts in reducing the fat content of hog carcasses in the late 1970's because of perceived and actual economic losses. The economic rationale underlying this re-orientation was that it was recognized that the reduction of fat in hog carcasses was resulting in an increase the costs of producing liveweight. Since most hogs in the U.S. are marketed on a liveweight basis, compensation for producing a leaner carcass would not be directly perceived. Furthermore, because the USDA hog grading system by the late 1970's was classifying nearly all hog carcasses graded in the top two categories, marginal improvements in lean content of carcasses were not recognized. Since genetic improvements occur slowly from generation to generation, there was little economic incentive to make further progress.

This chapter defines genetic selection as a means of directing the development of the technology to produce hogs which have characteristics most valued by consumers. Inadequate information with regard to the relative values of these characteristics is shown to lead to inefficiencies in selection pressure. In the case of the U.S., where most hogs are marketed on a liveweight basis the efficiency of selection for lean carcasses is shown to be about 10 to 20 per cent as efficient

as compared to Canada, where most hogs are marketed on carcass graded basis. Estimates of the reduction in the costs of producing lean carcasses due to genetic selection for leaner carcasses are given.

Chapter 5

In this chapter, economic theory explaining trade patterns which arise from production advantages arising from the levels of technology utilized in the production process rather than in differences in relative factor endowments is outlined. The technology referred to here is the increase of genetic potential in Canadian hogs to produce lean pork which is a result of selection pressures guided by the enforcement of a third party grading system. The theoretical basis for measuring welfare gains due to technologically induced trade will be introduced after a brief discussion of welfare theory.

5.1 Trade Theory

The basis for explaining Canada-U.S. trade patterns of live swine and pork products, beyond claims of relatively higher government subsidization in Canada, can be found in the theory of comparative advantage. The modern interpretation of comparative advantage finds its roots in the Ricardian labour theory of value. Ricardo proposed that the value of any good was determined by the relative amount of labour which is required to produce a unit of a particular good. Further, labour was assumed to be perfectly mobile from one economic activity to another, but not between countries. Ricardo's model of comparative advantage was constructed on the premise of two countries producing two types of goods. One country was able to produce both types of goods with a lesser amount of labour per unit of output, thus having an absolute advantage in the production of both goods. Ricardo imposed the condition that the relative amounts of labour required to produce both goods differed between two countries. He demonstrated that each country would benefit from trade if at least one, or both countries, produced more of the good which required comparatively less labour to produce than the other country.

The Hecksher-Ohlin trade model extended trade theory by focusing on relative endowments of factors of production. According to this

model, in an autarkic situation, the value of a good is determined by the relative abundance of all the factors of production required to produce a good. Under the assumption that technology was freely traded between countries, the Hecksher-Ohlin model concluded that countries would tend to produce and export goods which use most intensively the factors which are relatively abundant. In contrast, countries import goods which require relatively scarce factors to production.

5.2 The Effects of Technology on Trade

Posner (1961) proposed a simple model of how trade patterns are affected by changes in relative technology between two countries. The model extended the Hecksher-Ohlin trade model by relaxing the assumption of equality of technological knowledge. Posner's objective was to lay a theoretical groundwork for the development of trade models which explain why trade takes place when the fundamental differences between two countries are not necessarily factor endowments. He argued that "trade may be caused by technical changes and developments that influence some industries and not others; because particular technical changes originate in one country, 'comparative cost differences' may induce trade in particular goods during the lapse of time taken for the rest of the world to imitate one country's innovation" (Posner, 1961).

Posner (1961) assumed that all factors of production are equally distributed in all trading countries, where each factor earns the same relative proportion of income in each of two countries. The fundamental difference between the two countries is that one country possesses superior factor-saving knowledge in one specific industry. The model also specifies that all industries exist in all countries, so that the imitation of a country's superior technology can take place over a finite period of time. If a country does not possess the industry for which an innovation occurs in another country, it may take an infinite amount of time for the non-innovating country to develop that industry and then to imitate the foreign technology. Supplementary assumptions

are that no tariff or non-tariff barriers to trade exist, exchange rates are fixed, consumer preferences are identical and that domestic forces exist which maintain full employment of factors and a stable growth rate. Transportation costs are also assumed to be insignificant.

Posner (1961) outlined a process by which trade patterns adjust to changes in technology over a specific set of time periods. In the first period, an innovation made by a firm is recognized and imitated by the rest of the domestic industry. The second period is the time taken by a foreign industry to recognize that an innovation has occurred in another country. Finally, there is a learning period associated with the imitation of the new technology by the foreign industry. The sum of these time periods is described as the "imitation lag", which is a supply side phenomenon. A "demand lag" is described as the period of time in which the foreign consumers are not aware of the price differences between their domestically produced product and the cheaper one produced by the innovating country. The "demand lag" is subtracted from "the imitation lag" to yield the period of time in which a product would be imported from the innovating country by the imitating country. Posner's model is summarized in the following table from the point of view of the imitating country as follows:

L_1:	the foreign reaction lag
L_2:	the domestic reaction lag
L_3:	the learning period
$L = L_1 + L_2 + L_3$:	the total imitation lag
d:	the demand lag
L - d:	net import period

The Posner model gives some insights into the patterns of trade of hogs and pork that have developed between the U.S. and Canada. The model provides the theoretical framework to explain trade due to technological differences in the form of cumulative genetic potential and the dynamic nature of technological innovation and adoption over time. The

assumptions of the Posner model can be reconciled to a technology-based explanation of trade between the United States and Canada in live hogs, pork products and genetics with the assumption that genetic selection results in a dynamic accumulation of technology.

The set of lags need not be thought of as fixed time periods but as dynamic rates of innovation and imitation. For instance, the "foreign reaction lag" can be interpreted as representing the rate at which Canadian producers apply genetic selection pressure in order to increase the productivity and efficiency of their swine herds. The rate of decrease of the proportion of fat in hog carcasses produced in Canada is capable of practical measurement.

Similarly, the "domestic reaction lag" is representative of the rate at which individual U.S. producers recognize that their production efficiency and/or product quality is trailing that of Canadian producers. A practical measure of this phenomenon can be the rate at which U.S. producers switch from marketing their hogs on a live weight basis to marketing them on the basis of carcass quality.

The rate of selection pressure applied by American producers in order to catch up to Canadian producers is the "learning lag". The "learning lag" may also include the rate of import of superior genetic potential in the form of breeding animals, sperm, embryos etc. Imports of superior genetics or the elimination of inferior herds of swine may be a strategy adopted by U.S. producers in order to imitate the superior foreign technology.

Finally, the "demand lag" may be described as the rate at which individual U.S. processors recognize that there are differences in the quality of hog carcasses produced in the U.S. as opposed to those produced in Canada. A possible measurement of this lag may be the change in the number of U.S. processors willing to pay premiums on leaner carcasses produced in Canada or simply the rate of increase of premiums paid by U.S. processors for Canadian hogs.

Posner (1961) commented that success in the export of a "innovated" commodity could lead to increased investment in the development of technology by that industry. The increased rate of innovation or technical progress by an innovating country could perpetuate a trade advantage; however it is recognized that there may be some limitations in applying this concept to the hog industry in the long term.

In considering the total process of swine production, the possibility does exist that constraints to genetic selection for leanness may develop if a plateau of technological and economic efficiency is reached. If this was to occur, the quality of pork carcasses could no longer be improved without sacrificing other important production parameters such as sow productivity.

5.3 Other Factors Affecting Trade

A model to analyze the patterns of trade in live swine and pork products that have resulted from technological differences between the United States and Canada must incorporate descriptive parameters, which take into account the differences in the size and structure of the hog markets of each country. These parameters are not usually dealt with in economic literature dealing with technological gap trade theory, since most of these models impose the assumption of instantaneous and complete factor price equalization due to trade. A trade model based on technical differences created by differences in genetic selection may only explain trade as long as all other assumptions of the model hold.

5.3.1 Exchange Rates

One key factor known to affect trade is the variation in exchange rates between the two countries. The Canadian dollar is subject to stabilization policies by the Bank of Canada as is the U.S. dollar by the U.S. Treasury. However, the relative nominal value of the U.S. and Canadian dollar has fluctuated significantly in the recent past. The nominal appreciation of the US dollar against the Canadian dollar has

been widely thought to be responsible for causing a surplus of trade with the United States in the nineteen-eighties. Canadian hog and pork exports to the United States increased over this period. However, Henneberry et al.(1987) contended in a study focused on exchange rate effects on trade, that differences in relative rates of inflation resulted in an actual depreciation in the value of U.S. currency against the Canadian dollar. That is, the Canadian inflation rate was higher than that in the United States during the period when Canadian exports of hogs and pork surged.

The Posner model makes the assumption that exchange rates are fixed, which is not realistic in describing the conditions of trade in live hogs and pork between the U.S. and Canada. However, since exports of hogs increased in spite of unfavourable changes in real exchange rates, it seems reasonable to assume that changes in the exchange rate did not materially affect trade. As Henneberry et al.(1987) concluded "the rising US dollar was not responsible for increasing Canadian hog imports into the US from 1980 to 1983".

5.3.2 Government Subsidization

As noted in the first chapter, OECD mid 1980's estimates of Producer Subsidy Equivalents for pork production in Canada and the U.S. were about the same on a per cent basis. Therefore, a number of other possible economic scenarios could account for the increase in exports of Canadian hogs to the United States from 1978 to 1989. The first is that the costs of production and therefore the price of U.S. hogs rose at a faster rate than the general inflation rate in the United States. The logic of this scenario would be difficult to defend, since most factors of hog production, such as corn, soybean meal, buildings and labour, are not exclusively used in hog production and are subject to domestic and international market forces. Another possible scenario is that U.S. demand for pork increased relative to the demand for pork in Canada. This is clearly not the case, since per capita consumption of pork

declined in the United States and rose in Canada in the same period. It is also unlikely that the relative costs of inputs to hog production in Canada decreased as compared to the United States. Canadian capital costs as represented by relative interest rates tend to be higher than in the U.S.(Bank of Canada Review), although there are a number of national and provincial programs which reduce the costs of capital to Canadian farmers. Labour rates are also generally higher in Canada than in the U.S., while prices of inputs to hog production, such as feedgrains and protein supplements, are closely linked to the United States.

The explanation for trade flows that appears to be most likely is that the Canadian hog industry has become more technically efficient in producing swine and pork relative to the United States. Canada and the United States both produce surplus grains and protein supplements; commodity prices in both countries generally move in tandem and information on most production technology is freely exchanged between countries through international companies servicing the industries, government extension services and academic publications. The Posner model of trade due to differences in technical knowledge can only be applied to the limited case where there are differences in the genetic potential of producing lean carcasses from fast growing swine in both countries. As discussed earlier, the cause of this technological difference appears to be due to the inability of the U.S. hog marketing institutions to articulate consumer preferences for leaner pork and the feature that lard is no longer a highly valuable by-product of pork production.

5.4 Benefits of Trade Induced by Technology

Borkakoti (1975) extended the Posner trade model by analyzing the welfare implications of trade patterns caused by technological innovation with a series of production frontier and utility diagrams. Borkakoti (1975) essentially attempted to assess the gains and losses to

an innovating country and a non-innovating country at various stages of a trade cycle which is initially caused by a technological innovation in one country.

Two specific forms of technological innovation are described: process and product innovations. Process innovation involves a shift in the production function, such that the cost of production declines at all levels of production. Product innovation is an improvement in the quality and/or an expansion in the valued characteristics of a good. In regarding genetic selection as a technology, an increase in process efficiency is analogous to an increase in feed efficiency and/or growth rates, which reduce feed requirements and therefore costs of production. Genetic change that reduces fat content and/or increases lean content in a carcass is analogous to product innovation. Since genetic selection for lean carcasses reduces the costs of producing lean carcasses, it is a process innovation, as well as being reflected as a product innovation.

The earlier discussion of Tess (1983b, 1986) demonstrated that expected genetic selection strategies, when selling on a liveweight basis, would be to minimize costs of production of liveweight hogs by increasing the growth rates of both fat and lean. Because the majority of hogs produced in the U.S. are marketed on a liveweight basis, it can be argued that only this type of process innovation is occurring extensively in the U.S. hog industry with no improvement in the quality of pork occurring. Conversely, when selling on a graded carcass basis, profit maximizing strategies would be oriented to minimizing fat growth rates and maximizing lean growth rate in order to minimize the costs of producing lean carcasses. This type of process innovation appears to be occurring in Canadian swine herds because of carcass grading resulting in the improved quality of pork.

5.4.1 Benefits from Trade Due to Process Innovation

The analysis of the benefits of trade in this study will be confined to that induced by process innovation with recognition that product innovation is simultaneously occurring in Canada. Borkakoti deals with two different sets of assumptions based on a two country, two factor, two output model, where the assumptions postulated by Posner also hold, to examine the distributions of benefits from trade due to technology innovation. The factors of production are assumed to be growing at exogenously determined "relevant rates".

In one scenario described, one country develops a once-and-for-all technological innovation in the process production of the commodity. The innovating country begins to export the commodity and a readjustment of output prices results because of an initial trade imbalance. The terms of trade are altered such that the relative value of the process-innovated export product has declined.

The welfare implications of the this case can be summarized as follows: initially, the innovating country experiences an actual loss of welfare due to the unfavourable change in the terms of trade. The innovating country's export product has been reduced in relative value. When the imitating country is able to develop the new technology, the innovating country again experiences a welfare loss because of the increased relative growth of the imitating foreign industry, which causes a further reduction in value of the innovating country's export product. Conversely, had the innovation occurred in a product which the innovating country imported, there would be a "double" gain in welfare. Initially the gain would be from the growth of its import industry and as the technology was imitated by the foreign industry, imports would again expand, but would be relatively less costly.

Considering the first case as a model for describing the implications of trade between Canada and the U.S. due to the development of technology through genetic selection, some of the assumptions and

predicted results must be considered. The effect of changes in the relative efficiencies of the swine industries of each country on the terms of trade between both countries need to be examined. The point of the first case is that the innovating country experienced a net welfare loss because its terms of trade have been adversely affected due to the innovation. Canada, during the 1980's, faced unfavourable real terms of trade, yet experienced increased exports of hogs and pork to the United States (Henneberry, 1987).

The assumption of equal relative expansion of the factors of production which implies that the relative value of inputs is constant is also unrealistic. However the existence of this assumption simplifies the analysis. Feed ingredient prices are not only affected by the market forces of supply and demand within the hog industry, but by supply and demand effects from domestic production of other animal products, by world markets for all of these commodities and by government subsidies. Changes in the relative value of, for instance, feed, energy and labour, not only affect current production decisions, but also genetic selection criteria. Such changes likely had multiple effects on the swine industries of both countries.

A second area of potential difficulty is that innovations occurring in the swine industries are not once-and-for-all technological advancements, but cumulative. The first case of the model would have to be extended such that all factors including technology are expanding at "relevant" rates to reflect the dynamic nature of the hog industries.

A second case is described with the further assumption that trade only occurred between two countries, if and only if, there was a change in technological expertise of either country. Another assumption is that all other factors of production, including technology, were initially endowed in equal proportions. The assumption of relatively equal exogenous growth of all factors, excluding technology, is also imposed.

The results of the diagrammatic analysis by Borkakoti (1975) of the net welfare gain from a process innovation of a commodity showed that both countries benefited from the innovation through trade, but the non-innovating country was shown to benefit more. When the technology was imitated in the non-innovating country, trade ceased but both countries continued to experience the net benefit of the innovation due to the accelerated growth of the industry affected.

The Posner model and Borkakoti's extensions provide some theoretical base for the analysis of the impact of trade due to technological differences in the form of genetics on the North American swine industry. Borkakoti's method of analysis allows for the intuitive understanding of the potential impact of technological innovation. However, the analysis and results of the analysis are highly dependent on how the diagrams are drawn, that is on the assumptions of the model. Variations of the production possibilities curves could completely reverse the conclusions reached by Borkakoti (1975). The production possibilities curves drawn by Borakoti (1975) are based on the assumption of decreasing returns to scale. It is likely that the hog industries in Canada and the United States have not reached the stage of fully exploiting scale efficiencies. Van Arsdall and Nelson (1985) indicated that there is strong evidence that economies of scale are increasingly being exploited by many U.S. swine producers with the increase in the size of hog farms. Canadian hog farms are continuing to increase in size, providing evidence that swine producers also appear to be attempting to exploit scale economies with herds producing poor quality carcasses exiting the industry the most rapidly (Fredeen, 1984).

5.5 Welfare Theory

Currie, Murphy and Schmitz (1971) summarized the development of the concept and economic measures of consumer and producer surplus. Dupuit is reported to have proposed the area above the price line and below the demand curve as a measure of consumer surplus. Dupuit first

defined consumer surplus as "the difference between the sacrifice which the purchaser would be willing to make in order to get it and the purchase price he has to pay in exchange". Marshall's approach was to define consumer surplus as the extra utility a consumer obtains when purchasing a commodity at a particular price. Consumer surplus could then be measured as the extra expenditure a consumer is willing to make rather than forego consumption relative to the actual price paid for the commodity. These approaches are restricted to the case where the expenditures for the commodity are a relatively small portion of consumers' total expenditure, since they assume that the marginal utility of money is approximately constant.

Developments by Hicks and Henderson focused on the issue of adjusting consumer income to maintain the individual on the same utility curve, while varying the prices and consumption of a commodity. Hicks stressed the importance of compensating variation and equivalent variation in the measurement of utility from consumption if the income effect is not zero. For most goods, using the ordinary demand curve to measure consumer surplus may exaggerate the gains or losses of consumer surplus from a price change for that commodity.

Marshall is reported to have introduced the concept of producer surplus as either direct or indirect surplus utility a seller obtains from the thing that he receives over the thing that he gives up. As a point of contention, a number of authors including Mishan(1959) have contended that the term "producer surplus" is a misnomer and the concept should more correctly be described as economic rent, since the area below the price line and above the supply line represents returns to all factors of production.The measurement of economic rent is similar to but the converse of that of consumer surplus. It is the triangular area below the price line and above the supply curve.

The quantitative measurement of consumer and producer surplus due to agriculture research was first attempted by Schultz, who in 1953

estimated the value of inputs saved from increased agriculture technology. This was accomplished by estimating the cost of producing the 1950 agriculture output of the United States by using 1910 agriculture technology. Griliches (1958) used a similar approach to estimate the social benefit of hybrid corn. Consumer surplus was calculated by estimating the increase in cost of production of corn for a perfectly elastic supply curve if the hybrid technology were lost. Grilliches calculated the net economic surplus in the situation of outward shifts in perfectly inelastic supply curves with the development of hybrid technology.

In a review article, Norton and Davis (1981) pointed out several sets of formulas that have been developed to estimate consumer and producer surplus under varying conditions. Linder and Jarrett(1978) pointed out the importance of recognizing that biases in estimates in consumer and producer surpluses could occur if the shift in the supply function was not parallel. A non-parallel shift in the supply function could occur if the technology developed were related to scale efficiency or not adopted uniformly throughout the industry in question. Linder and Jarrett provide a general model to estimate the consumer and producer surplus for linear supply and demand curves, however their work was criticized for a computational error by Rose (1980) and by Wise and Fell (1980).

The primary differences between these models are the nature of the supply shifts, these being either divergent, convergent or parallel. Technological innovation can either have an output effect causing a vertical shift of the supply function or a cost reducing effect which would be associated with a horizontal shift of the supply function. Another important consideration is the elasticity of demand. The more inelastic the demand for a commodity, the less the producer will gain from a technological innovation while the consumer gains.

5.6 Measuring the Benefits of Technologically Induced Trade

To measure the benefits of improving technology in producing a tradeable commodity, a number of factors must first be taken into account. Akino and Hayami (1975), Ramalho de Castro (1974) and Schuh (1979) developed models to measure the aggregate level and distribution of the benefits derived from research into tradeable commodities, based on the assumption that improved technology shifts the supply curve in any country out. Edwards and Freebairn (1984) developed a model which does not impose the assumption that world prices would not vary due to trade that results from a cost reducing improvement in production technology in a trading country. This is a more generalized approach than the models used by Martin and Havlicek (1977) and Sarris and Schmidtz (1981) which allowed for changes in world prices through the use of an excess demand curve but constrained shifts of the supply curve to occur within one of the two trading countries. Furthermore the Edwards-Freebairn model also measures welfare benefits from research in both countries and not just the innovating country. Welfare benefits are measured in isolation from other factors which may shift either

The Edwards-Freebairn model assumes competitive market clearing between two freely trading countries. Supply and demand functions for the commodity are determined independently within each country. Prices are obtained by horizontally summing the supply and demand for each country. All producers and consumers face the same price for a commodity and exports from one country equal imports of the other country. Shifts in the supply curves are assumed to be parallel which gives a first approximation of the research benefits which can be measured gross or net of the costs of research. For the sake of simplicity, payments for the exchange of the new technology were not taken into consideration.

A number of outcomes are predicted by Edwards and Freebairn (1984) based on their model: The first is that an innovating country's producers will always gain from technical change, when costs of

production in other countries are unaffected. Secondly, a country will receive a net social benefit from research, if this causes costs in other countries to fall by no more than twice as much as in the innovating country. Thirdly, as a country's share of world trade increases, the gains from technical change stimulated by research decline. For a large exporter, the gain to national welfare is decreased substantially if the commodity faces inelastic demand. Furthermore, innovations which overcome those problems of production for an exportable commodity that are unique to the region, will have higher national benefits. Benefits tend to be greater, the longer it takes other countries to innovate. Finally, a country will gain more from research in a non-traded commodity than an exported commodity.

Chapter 6

This chapter deals with the empirical analysis of the welfare benefits of the trade of hogs and pork induced by changes in technological efficiency between Canada and the United States.

6.1 Model for Estimating Welfare Benefits

The Edwards-Freebairn model, outlined in Chapter 5, is used to estimate the current value of the welfare benefits derived from the trade in hogs and pork, on a carcass basis, between the United States and Canada due to on-going genetic selection for leaner carcasses. The periods analyzed are from 1970 to 1979 and 1980 to 1989.

The period from 1970 to 1979 covers the initial effects of the Canadian hog carcass grading system implemented in 1968. During this period, U.S. lard production declined steadily relative to pork production while the proportion of hogs grading U.S. #1 and #2 increased steadily. Therefore, the period from 1970 to 1979 is assumed to be characterized by equal selection intensity for leanness in hogs in both Canada and the United States. During this time period, the United States as a consistent net exporter of pork to Canada. Tariffs on imports of pork products in Canada were ten times as great as tariffs applied to U.S. imports of pork.

During the period 1980 to 1989, in the U.S., eighty to ninety per cent of hogs were marketed on a liveweight basis, which provides little incentive to reduce fat in hog carcasses. The estimate of selection efficiency when the economic value of fat and lean content are equally weighted is about 13 per cent. Most U.S. hog carcasses graded either #1 or #2 from 1980, until the revision of the USDA grading system in 1984. This revision to the USDA hog grading system does not directly and objectively provide economic incentives to increase the lean content of hog carcasses. Therefore, it is assumed that there was only marginal selection intensity for leanness in the United States from 1980 to 1989 as compared to the period from 1970 to 1979 of between ten and twenty

per cent. Because of the broad use of the hog carcass grading system in Canada and the revisions to the system which increasingly penalized the production of fat hog carcasses and provided premiums to lean carcasses, it is assumed that there was continued selection intensity for leanness in Canada from 1980 to 1989 as compared to the previous ten years. During this period, Canada became a consistent exporter of hogs and pork to the United States.

As discussed in Chapter 1, there were no tariffs applied to pork imports by either country after 1979, although countervailing duties were applied to U.S imports of pork and live hogs from Canada during the latter half of the 1980's. These countervailing duties likely offset any increases in relative government subsidization of pork production in Canada. The time periods chosen for analysis are equal in length in order to facilitate direct comparisons of the estimates of welfare gains.

The model specifies four linear supply and demand functions for two countries plus the market equilibrium condition that all that is produced is consumed. The basic model is summarized below:

Canadian demand for pork $$Q_{dCt} = a_t - bP_t \qquad (1)$$

Canadian supply of pork $$Q_{sCt} = \alpha_t + \beta P_t \qquad (2)$$

U.S. demand for pork $$Q_{dUt} = c_t - dP_t \qquad (3)$$

U.S. supply of pork $$Q_{sUt} = \tau_t + \eta P_t \qquad (4)$$

Market Equilibrium

$$Q_t = Q_{dct} + Q_{dut} = Q_{sCt} + Q_{sUt} \quad (5)$$

where P_t is the price at time, t, Q_{dc} and Q_{du} are the quantities of pork consumed in Canada and the United States, respectively, at price, P_t, while Q_{sc} and Q_{su} are the quantities of pork produced in Canada and the United States, respectively at price, P_t. The parameters b and d represent the slopes of the demand curves for pork in Canada and the United States, respectively, while β and η represent the slopes of the supply curves. The slopes of the demand and supply curves are calculated by multiplying the relevant elasticity by the quantity demanded or supplied at the equilibrium price divided by the equilibrium price. Since annual cost reductions due to genetic improvements are relatively small as compared to total costs of production and represent minor annual shifts of the supply curves, the slopes of the supply and demand curves are assumed to be linear. The parameters a, α, c, and τ are defined as constants.

Vertical supply shifts resulting from technological change are cost reductions represented by a per unit decline in the cost of production, k_t in Canada and h_t in the United States and lead to lower prices, P'. Where Φ is defined as equal to the sum of the per unit cost declines for each country multiplied by their respective supply slopes and Γ is defined as the sum of the slopes of the supply and demand curves in each country as follows:

$$\Phi_t = \beta k_t + \eta h_t \quad (6)$$

$$\Gamma = b + \beta + d + \eta \quad (7)$$

The effects of research on the supply equations are defined as:

$$Q'_{sCt} = \alpha_t + \beta k_t + \beta P'_t \tag{8}$$

$$Q'_{sUt} = \tau_t + \eta h_t + \eta P'_t \tag{9}$$

From the Edwards-Freebairn model, the computational formulas for estimating gains to consumers and producers in Canada and the United States resulting from the adoption of cost reducing technology in the hog industry are as follows:

Consumer gains in Canada,

$$\begin{aligned} G^C_{ct} &= 1/2\,(P - P')\ (Q_{dCt} + Q'_{dCt}) \\ &= \frac{\phi_t}{\Gamma}\, Q_{dCt} + \frac{b\phi_t^2}{2\Gamma^2} \end{aligned} \tag{10}$$

Producer gains in Canada,

$$\begin{aligned} G^C_{pt} &= 1/2\,[k_t - (P - P')]\ (Q_{sCt} + Q'_{sCt}) \\ &= (k_t - \frac{\phi_t}{\Gamma})\, Q_{sCt} + \frac{\beta}{2}(k_t - \frac{\phi_t}{\Gamma})^2 \end{aligned} \tag{11}$$

Aggregate gains in Canada,

$$\begin{aligned} G^C_t &= G^C_{ct} + G^C_{pt} \\ &= k_t\, Q_{sCt} - \frac{\phi_t}{\Gamma}(Q_{sCt} - Q_{dCt}) + \frac{b\phi^{2r}}{2\Gamma^2} + \frac{\beta}{2}(k_T - \frac{\phi_t}{\Gamma})^2 \end{aligned} \tag{12}$$

Consumer gains in the United States,

$$\begin{aligned} G^U_{ct} &= 1/2\,(P - P')\ (Q_{dUt} + Q'_{dUt}) \\ &= \frac{\phi_t}{\Gamma}\, Q_{dUt} + \frac{d\phi_t^2}{2\Gamma^2} \end{aligned} \tag{13}$$

Producer gains in the United States

$$\begin{aligned} G^U_{pt} &= 1/2\,[h_t - (P - P')]\ (Q_{sUt} + Q'_{sUt}) \\ &= (h_t - \frac{\phi_t}{\Gamma})\, Q_{sUt} + \frac{\eta}{2}(h_t - \frac{\phi_t}{\Gamma})^2 \end{aligned} \tag{14}$$

Aggregate gains in the United States,

$$G_t^U = G_{ct}^U + G_{pt}^U$$
$$= h_t Q_{sUt} - \frac{\phi_t}{\Gamma}(Q_{sUt} - Q_{dUt}) + \frac{d\phi^2\tau}{2\Gamma^2} + \frac{\eta}{2}(h_T - \frac{\phi_t}{\Gamma})^2 \qquad (15)$$

Total consumer gains,

$$G_{ct} = G_{ct}^C + G_{ct}^U \qquad (16)$$

Total producer gains,

$$G_{pt} = G_{pt}^C + G_{pt}^U \qquad (17)$$

World aggregate gain,

Costs of transportation between areas of production and consumption in both countries are ignored since regions of surplus production of hogs and pork in eastern Canada are relatively close to the U.S. border and are almost as close to major areas of pork consumption in the eastern United States as the mid-western states. Most of the Canadian population is located relatively close to the U.S. border. It appears that much of the transportation costs of moving hogs and pork to and from the U.S. and Canada would be based on U.S. rates.

Although western provinces, in particular Alberta, are distant from eastern U.S. markets, they are relatively as close to west coast markets as mid-western states. Further, because shipping costs tend to be higher within Canada than in the U.S., there may be occasions in western provinces, where the costs of shipping hogs and pork to other provinces is as high or higher than exporting to the United States. This situation may provide some incentive to export rather than supply the domestic market. However, the incentive would have to be large enough to overcome other trade barriers such as quarantine and health inspection costs and border processing time. Overall, it is concluded that the cost of transportation is probably not a critical factor affecting Canadian exports of pork to the United States.

Welfare gains and losses are calculated for each individual year for Canadian and U.S. consumers and producers. The present value of this stream of gains or losses is calculated assuming a real interest rate of five percent with the following formula:

$$P.V.\ (i) = \sum\ (1+r)^{-t} \cdot G_t\ (i) \qquad (18)$$

where: P.V. (i) are the sums of the present values of gains for group, i at time, t, and G_t is the gain to group i, in years one to t. Although interest rates tend to be higher in Canada than in the U.S., after taking into consideration relative rates of inflation, real interest rates were about five per cent from 1970 to 1989 in both countries. For the sake of comparison, the present values of welfare gains are calculated at the ends of the periods from 1970 to 1979 and 1980 to 1989 separately and then over the whole period of study from 1970 to 1989 in Tables 6.10 to 6.17.

6.2 Canadian and U.S. Hog Carcass Prices

From the results of Tess (1981) and other researchers, the reduction of fat in pork carcasses leads to an increased cost of liveweight production but a decreased cost of lean pork production. Therefore, to estimate the welfare gains from reducing fat in pork carcasses and the subsequent reduction in the cost of producing pork, carcass prices must be used rather than liveweight values.

The Ontario hog market is a central Canadian market where large numbers of hogs are produced and consumed. There is also significant trade in hogs and pork between Ontario and other provinces as well as the United States. Given Ontario's market size and trade volumes, the Toronto index-100 hog carcass price per kilogram established by the Ontario Hog Marketing Board is used here as a representative price for Canadian hog producers. Agriculture Canada in the *Livestock and Meat Trade Report* publishes the weekly pooled producer payment for index-100 hogs for each significant province or region in Canada. The weighted

average annual price is published by Statistics Canada in *Livestock and Animal Products Statistics*, Catalogue No. 23-203.

Hog producers are capable of adjusting their production and breeding practices to improve the quality of the hogs that they market. Through the structure of grades for slaughter hogs, Canadian hogs producers have a price incentive to produce hogs that will receive a premium according to the carcass grade. Agriculture Canada publishes the weekly average grades of marketed slaughter hogs by province as well as the National weighted average index. The average annual index-100 price is multiplied by the average index of hogs to obtain the annual average carcass price for hogs marketed in Ontario on a Canadian dollars per kilogram basis.

This series of nominal prices is converted to comparable real prices by expressing them in terms of the base year of 1987. The annual Consumer Price Index (CPI) series published by Statistics Canada is used to adjust the average hog carcass prices to the base year of 1987. The CPI is used rather than those estimated for the food sector alone or for livestock in particular since a comparable representative U.S. series is needed for the comparison and the objective of this study is to estimate welfare gains in the context of the whole economies of the U.S. and Canada. The real prices were then multiplied by one thousand to convert them to a per tonne basis to accommodate the use of large numbers associated with national production and consumption. The average real price of hog carcasses in Ontario from 1970 to 1979 was $2,823 per tonne in 1987 dollars. From 1980 to 1989 the comparable average price was $1,854 per tonne and from 1970 to 1989 this was $2,339 per tonne.

TABLE 6.1 Ontario Average Indexed Hog Carcass Prices (Base 1987=100)

YEAR	ONTARIO INDEX-100 HOG CARCASS PRICES $CAN/KG	AVERAGE INDEX OF ONTARIO HOG CARCASSES	AVERAGE ONTARIO HOG CARCASSES $CAN/KG	CANADIAN CONSUMER PRICE INDEX 1987=100	REAL ADJUSTED ONTARIO HOG CARCASS PRICES $CAN/TONNE
1970	0.710	100.5	0.714	29.67	2,405
1971	0.570	100.7	0.574	30.54	1,875
1972	0.826	100.8	0.833	31.98	2,597
1973	1.208	100.7	1.217	34.44	3,523
1974	1.111	101.2	1.124	38.21	2,938
1975	1.486	101.7	1.511	42.33	3,560
1976	1.417	101.8	1.443	45.51	3,160
1977	1.347	102.0	1.374	49.13	2,791
1978	1.543	101.0	1.558	53.47	2,906
1979	1.418	102.1	1.448	58.39	2,474
1980	1.306	102.4	1.337	64.33	2,073
1981	1.547	102.4	1.584	72.36	2,185
1982	1.841	102.6	1.889	80.17	2,351
1983	1.564	102.9	1.609	84.80	1,893
1984	1.606	103.3	1.659	88.49	1,870
1985	1.514	103.7	1.570	92.04	1,701
1986	1.798	103.7	1.865	95.80	1,941
1987	1.759	103.5	1.817	100.00	1,817
1988	1.393	103.6	1.443	103.62	1,390
1989	1.384	104.10	1.441	109.26	1,315

Statistics Canada, *Livestock and Animal Products Statistics*, Cat. No. 23-203.

In the United States, hog prices are usually quoted on a liveweight basis, which does not give a direct indication of relative carcass value. The USDA does, however, estimate a farm level average carcass value of hogs monthly and annually. These values are published in the monthly USDA Livestock and Poultry Situation and Outlook Report. These carcass value estimates are indexed to the base year of 1987 using the consumer price index estimated by the U.S. Bureau of Labor

Statistics published in the annual USDA *Agricultural Statistics*. The average real farm value of U.S. hog carcasses from 1970 to 1979 was $3,233 per tonne in 1987 Canadian dollars; from 1980 to 1989, the value was $2,205 per tonne and from 1970 to 1989, this was $2,719 per tonne.

TABLE 6.2 U.S. Average Gross Farm Hog Carcass Values (Base 1987=100)

YEAR	U.S. GROSS FARM VALUE OF HOG CARCASSES $U.S./CWT	U.S. GROSS FARM VALUE OF HOG CARCASSES $US/TONNE	U.S. CONSUMER PRICE INDEX 1987=100	EXCHANGE RATE $CAN/$US	INDEXED U.S. GROSS FARM VALUE OF HOG CARCASSES $CAN/TONNE
1970	43.00	948	34.18	1.0440	2,895
1971	34.90	769	35.65	1.0098	2,179
1972	49.60	1,093	36.83	0.9905	2,941
1973	73.80	1,627	39.12	1.0010	4,163
1974	63.60	1,402	43.41	0.9780	3,159
1975	86.50	1,907	47.38	1.0173	4,094
1976	75.80	1,671	50.11	0.9861	3,288
1977	70.20	1,548	53.35	1.0635	3,085
1978	82.50	1,819	57.43	1.1402	3,611
1979	72.20	1,592	63.90	1.1715	2,918
1980	68.30	1,506	72.54	1.1690	2,427
1981	75.50	1,664	80.07	1.1990	2,493
1982	94.30	2,079	84.97	1.2341	3,019
1983	81.40	1,795	87.71	1.2324	2,522
1984	83.30	1,836	91.44	1.2948	2,600
1985	76.20	1,680	94.70	1.3652	2,422
1986	87.30	1,925	96.53	1.3894	2,770
1987	87.90	1,938	100.00	1.3260	2,570
1988	73.80	1,627	104.10	1.2309	1,924
1989	75.00	1,653	109.10	1.1842	1794.8

USDA, *Agricultural Statistics*

The estimated U.S. carcass prices are then converted to Canadian dollar equivalents using annual average noon exchange rates for U.S.

dollars published monthly in the *Bank of Canada Review*. The values are then converted to a per tonne basis by multiplying by one thousand.

6.3 Canadian and U.S. Pork Production and Consumption

The objective of this study is to estimate the welfare gains and losses from genetic selection for lean carcasses in Canada and the United States. Following the Edwards-Freebairn model, the requirement that total consumption must equal total production is imposed as estimation of welfare gains and losses would be complicated if trade with third countries or the rest of the world were to be included. In any event, Canada and the United States do not engage in appreciable trade of live hogs, other than small numbers of breeding stock, with third countries. Typically, Canada exports from two to three thousand hogs per annum to countries other than the U.S. and these exports are primarily purebred breeding stock. The U.S. exports of live hogs varied from ten to twenty-five thousand head per annum through most of the 1970's and 1980's with the majority being exported to Mexico. In 1988 and 1989 Mexico increased its imports of live swine from the U.S. to about ninety thousand head, however, this was only one tenth of a per cent of total U.S. slaughter for those years. There is also little trade in fresh or frozen pork with third countries with the exception of Denmark and Poland, which exports quantities of prepared or preserved pork products to the United States (Fig. 1.1, p.2). Overall, these quantities are not likely to affect prices of pork carcasses in Canada and the United States. However, if these volumes were included in the estimation of the model, they would bias the estimates of welfare gains and losses. Therefore, all the production and consumption data for the United States and Canada are adjusted to net out imports and exports of hogs and pork to and from third countries.

Canadian hog carcass production is estimated for each year from 1970 to 1989 by adding the total number of hogs slaughtered to total exports of live hogs to the United States and subtracting total imports

of live hogs. These numbers are then multiplied by the average cold trimmed carcass weight in kilograms as published by Statistics Canada in *Livestock and Animal Products Statistics*, Catalogue No. 23-203.

Canadian consumption of pork is estimated by adding imports of pork from the United States to total Canadian production including production from hogs imported for slaughter from the US and subtracting total exports of pork. The data for these calculations are presented in Table 6.3.

TABLE 6.3 Canadian Pork Supply and Disappearance (THOUSANDS OF TONNES)

YEAR	CANADIAN SLAUGHTER '000 HEAD	LIVE IMPORTS FROM U.S. '000 HEAD	AVERAGE CARCASS WEIGHT (KG.)	PORK IMPORTS FROM U.S.	TOTAL PORK IMPORTS	TOTAL PORK EXPORTS
1970	10,599	0.0	70.2	10,833	11,994	32,340
1971	11,351	0.0	71.5	6,631	7,758	45,160
1972	10,997	0.0	71.4	15,696	20,510	52,400
1973	10,656	0.0	71.3	18,450	24,639	57,070
1974	10,700	0.0	71.7	36,484	39,307	41,960
1975	9,164	0.0	71.4	53,118	55,462	40,800
1976	8,969	0.0	71.7	109,540	111,803	39,350
1977	9,037	0.0	71.7	116,143	117,856	59,456
1978	9,940	0.0	74.6	67,577	70,061	72,139
1979	1,201	0.0	74.1	40,375	42,693	101,612
1980	13,977	0.0	73.9	21,171	22,081	149,277
1981	13,691	0.6	74.2	22,952	25,007	164,354
1982	13,458	0.4	74.8	17,504	18,976	207,898
1983	13,702	0.2	75.2	19,975	24,316	201,205
1984	13,886	0.0	75.2	11,076	18,531	223,869
1985	14,452	0.0	75.3	8,071	21,571	250,806
1986	14,443	0.0	76.0	9,794	18,006	271,898
1987	14,853	0.0	76.1	7,999	22,181	301,086
1988	15,553	0.0	76.5	8,921	14,835	318,787
1989	15,530	0.0	76.2	9,258	12,643	304,817

Statistics Canada, Cat. No. 23-203

Hog carcass production and consumption in the United States was estimated in a similar fashion using statistics published by the USDA in *Agricultural Statistics*. The data for these calculations are presented in Table 6.4.

TABLE 6.4 U.S. Pork Supply and Disappearance (THOUSANDS OF TONNES)

YEAR	U.S. SLAUGHTER '000 HEAD	LIVE IMPORTS FROM CANADA '000 HEAD	AVERAGE CARCASS WEIGHT (KG.)	PORK IMPORTS FROM CANADA	TOTAL PORK IMPORTS	TOTAL PORK EXPORTS
1970	85,817	73	69.9	27,567	222,716	27,749
1971	94,438	84	70.3	31,145	224,984	29,618
1972	84,707	87	72.1	28,199	244,035	45,022
1973	76,795	88	74.4	31,010	241,767	72,874
1974	81,762	196	75.3	21,790	221,355	42,913
1975	68,687	29	74.8	13,624	199,129	91,134
1976	73,784	44	75.3	9,837	212,737	137,469
1977	77,303	41	77.1	11,902	199,583	125,140
1978	77,315	186	77.6	25,530	224,531	100,166
1979	89,099	130	78.0	49,484	226,345	97,385
1980	96,074	236	78.0	94,474	249,478	84,215
1981	91,575	144	78.5	97,323	245,396	100,885
1982	82,190	303	78.5	139,558	277,601	69,477
1983	87,584	455	78.5	136,569	318,425	70,787
1984	85,168	1,345	78.5	178,846	432,695	51,522
1985	84,492	1,150	79.4	213,190	511,567	40,723
1986	79,598	500	80.3	235,254	502,132	27,209
1987	81,081	425	80.3	266,037	542,048	34,963
1988	87,794	865	83.1	269,765	515,740	88,583
1989	88,691	1,213	79.9	240,428	406,423	121,393

USDA, *Agricultural Statistics*.

Initial analysis of the adjusted pork production and consumption figures for Canada and the United States indicates that the size of the North American pork market expanded almost continuously from 1970 to 1989 (Table 6.5). Until 1980, pork production in the United States was

usually larger than consumption, while after 1980, the reverse became true. Canadian consumption of pork grew steadily from 1970 to 1989, while pork production had a variable growth rate until 1979. Since 1980, Canadian pork production grew at a more rapid rate than consumption.

TABLE 6.5 U.S. and Canadian Adjusted Pork Production and Consumption (THOUSANDS OF TONNES)

YEAR	ADJUSTED U.S. PRODUCTION	ADJUSTED U.S. CONSUMPTION	ADJUSTED CANADIAN PRODUCTION	ADJUSTED CANADIAN CONSUMPTION
1970	5,972,657	5,994,473	744,649	722,833
1971	6,610,834	6,641,231	803,437	773,041
1972	6,073,600	6,092,409	767,636	748,826
1973	5,652,779	5,670,909	743,530	725,400
1974	6,134,875	6,135,319	761,765	761,321
1975	5,100,564	5,063,266	629,359	666,656
1976	5,524,485	5,428,089	616,885	713,282
1977	5,948,773	5,847,711	603,600	704,661
1978	5,949,958	5,922,309	709,276	736,925
1979	6,884,263	6,903,086	847,246	828,022
1980	7,414,116	7,505,826	996,541	904,831
1981	7,096,905	7,182,538	960,170	874,537
1982	6,373,744	6,519,530	962,058	816,272
1983	6,786,394	6,938,699	1,001,502	849,198
1984	6,537,359	6,810,652	1,104,727	831,434
1985	6,582,974	6,879,398	1,141,925	845,501
1986	6,333,085	6,598,704	1,101,235	835,617
1987	6,448,632	6,740,798	1,129,460	837,295
1988	7,143,293	7,476,035	1,212,694	879,954
1989	6,874,740	7,202,825	1,215,911	887,827
ANNUAL AVERAGES				
1970-79	5,985,279	5,969,920	722,738	738,097
1980-89	6,759,242	6,985,500	1,082,622	856,247
1970-89	6,372,261	6,477,710	902,680	797,172

6.4 Price Elasticities of Supply and Demand

Since, in this study, the estimates of quantities of pork supplied and consumed in Canada and the United States are artificially adjusted to exclude imports and exports from third countries, they are not suitable for the estimation of supply and demand elasticities. Further, it is not within the scope of this study to estimate supply and demand elasticities for pork, since relatively sophisticated and consistent estimates have been made by other researchers for the period in question in this study.

In Tables 6.1 to 6.15, welfare estimates are calculated with the assumption that the supply and demand elasticities for pork in Canada and the U.S. are the same to allow for comparisons of the effects of factors not related to differences in supply and demand elasticities between the two countries. Since a number of studies indicate that there are differences between the supply and demand elasticities in Canada and the U.S., in Tables 6.16 and 6.17, actual estimates of supply and demand elasticities for pork in Canada and the U.S. are used to approximate more realistic estimates of welfare benefits.

Relevant estimates of demand elasticities for pork in Canada and the United States from various studies have been described and discussed in the second and third chapters and the results of these are summarized in Table 6.6. Estimates of demand elasticities for meat, including pork, in the United States by Moschini and Meilke (1989) provide estimates covering much of the period of time examined in this study. The estimates of elasticity of demand for pork in Canada by Reynolds and Goddard (1991) parallel those by Moschini and Meilke (1989). Both studies concluded that demand structures for meat including pork in Canada and the United States had changed over the period of this study.

TABLE 6.6 Canadian and U.S. Pork Demand and Supply Elasticities

AUTHOR	DATA	MODEL	ELASTICITIES
CANADIAN DEMAND ELASTICITIES FOR PORK			
Reynolds and Goddard (1991)	1968-1987	AIDS	1971 -0.81 1984 -0.68
Chen and Veeman (1991)	1960-1987	Dynamic AIDS	-0.82
Al-Zand and Lavoie (1987)	1970-1984	OLS	-0.80
Young (1987)	1967-1984	Maximum Likelihood	-0.55 to -0.67
Curtin, Theoret and Zafiriou (1987)	1968-1983	OLS	-0.75
Hassan and Johnson (1979)	1965-1976	Maximum Likelihood	-0.89
Martin and Zwart (1974)	1961-1972		-0.47
CANADIAN SUPPLY ELASTICITIES FOR PORK			
Martin and Zwart (1974)	1961-1972	E. Canada	Short Run 0.22 Long Run 0.89
UNITED STATES DEMAND ELASTICITIES FOR PORK			
Moschini and Meilke (1989)	1967-1987	AIDS	1975 -1.02 1976 -0.84
Hahn (1988)	1960-1984	MGF	-0.78
Byong-Ho Kim (1984)	1983	AIDS	-0.86
Hayenga et al. (1981)	1970-1979	OLS	-0.48 to -0.51
Yeboah (1981)	1960-1977	2SLS	-0.65 to -0.68
Martin and Zwart (1974)	1961-1972		-0.37
George and King (1971)	1962-1966	OLS	-0.41
UNITED STATES SUPPLY ELASTICITIES FOR PORK			
Yeboah (1981)	1960-1977	2SLS	0.02 to 0.10
MacAuley (1978)	1966-1976	OLS	0.09 to 0.50
Martin and Zwart (1974)	1961-1972		Short Run 0.16 Long Run 0.43
Holt and Johnson			10 QTRS 0.66 20 QTRS 1.60 Long Run 2.01

The Edwards-Freebairn model assumes constant elasticity of supply and demand in both countries, but allows for parallel shifts in the supply and demand curves over time. In this study elasticities of supply and demand are assumed to be constant within the period, but not necessarily between periods.

Since production and consumption has headed upward in both countries, estimates of the slopes of the supply and demand curves used in the estimation of the Edwards-Freebairn model are calculated and compared at the means of both the adjusted production and consumption levels for the entire period from 1970 to 1989 and at the means of production and consumption for the two periods of 1970 to 1979 and 1980 to 1989. For each period, the slopes of the demand curves within each country are calculated by multiplying the estimate of demand elasticity for pork by the average consumption of pork carcasses over the period in question and dividing by the average price of pork carcasses for that period. Similarly, the slopes of the supply curves for each country and period are calculated by multiplying the estimate of supply elasticity of pork carcasses by the average production in the period in question and dividing by the average price of carcasses in that period.

The slopes of the supply and demand curves are calculated using both Ontario average hog carcass prices and U.S. gross farm values of hog carcasses in 1987 real Canadian dollars. These estimates are summarized in Tables 6.7 and 6.8. It should be noted that the slopes calculated based on U.S. farm carcass values are consistently about eighty per cent of the comparable slopes estimated using Canadian hog carcass prices. This is because average Ontario hog carcass prices tend to be about eighty per cent of U.S. gross farm hog carcass values.

TABLE 6.7 Slope Estimates of U.S and Canadian Pork Supply and Demand Curves Using Adjusted Indexed Ontario Hog Carcass Prices (TONNES PER CANADIAN DOLLAR)

ESTIMATE OF ELASTICITY	U.S. SUPPLY	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN SUPPLY	SLOPE ESTIMATE
1.60	1970-1989	4360	0.89	1970-1989	344
	1970-1979	3392		1970-1979	228
	1980-1989	5835		1980-1989	520
1.00	1970-1989	2725	1.00	1970-1989	386
	1970-1979	2120		1970-1979	256
	1980-1989	3647		1980-1989	584
0.50	1970-1989	1363	0.50	1970-1989	193
	1970-1979	1060		1970-1979	128
	1980-1989	1823		1980-1989	292
ESTIMATE OF ELASTICITY	U.S. DEMAND	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN DEMAND	SLOPE ESTIMATE
-1.02	1970-1989	-2826	-0.81	1970-1989	-276
	1970-1979	-2157		1970-1979	-212
	1980-1989	-3844		1980-1989	-374
-0.84	1970-1989	-2327	-0.68	1970-1989	-232
	1970-1979	-1776		1970-1979	-178
	1980-1989	-3166		1980-1989	-314
-0.90	1970-1989	-2493	-0.90	1970-1989	-307
	1970-1979	-1903		1970-1989	-235
	1980-1989	-3392		1980-1989	-416
-0.60	1970-1989	-1662	-0.60	1970-1989	-205
	1970-1979	-1269		1970-1979	-157
	1980-1989	-2261		1980-1989	-277

TABLE 6.8 Slope Estimates of U.S and Canadian Pork Supply and Demand Curves Using U.S. Gross Farm Values of Hog Carcasses (TONNES PER CANADIAN DOLLAR)

ESTIMATE OF ELASTICITY	U.S. SUPPLY	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN SUPPLY	SLOPE ESTIMATE
1.60	1970-1989	3585	0.89	1970-1989	282
	1970-1979	2962		1970-1979	199
	1980-1989	4407		1980-1989	393
1.00	1970-1989	2241	1.00	1970-1989	317
	1970-1979	1851		1970-1979	224
	1980-1989	2754		1980-1989	441
0.50	1970-1989	1120	0.50	1970-1989	159
	1970-1979	926		1970-1979	112
	1980-1989	1377		1980-1989	221
ESTIMATE OF ELASTICITY	U.S. DEMAND	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN DEMAND	SLOPE ESTIMATE
-1.02	1970-1989	-2323	-0.81	1970-1989	-227
	1970-1979	-1883		1970-1979	-185
	1980-1989	-2903		1980-1989	-283
-0.84	1970-1989	-1913	-0.68	1970-1989	-191
	1970-1979	-1551		1970-1979	-155
	1980-1989	-2391		1980-1989	-237
-0.90	1970-1989	-2050	-0.90	1970-1989	-252
	1970-1979	-1662		1970-1989	-205
	1980-1989	-2562		1980-1989	-314
-0.60	1970-1989	-1367	-0.60	1970-1989	-168
	1970-1979	-1108		1970-1979	-137
	1980-1989	-1708		1980-1989	-209

6.5 Estimation of Cost Changes due to Genetic Selection

The estimation of changes in costs of production due to technological change is based on the relative changes in the costs estimated by Tess (1981). As described in Chapter 4, Tess used average costs of production in Nebraska for the average type of pig produced on moderately sized U.S. farms in 1979. The model is assumed to apply also to Central Canadian hog production. The largest portion of costs of production can be attributed to feed costs with the grain portion of the feed generally obtained from local markets, while the protein portion of the feed is purchased from soybean or canola crushers or their agents. It is assumed that feed ingredient prices in both countries are determined exogenously to the hog industry and are the same in each country. For instance average Chatham corn prices in Ontario have been generally within $5 to $15 per tonne of the USDA's estimates of the national average price for farmer owned reserves since 1970. Although soybean meal prices are generally higher in Canada than in the U.S., there has been growing use of canola meal in hog rations in Canada to offset this difference. The assumption seems reasonable since in general these inputs are subject to the same changes in global fundamental supply and demand factors and because of the opportunities for arbitrage between markets in North America. Similarly, as discussed in Chapter 1, it is assumed that the costs of other inputs such as capital and labour costs have not differed appreciably in the two countries.

Tess (1981) estimated the change in the total cost of production of lean carcass for incremental changes of body fat in a 95 kilogram carcass for reductions in bodyfat of 5, 10, 20, 30 and 40 per cent for the average type of hog produced in Nebraska in 1979. These impacts on total production costs were estimated by Tess (1981) to be -2.176, -2.000, -3.842, -3.720 and -3.517 per cent, respectively (Table 4.1). Relative cost changes associated with incremental changes in fat content arise from a non-linear function of diminishing returns as carcass fat

content is reduced. Since the reduction of fat content in hog carcasses does not occur in large increments from year to year, cost changes are interpolated between these points, assuming constant linear change occurred between the points. The rate of cost reduction is pro-rated into the time period before 1979 using the same rate of cost reduction arising from decreased fat content(Tess, 1981).

As discussed in Chapter 3, the effects of the Canadian grading system resulted in a steady reduction of the amount of fat in Canadian hog carcasses. Hewston and Rosien (1989) estimated that the change of fat content in Canadian hog carcasses declined at a linear rate of 0.388 per cent per annum from 1960 to 1985. This calculation is based on the fat content of hog carcasses of 14.7 per cent in 1960 and 5.0 per cent in 1985. For the purposes of this study, the fat content of hog carcasses is assumed to have declined linearly from 10.82 per cent in 1970 to 3.06 per cent in 1989, a 7.76 per cent decline in fat content.

The fat content of U.S. hog carcasses is assumed to have been the same as Canadian carcasses in 1970, and to have declined at the same rate as in Canada until 1979. This assumption is based in part on the reduction of U.S. lard production and the steady increase in the numbers of hogs gradin USDA #1 and #2 during this period. From 1980 to 1989, the content of fat in U.S. hog carcasses is assumed to have declined at the reduced rate of 0.0388 per cent per annum. This assumption is based on the reasoning that since only ten percent of animals were marketed on a graded basis, selection for leanness was only able to be optimized based on the information on the grading of these hogs. It is assumed that if hogs were sold on a liveweight basis, there is no carcass quality information available to producers for selection purposes. Furthermore, in Chapter 4, selection efficiency with respect to increasing lean content and reducing fat content is calculated to be about 13 per cent when hogs are marketed on a liveweight basis. Therefore, little progress in selection for leanness could be expected due to a lack of focused

selection pressure. In practice, in such situations, it is not impossible that a slight regression of genetic selection for leanness may even have occurred; this is ignored.

The estimates of cost reductions associated with each percentage decline in fat content of hog carcasses is $US 0.74 per 100 kilograms of carcass produced in 1979 dollars by Tess (1981) based on production conditions in Nebraska for 1979. The assumption that production conditions in Canada are similar is invoked. The change in the costs of production of hog carcasses are estimated based on the annual decrease in production costs resulting from a reduction in the level of carcass fat by 0.388 per cent per annum to be $US 0.39 per 100 kilogram of carcass produced in 1979. This rate is equivalent to a real rate of decline of about $5.73 in 1987 Canadian dollars per tonne per annum of hog carcasses produced in Canada.

6.6 Estimates of Benefits of Technology Induced Trade

Eight sets of estimates of welfare gain are calculated to determine the variability of the welfare estimates from the Edwards-Freebairn model when this is applied to the North American hog industry. The results are given below in Tables 6.9 through to 6.17. In all cases except that summarized in Table 6.10, welfare gains and losses are estimated using supply and demand slope estimates calculated at the respective means of the price, production and consumption for the periods from 1970 to 1979 and 1980 to 1989. The net present values of total welfare gains are then calculated at the end of each individual period and then over the entire period. The average welfare gain on a per tonne basis is then calculated by dividing by respective total production or consumption of pork for each period. Table 6.9 is used as the base scenario to which other cases are compared. The calculations for the case summarized in Table 6.10 are based on the same assumptions as the base scenario except that the slopes of the supply and demand

curves are estimated at the means of prices, production and consumption levels for the whole period of study from 1970 to 1989.

The elasticities of supply and demand for pork in Canada and the U.S. used in the calculation of each case are given at the top of each table. The periods for which the estimates slopes of the supply and demand curves are estimated from average production, consumption and prices are listed next. The net present values for aggregate welfare gains for each period and the whole period to consumers and producers in each country are then given followed by a calculation of welfare gains on a per tonne consumed or produced basis. The specific assumptions of each case are then listed at the bottom of the table.

6.6.1 Affects of estimates of the Means of Production and Consumption

When slopes of the supply and demand curves are estimated at the means of consumption and production for the entire period from 1970 to 1989, estimates of consumer gains in both countries are less in the period from 1970 to 1979 and more in the period from 1980 to 1989 as compared to estimates made at the means of production and consumption of the half periods.(Tables 6.9 and 6.10). Both Canadian and U.S. producers gain less in the second period. Estimates of total welfare gains tend to be less when estimates are made using the means of production and consumption for the entire period 1970 to 1989.

This feature of the results can be attributed to the continuous expansion of aggregate pork consumption and production from 1970 to 1989 in Canada and the United States. Mean production and consumption are less in the period 1970 to 1979 than in the period 1980 to 1989. Further, the mean price of hog carcasses declined from 1970 to 1989. Consequently, if elasticities are held constant, then the slopes of the supply and demand curves in the period from 1970 to 1979 are expected to be much steeper than in the period 1980 to 1989. It follows that calculation of the slopes at the means of consumption and production levels from 1970 to 1989 can be expected to bias welfare estimates in

sub periods giving larger estimates from 1970 to 1979 and smaller estimates in the period from 1980 to 1989. Because of these biases, Tables 6.11 to 6.17 give the results of welfare estimations calculated on the basis of slopes of the supply and demand curves calculated at the means of the individual periods from 1970 to 1979 and from 1980 and 1989.

TABLE 6.9 Welfare Gains - Base Scenario I

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. MEANS AT OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	8	53
	PRODUCERS	25	67	108
U.S.:	CONSUMERS	227	58	427
	PRODUCERS	204	-9	323
NET TO:	CONSUMERS	255	65	480
	PRODUCERS	229	58	431
NET WELFARE:		483	123	911
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	0.89	3.32
	PRODUCERS	3.44	6.21	5.97
U.S.:	CONSUMERS	3.80	0.82	3.30
	PRODUCERS	3.41	-0.13	2.54
NET TO:	CONSUMERS	3.80	0.83	3.30
	PRODUCERS	3.41	0.74	2.96
NET WELFARE:		7.21	1.57	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT FROM 1970 TO 1979 AND AT A RATE OF 0.0388 PER CENT FROM 1980 TO 1989

TABLE 6.10 Welfare Gains - Slopes of Supply and Demand Curves Est. at Means of Production and Consumption from 1970-1989

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF $P_t, Q_{cCt}, Q_{sCt}, Q_{cUt}$ & Q_{sUt}

FOR 1970 TO 1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	25	7	47
	PRODUCERS	25	68	108
U.S.:	CONSUMERS	209	54	394
	PRODUCERS	190	-6	305
NET TO:	CONSUMERS	233	62	442
	PRODUCERS	215	62	412
NET WELFARE:		449	124	854
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.34	0.84	2.97
	PRODUCERS	3.42	6.25	5.98
U.S.:	CONSUMERS	3.50	0.78	3.04
	PRODUCERS	3.18	-0.08	2.39
NET TO:	CONSUMERS	3.48	0.79	3.04
	PRODUCERS	3.21	0.79	2.83
NET WELFARE:		6.69	1.58	5.87

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT FROM 1970 TO 1979 AND AT A RATE OF 0.0388 PER CENT FROM 1980 TO 1989

6.6.2 Effects of Changes in U.S. Selection Pressure

Since there are only indirect estimates of actual changes in the lean content of U.S. hog carcasses, it is necessary to assess the sensitivity of the results to changes in selection pressure. Estimates of welfare changes, expressed as aggregate and per tonne measures are therefore calculated based on the assumption that in the U.S., selection pressure to reduce fat in carcasses decreased to 0.0776 per cent per annum from 1980 to 1989 rather than to the 0.0388 per cent per annum assumed in the base case. These results are summarized in Table 6.11. For the purposes of comparison, welfare estimates are also calculated under the assumption that selection pressure in the U.S. was maintained at the Canadian level of 0.388 per annum. These results are summarized and presented in Table 6.12.

When the results in Table 6.11 are compared to those in Table 6.9, it appears that under the assumption the selection pressure in the U.S. was increased to double the level of the base case, (but still at only one fifth of the Canadian level), the main beneficiaries were U.S. consumers. Consumer welfare gains in the period 1980 to 1989 are estimated to be higher by about 40 per cent, while producer gains in Canada are less by about 7 per cent. The U.S. producer losses estimated in Table 6.9 become slight gains. Net welfare gains summed across all sectors are found to increase about 40 per cent overall.

The effects on aggregate welfare gains and distribution of this are more pronounced when results in Table 6.12 are compared to those 6.9. Under the assumption of equivalent selection pressure in the U.S. and Canada, consumer welfare gains in both countries during the period 1980 to 1989 are estimated to be greater by about 526 per cent. Producer gains in Canada are found to be less by about 60 per cent compared to the base scenario and instead of producer losses in the U.S., appreciable gains to producers are estimated. Net welfare gains are

estimated to be about 353 per cent greater when sustained, rather than reduced selection pressure, is assumed for the U.S. sector.

TABLE 6.11 Welfare Gains - U.S. Selection Pressure at Double the Rate of Base Scenario in Period 1980 to 1989

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	10	56
	PRODUCERS	25	64	104
U.S.:	CONSUMERS	227	80	449
	PRODUCERS	204	18	351
NET TO:	CONSUMERS	255	90	505
	PRODUCERS	229	82	455
NET WELFARE:		483	172	960
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	1.24	3.51
	PRODUCERS	3.44	5.89	5.78
U.S.:	CONSUMERS	3.80	1.14	3.47
	PRODUCERS	3.41	0.27	2.75
NET TO:	CONSUMERS	3.80	1.15	3.47
	PRODUCERS	3.41	1.05	3.13
NET WELFARE:		7.21	2.20	6.60

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAI ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT FROM 1970 TO 1979 AND AT A RATE OF 0.0776 PER CENT FROM 1980 TO 1989

TABLE 6.12 Welfare Gains - U.S. Selection Pressure Maintained from 1970 to 1989

ELASTICITIES:		DEMAND	SUPPLY	
CANADA		-0.90	1.00	
U.S.		-0.90	1.00	
SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt} FOR 1970-1979 & 1980-1989				
		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	34	79
	PRODUCERS	25	36	77
U.S.:	CONSUMERS	227	257	626
	PRODUCERS	204	238	570
NET TO:	CONSUMERS	255	291	706
	PRODUCERS	229	274	646
NET WELFARE:		483	565	1352
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	3.98	4.98
	PRODUCERS	3.44	3.33	4.24
U.S.:	CONSUMERS	3.80	3.68	4.83
	PRODUCERS	3.41	3.52	4.47
NET TO:	CONSUMERS	3.80	3.71	4.85
	PRODUCERS	3.41	3.49	4.44
NET WELFARE:		7.21	7.20	9.29

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT PER ANNUM FROM 1970 TO 1989

6.6.3 Effects of Changes in the Elasticity of Supply

One consideration of this study is to understand how estimates of the welfare impacts of technical change in hog production may be affected by the ability of producers to adjust to market prices. Estimates of welfare based on supply estimates illustrative of short run and long run reactions may indicate the impact of the ability to react quickly to price changes benefits hog producers. The results using an assumed long run estimate of supply elasticity of 1.00 for both countries are given in Table 6.9. Welfare estimates using an assumed short run elasticity estimate for both countries of 0.50 are summarized in Table 6.13.

The different estimates of supply elasticities, all other factors remaining the same, do not alter estimates of aggregate welfare benefits but do result in a redistribution of these benefits between producers and consumers. When the supply of pork becomes relatively inelastic, Canadian and U.S. consumers gain relatively less, while Canadian and U.S. producers gain relatively more.

TABLE 6.13 Welfare Gains - Inelastic Supply

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	0.50
U.S.	-0.90	0.50

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	19	5	36
	PRODUCERS	34	70	125
U.S.:	CONSUMERS	154	39	290
	PRODUCERS	277	10	461
NET TO:	CONSUMERS	173	44	326
	PRODUCERS	310	80	586
NET WELFARE:		483	124	911
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	2.56	0.61	2.25
	PRODUCERS	4.67	6.47	6.93
U.S.:	CONSUMERS	2.58	0.56	2.24
	PRODUCERS	4.62	0.15	3.61
NET TO:	CONSUMERS	2.58	0.56	2.24
	PRODUCERS	4.63	1.02	4.03
NET WELFARE:		7.20	1.58	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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6.6.4 Effects of Changes in the Elasticity of Demand

A consideration of this study is to assess how estimates of welfare changes are affected by different estimates of the elasticity of demand. Moschini and Meilke (1989) concluded that the demand for pork in the U.S. had become more inelastic over the period covered in this study. Reynolds and Goddard (1991), using a similar model, came to similar conclusions for Canada. Estimates of welfare based on relatively inelastic demand parameters are compared to estimates based on more elastic demand parameters in order to assess the sensitivity of the estimates of welfare benefits to different demand elasticities. Table 6.9 contains estimates of welfare based on an assumed elasticity of demand for pork in both countries of -0.90. Welfare estimates based on a relatively inelastic demand estimate of -0.60 with all other factors remaining the same are summarized in Table 6.14.

Total net welfare gains remain the same and there is a redistribution of welfare from producers to consumers. Consumer welfare gain estimates are found to increase as the demand for pork becomes more inelastic. Producer gains in Canada are found to decrease, while U.S. producer losses increase.

TABLE 6.14 Welfare Gains - Inelastic Demand

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.60	1.00
U.S.	-0.60	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	33	9	63
	PRODUCERS	20	65	98
U.S.:	CONSUMERS	269	68	507
	PRODUCERS	161	-20	243
NET TO:	CONSUMERS	302	77	570
	PRODUCERS	181	45	340
NET WELFARE:		483	123	910
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	4.48	0.88	3.95
	PRODUCERS	2.73	6.21	6.05
U.S.:	CONSUMERS	4.51	0.81	3.91
	PRODUCERS	2.70	-0.12	1.91
NET TO:	CONSUMERS	4.51	0.82	3.92
	PRODUCERS	2.70	0.75	2.34
NET WELFARE:		7.21	1.57	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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6.6.5 Effects of Using Canadian versus U.S. Prices

This study assumes that because the North American hog market is highly intertwined, hog carcass prices in Canada and the United States should follow similar patterns. From 1970 to 1979, the average price of hog carcasses in Ontario was 87 per cent of the average value of U.S. carcasses, while, from 1980 to 1989, the average price was 84 percent of the value of U.S. hog carcasses. Because of the consistent relationship between U.S. and Canadian hog carcass values, estimates of welfare losses and gains are expected to be similar when either representative U.S. or Canadian prices are used. Two sets of estimates of welfare gains and losses are estimated using long run estimates of supply elasticities for both countries. The first set of results using Ontario adjusted hog carcass prices indexed to base year 1987 as the measure of P_t are summarized in Table 6.9 and those using U.S. gross farm carcass values, converted to Canadian dollars and indexed to base year 1987 as the measure of this variable are given in Table 6.15. Welfare estimates using U.S. and Ontario market prices are virtually identical.

TABLE 6.15 Welfare Gains - Base Scenario Using U.S. Carcass Values

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	8	53
	PRODUCERS	25	67	108
U.S.:	CONSUMERS	227	58	427
	PRODUCERS	204	-9	323
NET TO:	CONSUMERS	255	65	480
	PRODUCERS	229	58	431
NET WELFARE:		483	123	911
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	0.89	3.32
	PRODUCERS	3.44	6.20	5.97
U.S.:	CONSUMERS	3.80	0.82	3.30
	PRODUCERS	3.41	-0.13	2.54
NET TO:	CONSUMERS	3.80	0.83	3.30
	PRODUCERS	3.41	0.74	2.96
NET WELFARE:		7.21	1.57	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

REAL U. S. FARM CARCASS VALUES, BASE YEAR 1987,

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FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT FROM 1970 TO 1979 AND AT A RATE OF 0.0388 PER CENT FROM 1980 TO 1989

6.6.6 Estimates of Plausible and Potential Welfare Gains

In this section, estimates of welfare gains are made using plausible estimates of elasticity of demand and supply of pork in Canada and the United States.

Moschini and Mielke (1989) concluded that the elasticity of demand for pork in the U.S. became more inelastic in the mid 1970's. Reynolds and Goddard (1991) using similar estimation techniques found that the elasticity of demand for pork in Canada progressively became more inelastic during the late 1970's and early 1980's. Estimates of elasticity of demand for pork before structural change in the demand for meat by Moschini and Mielke (1989) of -1.02 and by Reynolds and Goddard (1991) of -0.81 are used to represent the elasticity of demand for pork in the U.S. and Canada, respectively from 1970 to 1979. The estimates of elasticity of demand after structural change in the demand for meat of -0.84 by Moschini and Mielke (1989) for the U.S. and -0.68 by Reynolds and Goddard (1991) for Canada are used to represent demand elasticity for the period 1980 to 1989.

Long term estimates of supply elasticities are used, since estimates of welfare cover two ten year periods. The long run pork supply elasticity estimated for eastern Canada by Martin and Zwart (1975) of 0.89 is used as a representative supply elasticity for Canada The supply elasticity estimated by Holt and Johnson (1985) covering 20 quarters of 1.60 is assumed to be a representative supply elasticity for U.S. hog production. The Canadian estimate of elasticity of pork supply is more inelastic than the U.S. estimate, since the conditions for hog production in Canada require larger investments in buildings and fixtures, constraining entry and exit from the industry.

Table 6.16 summarizes estimates of actual welfare gains under the base scenario assumptions that fat content in hog carcasses declined at the rate of 0.388 per cent per annum from 1970 to 1979 in both Canada and the United States. From 1980 to 1989, it is assumed that fat content

of hog carcasses continued to decline at the rate of 0.388 per cent per annum in Canada, while in the United States, the rate was 0.0388 per cent per annum. Table 6.17 summarizes approximations of potential welfare gains under the condition that selection for fat reduction continued at the rate of 0.388 per cent per annum from 1980 to 1989 in the United States.

Comparisons of estimated plausible welfare gains to potential welfare gains, suggest that the welfare of consumers in the United States and Canada was the most adversely affected by the U.S. curtailment in selecting for lean hog carcasses. U.S. producers also suffered considerable losses in potential welfare benefits, while Canadian producers benefitted. It should be noted that the estimates of potential welfare benefits from continued selection intensity for lean hog carcasses in the United States are lower bound estimates, since consumption of pork may have been greater in the period 1980 to 1989, if the quality of pork had continued to improve at the same rate as during the period 1970 to 1979. Further, consumption of pork might have also increased if production costs had declined and resulted in pork becoming more price competitive with other meats, such as chicken.

TABLE 6.16 Estimates of Plausible Welfare Gains Using Base Scenario

ELASTICITIES:	DEMAND (1970-79)	DEMAND (1980-89)	SUPPLY
CANADA	-0.82	-0.68	0.89
U.S.	-1.02	-0.84	1.60

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	32	6	58
	PRODUCERS	21	69	103
U.S.:	CONSUMERS	260	43	467
	PRODUCERS	170	6	283
NET TO:	CONSUMERS	292	49	525
	PRODUCERS	191	75	387
NET WELFARE:		484	124	912
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	4.33	0.67	3.61
	PRODUCERS	2.88	6.41	5.73
U.S.:	CONSUMERS	4.36	0.62	3.59
	PRODUCERS	2.85	0.08	2.24
NET TO:	CONSUMERS	4.36	0.62	3.60
	PRODUCERS	2.85	0.96	2.67
NET WELFARE:		7.21	1.58	6.27

ASSUMPTIONS:

ACTUAL EST. OF ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ACTUAL EST. OF ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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TABLE 6.17 Estimates of Potential Welfare Gains

ELASTICITIES:	DEMAND (1970-79)	DEMAND (1980-89)	SUPPLY
CANADA	-0.82	-0.68	0.89
U.S.	-1.02	-0.84	1.60

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	32	41	93
	PRODUCERS	21	28	62
U.S.:	CONSUMERS	260	311	735
	PRODUCERS	170	182	460
NET TO:	CONSUMERS	292	352	828
	PRODUCERS	191	210	521
NET WELFARE:		484	562	1350
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	4.33	4.82	5.85
	PRODUCERS	2.88	2.55	3.41
U.S.:	CONSUMERS	4.36	4.45	5.67
	PRODUCERS	2.85	2.70	3.61
NET TO:	CONSUMERS	4.36	4.49	5.69
	PRODUCERS	2.85	2.68	3.58
NET WELFARE:		7.21	7.17	9.28

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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Chapter 7

7.1 Summary

This study presents evidence that consumer preferences for meat in general and for pork, in particular, are changing and that leaner meat is becoming more desired by consumers. These changes in consumers' preferences have occurred because of increased knowledge and awareness of health risks associated with high levels of fat in diets. One problem faced by consumers is how to articulate their preferences to producers through a market structure other than by decreasing their consumption of a good. If only the latter reaction is evident, producers may perceive that the reduction in the consumption of a good is related to rising prices for that good or is due to declining prices of other competitive goods; producers may therefore seek to decrease their costs of production without improving the quality of the good. Further, reduction in the consumption of a good does not give direct guidance to the producer of what qualities or characteristics of a good are most or least desired. For example: a joint product of pork, namely lard, has consistently declined in relative value for the past twenty years. Producers are able to use genetic selection to increase genetic traits that are the most productive or economically valuable. Therefore, if producers had full market information of consumer preferences, they would logically chose to produce more lean carcass than fat.

There are a number of factors which appear to prevent the pursuit of this strategy which are briefly summarized below:

First, this study establishes that producers in the United States do not have full market information as to consumer preferences for their output, since they market most of their hogs on a liveweight basis. Because most producers do not receive objective grading information on the relative values of carcasses produced in their herds, they have few incentives and little guidance in making selection decisions based on leanness or on the relative values of carcasses.

Because most meat packers in the United States grade almost every carcass that is processed, they have information on the relative quality of carcasses shipped to them by individual producers. They are then able to identify those producers who produce high or low quality carcasses and adjust their liveweight bids accordingly without explicitly informing the producer of the basis for such premiums and discounts.

In contrast, Canadian producers of slaughter hogs have marketed their hogs under the auspices of an independent, progressively more objective, grading system since 1968. This rewards producers for producing lean carcasses at optimum weights. These producers have been provided with information and financial rewards that encourages the genetic selection of hogs that are both fast growing and produce lean carcasses.

Further, the costs of producing pork and lard in the context of a full life cycle production model are about the same on a liveweight basis. Efforts to genetically select for leaner carcasses result in a marginal increase in the economic costs of producing liveweight, while the cost of producing lean carcasses declines. U.S. producers, marketing on a liveweight basis, are likely motivated to make their selection decisions to reduce costs of producing liveweight rather than to reduce the cost of producing lean carcass.

The two country, two product trade model outlined by Posner (1961) and its extensions provides a basis for understanding trade patterns when one country possesses technology which the other has not developed. In the innovating country, the relative values of the two products is recognized and determines the relative direction of technological development. In this case, as the relative value of lean carcass has increased over the value of lard, genetic selection as a technology should be focused towards increasing the production of lean muscle rather than fat. The welfare of the innovating country increases through

trade if the non-innovating country lags behind and if prices in the non-innovating country remain relatively unaffected.

The Posner model is related to hog production trends in Canada and the United States. Canadian hog producers are characterized as an innovating industry which has reduced the relative production of lard as compared to pork, since the relative value of lard is recognized as declining. U.S. producers are characterized as an industry which does not recognize that the value of lard is declining relative to lean pork and therefore continues to produce lean pork and lard in the same relative amounts. The outcome is that Canada is transformed from being a net importer of pork from the United States to a net exporter to the United States.

The Edwards-Freebairn model (1984) was used to estimate the welfare gains and losses to producers and consumers in the United States and Canada which resulted from the increase in the lean content in hog carcasses for the periods 1970 to 1979 and 1980 to 1989. The net present value of the welfare gain/loss for each year was calculated and summed using a five per cent discount rate. In the basic scenario, it is assumed that selection for leanness in Canada was continuous from 1970 to 1989 with fat content declining at a rate of 0.388 per cent per annum. In the United States, it was assumed that fat content declined at a rate of 0.388 per cent per annum from 1970 to 1979 and at a rate of 0.0388 per cent from 1980 to 1989.

Estimates of welfare gains are made in hypothetical cases, where it is assumed that consumer demand and producer supply elasticities for pork are equal and remain unchanged over the period 1970 to 1989. Impacts of and sensitivity to assumed changes in U.S. genetic selection pressure for lean carcasses are assessed. Selection pressure is assumed to increase from 0.0388 per cent per annum to 0.0776 from 1980 to 1989, and also to be at the even higher level of 0.388 per cent per annum. This experiment indicates that the welfare of consumers and U.S.

producers increases, while the welfare of Canadian producers declines, when the gap in selection pressure in the two countries is reduced or eliminated. Net welfare is found to increase with increased selection pressure.

In an assumed case, where the supply elasticities of both countries is halved from 1.00 to 0.50, consumers are found to gain less, producers gain more, while net welfare remains unchanged. In another scenario, where the assumed demand elasticities for pork in both countries is reduced from -0.90 to -0.50, consumers are found to gain more and producers gain less, while net welfare remains unchanged. When average U.S. gross farm values of hog carcasses are used to estimate welfare effects, there are no substantial differences since relative prices of hogs remain sufficiently constant as to leave the resulting estimates of welfare from the model unaffected.

A more realistic case is defined and welfare gains are estimated, using published estimates of supply and demand elasticities, based on similar methodologies, for the U.S. and Canada. In this case, the assumed supply and demand of pork are more inelastic in Canada as compared to the U.S. and the demand for pork in both countries is assumed to be more inelastic in the period from 1980 to 1989 than in the period from 1970 to 1979. In the period from 1970 to 1979, when selection pressure is assumed to be equal in both countries at the rate of fat reduction in carcasses of 0.388 per cent per annum, consumers in both countries are estimated to gain more than producers on a per tonne consumed or produced basis. In the period from 1980 to 1989, assuming selection pressure in Canada remains at 0.388 per cent per annum, but that this is 0.0388 per cent in the U.S., consumers gain less by about the same amount on a per tonne consumed basis. U.S. producers gain almost nothing, while Canadian producer gains more than double, overall, estimated net welfare gains drop substantially.

A hypothetical case to assess the potential gains from increased U.S. selection pressure is considered. U.S. selection pressure to increase the lean content of hog carcasses is assumed to be at the same rate as in Canada at the rate of 0.388 per cent per annum. Relative consumer gains increase slightly and producer gains decrease slightly in the period from 1980 to 1989 as compared to from 1970 to 1979. Welfare gains increase in total and on a per tonne basis.

A comparison of the realistic case to the hypothetical case shows that the reduction of selection pressure for lean carcasses by producers in U.S. was detrimental to themselves and to consumers in both countries while producers in Canada benefitted. This result is consistent with results predicted by Posner-based trade models and is similar to results estimated by Edwards and Freebairn (1984) for Australian wheat and wool production.

7.2 Conclusions

The adaption of the Edwards-Freebairn model to estimate welfare gains which result from differences in selection intensities for lean hog carcasses in the U.S. and Canada gave estimates of the present value of increased benefits of about 900 million dollars Canadian for the period 1970 to 1989. The estimates of potential welfare gains under the assumption of identical selection pressure represent minimal levels of potential welfare gain from 1980 to 1989, since the estimates are based on actual production and consumption levels. They do not account for other components of potential welfare gains that might have occurred if costs of production of lean carcasses had declined and the quality of pork increased at the same rate as from 1970 to 1979. Specifically, the increased quality and competitiveness of pork relative to other meats would likely have resulted in expanded U.S. pork production and consumption from 1980 to 1989.

The model demonstrates the beneficial affects the development of the Canadian hog grading system has had for producers in Canada.

Furthermore, the results point to the detrimental affects that the lack of focused direction in the production for lean carcasses in the U.S. has had on U.S. producers and consumers in both countries. In general, the results of this study demonstrate that relatively low cost market institutions, such as grading systems, which encourage and enable producers to increase their efficiency in producing a product preferred by consumers, can result in significant welfare benefits for both producers and consumers.

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defined consumer surplus as "the difference between the sacrifice which the purchaser would be willing to make in order to get it and the purchase price he has to pay in exchange". Marshall's approach was to define consumer surplus as the extra utility a consumer obtains when purchasing a commodity at a particular price. Consumer surplus could then be measured as the extra expenditure a consumer is willing to make rather than forego consumption relative to the actual price paid for the commodity. These approaches are restricted to the case where the expenditures for the commodity are a relatively small portion of consumers' total expenditure, since they assume that the marginal utility of money is approximately constant.

Developments by Hicks and Henderson focused on the issue of adjusting consumer income to maintain the individual on the same utility curve, while varying the prices and consumption of a commodity. Hicks stressed the importance of compensating variation and equivalent variation in the measurement of utility from consumption if the income effect is not zero. For most goods, using the ordinary demand curve to measure consumer surplus may exaggerate the gains or losses of consumer surplus from a price change for that commodity.

Marshall is reported to have introduced the concept of producer surplus as either direct or indirect surplus utility a seller obtains from the thing that he receives over the thing that he gives up. As a point of contention, a number of authors including Mishan(1959) have contended that the term "producer surplus" is a misnomer and the concept should more correctly be described as economic rent, since the area below the price line and above the supply line represents returns to all factors of production.The measurement of economic rent is similar to but the converse of that of consumer surplus. It is the triangular area below the price line and above the supply curve.

The quantitative measurement of consumer and producer surplus due to agriculture research was first attempted by Schultz, who in 1953

estimated the value of inputs saved from increased agriculture technology. This was accomplished by estimating the cost of producing the 1950 agriculture output of the United States by using 1910 agriculture technology. Griliches (1958) used a similar approach to estimate the social benefit of hybrid corn. Consumer surplus was calculated by estimating the increase in cost of production of corn for a perfectly elastic supply curve if the hybrid technology were lost. Grilliches calculated the net economic surplus in the situation of outward shifts in perfectly inelastic supply curves with the development of hybrid technology.

In a review article, Norton and Davis (1981) pointed out several sets of formulas that have been developed to estimate consumer and producer surplus under varying conditions. Linder and Jarrett(1978) pointed out the importance of recognizing that biases in estimates in consumer and producer surpluses could occur if the shift in the supply function was not parallel. A non-parallel shift in the supply function could occur if the technology developed were related to scale efficiency or not adopted uniformly throughout the industry in question. Linder and Jarrett provide a general model to estimate the consumer and producer surplus for linear supply and demand curves, however their work was criticized for a computational error by Rose (1980) and by Wise and Fell (1980).

The primary differences between these models are the nature of the supply shifts, these being either divergent, convergent or parallel. Technological innovation can either have an output effect causing a vertical shift of the supply function or a cost reducing effect which would be associated with a horizontal shift of the supply function. Another important consideration is the elasticity of demand. The more inelastic the demand for a commodity, the less the producer will gain from a technological innovation while the consumer gains.

5.6 Measuring the Benefits of Technologically Induced Trade

To measure the benefits of improving technology in producing a tradeable commodity, a number of factors must first be taken into account. Akino and Hayami (1975), Ramalho de Castro (1974) and Schuh (1979) developed models to measure the aggregate level and distribution of the benefits derived from research into tradeable commodities, based on the assumption that improved technology shifts the supply curve in any country out. Edwards and Freebairn (1984) developed a model which does not impose the assumption that world prices would not vary due to trade that results from a cost reducing improvement in production technology in a trading country. This is a more generalized approach than the models used by Martin and Havlicek (1977) and Sarris and Schmidtz (1981) which allowed for changes in world prices through the use of an excess demand curve but constrained shifts of the supply curve to occur within one of the two trading countries. Furthermore the Edwards-Freebairn model also measures welfare benefits from research in both countries and not just the innovating country. Welfare benefits are measured in isolation from other factors which may shift either

The Edwards-Freebairn model assumes competitive market clearing between two freely trading countries. Supply and demand functions for the commodity are determined independently within each country. Prices are obtained by horizontally summing the supply and demand for each country. All producers and consumers face the same price for a commodity and exports from one country equal imports of the other country. Shifts in the supply curves are assumed to be parallel which gives a first approximation of the research benefits which can be measured gross or net of the costs of research. For the sake of simplicity, payments for the exchange of the new technology were not taken into consideration.

A number of outcomes are predicted by Edwards and Freebairn (1984) based on their model: The first is that an innovating country's producers will always gain from technical change, when costs of

production in other countries are unaffected. Secondly, a country will receive a net social benefit from research, if this causes costs in other countries to fall by no more than twice as much as in the innovating country. Thirdly, as a country's share of world trade increases, the gains from technical change stimulated by research decline. For a large exporter, the gain to national welfare is decreased substantially if the commodity faces inelastic demand. Furthermore, innovations which overcome those problems of production for an exportable commodity that are unique to the region, will have higher national benefits. Benefits tend to be greater, the longer it takes other countries to innovate. Finally, a country will gain more from research in a non-traded commodity than an exported commodity.

Chapter 6

This chapter deals with the empirical analysis of the welfare benefits of the trade of hogs and pork induced by changes in technological efficiency between Canada and the United States.

6.1 Model for Estimating Welfare Benefits

The Edwards-Freebairn model, outlined in Chapter 5, is used to estimate the current value of the welfare benefits derived from the trade in hogs and pork, on a carcass basis, between the United States and Canada due to on-going genetic selection for leaner carcasses. The periods analyzed are from 1970 to 1979 and 1980 to 1989.

The period from 1970 to 1979 covers the initial effects of the Canadian hog carcass grading system implemented in 1968. During this period, U.S. lard production declined steadily relative to pork production while the proportion of hogs grading U.S. #1 and #2 increased steadily. Therefore, the period from 1970 to 1979 is assumed to be characterized by equal selection intensity for leanness in hogs in both Canada and the United States. During this time period, the United States as a consistent net exporter of pork to Canada. Tariffs on imports of pork products in Canada were ten times as great as tariffs applied to U.S. imports of pork.

During the period 1980 to 1989, in the U.S., eighty to ninety per cent of hogs were marketed on a liveweight basis, which provides little incentive to reduce fat in hog carcasses. The estimate of selection efficiency when the economic value of fat and lean content are equally weighted is about 13 per cent. Most U.S. hog carcasses graded either #1 or #2 from 1980, until the revision of the USDA grading system in 1984. This revision to the USDA hog grading system does not directly and objectively provide economic incentives to increase the lean content of hog carcasses. Therefore, it is assumed that there was only marginal selection intensity for leanness in the United States from 1980 to 1989 as compared to the period from 1970 to 1979 of between ten and twenty

per cent. Because of the broad use of the hog carcass grading system in Canada and the revisions to the system which increasingly penalized the production of fat hog carcasses and provided premiums to lean carcasses, it is assumed that there was continued selection intensity for leanness in Canada from 1980 to 1989 as compared to the previous ten years. During this period, Canada became a consistent exporter of hogs and pork to the United States.

As discussed in Chapter 1, there were no tariffs applied to pork imports by either country after 1979, although countervailing duties were applied to U.S imports of pork and live hogs from Canada during the latter half of the 1980's. These countervailing duties likely offset any increases in relative government subsidization of pork production in Canada. The time periods chosen for analysis are equal in length in order to facilitate direct comparisons of the estimates of welfare gains.

The model specifies four linear supply and demand functions for two countries plus the market equilibrium condition that all that is produced is consumed. The basic model is summarized below:

Canadian demand for pork $$Q_{dCt} = a_t - bP_t \qquad (1)$$

Canadian supply of pork $$Q_{sCt} = \alpha_t + \beta P_t \qquad (2)$$

U.S. demand for pork $$Q_{dUt} = c_t - dP_t \qquad (3)$$

U.S. supply of pork $$Q_{sUt} = \tau_t + \eta P_t \qquad (4)$$

Market Equilibrium

$$Q_t = Q_{dct} + Q_{dut} = Q_{sct} + Q_{sut} \quad (5)$$

where P_t is the price at time, t, Q_{dc} and Q_{du} are the quantities of pork consumed in Canada and the United States, respectively, at price, P_t, while Q_{sc} and Q_{su} are the quantities of pork produced in Canada and the United States, respectively at price, P_t. The parameters b and d represent the slopes of the demand curves for pork in Canada and the United States, respectively, while β and η represent the slopes of the supply curves. The slopes of the demand and supply curves are calculated by multiplying the relevant elasticity by the quantity demanded or supplied at the equilibrium price divided by the equilibrium price. Since annual cost reductions due to genetic improvements are relatively small as compared to total costs of production and represent minor annual shifts of the supply curves, the slopes of the supply and demand curves are assumed to be linear. The parameters a, α, c, and τ are defined as constants.

Vertical supply shifts resulting from technological change are cost reductions represented by a per unit decline in the cost of production, k_t in Canada and h_t in the United States and lead to lower prices, P'. Where Φ is defined as equal to the sum of the per unit cost declines for each country multiplied by their respective supply slopes and Γ is defined as the sum of the slopes of the supply and demand curves in each country as follows:

$$\Phi_t = \beta k_t + \eta h_t \quad (6)$$

$$\Gamma = b + \beta + d + \eta \quad (7)$$

The effects of research on the supply equations are defined as:

$$Q'_{sCt} = \alpha_t + \beta k_t + \beta P'_t \tag{8}$$

$$Q'_{sUt} = \tau_t + \eta h_t + \eta P'_t \tag{9}$$

From the Edwards-Freebairn model, the computational formulas for estimating gains to consumers and producers in Canada and the United States resulting from the adoption of cost reducing technology in the hog industry are as follows:

Consumer gains in Canada,

$$\begin{aligned} G^C_{ct} &= 1/2\,(P - P')\ (Q_{dCt} + Q'_{dCt}) \\ &= \frac{\phi_t}{\Gamma}\, Q_{dCt} + \frac{b\phi_t^2}{2\Gamma^2} \end{aligned} \tag{10}$$

Producer gains in Canada,

$$\begin{aligned} G^C_{pt} &= 1/2\,[k_t - (P - P')]\ (Q_{sCt} + Q'_{sCt}) \\ &= (k_t - \frac{\phi_t}{\Gamma})\, Q_{sCt} + \frac{\beta}{2}(k_t - \frac{\phi_t}{\Gamma})^2 \end{aligned} \tag{11}$$

Aggregate gains in Canada,

$$\begin{aligned} G^C_t &= G^C_{ct} + G^C_{pt} \\ &= k_t\, Q_{sCt} - \frac{\phi_t}{\Gamma}(Q_{sCt} - Q_{dCt}) + \frac{b\phi^2 r}{2\Gamma^2} + \frac{\beta}{2}(k_T - \frac{\phi_t}{\Gamma})^2 \end{aligned} \tag{12}$$

Consumer gains in the United States,

$$\begin{aligned} G^U_{ct} &= 1/2\,(P - P')\ (Q_{dUt} + Q'_{dUt}) \\ &= \frac{\phi_t}{\Gamma}\, Q_{dUt} + \frac{d\phi_t^2}{2\Gamma^2} \end{aligned} \tag{13}$$

Producer gains in the United States

$$\begin{aligned} G^U_{pt} &= 1/2\,[h_t - (P - P')]\ (Q_{sUt} + Q'_{sUt}) \\ &= (h_t - \frac{\phi_t}{\Gamma})\, Q_{sUt} + \frac{\eta}{2}(h_t - \frac{\phi_t}{\Gamma})^2 \end{aligned} \tag{14}$$

Aggregate gains in the United States,

$$G_t^U = G_{ct}^U + G_{pt}^U$$
$$= h_t Q_{sUt} - \frac{\phi_t}{\Gamma}(Q_{sUt} - Q_{dUt}) + \frac{d\phi^2 r}{2\Gamma^2} + \frac{\eta}{2}(h_T - \frac{\phi_t}{\Gamma})^2 \qquad (15)$$

Total consumer gains,

$$G_{ct} = G_{ct}^C + G_{ct}^U \qquad (16)$$

Total producer gains,

$$G_{pt} = G_{pt}^C + G_{pt}^U \qquad (17)$$

World aggregate gain,

Costs of transportation between areas of production and consumption in both countries are ignored since regions of surplus production of hogs and pork in eastern Canada are relatively close to the U.S. border and are almost as close to major areas of pork consumption in the eastern United States as the mid-western states. Most of the Canadian population is located relatively close to the U.S. border. It appears that much of the transportation costs of moving hogs and pork to and from the U.S. and Canada would be based on U.S. rates.

Although western provinces, in particular Alberta, are distant from eastern U.S. markets, they are relatively as close to west coast markets as mid-western states. Further, because shipping costs tend to be higher within Canada than in the U.S., there may be occasions in western provinces, where the costs of shipping hogs and pork to other provinces is as high or higher than exporting to the United States. This situation may provide some incentive to export rather than supply the domestic market. However, the incentive would have to be large enough to overcome other trade barriers such as quarantine and health inspection costs and border processing time. Overall, it is concluded that the cost of transportation is probably not a critical factor affecting Canadian exports of pork to the United States.

Welfare gains and losses are calculated for each individual year for Canadian and U.S. consumers and producers. The present value of this stream of gains or losses is calculated assuming a real interest rate of five percent with the following formula:

$$P.V.\ (i) = \sum\ (1+r)^{-t} \cdot G_t\ (i) \qquad (18)$$

where: P.V. (i) are the sums of the present values of gains for group, i at time, t, and G_i is the gain to group i, in years one to t. Although interest rates tend to be higher in Canada than in the U.S., after taking into consideration relative rates of inflation, real interest rates were about five per cent from 1970 to 1989 in both countries. For the sake of comparison, the present values of welfare gains are calculated at the ends of the periods from 1970 to 1979 and 1980 to 1989 separately and then over the whole period of study from 1970 to 1989 in Tables 6.10 to 6.17.

6.2 Canadian and U.S. Hog Carcass Prices

From the results of Tess (1981) and other researchers, the reduction of fat in pork carcasses leads to an increased cost of liveweight production but a decreased cost of lean pork production. Therefore, to estimate the welfare gains from reducing fat in pork carcasses and the subsequent reduction in the cost of producing pork, carcass prices must be used rather than liveweight values.

The Ontario hog market is a central Canadian market where large numbers of hogs are produced and consumed. There is also significant trade in hogs and pork between Ontario and other provinces as well as the United States. Given Ontario's market size and trade volumes, the Toronto index-100 hog carcass price per kilogram established by the Ontario Hog Marketing Board is used here as a representative price for Canadian hog producers. Agriculture Canada in the *Livestock and Meat Trade Report* publishes the weekly pooled producer payment for index-100 hogs for each significant province or region in Canada. The weighted

average annual price is published by Statistics Canada in *Livestock and Animal Products Statistics*, Catalogue No. 23-203.

Hog producers are capable of adjusting their production and breeding practices to improve the quality of the hogs that they market. Through the structure of grades for slaughter hogs, Canadian hogs producers have a price incentive to produce hogs that will receive a premium according to the carcass grade. Agriculture Canada publishes the weekly average grades of marketed slaughter hogs by province as well as the National weighted average index. The average annual index-100 price is multiplied by the average index of hogs to obtain the annual average carcass price for hogs marketed in Ontario on a Canadian dollars per kilogram basis.

This series of nominal prices is converted to comparable real prices by expressing them in terms of the base year of 1987. The annual Consumer Price Index (CPI) series published by Statistics Canada is used to adjust the average hog carcass prices to the base year of 1987. The CPI is used rather than those estimated for the food sector alone or for livestock in particular since a comparable representative U.S. series is needed for the comparison and the objective of this study is to estimate welfare gains in the context of the whole economies of the U.S. and Canada. The real prices were then multiplied by one thousand to convert them to a per tonne basis to accommodate the use of large numbers associated with national production and consumption. The average real price of hog carcasses in Ontario from 1970 to 1979 was $2,823 per tonne in 1987 dollars. From 1980 to 1989 the comparable average price was $1,854 per tonne and from 1970 to 1989 this was $2,339 per tonne.

TABLE 6.1 Ontario Average Indexed Hog Carcass Prices (Base 1987=100)

YEAR	ONTARIO INDEX-100 HOG CARCASS PRICES $CAN/KG	AVERAGE INDEX OF ONTARIO HOG CARCASSES	AVERAGE ONTARIO HOG CARCASSES $CAN/KG	CANADIAN CONSUMER PRICE INDEX 1987=100	REAL ADJUSTED ONTARIO HOG CARCASS PRICES $CAN/TONNE
1970	0.710	100.5	0.714	29.67	2,405
1971	0.570	100.7	0.574	30.54	1,875
1972	0.826	100.8	0.833	31.98	2,597
1973	1.208	100.7	1.217	34.44	3,523
1974	1.111	101.2	1.124	38.21	2,938
1975	1.486	101.7	1.511	42.33	3,560
1976	1.417	101.8	1.443	45.51	3,160
1977	1.347	102.0	1.374	49.13	2,791
1978	1.543	101.0	1.558	53.47	2,906
1979	1.418	102.1	1.448	58.39	2,474
1980	1.306	102.4	1.337	64.33	2,073
1981	1.547	102.4	1.584	72.36	2,185
1982	1.841	102.6	1.889	80.17	2,351
1983	1.564	102.9	1.609	84.80	1,893
1984	1.606	103.3	1.659	88.49	1,870
1985	1.514	103.7	1.570	92.04	1,701
1986	1.798	103.7	1.865	95.80	1,941
1987	1.759	103.5	1.817	100.00	1,817
1988	1.393	103.6	1.443	103.62	1,390
1989	1.384	104.10	1.441	109.26	1,315

Statistics Canada, *Livestock and Animal Products Statistics*, Cat. No. 23-203.

In the United States, hog prices are usually quoted on a liveweight basis, which does not give a direct indication of relative carcass value. The USDA does, however, estimate a farm level average carcass value of hogs monthly and annually. These values are published in the monthly USDA Livestock and Poultry Situation and Outlook Report. These carcass value estimates are indexed to the base year of 1987 using the consumer price index estimated by the U.S. Bureau of Labor

Statistics published in the annual USDA *Agricultural Statistics*. The average real farm value of U.S. hog carcasses from 1970 to 1979 was $3,233 per tonne in 1987 Canadian dollars; from 1980 to 1989, the value was $2,205 per tonne and from 1970 to 1989, this was $2,719 per tonne.

TABLE 6.2 U.S. Average Gross Farm Hog Carcass Values (Base 1987=100)

YEAR	U.S. GROSS FARM VALUE OF HOG CARCASSES $U.S./CWT	U.S. GROSS FARM VALUE OF HOG CARCASSES $US/TONNE	U.S. CONSUMER PRICE INDEX 1987=100	EXCHANGE RATE $CAN/$US	INDEXED U.S. GROSS FARM VALUE OF HOG CARCASSES $CAN/TONNE
1970	43.00	948	34.18	1.0440	2,895
1971	34.90	769	35.65	1.0098	2,179
1972	49.60	1,093	36.83	0.9905	2,941
1973	73.80	1,627	39.12	1.0010	4,163
1974	63.60	1,402	43.41	0.9780	3,159
1975	86.50	1,907	47.38	1.0173	4,094
1976	75.80	1,671	50.11	0.9861	3,288
1977	70.20	1,548	53.35	1.0635	3,085
1978	82.50	1,819	57.43	1.1402	3,611
1979	72.20	1,592	63.90	1.1715	2,918
1980	68.30	1,506	72.54	1.1690	2,427
1981	75.50	1,664	80.07	1.1990	2,493
1982	94.30	2,079	84.97	1.2341	3,019
1983	81.40	1,795	87.71	1.2324	2,522
1984	83.30	1,836	91.44	1.2948	2,600
1985	76.20	1,680	94.70	1.3652	2,422
1986	87.30	1,925	96.53	1.3894	2,770
1987	87.90	1,938	100.00	1.3260	2,570
1988	73.80	1,627	104.10	1.2309	1,924
1989	75.00	1,653	109.10	1.1842	1794.8

USDA, *Agricultural Statistics*

The estimated U.S. carcass prices are then converted to Canadian dollar equivalents using annual average noon exchange rates for U.S.

dollars published monthly in the *Bank of Canada Review*. The values are then converted to a per tonne basis by multiplying by one thousand.

6.3 Canadian and U.S. Pork Production and Consumption

The objective of this study is to estimate the welfare gains and losses from genetic selection for lean carcasses in Canada and the United States. Following the Edwards-Freebairn model, the requirement that total consumption must equal total production is imposed as estimation of welfare gains and losses would be complicated if trade with third countries or the rest of the world were to be included. In any event, Canada and the United States do not engage in appreciable trade of live hogs, other than small numbers of breeding stock, with third countries. Typically, Canada exports from two to three thousand hogs per annum to countries other than the U.S. and these exports are primarily purebred breeding stock. The U.S. exports of live hogs varied from ten to twenty-five thousand head per annum through most of the 1970's and 1980's with the majority being exported to Mexico. In 1988 and 1989 Mexico increased its imports of live swine from the U.S. to about ninety thousand head, however, this was only one tenth of a per cent of total U.S. slaughter for those years. There is also little trade in fresh or frozen pork with third countries with the exception of Denmark and Poland, which exports quantities of prepared or preserved pork products to the United States (Fig. 1.1, p.2). Overall, these quantities are not likely to affect prices of pork carcasses in Canada and the United States. However, if these volumes were included in the estimation of the model, they would bias the estimates of welfare gains and losses. Therefore, all the production and consumption data for the United States and Canada are adjusted to net out imports and exports of hogs and pork to and from third countries.

Canadian hog carcass production is estimated for each year from 1970 to 1989 by adding the total number of hogs slaughtered to total exports of live hogs to the United States and subtracting total imports

of live hogs. These numbers are then multiplied by the average cold trimmed carcass weight in kilograms as published by Statistics Canada in *Livestock and Animal Products Statistics*, Catalogue No. 23-203.

Canadian consumption of pork is estimated by adding imports of pork from the United States to total Canadian production including production from hogs imported for slaughter from the US and subtracting total exports of pork. The data for these calculations are presented in Table 6.3.

TABLE 6.3 Canadian Pork Supply and Disappearance (THOUSANDS OF TONNES)

YEAR	CANADIAN SLAUGHTER '000 HEAD	LIVE IMPORTS FROM U.S. '000 HEAD	AVERAGE CARCASS WEIGHT (KG.)	PORK IMPORTS FROM U.S.	TOTAL PORK IMPORTS	TOTAL PORK EXPORTS
1970	10,599	0.0	70.2	10,833	11,994	32,340
1971	11,351	0.0	71.5	6,631	7,758	45,160
1972	10,997	0.0	71.4	15,696	20,510	52,400
1973	10,656	0.0	71.3	19,450	24,639	57,070
1974	10,700	0.0	71.7	36,784	39,307	41,960
1975	9,164	0.0	71.4	53,118	55,462	40,800
1976	8,969	0.0	71.7	109,540	111,803	39,350
1977	9,037	0.0	71.7	116,143	117,856	59,456
1978	9,940	0.0	74.6	67,577	70,061	72,139
1979	1,201	0.0	74.1	40,375	42,693	101,612
1980	13,977	0.0	73.9	21,171	22,081	149,277
1981	13,691	0.6	74.2	22,952	25,007	164,354
1982	13,458	0.4	74.8	17,504	18,976	207,898
1983	13,702	0.2	75.2	19,975	24,316	201,205
1984	13,886	0.0	75.2	11,076	18,531	223,869
1985	14,452	0.0	75.3	8,071	21,571	250,806
1986	14,443	0.0	76.0	9,794	18,006	271,898
1987	14,853	0.0	76.1	7,999	22,181	301,086
1988	15,553	0.0	76.5	8,921	14,835	318,787
1989	15,530	0.0	76.2	9,258	12,643	304,817

Statistics Canada, Cat. No. 23-203

Hog carcass production and consumption in the United States was estimated in a similar fashion using statistics published by the USDA in *Agricultural Statistics*. The data for these calculations are presented in Table 6.4.

TABLE 6.4 U.S. Pork Supply and Disappearance (THOUSANDS OF TONNES)

YEAR	U.S. SLAUGHTER '000 HEAD	LIVE IMPORTS FROM CANADA '000 HEAD	AVERAGE CARCASS WEIGHT (KG.)	PORK IMPORTS FROM CANADA	TOTAL PORK IMPORTS	TOTAL PORK EXPORTS
1970	85,817	73	69.9	27,567	222,716	27,749
1971	94,438	84	70.3	31,145	224,984	29,618
1972	84,707	87	72.1	28,199	244,035	45,022
1973	76,795	88	74.4	31,010	241,767	72,874
1974	81,762	196	75.3	21,790	221,355	42,913
1975	68,687	29	74.8	13,624	199,129	91,134
1976	73,784	44	75.3	9,837	212,737	137,469
1977	77,303	41	77.1	11,902	199,583	125,140
1978	77,315	186	77.6	25,530	224,531	100,166
1979	89,099	130	78.0	49,484	226,345	97,385
1980	96,074	236	78.0	94,474	249,478	84,215
1981	91,575	144	78.5	97,323	245,396	100,885
1982	82,190	303	78.5	139,558	277,601	69,477
1983	87,584	455	78.5	136,569	318,425	70,787
1984	85,168	1,345	78.5	178,846	432,695	51,522
1985	84,492	1,150	79.4	213,190	511,567	40,723
1986	79,598	500	80.3	235,254	502,132	27,209
1987	81,081	425	80.3	266,037	542,048	34,963
1988	87,794	865	83.1	269,765	515,740	88,583
1989	88,691	1,213	79.9	240,428	406,423	121,393

USDA, *Agricultural Statistics*.

Initial analysis of the adjusted pork production and consumption figures for Canada and the United States indicates that the size of the North American pork market expanded almost continuously from 1970 to 1989 (Table 6.5). Until 1980, pork production in the United States was

usually larger than consumption, while after 1980, the reverse became true. Canadian consumption of pork grew steadily from 1970 to 1989, while pork production had a variable growth rate until 1979. Since 1980, Canadian pork production grew at a more rapid rate than consumption.

TABLE 6.5 U.S. and Canadian Adjusted Pork Production and Consumption (THOUSANDS OF TONNES)

YEAR	ADJUSTED U.S. PRODUCTION	ADJUSTED U.S. CONSUMPTION	ADJUSTED CANADIAN PRODUCTION	ADJUSTED CANADIAN CONSUMPTION
1970	5,972,657	5,994,473	744,649	722,833
1971	6,610,834	6,641,231	803,437	773,041
1972	6,073,600	6,092,409	767,636	748,826
1973	5,652,779	5,670,909	743,530	725,400
1974	6,134,875	6,135,319	761,765	761,321
1975	5,100,564	5,063,266	629,359	666,656
1976	5,524,485	5,428,089	616,885	713,282
1977	5,948,773	5,847,711	603,600	704,661
1978	5,949,958	5,922,309	709,276	736,925
1979	6,884,263	6,903,186	847,246	828,022
1980	7,414,116	7,505,826	996,541	904,831
1981	7,096,905	7,182,538	960,170	874,537
1982	6,373,744	6,519,530	962,058	816,272
1983	6,786,394	6,938,699	1,001,502	849,198
1984	6,537,359	6,810,652	1,104,727	831,434
1985	6,582,974	6,879,398	1,141,925	845,501
1986	6,333,085	6,598,704	1,101,235	835,617
1987	6,448,632	6,740,798	1,129,460	837,295
1988	7,143,293	7,476,035	1,212,694	879,954
1989	6,874,740	7,202,825	1,215,911	887,827
ANNUAL AVERAGES				
1970-79	5,985,279	5,969,920	722,738	738,097
1980-89	6,759,242	6,985,500	1,082,622	856,247
1970-89	6,372,261	6,477,710	902,680	797,172

6.4 Price Elasticities of Supply and Demand

Since, in this study, the estimates of quantities of pork supplied and consumed in Canada and the United States are artificially adjusted to exclude imports and exports from third countries, they are not suitable for the estimation of supply and demand elasticities. Further, it is not within the scope of this study to estimate supply and demand elasticities for pork, since relatively sophisticated and consistent estimates have been made by other researchers for the period in question in this study.

In Tables 6.1 to 6.15, welfare estimates are calculated with the assumption that the supply and demand elasticities for pork in Canada and the U.S. are the same to allow for comparisons of the effects of factors not related to differences in supply and demand elasticities between the two countries. Since a number of studies indicate that there are differences between the supply and demand elasticities in Canada and the U.S., in Tables 6.16 and 6.17, actual estimates of supply and demand elasticities for pork in Canada and the U.S. are used to approximate more realistic estimates of welfare benefits.

Relevant estimates of demand elasticities for pork in Canada and the United States from various studies have been described and discussed in the second and third chapters and the results of these are summarized in Table 6.6. Estimates of demand elasticities for meat, including pork, in the United States by Moschini and Meilke (1989) provide estimates covering much of the period of time examined in this study. The estimates of elasticity of demand for pork in Canada by Reynolds and Goddard (1991) parallel those by Moschini and Meilke (1989). Both studies concluded that demand structures for meat including pork in Canada and the United States had changed over the period of this study.

TABLE 6.6 Canadian and U.S. Pork Demand and Supply Elasticities

AUTHOR	DATA	MODEL	ELASTICITIES
CANADIAN DEMAND ELASTICITIES FOR PORK			
Reynolds and Goddard (1991)	1968-1987	AIDS	1971 -0.81 1984 -0.68
Chen and Veeman (1991)	1960-1987	Dynamic AIDS	-0.82
Al-Zand and Lavoie (1987)	1970-1984	OLS	-0.80
Young (1987)	1967-1984	Maximum Likelihood	-0.55 to -0.67
Curtin, Theoret and Zafiriou (1987)	1968-1983	OLS	-0.75
Hassan and Johnson (1979)	1965-1976	Maximum Likelihood	-0.89
Martin and Zwart (1974)	1961-1972		-0.47
CANADIAN SUPPLY ELASTICITIES FOR PORK			
Martin and Zwart (1974)	1961-1972	E. Canada	Short Run 0.22 Long Run 0.89
UNITED STATES DEMAND ELASTICITIES FOR PORK			
Moschini and Meilke (1989)	1967-1987	AIDS	1975 -1.02 1976 -0.84
Hahn (1988)	1960-1984	MGF	-0.78
Byong-Ho Kim (1984)	1983	AIDS	-0.86
Hayenga et al. (1981)	1970-1979	OLS	-0.48 to -0.51
Yeboah (1981)	1960-1977	2SLS	-0.65 to -0.68
Martin and Zwart (1974)	1961-1972		-0.37
George and King (1971)	1962-1966	OLS	-0.41
UNITED STATES SUPPLY ELASTICITIES FOR PORK			
Yeboah (1981)	1960-1977	2SLS	0.02 to 0.10
MacAuley (1978)	1966-1976	OLS	0.09 to 0.50
Martin and Zwart (1974)	1961-1972		Short Run 0.16 Long Run 0.43
Holt and Johnson			10 QTRS 0.66 20 QTRS 1.60 Long Run 2.01

The Edwards-Freebairn model assumes constant elasticity of supply and demand in both countries, but allows for parallel shifts in the supply and demand curves over time. In this study elasticities of supply and demand are assumed to be constant within the period, but not necessarily between periods.

Since production and consumption has headed upward in both countries, estimates of the slopes of the supply and demand curves used in the estimation of the Edwards-Freebairn model are calculated and compared at the means of both the adjusted production and consumption levels for the entire period from 1970 to 1989 and at the means of production and consumption for the two periods of 1970 to 1979 and 1980 to 1989. For each period, the slopes of the demand curves within each country are calculated by multiplying the estimate of demand elasticity for pork by the average consumption of pork carcasses over the period in question and dividing by the average price of pork carcasses for that period. Similarly, the slopes of the supply curves for each country and period are calculated by multiplying the estimate of supply elasticity of pork carcasses by the average production in the period in question and dividing by the average price of carcasses in that period.

The slopes of the supply and demand curves are calculated using both Ontario average hog carcass prices and U.S. gross farm values of hog carcasses in 1987 real Canadian dollars. These estimates are summarized in Tables 6.7 and 6.8. It should be noted that the slopes calculated based on U.S. farm carcass values are consistently about eighty per cent of the comparable slopes estimated using Canadian hog carcass prices. This is because average Ontario hog carcass prices tend to be about eighty per cent of U.S. gross farm hog carcass values.

TABLE 6.7 Slope Estimates of U.S and Canadian Pork Supply and Demand Curves Using Adjusted Indexed Ontario Hog Carcass Prices (TONNES PER CANADIAN DOLLAR)

ESTIMATE OF ELASTICITY	U.S. SUPPLY	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN SUPPLY	SLOPE ESTIMATE
1.60	1970-1989	4360	0.89	1970-1989	344
	1970-1979	3392		1970-1979	228
	1980-1989	5835		1980-1989	520
1.00	1970-1989	2725	1.00	1970-1989	386
	1970-1979	2120		1970-1979	256
	1980-1989	3647		1980-1989	584
0.50	1970-1989	1363	0.50	1970-1989	193
	1970-1979	1060		1970-1979	128
	1980-1989	1823		1980-1989	292
ESTIMATE OF ELASTICITY	U.S. DEMAND	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN DEMAND	SLOPE ESTIMATE
-1.02	1970-1989	-2826	-0.81	1970-1989	-276
	1970-1979	-2157		1970-1979	-212
	1980-1989	-3844		1980-1989	-374
-0.84	1970-1989	-2327	-0.68	1970-1989	-232
	1970-1979	-1776		1970-1979	-178
	1980-1989	-3166		1980-1989	-314
-0.90	1970-1989	-2493	-0.90	1970-1989	-307
	1970-1979	-1903		1970-1989	-235
	1980-1989	-3392		1980-1989	-416
-0.60	1970-1989	-1662	-0.60	1970-1989	-205
	1970-1979	-1269		1970-1979	-157
	1980-1989	-2261		1980-1989	-277

TABLE 6.8 Slope Estimates of U.S and Canadian Pork Supply and Demand Curves Using U.S. Gross Farm Values of Hog Carcasses (TONNES PER CANADIAN DOLLAR)

ESTIMATE OF ELASTICITY	U.S. SUPPLY	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN SUPPLY	SLOPE ESTIMATE
1.60	1970-1989	3585	0.89	1970-1989	282
	1970-1979	2962		1970-1979	199
	1980-1989	4407		1980-1989	393
1.00	1970-1989	2241	1.00	1970-1989	317
	1970-1979	1851		1970-1979	224
	1980-1989	2754		1980-1989	441
0.50	1970-1989	1120	0.50	1970-1989	159
	1970-1979	926		1970-1979	112
	1980-1989	1377		1980-1989	221
ESTIMATE OF ELASTICITY	U.S. DEMAND	SLOPE ESTIMATE	ESTIMATE OF ELASTICITY	CANADIAN DEMAND	SLOPE ESTIMATE
-1.02	1970-1989	-2323	-0.81	1970-1989	-227
	1970-1979	-1883		1970-1979	-185
	1980-1989	-2903		1980-1989	-283
-0.84	1970-1989	-1913	-0.68	1970-1989	-191
	1970-1979	-1551		1970-1979	-155
	1980-1989	-2391		1980-1989	-237
-0.90	1970-1989	-2050	-0.90	1970-1989	-252
	1970-1979	-1662		1970-1989	-205
	1980-1989	-2562		1980-1989	-314
-0.60	1970-1989	-1367	-0.60	1970-1989	-168
	1970-1979	-1108		1970-1979	-137
	1980-1989	-1708		1980-1989	-209

6.5 Estimation of Cost Changes due to Genetic Selection

The estimation of changes in costs of production due to technological change is based on the relative changes in the costs estimated by Tess (1981). As described in Chapter 4, Tess used average costs of production in Nebraska for the average type of pig produced on moderately sized U.S. farms in 1979. The model is assumed to apply also to Central Canadian hog production. The largest portion of costs of production can be attributed to feed costs with the grain portion of the feed generally obtained from local markets, while the protein portion of the feed is purchased from soybean or canola crushers or their agents. It is assumed that feed ingredient prices in both countries are determined exogenously to the hog industry and are the same in each country. For instance average Chatham corn prices in Ontario have been generally within $5 to $15 per tonne of the USDA's estimates of the national average price for farmer owned reserves since 1970. Although soybean meal prices are generally higher in Canada than in the U.S., there has been growing use of canola meal in hog rations in Canada to offset this difference. The assumption seems reasonable since in general these inputs are subject to the same changes in global fundamental supply and demand factors and because of the opportunities for arbitrage between markets in North America. Similarly, as discussed in Chapter 1, it is assumed that the costs of other inputs such as capital and labour costs have not differed appreciably in the two countries.

Tess (1981) estimated the change in the total cost of production of lean carcass for incremental changes of body fat in a 95 kilogram carcass for reductions in bodyfat of 5, 10, 20, 30 and 40 per cent for the average type of hog produced in Nebraska in 1979. These impacts on total production costs were estimated by Tess (1981) to be -2.176, -2.000, -3.842, -3.720 and -3.517 per cent, respectively (Table 4.1). Relative cost changes associated with incremental changes in fat content arise from a non-linear function of diminishing returns as carcass fat

content is reduced. Since the reduction of fat content in hog carcasses does not occur in large increments from year to year, cost changes are interpolated between these points, assuming constant linear change occurred between the points. The rate of cost reduction is pro-rated into the time period before 1979 using the same rate of cost reduction arising from decreased fat content(Tess, 1981).

As discussed in Chapter 3, the effects of the Canadian grading system resulted in a steady reduction of the amount of fat in Canadian hog carcasses. Hewston and Rosien (1989) estimated that the change of fat content in Canadian hog carcasses declined at a linear rate of 0.388 per cent per annum from 1960 to 1985. This calculation is based on the fat content of hog carcasses of 14.7 per cent in 1960 and 5.0 per cent in 1985. For the purposes of this study, the fat content of hog carcasses is assumed to have declined linearly from 10.82 per cent in 1970 to 3.06 per cent in 1989, a 7.76 per cent decline in fat content.

The fat content of U.S. hog carcasses is assumed to have been the same as Canadian carcasses in 1970, and to have declined at the same rate as in Canada until 1979. This assumption is based in part on the reduction of U.S. lard production and the steady increase in the numbers of hogs gradin USDA #1 and #2 during this period. From 1980 to 1989, the content of fat in U.S. hog carcasses is assumed to have declined at the reduced rate of 0.0388 per cent per annum. This assumption is based on the reasoning that since only ten percent of animals were marketed on a graded basis, selection for leanness was only able to be optimized based on the information on the grading of these hogs. It is assumed that if hogs were sold on a liveweight basis, there is no carcass quality information available to producers for selection purposes. Furthermore, in Chapter 4, selection efficiency with respect to increasing lean content and reducing fat content is calculated to be about 13 per cent when hogs are marketed on a liveweight basis. Therefore, little progress in selection for leanness could be expected due to a lack of focused

selection pressure. In practice, in such situations, it is not impossible that a slight regression of genetic selection for leanness may even have occurred; this is ignored.

The estimates of cost reductions associated with each percentage decline in fat content of hog carcasses is $US 0.74 per 100 kilograms of carcass produced in 1979 dollars by Tess (1981) based on production conditions in Nebraska for 1979. The assumption that production conditions in Canada are similar is invoked. The change in the costs of production of hog carcasses are estimated based on the annual decrease in production costs resulting from a reduction in the level of carcass fat by 0.388 per cent per annum to be $US 0.39 per 100 kilogram of carcass produced in 1979. This rate is equivalent to a real rate of decline of about $5.73 in 1987 Canadian dollars per tonne per annum of hog carcasses produced in Canada.

6.6 Estimates of Benefits of Technology Induced Trade

Eight sets of estimates of welfare gain are calculated to determine the variability of the welfare estimates from the Edwards-Freebairn model when this is applied to the North American hog industry. The results are given below in Tables 6.9 through to 6.17. In all cases except that summarized in Table 6.10, welfare gains and losses are estimated using supply and demand slope estimates calculated at the respective means of the price, production and consumption for the periods from 1970 to 1979 and 1980 to 1989. The net present values of total welfare gains are then calculated at the end of each individual period and then over the entire period. The average welfare gain on a per tonne basis is then calculated by dividing by respective total production or consumption of pork for each period. Table 6.9 is used as the base scenario to which other cases are compared. The calculations for the case summarized in Table 6.10 are based on the same assumptions as the base scenario except that the slopes of the supply and demand

curves are estimated at the means of prices, production and consumption levels for the whole period of study from 1970 to 1989.

The elasticities of supply and demand for pork in Canada and the U.S. used in the calculation of each case are given at the top of each table. The periods for which the estimates slopes of the supply and demand curves are estimated from average production, consumption and prices are listed next. The net present values for aggregate welfare gains for each period and the whole period to consumers and producers in each country are then given followed by a calculation of welfare gains on a per tonne consumed or produced basis. The specific assumptions of each case are then listed at the bottom of the table.

6.6.1 Affects of estimates of the Means of Production and Consumption

When slopes of the supply and demand curves are estimated at the means of consumption and production for the entire period from 1970 to 1989, estimates of consumer gains in both countries are less in the period from 1970 to 1979 and more in the period from 1980 to 1989 as compared to estimates made at the means of production and consumption of the half periods.(Tables 6.9 and 6.10). Both Canadian and U.S. producers gain less in the second period. Estimates of total welfare gains tend to be less when estimates are made using the means of production and consumption for the entire period 1970 to 1989.

This feature of the results can be attributed to the continuous expansion of aggregate pork consumption and production from 1970 to 1989 in Canada and the United States. Mean production and consumption are less in the period 1970 to 1979 than in the period 1980 to 1989. Further, the mean price of hog carcasses declined from 1970 to 1989. Consequently, if elasticities are held constant, then the slopes of the supply and demand curves in the period from 1970 to 1979 are expected to be much steeper than in the period 1980 to 1989. It follows that calculation of the slopes at the means of consumption and production levels from 1970 to 1989 can be expected to bias welfare estimates in

sub periods giving larger estimates from 1970 to 1979 and smaller estimates in the period from 1980 to 1989. Because of these biases, Tables 6.11 to 6.17 give the results of welfare estimations calculated on the basis of slopes of the supply and demand curves calculated at the means of the individual periods from 1970 to 1979 and from 1980 and 1989.

TABLE 6.9 Welfare Gains - Base Scenario I

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. MEANS AT OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	8	53
	PRODUCERS	25	67	108
U.S.:	CONSUMERS	227	58	427
	PRODUCERS	204	-9	323
NET TO:	CONSUMERS	255	65	480
	PRODUCERS	229	58	431
NET WELFARE:		483	123	911
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	0.89	3.32
	PRODUCERS	3.44	6.21	5.97
U.S.:	CONSUMERS	3.80	0.82	3.30
	PRODUCERS	3.41	-0.13	2.54
NET TO:	CONSUMERS	3.80	0.83	3.30
	PRODUCERS	3.41	0.74	2.96
NET WELFARE:		7.21	1.57	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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TABLE 6.10 Welfare Gains - Slopes of Supply and Demand Curves Est. at Means of Production and Consumption from 1970-1989

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970 TO 1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	25	7	47
	PRODUCERS	25	68	108
U.S.:	CONSUMERS	209	54	394
	PRODUCERS	190	-6	305
NET TO:	CONSUMERS	233	62	442
	PRODUCERS	215	62	412
NET WELFARE:		449	124	854
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.34	0.84	2.97
	PRODUCERS	3.42	6.25	5.98
U.S.:	CONSUMERS	3.50	0.78	3.04
	PRODUCERS	3.18	-0.08	2.39
NET TO:	CONSUMERS	3.48	0.79	3.04
	PRODUCERS	3.21	0.79	2.83
NET WELFARE:		6.69	1.58	5.87

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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6.6.2 Effects of Changes in U.S. Selection Pressure

Since there are only indirect estimates of actual changes in the lean content of U.S. hog carcasses, it is necessary to assess the sensitivity of the results to changes in selection pressure. Estimates of welfare changes, expressed as aggregate and per tonne measures are therefore calculated based on the assumption that in the U.S., selection pressure to reduce fat in carcasses decreased to 0.0776 per cent per annum from 1980 to 1989 rather than to the 0.0388 per cent per annum assumed in the base case. These results are summarized in Table 6.11. For the purposes of comparison, welfare estimates are also calculated under the assumption that selection pressure in the U.S. was maintained at the Canadian level of 0.388 per annum. These results are summarized and presented in Table 6.12.

When the results in Table 6.11 are compared to those in Table 6.9, it appears that under the assumption the selection pressure in the U.S. was increased to double the level of the base case, (but still at only one fifth of the Canadian level), the main beneficiaries were U.S. consumers. Consumer welfare gains in the period 1980 to 1989 are estimated to be higher by about 40 per cent, while producer gains in Canada are less by about 7 per cent. The U.S. producer losses estimated in Table 6.9 become slight gains. Net welfare gains summed across all sectors are found to increase about 40 per cent overall.

The effects on aggregate welfare gains and distribution of this are more pronounced when results in Table 6.12 are compared to those 6.9. Under the assumption of equivalent selection pressure in the U.S. and Canada, consumer welfare gains in both countries during the period 1980 to 1989 are estimated to be greater by about 526 per cent. Producer gains in Canada are found to be less by about 60 per cent compared to the base scenario and instead of producer losses in the U.S., appreciable gains to producers are estimated. Net welfare gains are

estimated to be about 353 per cent greater when sustained, rather than reduced selection pressure, is assumed for the U.S. sector.

TABLE 6.11 Welfare Gains - U.S. Selection Pressure at Double the Rate of Base Scenario in Period 1980 to 1989

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt} FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	10	56
	PRODUCERS	25	64	104
U.S.:	CONSUMERS	227	80	449
	PRODUCERS	204	18	351
NET TO:	CONSUMERS	255	90	505
	PRODUCERS	229	82	455
NET WELFARE:		483	172	960
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	1.24	3.51
	PRODUCERS	3.44	5.89	5.78
U.S.:	CONSUMERS	3.80	1.14	3.47
	PRODUCERS	3.41	0.27	2.75
NET TO:	CONSUMERS	3.80	1.15	3.47
	PRODUCERS	3.41	1.05	3.13
NET WELFARE:		7.21	2.20	6.60

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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TABLE 6.12 Welfare Gains - U.S. Selection Pressure Maintained from 1970 to 1989

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	34	79
	PRODUCERS	25	36	77
U.S.:	CONSUMERS	227	257	626
	PRODUCERS	204	238	570
NET TO:	CONSUMERS	255	291	706
	PRODUCERS	229	274	646
NET WELFARE:		483	565	1352
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	3.98	4.98
	PRODUCERS	3.44	3.33	4.24
U.S.:	CONSUMERS	3.80	3.68	4.83
	PRODUCERS	3.41	3.52	4.47
NET TO:	CONSUMERS	3.80	3.71	4.85
	PRODUCERS	3.41	3.49	4.44
NET WELFARE:		7.21	7.20	9.29

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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6.6.3 Effects of Changes in the Elasticity of Supply

One consideration of this study is to understand how estimates of the welfare impacts of technical change in hog production may be affected by the ability of producers to adjust to market prices. Estimates of welfare based on supply estimates illustrative of short run and long run reactions may indicate the impact of the ability to react quickly to price changes benefits hog producers. The results using an assumed long run estimate of supply elasticity of 1.00 for both countries are given in Table 6.9. Welfare estimates using an assumed short run elasticity estimate for both countries of 0.50 are summarized in Table 6.13.

The different estimates of supply elasticities, all other factors remaining the same, do not alter estimates of aggregate welfare benefits but do result in a redistribution of these benefits between producers and consumers. When the supply of pork becomes relatively inelastic, Canadian and U.S. consumers gain relatively less, while Canadian and U.S. producers gain relatively more.

TABLE 6.13 Welfare Gains - Inelastic Supply

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	0.50
U.S.	-0.90	0.50

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	19	5	36
	PRODUCERS	34	70	125
U.S.:	CONSUMERS	154	39	290
	PRODUCERS	277	10	461
NET TO:	CONSUMERS	173	44	326
	PRODUCERS	310	80	586
NET WELFARE:		483	124	911
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	2.56	0.61	2.25
	PRODUCERS	4.67	6.47	6.93
U.S.:	CONSUMERS	2.58	0.56	2.24
	PRODUCERS	4.62	0.15	3.61
NET TO:	CONSUMERS	2.58	0.56	2.24
	PRODUCERS	4.63	1.02	4.03
NET WELFARE:		7.20	1.58	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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6.6.4 Effects of Changes in the Elasticity of Demand

A consideration of this study is to assess how estimates of welfare changes are affected by different estimates of the elasticity of demand. Moschini and Meilke (1989) concluded that the demand for pork in the U.S. had become more inelastic over the period covered in this study. Reynolds and Goddard (1991), using a similar model, came to similar conclusions for Canada. Estimates of welfare based on relatively inelastic demand parameters are compared to estimates based on more elastic demand parameters in order to assess the sensitivity of the estimates of welfare benefits to different demand elasticities. Table 6.9 contains estimates of welfare based on an assumed elasticity of demand for pork in both countries of -0.90. Welfare estimates based on a relatively inelastic demand estimate of -0.60 with all other factors remaining the same are summarized in Table 6.14.

Total net welfare gains remain the same and there is a redistribution of welfare from producers to consumers. Consumer welfare gain estimates are found to increase as the demand for pork becomes more inelastic. Producer gains in Canada are found to decrease, while U.S. producer losses increase.

TABLE 6.14 Welfare Gains - Inelastic Demand

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.60	1.00
U.S.	-0.60	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	33	9	63
	PRODUCERS	20	65	98
U.S.:	CONSUMERS	269	68	507
	PRODUCERS	161	-20	243
NET TO:	CONSUMERS	302	77	570
	PRODUCERS	181	45	340
NET WELFARE:		483	123	910
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	4.48	0.88	3.95
	PRODUCERS	2.73	6.21	6.05
U.S.:	CONSUMERS	4.51	0.81	3.91
	PRODUCERS	2.70	-0.12	1.91
NET TO:	CONSUMERS	4.51	0.82	3.92
	PRODUCERS	2.70	0.75	2.34
NET WELFARE:		7.21	1.57	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

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FAT IN U.S. HOG CARCASSES DECLINES AT THE RATES OF 0.388 PER CENT PER ANNUM FROM 1970 TO 1989 AND 0.0388 FROM 1980 TO 1989

6.6.5 Effects of Using Canadian versus U.S. Prices

This study assumes that because the North American hog market is highly intertwined, hog carcass prices in Canada and the United States should follow similar patterns. From 1970 to 1979, the average price of hog carcasses in Ontario was 87 per cent of the average value of U.S. carcasses, while, from 1980 to 1989, the average price was 84 percent of the value of U.S. hog carcasses. Because of the consistent relationship between U.S. and Canadian hog carcass values, estimates of welfare losses and gains are expected to be similar when either representative U.S. or Canadian prices are used. Two sets of estimates of welfare gains and losses are estimated using long run estimates of supply elasticities for both countries. The first set of results using Ontario adjusted hog carcass prices indexed to base year 1987 as the measure of P_t are summarized in Table 6.9 and those using U.S. gross farm carcass values, converted to Canadian dollars and indexed to base year 1987 as the measure of this variable are given in Table 6.15. Welfare estimates using U.S. and Ontario market prices are virtually identical.

TABLE 6.15 Welfare Gains - Base Scenario Using U.S. Carcass Values

ELASTICITIES:	DEMAND	SUPPLY
CANADA	-0.90	1.00
U.S.	-0.90	1.00

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	28	8	53
	PRODUCERS	25	67	108
U.S.:	CONSUMERS	227	58	427
	PRODUCERS	204	-9	323
NET TO:	CONSUMERS	255	65	480
	PRODUCERS	229	58	431
NET WELFARE:		483	123	911
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	3.77	0.89	3.32
	PRODUCERS	3.44	6.20	5.97
U.S.:	CONSUMERS	3.80	0.82	3.30
	PRODUCERS	3.41	-0.13	2.54
NET TO:	CONSUMERS	3.80	0.83	3.30
	PRODUCERS	3.41	0.74	2.96
NET WELFARE:		7.21	1.57	6.26

ASSUMPTIONS:

ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

REAL U. S. FARM CARCASS VALUES, BASE YEAR 1987,

FAT IN HOG CARCASSES IN CANADA DECLINES AT A RATE OF 0.388 PER CENT PER ANNUM FROM 1970 TO 1989

FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT FROM 1970 TO 1979 AND AT A RATE OF 0.0388 PER CENT FROM 1980 TO 1989

6.6.6 Estimates of Plausible and Potential Welfare Gains

In this section, estimates of welfare gains are made using plausible estimates of elasticity of demand and supply of pork in Canada and the United States.

Moschini and Mielke (1989) concluded that the elasticity of demand for pork in the U.S. became more inelastic in the mid 1970's. Reynolds and Goddard (1991) using similar estimation techniques found that the elasticity of demand for pork in Canada progressively became more inelastic during the late 1970's and early 1980's. Estimates of elasticity of demand for pork before structural change in the demand for meat by Moschini and Mielke (1989) of -1.02 and by Reynolds and Goddard (1991) of -0.81 are used to represent the elasticity of demand for pork in the U.S. and Canada, respectively from 1970 to 1979. The estimates of elasticity of demand after structural change in the demand for meat of -0.84 by Moschini and Mielke (1989) for the U.S. and -0.68 by Reynolds and Goddard (1991) for Canada are used to represent demand elasticity for the period 1980 to 1989.

Long term estimates of supply elasticities are used, since estimates of welfare cover two ten year periods. The long run pork supply elasticity estimated for eastern Canada by Martin and Zwart (1975) of 0.89 is used as a representative supply elasticity for Canada The supply elasticity estimated by Holt and Johnson (1985) covering 20 quarters of 1.60 is assumed to be a representative supply elasticity for U.S. hog production. The Canadian estimate of elasticity of pork supply is more inelastic than the U.S. estimate, since the conditions for hog production in Canada require larger investments in buildings and fixtures, constraining entry and exit from the industry.

Table 6.16 summarizes estimates of actual welfare gains under the base scenario assumptions that fat content in hog carcasses declined at the rate of 0.388 per cent per annum from 1970 to 1979 in both Canada and the United States. From 1980 to 1989, it is assumed that fat content

of hog carcasses continued to decline at the rate of 0.388 per cent per annum in Canada, while in the United States, the rate was 0.0388 per cent per annum. Table 6.17 summarizes approximations of potential welfare gains under the condition that selection for fat reduction continued at the rate of 0.388 per cent per annum from 1980 to 1989 in the United States.

Comparisons of estimated plausible welfare gains to potential welfare gains, suggest that the welfare of consumers in the United States and Canada was the most adversely affected by the U.S. curtailment in selecting for lean hog carcasses. U.S. producers also suffered considerable losses in potential welfare benefits, while Canadian producers benefitted. It should be noted that the estimates of potential welfare benefits from continued selection intensity for lean hog carcasses in the United States are lower bound estimates, since consumption of pork may have been greater in the period 1980 to 1989, if the quality of pork had continued to improve at the same rate as during the period 1970 to 1979. Further, consumption of pork might have also increased if production costs had declined and resulted in pork becoming more price competitive with other meats, such as chicken.

TABLE 6.16 Estimates of Plausible Welfare Gains Using Base Scenario

ELASTICITIES:	DEMAND (1970-79)	DEMAND (1980-89)	SUPPLY
CANADA	-0.82	-0.68	0.89
U.S.	-1.02	-0.84	1.60

SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt}

FOR 1970-1979 & 1980-1989

		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	32	6	58
	PRODUCERS	21	69	103
U.S.:	CONSUMERS	260	43	467
	PRODUCERS	170	6	283
NET TO:	CONSUMERS	292	49	525
	PRODUCERS	191	75	387
NET WELFARE:		484	124	912
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	4.33	0.67	3.61
	PRODUCERS	2.88	6.41	5.73
U.S.:	CONSUMERS	4.36	0.62	3.59
	PRODUCERS	2.85	0.08	2.24
NET TO:	CONSUMERS	4.36	0.62	3.60
	PRODUCERS	2.85	0.96	2.67
NET WELFARE:		7.21	1.58	6.27

ASSUMPTIONS:

ACTUAL EST. OF ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES

ACTUAL EST. OF ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES

TORONTO CARCASS PRICES, BASE YEAR 1987, ADJUSTED BY AVERAGE INDEX

FAT IN HOG CARCASSES IN CANADA DECLINES AT A RATE OF 0.388 PER CENT PER ANNUM FROM 1970 TO 1989

FAT IN U.S. HOG CARCASSES DECLINES AT RATES OF 0.388 PER CENT FROM 1970 TO 1979 AND 0.0388 PER CENT FROM 1980 TO 1989

TABLE 6.17 Estimates of Potential Welfare Gains

ELASTICITIES:		DEMAND (1970-79)	DEMAND (1980-89)	SUPPLY
CANADA		-0.82	-0.68	0.89
U.S.		-1.02	-0.84	1.60
SLOPES EST. AT MEANS OF P_t, Q_{cCt}, Q_{sCt}, Q_{cUt} & Q_{sUt} FOR 1970-1979 & 1980-1989				
		1970-1979	1980-1989	1970-1989
AGGREGATE WELFARE GAINS IN MILLIONS OF CANADIAN DOLLARS:				
CANADIAN:	CONSUMERS	32	41	93
	PRODUCERS	21	28	62
U.S.:	CONSUMERS	260	311	735
	PRODUCERS	170	182	460
NET TO:	CONSUMERS	292	352	828
	PRODUCERS	191	210	521
NET WELFARE:		484	562	1350
UNIT WELFARE GAINS IN CANADIAN DOLLARS PER TONNE:				
CANADIAN:	CONSUMERS	4.33	4.82	5.85
	PRODUCERS	2.88	2.55	3.41
U.S.:	CONSUMERS	4.36	4.45	5.67
	PRODUCERS	2.85	2.70	3.61
NET TO:	CONSUMERS	4.36	4.49	5.69
	PRODUCERS	2.85	2.68	3.58
NET WELFARE:		7.21	7.17	9.28
ASSUMPTIONS:				
ARBITRARY, IDENTICAL ELASTICITIES OF DEMAND USED TO ESTIMATE SLOPES				
ARBITRARY, IDENTICAL ELASTICITIES OF SUPPLY USED TO ESTIMATE SLOPES				
TORONTO CARCASS PRICES, BASE YEAR 1987, ADJUSTED BY AVERAGE INDEX				
FAT IN HOG CARCASSES IN CANADA DECLINES AT A RATE OF 0.388 PER CENT PER ANNUM FROM 1970 TO 1989				
FAT IN U.S. HOG CARCASSES DECLINES AT A RATE OF 0.388 PER CENT PER ANNUM FROM 1970 TO 1989				

Chapter 7

7.1 Summary

This study presents evidence that consumer preferences for meat in general and for pork, in particular, are changing and that leaner meat is becoming more desired by consumers. These changes in consumers' preferences have occurred because of increased knowledge and awareness of health risks associated with high levels of fat in diets. One problem faced by consumers is how to articulate their preferences to producers through a market structure other than by decreasing their consumption of a good. If only the latter reaction is evident, producers may perceive that the reduction in the consumption of a good is related to rising prices for that good or is due to declining prices of other competitive goods; producers may therefore seek to decrease their costs of production without improving the quality of the good. Further, reduction in the consumption of a good does not give direct guidance to the producer of what qualities or characteristics of a good are most or least desired. For example: a joint product of pork, namely lard, has consistently declined in relative value for the past twenty years. Producers are able to use genetic selection to increase genetic traits that are the most productive or economically valuable. Therefore, if producers had full market information of consumer preferences, they would logically chose to produce more lean carcass than fat.

There are a number of factors which appear to prevent the pursuit of this strategy which are briefly summarized below:

First, this study establishes that producers in the United States do not have full market information as to consumer preferences for their output, since they market most of their hogs on a liveweight basis. Because most producers do not receive objective grading information on the relative values of carcasses produced in their herds, they have few incentives and little guidance in making selection decisions based on leanness or on the relative values of carcasses.

Because most meat packers in the United States grade almost every carcass that is processed, they have information on the relative quality of carcasses shipped to them by individual producers. They are then able to identify those producers who produce high or low quality carcasses and adjust their liveweight bids accordingly without explicitly informing the producer of the basis for such premiums and discounts.

In contrast, Canadian producers of slaughter hogs have marketed their hogs under the auspices of an independent, progressively more objective, grading system since 1968. This rewards producers for producing lean carcasses at optimum weights. These producers have been provided with information and financial rewards that encourages the genetic selection of hogs that are both fast growing and produce lean carcasses.

Further, the costs of producing pork and lard in the context of a full life cycle production model are about the same on a liveweight basis. Efforts to genetically select for leaner carcasses result in a marginal increase in the economic costs of producing liveweight, while the cost of producing lean carcasses declines. U.S. producers, marketing on a liveweight basis, are likely motivated to make their selection decisions to reduce costs of producing liveweight rather than to reduce the cost of producing lean carcass.

The two country, two product trade model outlined by Posner (1961) and its extensions provides a basis for understanding trade patterns when one country possesses technology which the other has not developed. In the innovating country, the relative values of the two products is recognized and determines the relative direction of technological development. In this case, as the relative value of lean carcass has increased over the value of lard, genetic selection as a technology should be focused towards increasing the production of lean muscle rather than fat. The welfare of the innovating country increases through

trade if the non-innovating country lags behind and if prices in the non-innovating country remain relatively unaffected.

The Posner model is related to hog production trends in Canada and the United States. Canadian hog producers are characterized as an innovating industry which has reduced the relative production of lard as compared to pork, since the relative value of lard is recognized as declining. U.S. producers are characterized as an industry which does not recognize that the value of lard is declining relative to lean pork and therefore continues to produce lean pork and lard in the same relative amounts. The outcome is that Canada is transformed from being a net importer of pork from the United States to a net exporter to the United States.

The Edwards-Freebairn model (1984) was used to estimate the welfare gains and losses to producers and consumers in the United States and Canada which resulted from the increase in the lean content in hog carcasses for the periods 1970 to 1979 and 1980 to 1989. The net present value of the welfare gain/loss for each year was calculated and summed using a five per cent discount rate. In the basic scenario, it is assumed that selection for leanness in Canada was continuous from 1970 to 1989 with fat content declining at a rate of 0.388 per cent per annum. In the United States, it was assumed that fat content declined at a rate of 0.388 per cent per annum from 1970 to 1979 and at a rate of 0.0388 per cent from 1980 to 1989.

Estimates of welfare gains are made in hypothetical cases, where it is assumed that consumer demand and producer supply elasticities for pork are equal and remain unchanged over the period 1970 to 1989. Impacts of and sensitivity to assumed changes in U.S. genetic selection pressure for lean carcasses are assessed. Selection pressure is assumed to increase from 0.0388 per cent per annum to 0.0776 from 1980 to 1989, and also to be at the even higher level of 0.388 per cent per annum. This experiment indicates that the welfare of consumers and U.S.

producers increases, while the welfare of Canadian producers declines, when the gap in selection pressure in the two countries is reduced or eliminated. Net welfare is found to increase with increased selection pressure.

In an assumed case, where the supply elasticities of both countries is halved from 1.00 to 0.50, consumers are found to gain less, producers gain more, while net welfare remains unchanged. In another scenario, where the assumed demand elasticities for pork in both countries is reduced from -0.90 to -0.60, consumers are found to gain more and producers gain less, while net welfare remains unchanged. When average U.S. gross farm values of hog carcasses are used to estimate welfare effects, there are no substantial differences since relative prices of hogs remain sufficiently constant as to leave the resulting estimates of welfare from the model unaffected.

A more realistic case is defined and welfare gains are estimated, using published estimates of supply and demand elasticities, based on similar methodologies for the U.S. and Canada. In this case, the assumed supply and demand of pork are more inelastic in Canada as compared to the U.S. and the demand for pork in both countries is assumed to be more inelastic in the period from 1980 to 1989 than in the period from 1970 to 1979. In the period from 1970 to 1979, when selection pressure is assumed to be equal in both countries at the rate of fat reduction in carcasses of 0.388 per cent per annum, consumers in both countries are estimated to gain more than producers on a per tonne consumed or produced basis. In the period from 1980 to 1989, assuming selection pressure in Canada remains at 0.388 per cent per annum, but that this is 0.0388 per cent in the U.S., consumers gain less by about the same amount on a per tonne consumed basis. U.S. producers gain almost nothing, while Canadian producer gains more than double, overall, estimated net welfare gains drop substantially.

A hypothetical case to assess the potential gains from increased U.S. selection pressure is considered. U.S. selection pressure to increase the lean content of hog carcasses is assumed to be at the same rate as in Canada at the rate of 0.388 per cent per annum. Relative consumer gains increase slightly and producer gains decrease slightly in the period from 1980 to 1989 as compared to from 1970 to 1979. Welfare gains increase in total and on a per tonne basis.

A comparison of the realistic case to the hypothetical case shows that the reduction of selection pressure for lean carcasses by producers in U.S. was detrimental to themselves and to consumers in both countries while producers in Canada benefitted. This result is consistent with results predicted by Posner-based trade models and is similar to results estimated by Edwards and Freebairn (1984) for Australian wheat and wool production.

7.2 Conclusions

The adaption of the Edwards-Freebairn model to estimate welfare gains which result from differences in selection intensities for lean hog carcasses in the U.S. and Canada gave estimates of the present value of increased benefits of about 900 million dollars Canadian for the period 1970 to 1989. The estimates of potential welfare gains under the assumption of identical selection pressure represent minimal levels of potential welfare gain from 1980 to 1989, since the estimates are based on actual production and consumption levels. They do not account for other components of potential welfare gains that might have occurred if costs of production of lean carcasses had declined and the quality of pork increased at the same rate as from 1970 to 1979. Specifically, the increased quality and competitiveness of pork relative to other meats would likely have resulted in expanded U.S. pork production and consumption from 1980 to 1989.

The model demonstrates the beneficial affects the development of the Canadian hog grading system has had for producers in Canada.

Furthermore, the results point to the detrimental affects that the lack of focused direction in the production for lean carcasses in the U.S. has had on U.S. producers and consumers in both countries. In general, the results of this study demonstrate that relatively low cost market institutions, such as grading systems, which encourage and enable producers to increase their efficiency in producing a product preferred by consumers, can result in significant welfare benefits for both producers and consumers.

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