RURAL ECONOMY

**Value-Adding 20 Billion by 2005: Impact at the
Alberta Farm Gate**

James R. Unterschultz, Scott R. Jeffrey and Kwamena K. Quagrainie

Project Report #00-05
AARI Project #980842

Project Report

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EXECUTIVE SUMMARY: Value-Adding 20 Billion By 2005: Impact At The Alberta

Farm Gate

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Introduction

In recent years in Canada, direct support provided by governments to the agricultural sector has been decreasing due to international obligations under the General Agreement on Tariff and Trade/World Trade Organization (GATT/WTO) and the North American Free Trade Agreement (NAFTA). Consequently, governments and the agriculture industry are exploring ways of generating and sustaining farmers' revenue from the marketplace.

In Western Canada, there is a renewed interest in the concept of "post-harvest value adding" and substantial investment has been made by the federal / provincial governments and the agriculture industry in value-added initiatives in the post-farm-gate sector. A greater part of farm products from western Canada is shipped and marketed as raw, bulky and unprocessed farm commodities. The value of processed food and beverages is low relative to the value of unprocessed farm commodities, reflecting a relatively lower level of value added to primary agricultural products in the prairies compared to Ontario. The annual rate of growth in processed food and beverages in the prairies is less than 5%. From 1988 to 1997, the average annual growth rate of processed food and beverages is calculated as 4.9% for Alberta, 4.4% for Saskatchewan, and 2.9% for Manitoba. Consequently, the potential for increased value-added processing has attracted much attention by both the federal and the prairie governments.

In 1996, the Alberta government provided $35 million in seed money towards the establishment of a new, not-for-profit Alberta institution, the Alberta Value Added Corporation (AVAC). This corporation was created to foster research and development into the commercialization of value-added products with a focus on the agriculture and food sector. In 1996, the Saskatchewan government instituted an Agri-Value Program (AVP). The purpose of the program is to encourage the development of agriculture-related, value-added industries in that province. In 1997, Manitoba Agriculture and Agriculture and Agri-Food Canada introduced the Agri-Food Research and Development Initiative (ARDI). This initiative was meant to encourage, promote, and conduct innovative research and development projects that contribute to economic development, sustained prosperity, and successful adaptation in the changing agricultural trading environments.

Post-harvest value-added activities are part of a continuous, complex economic development process within the food system. Assessing the effectiveness of value-added initiatives in the farm sector requires an understanding of the whole economic process. This includes an understanding of:

1. the growth in effective demand for value-added products and production of agricultural raw materials,
2. the multi-stage system of the food production process,
3. the structure of the food production technology, and
4. the payoffs of value-added investments to enable better policy decisions regarding alternative uses for these public funds.

Objectives of the Study

The primary objective of the study was to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers. However, given the complex process within the food system, this study also examined the linkages between processors and grain and livestock farmers in the prairie region using econometric modelling methods. Specifically, the objectives of the study were:

1. to examine the interrelationships in commodity production at the farm level in the prairies,
2. to evaluate food supply and farm commodity demand relationships in the processing sector in Canada,
3. to evaluate the existence of any oligopsony power in the domestic market for primary farm commodities, and
4. to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers.

Three crops and two livestock commodities were considered in this study, namely wheat, feed barley, canola, slaughter cattle and slaughter hogs. These are major farm commodities produced in western Canada.

Methodology

The procedure adopted to achieve the objectives of the project was first, model the farm sector and the processing sector separately and second, use parameter measures from those sectors to simulate the likely impact of value adding on commodity prices, quantities and producer welfare. The functional forms used allow the evaluation of cross commodity effects. The supply and demand relationships are then used to build a synthetic model that is used for the simulation exercises. For comparison purposes, the Canadian Regional Agricultural Model (CRAM) is also used to examine the potential impact of value adding on agricultural production and producer welfare. CRAM is a spatial equilibrium mathematical programming model of the Canadian agricultural sector, developed and maintained by Agriculture and Agri-Food Canada. It has been used extensively for various policy analyses related to Canadian agriculture. Policy runs are conducted using CRAM to examine any changes in the relevant variables due to increased value added activities in the prairies.

Analysis of the Farm Sector

It is believed that long-term growth in post-harvest value-adding activities depends not only on growth in effective retail demand, but also on the supply of agricultural raw materials. The supply of agricultural products depends on expected price and other exogenous factors including technology, weather and government policy. There are production interrelationships in the farm sector. Some major livestock feed inputs (e.g., barley) are obtained from crop production so that production decisions in the crop sector are directly associated with production decisions in the livestock sector. Moreover, major government policy decisions may change the economic environment affecting the crop sector and this may have an impact on the livestock sector. Even within the crops sector, changes in the economic factors affecting one crop may have an impact on other crops.

Changes in the economic environment affecting the agricultural sector can be expected to affect farm commodity prices. Often farmers' responses to changes in the agricultural economic environment are assessed in terms of the response of commodity supply to changes in prices. However, in the short run, some factors of production (e.g., land) may be irreversibly committed to particular uses. It is important, then, to examine farmers' ability to make long run structural adjustments in response to any broad-based changes that may confront the farm sector from increased value-added activities in the processing sector.

This study examined a model of three crops (wheat, barley and canola) and two livestock activities (cattle and hogs) which incorporated farmland allocation in the production of wheat, barley, canola and tame hay, as well as land allocation to summer-fallow. Supply functions derived from the Generalized Leontief profit function were specified and estimated simultaneously for the crops and livestock sectors using annual data from 1960 to 1997. The study assessed the extent of substitution/complementarity in production among the five commodities and the effects of price changes on production resulting directly from changes in price as well as indirectly from farmland reallocation. The statistical and economic implications of the models were assessed.

The results indicate the existence of significant economic interrelationships in the western Canadian agricultural sector. The partial and total effects of price changes on production were examined and the results show that the quantity supplied for each of the commodities examined is positively related to its own price (Tables 2.4, 2.5 and 2.6). Hog production is the most price-elastic among the five commodities examined suggesting that the inventory of animals can be reduced readily for slaughter with high market prices. Canola production is the least price-elastic. Wheat production and barley production appear as complements but canola production appears to be a substitute to wheat production. Hog production is positively related to the prices of wheat, barley and canola. Cattle production is positively related to the price of barley. A chi-square test of non-jointness in production indicates jointness in the production of grains and oilseeds, non-jointness in the production of cattle and hogs and jointness in the production of hogs and barley. These findings of complementarity and substitution provide insights into the potential effect of increased value added activities in the processing sector on the farm sector as well as the potential effects that changes in the economic conditions of one commodity may have on other commodities.

More specifically hog production is the most price-elastic among the five commodities with an own price elasticity of 0.83 when estimating short-run sensitivities. In other words, hog production is the most sensitive of the commodities included in the study to changes in it own price. A one percent increase in hog price will increase market supply by 0.83% in the short run. This appears to be a reasonable finding, since annual data are used and the hog cycle (from birth to market) is about 12 to 18 months. Consequently, inventory of animals can be reduced readily with high market prices within this time frame. Cattle production has a longer cycle (approximately 3 to 3½ years) and inventory reduction may not be readily accomplished as with hogs. Thus, the much lower estimated elasticity of cattle supply of 0.123 appears reasonable. Cattle supply in the short run is much less sensitive to changes in slaughter cattle prices than hogs. Cattle production also appears positively related to acreage allocated to tame hay acreage but negatively related to acreage allocated to wheat, barley, canola, and summer-

fallow. In the longer run, hog and cattle production are more responsive to price changes than in the short run.

The non-jointness in production between the cattle and hog sector indicates that Alberta can expand both the cattle sector and the hog sector at the same time with minimal economic conflict between the two sectors. The jointness in the hogs and barley sector indicates that any major increase in the hog sector will require adjustments in the barley sector.

Key crop production constraints are highlighted by the results. Wheat and barley are complementary with each other. Increasing wheat acreage tends to increase barley acreage. However increases in wheat and barley production tend to come at the expense of decreasing canola acres. The effect of interest rate (the price of capital) on commodity production is quite low for all commodities.

Policies encouraging the livestock industry, a key value-added industry in Alberta, need to consider the following points.

- The model estimates indicate that changes in the livestock sector impact on the grain and oilseed sector.
- A policy pursuing increases in hog and beef production will have little conflict between the cattle and hogs for resources.
- Increases in the livestock sector will have an impact on the barley sector and thus indirectly on wheat and oilseeds.

This suggests that any models need to consider the interactions between the different sectors considered here. Furthermore, the supply response changes with the length of time. The models used here do not account for livestock waste by-products.

Analysis of the Processing Sector:

Initiatives taken by the government in value adding activities are likely to encourage and promote projects that contribute to the economic development of the agricultural industry. Government initiatives in value adding include funding programs that encourage research and development into the commercialization of value-added products. With such programs, it is hoped that the food-processing sector will undertake structural adjustments that may eventually result in increased utilization of primary agricultural commodities.

Agricultural and food-processing industries in Canada and the United States have become increasingly concentrated, often resulting from mergers and acquisitions (Green 1985). The trend toward fewer and larger firms has raised concerns about potential market power and its exploitation. In particular, if increasing concentration allows firms to exploit the domestic market for farm commodities, then farmers will be affected if the food processing firms are able to use their power to hold commodity prices at low levels. However, previous studies have documented the efficiency of increasingly large plants in the food-processing industries when plant size is determined by production structure characteristics such as cost economies and technical change (Hazeldine 1991; Goodwin and Brester 1995; Holloway and Goddard 1988;   1999b). In these circumstances increased import and export competition may modify market power. In Canada, a significant proportion of primary agricultural products, particularly grains and oilseeds is exported. This suggests that, with export competition, food-processing firms may not be able to exercise any market power in the domestic market for farm outputs.

This portion of the project examined aggregate demand of the processing sector for wheat, barley, canola, slaughter cattle and hogs in order to:

- evaluate the interaction between the primary sector and the processing sector,
- assess potential market power exploitation between the primary agriculture sector and the processing sector.

The resulting model estimates between the primary sector and the processing sector were used to understand the interactions between the primary and processing sector. A measure of market power was used to determine whom, if anyone would receive any "extra" profits from increased production in the processing and primary sector. An alternative index for measuring industry-wide market power was developed for use in the study. The procedure used here differed from previous studies in that conjectural marginal input cost was explicitly incorporated into a profit function allowing a system of factor demand and output supply equations to be estimated. Conjectural marginal input cost is a method of measuring market power. With this procedure and sufficient data, policy analyses were conducted by assessing the conduct of the industry over time in response to certain changes. This framework was applied to four Standard Industrial Classification (SIC) food-processing industries in Canada; the meat and meat products industry (excluding poultry), the cereal grain flour industry, the livestock feed industry and the vegetable oil industry (excluding corn oil). These are the major food processing industries for Western Canadian agricultural outputs. The profit function for each industry was specified as a translog functional form and one output supply and two factor demand models were estimated for each industry.

The results suggest that the supply curves for meat and meat products, cereal grain flour, livestock feed and vegetable oil are upward sloping (Table 3.3). Increased output prices result in an increased supply of these products. The results also indicate that the processing industry demand curves for slaughter cattle, wheat, feed barley, canola and labour are downward sloping. Increases in commodity prices reduce the demand for farm commodities. Own-price elasticity measures evaluated at the mean of the period 1991-1996 are larger in absolute value than estimates that are based on the sample mean which covers the period from 1974-1996 (Table 3.4). The results portray labour and farm commodities as complements in the food production process. Not all of the increase in processing occurs through acquisition of more capital. For example, increases in post-farm gate processing result in increased amounts of labour being used in the processing sector. The elasticity measures have signs that make economic sense and may be of interest for policy analysis. Supply quantities of meats, flour and vegetable oil are sensitive to output price. Specifically, a one percent increase in output prices leads to a greater than one percent increase in output.

Regarding the issue of market power held by processors, there is no evidence of non-competitive behaviour in any of the commodity markets examined. The absence of non-competitive behaviour may be attributed to the structure of the commodity markets as well as other factors such as the increased competition from world trade that has accompanied technical change, and increased scale of food processing operations. Based on historical relationships, increases in processing of farm commodities in Alberta will not lead to any significant exercising of market power by these firms. The sectors are competitive in their pricing. In conclusion, it should be pointed out that the approach employed in the study may be useful in other empirical evaluations of potential

imperfections and distortions in the domestic market for farm commodities. These model estimates for the processing sector provide further information of use when modelling the overall impact of increased value-added activities on primary agriculture.

Simulation of the Impact of Value-Adding on the Farm Sector using Dual Models

Agricultural economists have expended much effort toward evaluating the economic benefits from cost-reducing research in agriculture. Economic research in this area has focused on the multi-stage production system in a partial-equilibrium framework. Studies have examined the distribution of economic benefits from government policy such as investment in research and development. Other studies have examined the benefits from investments in commodity promotion and advertising. The literature provides important insights into the effects of different types of exogenous factors on commodity prices and quantities as well as the effects on welfare of particular groups in the food production system. The effects of promotion and/or advertising are evaluated under the assumption that promotion and/or advertising shift the retail demand curve while for research, the effects are evaluated under the assumption that research shifts the farm input supply curves. While this multi-stage approach is equally applicable to estimating the effects of value adding investment, no attention as yet has been given to economic research on this particular issue. This portion of the project extended the literature on distribution of gains in a multi-stage production system to include gains/losses from investment in value adding in the post-farm-gate sector.

The study followed and adapted the work of other researchers who have measured the impact of a technological change in the supply curve for farm commodities. This study was concerned with the impact of investment in value added processing that may shift the derived demand curve for farm commodities. Five commodities were examined; wheat, feed barley, canola, slaughter cattle and slaughter hogs. Functional equations representing the supply and demand for the commodities were applied in experiments based on the assumption of increased demand for the commodities. The sector models were built using estimated coefficients from the primary farm sector and the processing sector models.

Model results provide insights into the effects of investment in value adding on prices, quantities and farmers' welfare. Overall, the various simulation results suggest that farmers would be better off with increased prices of grains/oilseed. However, the results indicate that increases in commodity prices cannot be realized in the short term from increased domestic demand for commodities.

Effects of a 20% Increase in Domestic Demand for Wheat

With an increase in domestic wheat demand, the price of wheat declined by 9.04% and barley by 2.81%. There is however an increase in canola price. With the decline in prices, wheat and barley production experienced some decline in production. Canola production declined as well. The decline in barley price did not result in an increase in domestic demand for this grain. The increase in the price of canola caused the domestic demand for this oilseed to fall by 4.19%. Canola exports increased by 60%, which probably explains the increase in canola price. Wheat exports also increased by 10.78%. However, this change in export volume was not enough to result in a rise in wheat price. The changes in wheat and canola exports appear to be more pronounced than the changes in production

of the commodities. The effects on barley were quite minimal. Although the price of barley declined by 2.81%, domestic demand declined and production did not increase. This solution may appear counter-intuitive but considering the fact that barley is used as feed for the livestock industry, we observe that the production of cattle and hogs does not increase. Changes in the hog industry were modest and it appears that the cattle industry was not affected by the increase in domestic wheat demand. In terms of welfare, producer profits declined by 5.77%, which may be attributed to the unrealized increase in farm prices, particularly for the grains.

Effects of a 20% Increase in Domestic Demand for Canola

A 20% increase in the domestic demand for canola caused an increase in the price of canola by 5.45% but a decline in the price of wheat and barley. With an increase in price, canola production increased by 21.06%. The production of wheat and barley declined which may be attributed to the decline in price and to substitution effects in production with canola. Exports of canola increased by 50%. The decline in wheat price, however, caused an increase in domestic demand for wheat by 21.69%. The effect on barley was not significant. Unlike wheat, a significant amount of canola is processed locally. Thus, the finding of an increase in canola price and production with an increase in domestic demand may be in order.

An increase in the domestic demand for canola resulted in an increase in hog price but a decrease in cattle price. Nonetheless, the production of both cattle and hogs decreased by 0.32 and 11.11 percent, respectively. The domestic demand for the two commodities also declined and for exports, hogs exported increased by 3.25% while export of cattle decreased by 5.88%.

Effects of a 20% Increase in Domestic Demand for Cattle

With a 20% increase in domestic cattle demand, the price of cattle declines by 1.14%. The price decline is contrary to what would be expected. Nevertheless there is an increase in cattle production by 16.9% suggesting a positive net effect for the cattle industry. Export of cattle decreased by 64.71%. The price of hogs fell by 0.18% but hog production increased by 4.86%. However, the decrease in hog price resulted in a 42.86% increase in the domestic demand for hogs. Export of hogs decreased by 1.63%.

Changes in the prices and production of the crops were modest but adjustments in the quantities exported were significant. The price of barley was unchanged yet production and domestic demand decreased. This solution appears counter-intuitive when assessed relative to the increased production of both cattle and hogs, as it was expected that an increase in the production of cattle and hogs would result in an increase in domestic demand for barley. In terms of producer welfare, total profits increased by 5.09%. The significant increase in the production of cattle and hogs coupled with the relatively stable livestock prices, may have contributed to the increase in farmers' welfare. This solution may suggest that farmers would be better off with increased investments and capacity-expansions in the domestic cattle slaughtering industry.

Effects of a 20% Increase in Domestic Demand for Hogs

Generally, a 20% increase in domestic demand for slaughter hogs resulted in price increases for all five commodities, ranging from 0.09% to 1.13%. The price rise did not

cause significant change in commodity supply except for hog production. The production of hogs increased by 2.78%. There was no change in hog exports. With a price increase, the domestic demand for wheat, canola and cattle decreased. The export quantities for canola and cattle increased by 20 and 2.94%, respectively. The effects on barley were minimal.

In terms of producer welfare, total profits increased by 4.72%, which may be attributed to the resulting increases in commodity prices. This solution is consistent with the solution from the cattle scenario above, in which farmers may be better off with capacity expansions in the domestic meat processing industry.

Simulation of the Impact of Value-Adding on the Farm Sector using the Canadian Regional Agricultural Model (CRAM):

The Canadian Agricultural Regional Model (CRAM) is a spatial equilibrium policy analysis model developed and maintained by Agriculture and Agri-Food Canada. It provides significant regional and commodity detail of the Canadian agricultural sector and is an important instrument for the analysis of policy changes on the Canadian agriculture industry at a disaggregated level, in terms of the impacts on production (i.e., supply) and demand.

In this study, two case situations were analyzed using CRAM: (a) the domestic demand for each of the commodities, wheat (high quality), beef (high quality), and pork was increased by 5% and by 10% and (b) the domestic demand for all three commodities was increased simultaneously by 5% and by 10%. The results obtained generally confirmed those from the dual model. An increase in the domestic demand for individual commodities did not result in any change in the relevant variables compared to a simultaneous increase in all commodities. In the latter scenario, results suggest that, in each case, producer and consumer welfare declined but by less than 1%. In the model, increases in domestic demand were all accounted for from export demand by the rest of the world. This may have contributed to the decline in welfare. Specifically, with a simultaneous 10% increase in production, we observe a 1.79% decline in world demand for high quality wheat, 14.46% decline in world demand for Heifers & steers, a 3.1% increase in world demand for low quality dressed beef, and a 3.77% decline in export demand for pork.

There was no significant change in production for any of the commodities. Any changes in production were less than 1% from the base results. However, for beef, a simultaneous increase in domestic demand resulted in an increased in beef slaughter in Alberta. In the case of a simultaneous 5% increase in domestic demand, there was a 2% increase in Alberta beef slaughter. With a simultaneous 10% increase in domestic demand, there was a 4% increase in Alberta beef slaughter. Other minor changes that are observed, particularly with a simultaneous 10% increase in domestic demand, are changes in production and input use (i.e., fertilizer, chemicals and fuel). Overall the impact of increased domestic demand for primary agricultural products on farm incomes was minimal.

Conclusions

It is clear from the results that the volume of Canadian agricultural commodities traded on the world market is too small to permit Canada to influence world price. On an

individual commodity basis, however, Canada may be able to influence prices received by farmers. The results from the simulation exercises indicate that farmers' welfare is increased with increased commodity price. Prices are determined by the market. Therefore, there is the need for strategies directed at specific markets to effect an increase in price. In foreign markets, strategies could be directed at increasing market share. Canada's average market shares in the world market for wheat and barley from 1988 to 1997 are approximately 18% and 19%, respectively (Canadian Wheat Board 1999; Food and Agriculture Organization 1999; International Grains Council 1999). Canada's share of the world market for canola is approximately 48%. However this would not lead to a larger economic sector devoted to further processing.

Canada's potential to influence prices on the world market depends critically on the world demand for commodities, which is erratic. Consequently, domestic value-added processing has been seen as an opportunity for guaranteed markets that would facilitate high prices of commodities. Adding value to enhance the price of commodities will be effective when an appreciable proportion of domestic production is processed domestically and a smaller proportion of the commodity is exported. The current development of new value-added processing opportunities on the prairies (e.g., canola crushing plants and livestock slaughter facilities) will provide some economic activity in the prairies. However, these activities will not enhance the price of commodities at the farm gate, which will continue to be set by the world price, net of transportation costs. The loss of direct support from the government means that farmers will continue to face the full impact of downturns in agricultural commodity prices. Increasing the value of processing and related activities to $20 billion will have minimal direct impact on the welfare of primary agriculture producers who are engaged in producing the typical commodities such as wheat or beef. The domestic market will replace some of the export demand for Alberta commodities.

If primary agricultural producers are to benefit directly from increased processing in Alberta and Canada, then these producers will have to participate directly in value-adding industries, through direct ownership or through cooperatives. Alternative structures may be alliances between various players in the sectors or primary agricultural producers may have to move into niche markets where current demand exceeds the supply. However, typically, niche markets, unless consumer demand is growing rapidly, are often rapidly saturated and any "excess profits" at the farm gate removed.

Although farmer involvement in processing can take many forms, the formation of new structures of co-operation and vertical co-ordination in the food chain must be given special attention. New management structures are required to meet the challenges of the new agricultural economy. The "New Generation Co-operatives" (NGCs) initiated in the US in North Dakota and Minnesota provide a potential model that may be followed. New Generation Co-operatives integrate farmers into domestic processing activities, with focus on vertical integration between these levels. Such arrangements provide farmers with a set price for their primary commodities as well as earnings from the processing and value adding activities. Thus, NGCs may have the potential with respect to first, their inherent ability to compete in value-added products market and second, providing ways of generating and sustaining producers' revenues from the marketplace.

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Abstract

The primary objective of the study was to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers in the prairie region in Canada. Three crops and two livestock commodities were considered in this study, namely wheat, feed barley, canola, slaughter cattle and slaughter hogs. The procedure adopted to achieve the objectives of the project was first, model the farm sector and the processing sector separately and second, use parameter measures from those sectors to simulate the likely impact of value adding on commodity prices, quantities and producer welfare.

Hog production is the most price-elastic among the five commodities with an own price elasticity of 0.83 when estimating short-run sensitivities. Thus, the much lower estimated elasticity of cattle supply of 0.123 appears reasonable. Cattle supply in the short run is much less sensitive to changes in slaughter cattle prices than hogs. Hog and cattle production are more responsive to price changes in the long run than in the short run. The non-jointness in production between the cattle and hog sector indicates that Alberta can expand both the cattle sector and the hog sector at the same time with minimal economic conflict between the two sectors. The jointness in the hogs and barley sector indicates that any major expansion in the hog sector will require adjustments in the barley sector. The results from the model in the processing sector suggest that the supply curves for meat and meat products, cereal grain flour, livestock feed and vegetable oil are upward sloping. The simulation model indicated that the current development of new value-added processing opportunities on the prairies (e.g., canola crushing plants and livestock slaughter facilities) will provide some economic activity in the prairies. However, these activities will not enhance the price of commodities at the farm gate, which will continue to be set by the world price, less transportation cost. Increasing the value of processing and related activities to $20 billion will have minimal direct impact on the welfare of primary agriculture producers who are engaged in producing the typical commodities such as wheat or beef.

If primary agricultural producers are to benefit directly from increased processing in Alberta and Canada, then they will have to participate directly in the value-adding industries by investing directly in processing plants either through direct ownership or through cooperatives. Alternative structures may involve alliances between various players in the sectors, or primary agricultural producers may have to move into niche markets where current demand exceeds the supply. However, niche markets, unless consumer demand is growing rapidly, are often rapidly saturated and any "excess profits" at the farm gate will be removed.

1. INTRODUCTION

In recent years in Canada, domestic government policies have been undertaken to reduce budget deficits. Direct support provided by governments to the agricultural sector is being reduced due to international obligations under the General Agreement on Tariffs and Trade/World Trade Organization (GATT/WTO) and the North American Free Trade Agreement (NAFTA). For example, in 1995 the Western Grain Transportation Subsidy (WGTS) was eliminated, altering the economics of agricultural production and food processing in western Canada. Faced now with higher grain transportation rates, farmers in the Canadian prairies (the provinces of Manitoba, Saskatchewan and Alberta) have to explore new ways for sustaining the farming business. The problem facing farmers is further aggravated with the cyclical nature of agricultural markets and volatile commodity prices. If agricultural production and productivity remain at constant levels and long run declining trends in commodity prices continue, farmers' revenues per unit of production are likely to decline over time in the absence of any government support. These developments confronting farmers are creating the necessity for governments and the agriculture industry to explore ways of generating and sustaining producers' revenue from market sales and revenues. They also pose immediate challenges for adaptation and adjustment through diversification, expansion and value-added processing activities beyond the farm gate[1].

1.2 Government Initiatives on Value-Adding

The agricultural sector in the Canadian prairies is characterized by the production of grains, oil-seeds and livestock. A significant proportion of farm production is marketed as raw, bulky and unprocessed farm commodities. The value of processed food and beverages is low relative to the value of unprocessed farm commodities (Table 1.1). The ratio of the two values is less than one and it appears to be stable (Figure 1.1). These values reflect the relatively lower level of value added to primary agricultural products in the prairies compared to Ontario. Consequently, the potential for increased value-added processing has attracted much attention by both the federal and the prairie governments. The annual rate of growth in processed food and beverages in the prairies is less than 5%. From 1988 to 1997, the average annual growth rate of processed food and beverages is calculated as 4.9% for Alberta, 4.4% for Saskatchewan, and 2.9% for Manitoba.

In 1996, the Alberta government provided $35 million in seed money towards the establishment of a new, not-for-profit Alberta institution, the Alberta Value Added Corporation (AVAC). This corporation was created to foster research and development into the commercialization of value-added products with a focus on the agriculture and food sector. Also in 1996, the Saskatchewan government instituted an Agri-Value Program (AVP). The purpose of the program was to encourage the development of agriculture-related, value-added industries in that province. In 1997, Manitoba Agriculture and Agriculture and Agri-Food Canada introduced the Agri-Food Research and Development Initiative (ARDI). This initiative was intended to encourage, promote,

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[1] In this study, the concept of value adding refers to any activity that increases the value of raw agricultural commodities through processing. It includes improvement in quality and the production of alternative products that meet consumer approval.

and conduct innovative research and development projects that contribute to economic development, sustained prosperity, and successful adaptation in the changing agricultural trading environments. The objective of these value-added initiatives is to induce post-harvest value-added growth in most sectors of the prairie agricultural economy. It is hoped that this may have a broad and potentially significant economic impact at the farm level as a result of increased demand for primary commodities produced in the prairies.

1.3   Problem Statement

Development of post-harvest value-added activities should be viewed as part of a continuous, complex economic development process within the food system. An assessment of the value-added initiatives within the farm sector requires an understanding of the entire economic process. First, long-term growth in value-adding activities depends primarily on growth in effective demand for value-added products and on production of agricultural raw materials. Demand for food is a function of income, prices, taste and demographic factors. Empirical evidence suggests that food is price inelastic, although elasticity measures may differ between various categories of food. On the other hand, the supply of raw agricultural commodities depends primarily on expected prices and exogenous factors such as technology and weather.

Second, the food production process is a multi-stage production system. Figure 1.2 is a simplified chart illustrating product flow and the marketing system in Canada. There are intra- and inter-relationships between the grains and livestock sectors. For example, interrelationships exist between beef and pork, and between barley and slaughter hog production. Thus, any value adding in cereals may have a significant impact on the livestock industry and vice versa.

Third, any investments can change the structure of the production technology in the processing sector. Figure 1.3 depicts two possible effects of value-added investments assuming the prices of the inputs used are held constant. The curves are isoquants for a processed product assuming the use of two inputs, a farm commodity **X1** and a marketing input **X2**. In one scenario, an increase in processors' output from Q^0 to Q^1 causes an increase in the use of both inputs (i.e., giving a parallel shift in the isoquants). In this case more output is produced using more of the farm commodity and the marketing input. The same proportion of the inputs is used in the production process (from point **a** to **b**). Alternatively, as output increases from Q^0 to Q^1, the amount of **X1** used increases but the amount of **X2** used declines. In this scenario, there is a change in the shape and position of the isoquant. More of the farm commodity input is used relative to the marketing input (from point **c** to **d**).

Fourth, the value-adding policy initiatives involve publicly funded investments and policy makers should have information about payoffs in order to assess alternative uses for these public funds. There is also a public interest issue concerning the productivity and appropriate use of tax dollars. Besides farmers, other identifiable groups in the marketing system are processors, marketing input suppliers and consumers. Each of these agents may be affected by value adding policy. The size and distribution of any value-added based benefits/costs can be expected to depend on market structure. Consequently, there is a need to evaluate the size and distribution of benefits/costs of this policy among the various groups. Clearly, there are several factors at play in the food

production process that need to be understood if the impact of post-harvest value adding is to be assessed appropriately.

1.4   Objectives of the Study

The primary objective of this study is to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers. However, given the complex process within the food system, this study also examines the linkages among consumers, processors and grain and livestock farmers in the prairie region using econometric modelling methods. Specifically, the objectives of the study are:

- to examine the interrelationships in commodity production at the farm level in the prairies,
- to evaluate food supply and farm commodity demand relationships in the processing sector in Canada,
- to evaluate the existence of any oligopsony power in the domestic market for primary farm commodities,
- to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers.

To accomplish these objectives, three crops and two livestock commodities are considered in this study, namely wheat, feed barley, canola, slaughter cattle and slaughter hogs. These are major farm commodities produced in western Canada. Dual production models for wheat, barley, canola, slaughter cattle and slaughter hogs are estimated using a Generalized Leontief function. Using Translog specifications, the supply functions for wheat flour, canola oil and meat products and the demand functions for farm commodities are specified so that the extent of any oligopsony power in the domestic market for primary farm commodities can be determined. The functional forms used allow the evaluation of cross commodity effects. These supply and demand relationships are then incorporated into a synthetic simulation model to investigate the likely impact of increased value-added processing on commodity prices, quantities, and welfare of prairie farmers.

1.5   Relevance of the Study

The procedure applied here is expected to provide results that will give an insight into the relationships among the five commodities considered (wheat, feed barley, canola, slaughter cattle and slaughter hogs). An insight into the relationships at the farm level is very important as farm managers are determining their best strategies for future profit and farm growth. Results from the simulation analyses will assist governments in evaluating their policies for the agricultural sector and provide a framework for future policy decisions, particularly in the allocation of public resources. This is also important for policy planning purposes.

The project is presented as follows: Chapter 2 provides an examination of the production of wheat, feed barley, canola, slaughter cattle and slaughter hogs in the prairie region. The production of crops and livestock is examined simultaneously. In Chapter 3, the economic behaviour of the Canadian food-processing sector is examined to assess whether or not oligopsony power applies in this sector. The rationale for this assessment is that the distribution of economic benefits from investment in value-added activities

depends on market structure. In Canada, there are relatively few primary food processing establishments compared to the larger number of farm businesses and production. Thus, in the absence of more competition for farm commodities from the export market, concern has been expressed that these processing establishments will exert some market power in the domestic market for farm commodities. The final chapter incorporates the estimated supply and demand relationships in Chapters 2 and 3 into a static synthetic simulation model. The model is then used to simulate the likely impact of value adding on prices, quantities, resource allocation and net benefits to western Canadian farmers.

Figure 1.1:   Ratio of the Value of Shipments For Processed Food to the Value of Output For Unprocessed Farm Production
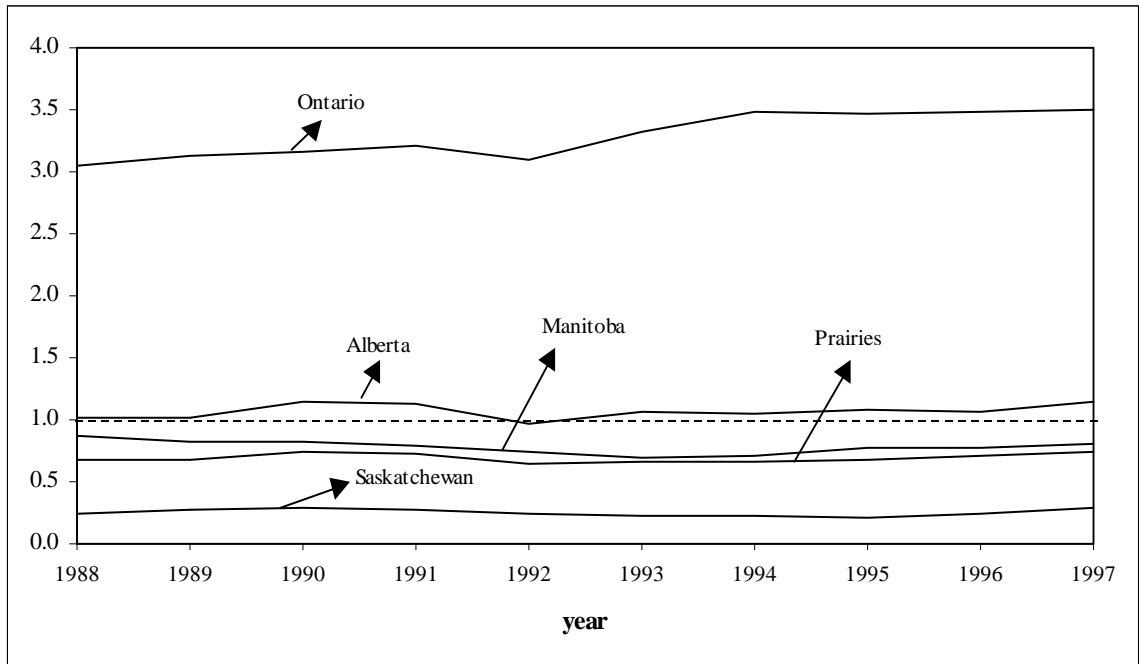
Source: Calculated from Table 1.1.

Figure 1.2:   A Simplified Diagram of Product Flow and the Marketing System for Food in Canada
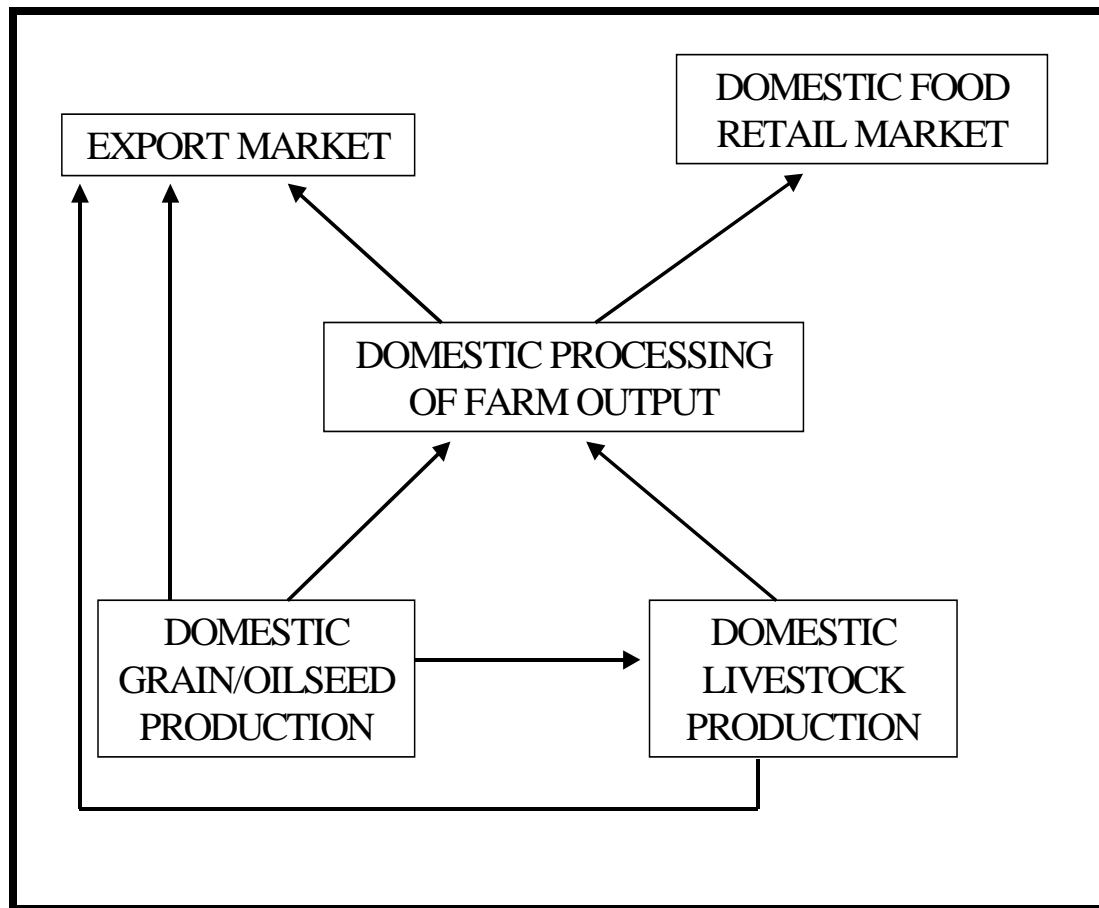
Figure 1.3:   Alternative Possible Impacts of Value Added Investments on Processors' Input Use

X1

(1) <u>Same proportion of inputs produce different output</u>

b

a

Q^1

Q^0

X2

X1

(2) <u>Different proportions of inputs produce different output</u>

d

Q^1

c

Q^0

X2
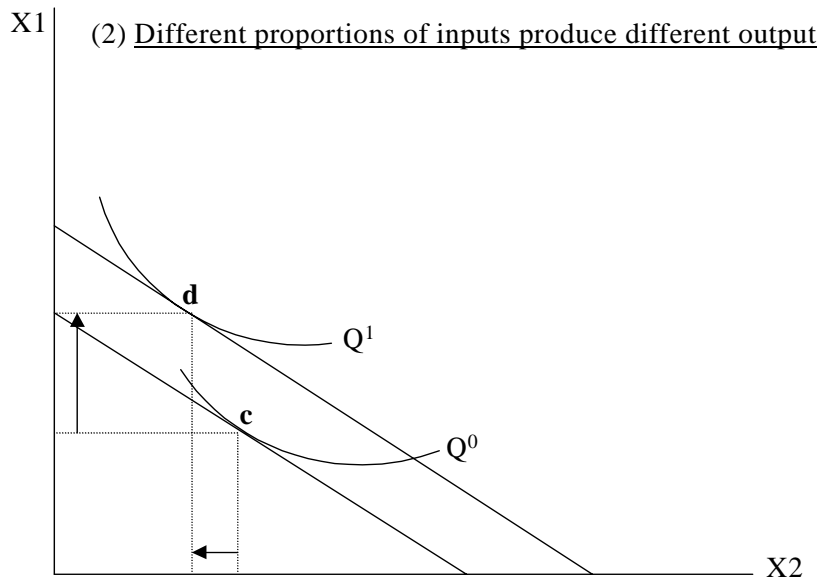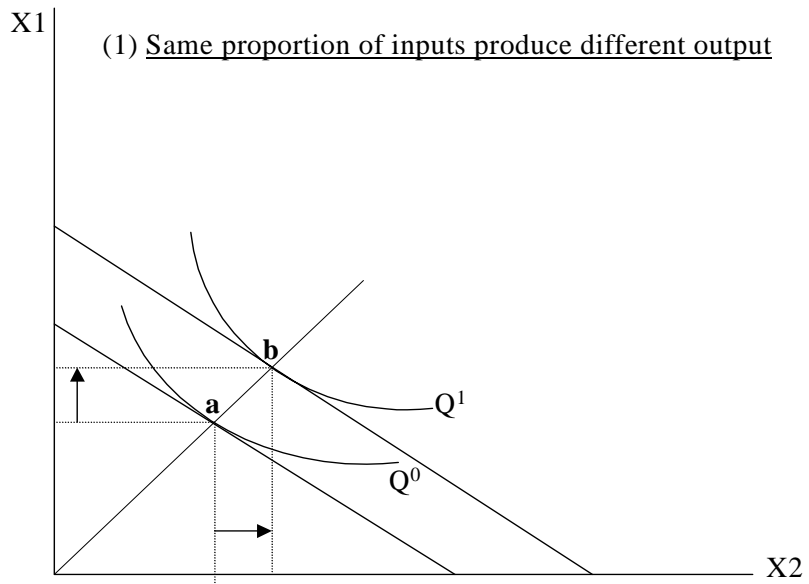
Table 1.1: **Nominal Values of Processed Food and Unprocessed Farm Commodities for Selected Provinces ($billion)[1]**

Year	Value of Processed Food & Beverage ($billion)					Value of Unprocessed Farm Commodities ($billion)				
	Alberta	Sask.	Manitoba	Prairies[2]	Ontario	Alberta	Sask.	Manitoba	Prairies	Ontario
1988	4.51	1.10	1.81	7.42	17.53	4.46	4.46	2.09	11.01	5.76
1989	4.64	1.20	1.73	7.57	18.07	4.59	4.49	2.10	11.18	5.77
1990	4.89	1.16	1.64	7.69	17.87	4.28	4.02	1.98	10.28	5.66
1991	4.78	1.11	1.57	7.46	17.80	4.23	4.12	2.00	10.35	5.55
1992	4.74	1.06	1.59	7.39	18.76	4.92	4.38	2.16	11.46	6.06
1993	5.29	1.01	1.66	7.96	19.70	5.00	4.55	2.38	11.93	5.92
1994	5.76	1.10	1.74	8.60	21.15	5.52	5.05	2.44	13.01	6.07
1995	6.33	1.16	1.94	9.43	21.87	5.89	5.37	2.51	13.77	6.31
1996	6.84	1.35	2.15	10.34	22.93	6.44	5.48	2.75	14.67	6.57
1997	7.25	1.70	2.42	11.37	23.72	6.34	5.90	3.03	15.27	6.77

1. Source: Statistics Canada (CANSIM). In CANSIM, the terminology "value of shipment of food and beverage" applies as the measure of the value of processed food and beverage and the data on "farm receipts" is applied as the measure of the value of output of unprocessed farm commodities.
2. Prairies are Alberta, Saskatchewan and Manitoba combined. Other analysis presented later also includes British Columbia

2.   SUPPLY RESPONSE OF WESTERN CANADIAN AGRICULTURE

Long-term growth in post-harvest value-adding activities depends not only on growth in effective retail demand, but also on the supply of agricultural raw materials. The supply of agricultural products depends on expected price and other exogenous factors including technology, weather and government policy. There are production interrelationships in the farm sector. Some major livestock feed inputs like barley are obtained from crop production so that production decisions in the crop sector are directly associated with production decisions in the livestock sector. Moreover, major government policy decisions may change the economic environment affecting the crop sector and this may have an impact on the livestock sector. Even within the crops sector, changes in the economic factors affecting one crop may have an impact on other crops. It is, therefore, important to examine these interrelationships at the farm level to enable a better prediction of farmers' behaviour resulting from increased value-added activities in the processing sector and any increased demand for farm output.

Changes in the economic environment affecting the agricultural sector can be expected to affect farm commodity prices. Often farmers' responses to changes in the agricultural economic environment are assessed in terms of the response of commodity supply to changes in prices. However, in the short run, some factors of production may be irreversibly committed to particular uses (e.g., land). It is important, then, to examine farmers' ability to make long run structural adjustments in response to any broad-based changes that may confront the farm sector from increased value-added activities in the processing sector.

This component of the project is organized as follows. The section that follows gives a brief review of studies on commodity supply in western Canada. Based on the review, the objectives of the study are outlined. This section is followed by an outline of a theoretical framework on which the models to be estimated are based. In this section, the formulation for incorporating farmland allocation decisions and the formulation for examining the total effect of a price change are developed. The formulations that are developed involve alternative ways of specifying a system of supply response models; these have not been applied in previous studies of western Canadian agriculture. Supply functions are specified as being conditional on farmland allocations using a Generalized Leontief profit function. Following this are sections dealing with the empirical specification of the models, data description, estimation methods and presentation of estimation results. Some conclusions are then drawn from the estimation results.

2.2   Literature Review of Western Canadian Agriculture

Various studies of western Canadian agriculture have examined different modelling issues that include functional forms, the effects of government policy and technological changes, and risks. For example, Bewley et al. (1987), Coyle (1993b), Horbulyk (1990), Krakar and Paddock (1985), and Meilke and Weersink (1991) examined different functional forms for supply response models. Given that there are risks associated with the business of farming, Meilke and Weersink (1990, 1991), Schoney (1990, 1995), and Weisenel et al. (1991) introduced producer risk into supply response models for the prairie region. Other researchers have examined the effects of

price expectations on farmers' supply functions (Clark and Klein 1992; Clark et al. 1992). Carew et al. (1992) also investigated how technological changes brought about by agricultural research have influenced Canadian agriculture.

Another important issue that has confronted prairie farmers during the past two decades includes changes in government agricultural policy. Agricultural policies that have affected prairie agriculture include the Western Grains Stabilisation Program (WGSP), the Western Grain Transportation Subsidy (WGTS), as well as crop insurance and safety net programs. In 1990, the WGSP was abandoned in favour of an expanded crop insurance program and in 1995, the WGTS was eliminated. Studies that have examined the impact of government programs include Cameron and Spriggs (1991), Cluff et al. (1990), Coyle and Brink (1990), Fulton (1987), Meilke (1976), Meilke and Weersink (1990), and Miranda et al. (1994).

The current study builds on previous economic research on western Canadian agriculture in a number of ways. First, the studies cited above have analysed crops and livestock sectors separately, implicitly assuming weak separability between these two sectors in western Canada[2]. This assumption is somewhat restrictive and may be inappropriate if results are to be used for policy analyses since, as noted earlier, interrelationships exist between the livestock sector and the crops sector in western Canadian agriculture. This study examines supply response in the livestock and crops sectors simultaneously to enable a better prediction of farmers' behaviour.

Second, Coyle (1993b) examined western Canadian farmers' response incorporating farmland allocation for a four-crop model of wheat, barley, canola and "other" crops using data over the period 1961-1984. However, farmland is viewed as a quasi-fixed agricultural input that is allocatable not only to the production of wheat, barley, canola, oats, and "other" crops, but also to the production of tame hay (seeded hay as opposed to native grass) and for summer fallow. Hay is an important feed input for livestock and tame hay is increasingly becoming a commercial crop in western Canada. In 1960, 1.83 million hectares of land was seeded to tame hay in western Canada (Statistic Canada – CANSIM). In 1998, 4.45 million hectares of farmland was seeded to tame hay, an increase of about 143 percent. Despite decreases in this practice, summer-fallow is still a primary rotation practice in arid cropping areas of western Canada (Clark and Klein 1992). This study incorporates farmland allocation to the production of wheat, barley, canola, and tame hay, as well as considering land allocation to summer-fallow.

Finally, the present study examines farmers' ability to make long run adjustments by distinguishing between:
(a) a change in supply induced by a price change holding allocatable farmland constant (viewed as partial effects of a price change) and
(b) a change in supply associated with reallocation of farmland, in response to the price change (referred to as complete effects of the price change).

In summary, the models to be used in this component of the study include three crops (wheat, barley and canola) and two livestock activities (cattle and hogs). The models incorporate farmland allocation in the production of wheat, barley, canola and

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[2] The concept of weak separability involves aggregation to construct broad groups of commodities (e.g., crops and livestock) as well as separable decision making for each of the group sub-problems. This assumption permits the specification and estimation of a subgroup of commodities in isolation from other commodities.

tame hay as well as land allocation to summer-fallow. Results from this model will assist in providing a means of assessment and prediction of the effects of shifts in economic conditions on crop and livestock production and on farmland allocation in western Canada.

2.3 Theoretical Framework

This section outlines the economic theory of production and its application to the western Canadian agricultural sector. The "total" effect of price changes on farm production, based on interrelations between alternate farmland uses, is examined.

2.3.1 Basic Model Formulation

The approach of duality to production economics is applied in this study. The essence of the dual approach is that technology constrains optimizing behaviour of individuals. Thus, it is possible to use a representation of optimizing behaviour (e.g., cost minimization, profit maximization) to study technology (Chambers 1988). The dual approach avoids explicit specification of production functions and permits the specification of a system of output supply functions from the dual profit or cost function. This procedure is particularly appropriate when dealing with multiple commodities and/or products. It permits the incorporation of contemporaneous covariances of disturbances across equations in the estimation procedure and the specification of symmetry restrictions on coefficients across equations that are implied by theory. Consequently, a duality approach is appropriate to examine interrelationships between the crop and livestock sectors to enable an effective assessment of the effect of a price change on the production of other commodities.

Consider the farming business in western Canada as being a competitive industry with the objective of a farmer operating a multi-output farm enterprise being maximization of short run profit. A farmer's decision problem is then described as:

$$\Pi(w, r, d, z) \quad = \quad \max_{q,x} \{wq - rx \ : \ q \in Q(x, d, z)\} \tag{2.01}$$

where $q = (q_1, \ldots, q_m)$ is a vector of outputs for m enterprises; $w = (w_1, \ldots, w_m)$ is a vector of output prices; $x = (x_1, \ldots, x_v)$ is a vector of variable inputs; $r = (r_1, \ldots, r_v)$ is a vector of variable input prices; $d = (d_1, \ldots d_n)$ is a vector of exogenous variables (e.g., weather and interest rates); z is a fixed input that can be allocated among m enterprises (e.g., total

farmland) with $z \geq \sum_{i=1}^{m} z^i$, where z^i is farmland allocated to the ith enterprise; and Q is the

output set (i.e., the set of feasible outputs given x, d and z).

Equation (2.01) is an expression of the maximum level of variable profit (i.e., revenue minus variable cost) given the exogenous factors and the fixed input. Given standard assumptions for the underlying technology[3], the profit function is non-negative, reflecting the property of monotonicity, as well as being convex and continuous in (w, r), non-decreasing in w, non-increasing in r, and positively linearly homogenous in (w, r). By *Hotelling's lemma*, optimal output supply (q_i) and input demand functions (x_j) are obtained respectively as:

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[3] The assumptions are that the input requirement set is convex, closed and non-empty for all $q>0$ where the input requirement set is the set of all input combinations capable of producing output level q.

$$q_i(w, r, d, z^1, ..., z^m) \quad = \quad \frac{\partial \Pi(w, r, d, z^1, ..., z^m)}{\partial w_i} \qquad i = 1, 2, ..., m \qquad (2.02)$$

and $\quad x_j(w, r, d, z^1, ..., z^m) \quad = \quad -\frac{\partial \Pi(w, r, d, z^1, ..., z^m)}{\partial r_j} \qquad j = 1, 2, ..., n \qquad (2.03)$

All variables are as defined earlier. The output supply and input demand expressions are functions of all output prices, all variable input prices, exogenous factors and the fixed input.

An alternative expression of the farmer's decision problem equation (2.01) is:

$$\Pi(w, r, d, z) \quad = \quad \max_q \{ wq - c(r, q) : (q, d, z^1, ..., z^m) \in \tau \} \qquad (2.04)$$

where $c(r,q)$ is the cost function of the farm enterprise and τ is the technology set. Again, assuming standard properties for τ, the cost function is non-decreasing in r and q, concave and continuous in r and linearly homogenous in r. If the underlying production technology is assumed to be homothetic, the cost function can be written as[4]:

$$c(r, q) \quad = \quad c(r) g(q) \qquad (2.05)$$

where $g(q)$ is a function that is non-decreasing in q and $c(r)$ is now the cost function associated with a unit output, that is,

$$c(r) \quad = \quad \min \{ wx : (x, 1) \in \tau \}. \qquad (2.06)$$

With this technology, the profit function, $\Pi(w, c(r), d, z)$ is linearly homogenous in w and $c(r)$, and $c(r)$ is linearly homogenous in r; that is,

$$\Pi(w, d, z, r^*) \quad = \quad c(r) \Pi^*(w, d, z / c(r)) \qquad (2.07)$$

where $r^* = c(r)$ represents a single aggregate input price index; and Π^* is a function homogenous of degree zero in the output price and the aggregate input price (Chambers 1988 p. 149). Thus, the profit function can be expressed as: (a) a linearly homogenous function of output prices w, exogenous variables d, fixed allocatable input z, and a single aggregate input price r^*; and (b) a product of r^* and Π^* (Chambers 1988 p. 149; Coyle 1993a; Pope and Hallam 1988; Yuhn 1991). The aggregate input price may be defined as the cost-minimizing way of producing q. The short run profit-maximzing output supply functions are a system of equations represented by:

$$q_i(w, r^*, d, z^1, ..., z^m) \quad = \quad \frac{\partial \Pi(w, r^*, d, z^1, ..., z^m)}{\partial w_i} \qquad i = 1, 2, ..., m \qquad (2.08)$$

where $q_i(w, r^*, d, z^1, ..., z^m)$ is the profit-maximizing output supply of the ith farm commodity. The above model expresses output supply as a function of all output prices, a single aggregate input price, the exogenous factors and the fixed input. An expression for the effect of a change in output price is:

$$\frac{\partial^2 \Pi(w, r^*, d, z)}{\partial w_i \partial w_j} \quad = \quad \frac{\partial q_i(w, r^*, d, z)}{\partial w_j} \qquad (2.09)$$

The above formulation expresses a change in output supply induced by a price change (partial effect), ignoring the effect of the change in allocatable fixed input, z (indirect

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[4] The homothetic assumption permits researchers to construct aggregate price and quantity indices to study production decisions by analysing only a subgroup of all outputs and input (e.g., Coyle 1993a; Lawrence 1989; Paris et al. 1990; Pope and Hallam 1988; Roberts 1989; Yuhn 1991).

effect). It assumes that allocation of a fixed input such as farmland is independent of output prices which implies that the shadow price or marginal value of land is independent of output prices.

2.3.2 Modelling Fixed Allocatable Input

Chambers and Just (1989) suggest that when there is a fixed allocatable input such as farmland, an equivalent approach for obtaining the multi-output profit function is to choose the fixed allocatable farmland to maximize the profit function, that is:

$$\Pi(w,r^*,d,z) \quad = \quad \max_{z^1,\dots,z^m} \left\{ \Pi(w,r^*,d,z^1,\dots,z^m) \; : \; \sum_{i=1}^{m} z^i = z \right\} \qquad (2.10)$$

Equation (2.10) is the profit function associated with an optimal allocation of the fixed allocatable input. Given standard assumptions concerning technology, this function is also convex and continuous in (w, r), non-decreasing in w, non-increasing in r, and linearly homogenous in (w, r). If an interior solution ($z^i > 0$, $\forall$ i) to (2.10) exists, the envelope theorem and *Hotelling's lemma* suggests that:

$$\frac{\partial \Pi(w_i,r^*,d,z)}{\partial w_i} \quad = \quad q_i(w,r^*,d,z^1,\dots,z^m)$$

$$= \quad q_i(w,r^*,d,\tilde{z}^1,\dots,\tilde{z}^m) \qquad (2.11)$$

$$= \quad \frac{\partial \Pi(w,r^*,d,\tilde{z}^1,\dots,\tilde{z}^m)}{\partial w_i}$$

where $\tilde{z}^i$ is the optimal fixed input allocation[5]. The formulation above offers a decomposition of output response to price changes that illustrates the importance of the effects of output price changes on farmland values. Based on (2.10), the effect of an output price change may be specified as:

$$\frac{\partial q_i(w,r^*,d,z)}{\partial w_j} \quad = \quad \frac{\partial q_i(w,r^*,d,\tilde{z})}{\partial w_j} + \sum_{i=1}^{m}\sum_{k=1}^{s} \frac{\partial q_i(w,r^*,d,\tilde{z})}{\partial z_k^i} \left\{ \frac{\partial \tilde{z}_k^i}{\partial w_j} \right\} \qquad (2.12)$$

where i=1,…,m refers to supply and k=1,…,s refers to reallocated fixed input such as farmland. Horbulyk (1990) and Chambers and Just (1989) refer to the expression on the right side of (2.12) as the "total" effect of a price change. The expression may also be termed the "complete" effect of a price change. The first part expresses the change in supply induced by the price change (partial effect) holding the allocatable fixed input constant. The second part expresses the change in supply associated with reallocation of fixed input in response to the price change (indirect effect). Chambers and Just (1989) refer to the partial effect as the compensated effect (compensated for the induced fixed input change). The term in brackets is obtained from the first-order conditions of (2.10) with respect to z^i since the profit function contains the optimal fixed input allocations.

Diewert (1974), and Khatri and Thirtle (1996) suggest that land is a short run constraint on production. Therefore, in the long run, the effect of land is relaxed and the shadow value of land is obtained by differentiating the profit function with respect to land. Hence the shadow value of land is interpreted as the marginal change in profits for

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[5] The envelope theorem applied here makes use of the fact that the first order conditions of equations (2.04) and (2.10) always hold with equality at the optimal values of q_i.

an increment in land, or as the imputed rental value of an additional unit of land (Khatri and Thirtle 1996). In equilibrium, the shadow prices of optimal allocated farmland are equalized, that is:

$$\frac{\partial \Pi(w,r^*,d,\tilde{z})}{\partial z^k} = \frac{\partial \Pi(w,r^*,d,\tilde{z})}{\partial z^1}$$

$$= r_z(w,r^*,d,z) \qquad k = 1,...,s$$ (2.13)

where $r_z(.)$ is the equilibrium shadow price of farmland allocation. From the above expression, the change in supply associated with reallocation of fixed input in response to the price change can be obtained.

2.3.3   *Input Non-jointness*

The concept of input non-jointness is important in supply response models because it enhances econometric simplicity by implying that either the cost function $c(r,q)$ or the profit function $\Pi(w,r,d,z)$ can be modelled by their single-enterprise counterparts with no loss of generality (Chambers 1988, p. 293). This implies that both the profit and cost functions of a multi-output enterprise are the sum of the respective function for the m enterprises, that is:

$$\begin{aligned}
\Pi(w,r,d,z) &= \max_{q} \{wq - \sum_{i=1}^{m} c^i(r,q_i)\} \\
&= \sum_{i=1}^{m} \max \{w_i q_i - c^i(r,q_i)\} \\
&= \sum_{i=1}^{m} \Pi^i(w,r,d,z)
\end{aligned}$$ (2.14)

Input non-jointness derives from aggregation across farm enterprises. From (2.14), when z is truly fixed, Ball (1988) and Moschini (1988) show that input non-jointness implies:

$$\frac{\partial^2 \Pi(w,r^*,d,z)}{\partial w_i \partial w_j} = \frac{\partial q_i(w,r^*,d,z)}{\partial w_j} = 0$$ (2.15)

Equation (2.15) can be used to test non-jointness in production. However, given (2.12), the use of (2.15) to test non-jointness is inappropriate. Chambers and Just (1989) show that where z is an allocatable fixed input, the appropriate test for non-jointness in production is:

$$\frac{\partial q_i(w,r^*,d,z)}{\partial w_j} = 0 \qquad i,j = 1,...,m, \quad i \neq j$$

$$\frac{\partial q_i(w,r^*,d,z)}{\partial z_k^i} = 0 \qquad i,j = 1,...,m; \quad k = 1,...,s$$ (2.16)

$$\frac{\partial r_z(w,r^*,d,z)}{\partial z_k^i} = 0 \qquad k = 1,...,s$$

The hypothesis of non-jointness among various farm enterprises in western Canada can be tested in a straightforward manner using (2.16).

2.4 Empirical Specification

The first step in formulating the empirical model is to choose an appropriate functional form to parameterize the profit function provided by (2.04). Using the envelope theorem as applied in (2.11), supply functions can be obtained. These supply functions are estimated together with the first order conditions for an optimal fixed input allocation from equation (2.13). The inclusion of (2.13) in the estimation process suggests a long run framework since the allocation of farmland is not fixed (Diewert 1974; Khatri and Thirtle 1996)[6]. Such a formulation permits the examination of the long run production structure of prairie agriculture and the extent of interrelationships among crop and livestock enterprises. More importantly, the total effect of a price change including reallocation of farmland among farm enterprises can be examined.

As noted earlier, this study employs duality formulations as described above to examine the production of wheat, barley, canola, slaughter cattle and hogs in western Canada (i.e., in the provinces of Manitoba, Saskatchewan, Alberta and British Columbia). The inclusion of British Columbia adds minimally to the total quantities as when compared to the prairie region of Western Canada. The fixed allocatable input considered here is farmland, which is allocated to wheat, barley, canola, summer fallow and tame hay. The functional form used in the study is the Generalized Leontief profit function (Diewert 1974). This is a second-order Taylor series expansion, is linear in parameters and imposes few maintained hypotheses. The Generalized Leontief function has quantity as the dependent variable which allows easy implementation and interpretation of results, especially when model specifications are to be used for policy analyses (Martin and Alston 1994). The function is convenient for examination of comparative statics and imposing and testing theoretical restrictions. The Generalized Leontief function also allows explicit solutions of shadow values for the allocatable farmland. Other functional forms that have the expenditure share as the dependent variable (e.g., the translog function) do not allow this. An explicit solution of the shadow value for farmland is particularly important in this study because one of the study objectives is to assess long run adjustments in farmland use.

In spite of these advantages, the Generalized Leontief functional form has some limitations. It imposes assumptions with respect to quasi-homotheticity of the production technology (Chambers 1988, p. 173-177: Lopez 1985)[7]. A quasi-homothetic technology has straight-line expansion paths such as a homothetic technology except that these expansion paths do not emanate from the origin. The assumption of quasi-homotheticity is necessary in permitting the construction of aggregate price and quantity indices to study production decisions by analysing only a subgroup of outputs or input. In this study, the primary focus is on farm output. Therefore, the demand for individual variable farm inputs is not considered in the modelling procedure. The quasi-homotheticity assumption allows the use of a single aggregate input price index as a *numeraire* in the model. The *numeraire* price index is used to normalize the prices in the model, thereby imposing homogeneity.

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[6] When farmland is truly fixed and not allocatable between crops or land uses (i.e., in the short run), only the system of supply functions from (2.08) is estimated.

[7] This is a general limitation of flexible functional forms. Chambers (1988, p. 173-179) provides a thorough discussion concerning the limitations of flexible functional forms.

Following Shumway and Lim (1992), and Villezca-Becerra and Shumway (1992) the Generalized Leontief profit function of the four-crop and two-livestock farm enterprise with optimal farmland allocation is represented as follows:

$$\Pi = \alpha_0 + 2\sum_{i=1}^{5}\alpha_i w_i^{0.5} + 2\sum_{k=1}^{5}\beta_k z_k^{0.5} + 2\sum_{t=1}^{3}\gamma_t d_t^{0.5} + \sum_{i=1}^{5}\sum_{j=1}^{5}\alpha_{ij} w_i^{0.5} w_j^{0.5}$$

$$+ \sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl} z_k^{0.5} z_l^{0.5} + \sum_{t=1}^{3}\sum_{u=1}^{3}\gamma_{tu} d_t^{0.5} d_u^{0.5} + \sum_{i=1}^{5}\sum_{k=1}^{5}\delta_{ik} w_i z_k \qquad (2.17)$$

$$+ \sum_{i=1}^{5}\sum_{t=1}^{3}\lambda_{it} w_i d_t + \sum_{k=1}^{5}\sum_{u=1}^{3}\phi_{ku} z_k d_t$$

where Π = profit for the farm enterprise divided by an input price index;

w_i = price of the output divided by an input price index, and indexed $i,j = 1,\ldots,5$ to represent the production of wheat, barley, canola, cattle and hogs respectively;

z_k = allocated farmland, and indexed $k,l = 1,\ldots,5$ to represent hectares of wheat, barley, canola, tame hay and summer fallow respectively; and

d_t = quasi-fixed/exogenous factors, and indexed $t,u = 1,\ldots,3$ to represent cattle inventory, hog inventory and interest rate respectively. The rationale for including livestock inventories is that managers of livestock farms make production decisions involving livestock numbers, quality standards and weight produced per head. Therefore, production is the result of previous resource commitments and biological factors (Horbulyk 1990; Marsh 1999).

The first order conditions of equation (2.17) with respect to output prices give the short run output supply functions:

$$\frac{\partial\Pi}{w_i} = q_i(w,z,d) = \frac{\alpha_i}{w_i^{0.5}} + \alpha_{ii} + \sum_{j=2}^{5}\alpha_{ij}\frac{w_j^{0.5}}{w_i^{0.5}} + \sum_{k=1}^{5}\delta_{ik} z_k + \sum_{t=1}^{3}\lambda_{it} d_t \quad i \neq j \qquad (2.18)$$

Based on (2.13), the first order condition of (2.17) with respect to z_k gives the long run equilibrium market price (shadow price) of allocated farmland which is expressed as:

$$\frac{\partial\Pi}{z_1} = r_z(w,z,d) = \frac{\beta_k}{(z_1)^{0.5}} + \beta_{kk} + \sum_{l=2}^{5}\beta_{kl}\frac{(z_l)^{0.5}}{(z_1)^{0.5}} + \sum_{u=1}^{3}\phi_{ku} d_u + \sum_{j=1}^{5}\delta_{kj} w_j \quad k \neq l \qquad (2.19)$$

Parameters from the models are obtained by estimating (2.18) and (2.19) together as a system of seemingly unrelated regressions. As alluded to earlier, inclusion of (2.19) in the estimation process suggests a long run framework since farmland is not fixed. The system is made up of six equations that includes supply equations for wheat, barley, canola, slaughter cattle, and hogs and one equation for optimal land allocation[8].

Economic theory of the firm requires that the properties of the profit function be satisfied. These are monotonicity, symmetry, and homogeneity and convexity in output prices. Monotonicity implies that producers do not accept negative profits, which requires that the dependent variables fitted with the estimated coefficients be positive ($\hat{q}_i \geq 0$). The convexity property requires that all estimated own-price effects be positive ($\hat{\alpha}_i \geq 0$).

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[8] From equation (2.13), the shadow prices of optimal allocated farmland are equalized thus, only one equation is required which is specified for wheat because it is the dominant crop.

The properties of homogeneity and symmetry are imposed during estimation but the properties of monotonicity and convexity are tested after the estimation. Two major issues are examined in the study. The first is the evaluation of the partial effect of price changes on producers' response in terms of the production of wheat, barley, canola, cattle and hogs and assuming farmland allocation is unchanged. The second is the evaluation of the total effect of price changes on production of wheat, barley, canola, cattle and hogs that includes the effect of price changes and reallocation of farmland.

2.5   Data Requirements

Data required for estimating the models outlined above include production quantities and prices of wheat, barley, canola, slaughter cattle and slaughter hogs; area allocated to wheat, barley, canola, tame hay and summer-fallow; cattle and hog inventories; and the Canadian commercial interest rate, a proxy for the price of capital. A complete description of variables and data sources is provided in Table 2.1. The data series used in the study are scaled by their respective means because the data series vary significantly from each other in terms of values. For example, annual data series on commodity production and acreage allocations are expressed in millions, prices are expressed in hundreds and tens, and interest rate is expressed in decimals. Scaling of the data series by the respective means ensures uniformity in the data set (Coyle 1993b).

Most of the required data were obtained from Statistics Canada. These include production estimates for wheat, barley, and canola in western Canada. For livestock, Statistics Canada provided estimates of national production, not regional production. However, Agriculture Canada provided regional marketings of slaughter cattle and hogs. Production of slaughter cattle and hogs in western Canada is obtained by converting total numbers marketed into tonnes marketed using an estimated national conversion rate. The rationale behind this conversion is that carcass weight for slaughter cattle and hogs in Canada has changed over the years, probably from improvements in animal genetics and feeding technology (see Figures 2.1 and 2.2). In the U.S., changes in animal genetics and feed nutrition have resulted in heavier carcasses and higher carcass yields (Brester et al. 1997). This suggests that beef and pork supplies are now more dependent upon livestock productivity. Consequently, the average national carcass weight for Canada is calculated and applied to total livestock marketings in western Canada from 1960 to 1997.

The value of farmland in Saskatchewan is used as a proxy for the equilibrium price (shadow price) of allocated farmland. There is high correlation between the value of farmland in Saskatchewan and that in Manitoba and Alberta. The correlation coefficient between farmland values in Saskatchewan and Manitoba is 0.95; between farmland values in Saskatchewan and Alberta is 0.97; and between farmland values in Manitoba and Alberta the correlation coefficient is 0.99. A larger percentage of crop production occurs in Saskatchewan than in any other western province.

Grain prices were specified to be the prices received by western Canadian farmers for specified grades of selected grain (Table 2.1). Canola price series were obtained from Statistics Canada and Canadian Grains Council. Each series had a different time length. A procedure using linear regression was applied to obtain the series used in the study (see Appendix 2a). For livestock, prices in Alberta were used because a larger percentage of livestock production in western Canada occurs in that province. Cattle prices were assumed to be represented by slaughter cattle prices in Lethbridge and southern Alberta

where there is a relatively large concentration of cattle production. For hogs, the average price for Alberta was used. Definitions and sources of other variables used in the study are provided in Table 2.1.

2.6   Estimation Procedure

A common problem with estimating a system of equations for commodities is multicollinearity among price variables. Researchers have often addressed this problem by adopting extremely restrictive functional forms and arbitrarily omitting some price variables (e.g., Burt and Worthington 1988; Shumway et al. 1987). This type of *ad hoc* approach may ignore many cross-price effects. A better approach to minimize the problem of multicollinearity among prices may be to adopt restrictions on coefficients implied by behavioural theory, such as symmetry conditions. Alternatively, specifying supply response models in terms of revenues per acre rather than prices may reduce the problem (e.g., Bewley et al. 1987; Coyle 1993b). The reason for adopting this type of specification is that revenues per acre for different crops are often less correlated than are crop output prices. Alternatively, one of the price variables could be used to scale the other price variables to minimize multicollinearity (e.g., Coyle 1993b). This study uses commodity prices and imposes restrictions on coefficients implied by the symmetry conditions. Moreover, the Generalized Leontief function that is used for the model specifications incorporates price ratios (scaled prices) which will minimize the problem of multicollinearity.

The four-crop and two-livestock supply model (equations 2.18 and 2.19) for western Canada is specified using annual data for the region from 1960 to 1997. Dependent variables in equation (2.18) are annual production figures, in tonnes, for the six commodities[9]. In equation (2.19), the dependent variable is the shadow price of farmland. Explanatory variables in the system are the price per tonne of wheat, barley, canola, slaughter cattle, and slaughter hogs; acreage in hectares seeded to wheat, barley, canola, and tame hay; area allocated to summer-fallow; cattle and hog inventories; and interest rate from 1960 to 1997. The interest rate is used as a proxy for the price of capital.

The empirical formulation outlined in section 2.4 is based on farmers' expected prices of commodities. However, Pope (1982) contends that under risk neutrality, all dual properties of profit maximization that apply in the certainty case for *ex ante* choices also apply to expected profit maximization in the uncertainty case, so that expected prices can be replaced by presumed known prices. Thus, for wheat and barley, the average of prices for the previous two years is used as a proxy for expected price. For canola, a one-year lagged price is used for expected price. Livestock prices are current prices.

The process of normalization maintains global homogeneity. In other words, the profit function and supply equations are homogenous of degree zero in all prices as each price is divided by an aggregate input price index. A proportionate change in all prices thus has no impact on optimal production quantities. The second partial derivatives of the profit function are invariant to the order of differentiation so that the commodity supply

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[9] While estimation of supply relationships has been conducted using acreage planted to crops and livestock numbers as dependent variables, other studies have emphasized production (e.g., Arzac and Wilkinson 1979; Chambers and Just 1989; Clark et al. 1992; Coyle 1993a; Hayenga and Hacklander 1970; Kulshreshtha and Reimer 1975; Shumway et al. 1987).

equations are symmetrical in normalized prices (i.e., $\alpha_{ij}=\alpha_{ji}$ for $i \neq j$). Symmetry conditions are imposed during estimation. The disturbances in (2.18) and (2.19) are linearly dependent because, from the empirical formulation, acreage allocation is not a predetermined variable since it varies with price changes. Moreover, cattle and hog inventories are considered as endogenous variables. All data used are from secondary sources and may have some errors in the measurement. Thus, the model is estimated as a system of equations using the iterative three-stage least square (3SLS) regression techniques in the "SHAZAM" software program (Judge et al. 1988 p. 650; Kennedy 1992 p.161-162; White 1978). The Canada-U.S. exchange rate, U.S. corn and U.S. soybean prices are used as instrumental variables in addition to the explanatory variables in the system of equations.

Non-jointness in production is tested using equation (2.16). Four tests are performed. First, non-jointness in production for all enterprises is tested in each supply equation. Second, non-jointness in production of the three-crop enterprises is tested in each of the crop equations. Third, non-jointness in production of the two-livestock enterprises is tested in each of the livestock equations. Finally, non-jointness in production between barley and hogs is tested in both the barley supply and hog supply equations.

2.7   Results and Discussion

2.7.1   Model Diagnostics

A common econometric problem associated with the use of time series data in applied econometric work is spurious regression resulting from trending variables (Dickey and Fuller 1979). For example, if two variables both trend upward, a regression of one on the other is likely to find a "significant" relationship between them, even if the only thing they have in common is the upward trend. In this case, the results of such studies may be of limited use in conducting impact analysis. Therefore, a unit root test (Augmented Dickey-Fuller test) was conducted for all the variables used in the specifications. Results from the tests are reported in Table 2.2. The test results suggest that the variables have different structures. For example, the null hypothesis of unit root is rejected for the hay production, land price, hog/wheat ratio, hog/barley ratio, hog/canola ratio, canola/hog ratio and wheat acreage variables. These variables are said to be stationary in levels but the others are not.

The presence of non-stationary variables raises the possibility of cointegrating or long run relationships in the models being estimated. In this study, the possibility of estimating actual long run relationships is not verified because the common approach to estimation of a system of equations involving cointegrated variables developed by Johansen (1988), uses differenced variables in a vector autoregression (VAR). Some differenced variables have negative signs and cannot be used in the Generalized Leontief model. Moreover, there are limitations to the use of VAR techniques regarding the number of variables to include in the cointegration test. With more than one cointegrating relation, there is ambiguity in the interpretation of the estimated cointegrating vectors (Johansen 1988). Each of the estimated models in this study involves 13 variables. An alternative to differencing the data is the use of price ratios to estimate a system of

equations involving cointegrated variables. The Generalized Leontief function used for the model specifications incorporates price ratios.

The estimated coefficients, values of R-squared, variance of estimates and Durbin-Watson statistics are presented in Table 2.3. To gain insight into the statistical properties of the estimated models, scrutiny of the measure of R-squared values indicates a reasonable fit. This R-squared is not the goodness-of-fit measure which is calculated as one minus the ratio of the residual variance over the variance of the left-hand side (unexplained portion of the total variance) [10]. Rather, it is a measure between observed and predicted dependent variables (White 1993 p.12). R-squared values range from a high of 0.99 for the canola production equation to a low of 0.86 for the wheat production equation. The Durbin-Watson statistics, which measure the presence of first-order autocorrelation in the models, are also reasonable, suggesting autocorrelation is not a problem in these models.

Homogeneity and symmetry were imposed during estimation, but monotonicity and convexity in prices were not. Monotonicity requires that all dependent variables fitted with the estimated coefficients be positive. All estimated models at every data point satisfy monotonicity. This implies that producers do not accept negative profits and that there is no negative supply. Positive own-price elasticities are necessary conditions for satisfying the property of convexity. This condition is also satisfied in all of the models and is consistent with the fundamental property of supply; that is supply increases with an increase in price.

2.7.2   *Estimation Results*

In interpreting the results it should be noted that data were scaled by the respective means, so that, some coefficient estimates may be interpreted as partial elasticity measures, evaluated at the respective means. This applies specifically to acreage allocations, cattle numbers, hog numbers and the interest rate. The formulation for calculating partial elasticity of supply with respect to changes in own-price is presented in Appendix 2b. For ease of interpretation, estimated coefficients are reported in Table 2.3 and estimates of the partial elasticities are reported in Table 2.4. Table 2.5 compares some partial elasticity estimates from this study to estimates from selected studies of agricultural supply response for western Canada. Total elasticity estimates based on the expression in equation (2.12) are reported in Table 2.6.

As expected, the supply of each of the commodities has a positive relationship with own price. From Table 2.3, the parameter estimate for wheat price in the wheat equation is 0.037, the parameter estimate for barley price in the barley equation is 0.183, and the parameter estimate for canola price in the canola equation is 0.212. For livestock, the parameter estimate for slaughter cattle price in the slaughter cattle equation is 0.320, and the parameter estimate for slaughter hog price in the hog equation is 0.124. The positive signs confirm the convexity property of the profit function from which the supply functions were derived. They also reaffirm the fundamental property of supply that the commodity supply curves are upward sloping.

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[10] In 3SLS estimation the goodness-of-fit measure of R-squared is not well defined (Berndt 1991, p. 468; Judge et al. 1988 p. 650).

2.7.3   *Partial Price Responsiveness*

Table 2.4 reports the estimated partial elasticity measures for the economic variables. All own-price elasticity measures have a positive sign as expected. Estimated own-price elasticities are 0.449, 0.498, 0.064, 0.123 and 0.830 for wheat, barley, canola, cattle and hog production respectively, and estimates for barley and hogs are asymptotically significant at a 5% level. This implies that, in the long run, farmers respond positively to changes in barley and hog prices by altering production accordingly and that the supply functions for these commodities are positively sloped. Hog production is the most price-elastic among the five commodities. This appears to be a reasonable finding, since annual data are used and the hog cycle (from birth to market) is about 12 to 18 months. Consequently, inventory of animals can be reduced readily with high market prices within this time frame. Cattle production has a longer cycle, about 3 to 3½ years and inventory reduction may not be readily accomplished as with hogs. Thus, the estimated elasticity of cattle supply of 0.123 appears reasonable.

Cross-price effects among the commodities have signs that are reasonable and reflect cropping patterns in western Canada but most estimates are not statistically significant asymptotically. Hog production is positively related to wheat, barley and canola prices. Estimated elasticities of hog production with respect to changes in wheat, barley and canola prices are respectively, 0.294, 0.24 and 0.209 (Table 2.4). Estimates of hog production with respect to wheat and barley prices are statistically significant. Since hog production is expressed as pigs marketed in western Canada, the positive relationship suggests that as grain/oilseed prices increase, there is an increase in the number of pigs marketed. Wheat is a minor component of livestock feed but barley and canola meal are major feed components, so that increasing grain/oilseed prices can imply increasing feed cost. Profit maximizing hog producers will probably reduce inventory by marketing more animals if there are increasing costs of production. This argument may not be applicable to cattle because of the relatively long cycle.

Wheat production and barley production appear as substitutes with canola production. The estimated parameters on canola price in the wheat and barley production equations are -0.054 and –0.151 respectively. Wheat (barley) production has a positive relationship with barley (wheat) price, indicating complementarity in production. Though the estimated cross-price elasticities for these crops are not statistically significant, the signs on the estimates reflect the cropping pattern in western Canada. In the 1970s, 1980s and 1990s, wheat production averaged 13.9, 19.7 and 22.3 million tonnes respectively. Barley production in the same periods averaged 9.8, 11.1 and 11.8 million tonnes while canola production averaged 1.8, 2.5 and 4.1 million tonnes. From these figures, wheat, barley and canola production increased, on the average, by about 60%, 20% and 128% respectively from the 1970s to the 1990s, reflecting the increasing popularity of canola production among farmers during this period. Comparison of the increase in production since the 1970s suggests increasing substitution of wheat and barley production with canola production. Scrutiny of the elasticity estimates of commodity production with respect to acreage allocations confirms this cropping trend. Supply elasticities with respect to acreage allocations are discussed in a later section.

Comparison of the partial supply elasticity measures with those from previous studies is difficult because of different variable definitions, time periods and model specifications. However, Table 2.5 provides both the partial price elasticity measures

estimated in this study and those obtained in selected studies of supply response for western Canadian farmers. In terms of absolute values, own-price elasticity estimates from previous studies are quite different from those estimated in this study. For wheat, barley and canola, estimates from Meilke and Weersink (1991) are relatively larger than estimates from this study. For livestock, estimates from this study and that from Coleman and Meilke (1988) suggest cattle supply is price-inelastic while hog supply is relatively price-elastic. In Table 2.5, cross-price elasticities for wheat and barley indicate a complete contrast in results in terms of signs. Both Coyle (1993b) and Meilke and Weersink (1991) find wheat and barley to be substitutes in production. In this study, wheat and barley are found to be complementary in production. The difference might be due to differences in time periods and model specifications. The dependent variable used by Coyle (1993b) and Meilke and Weersink (1991) is seeded area rather than production. The data period also differs (Table 2.5). Nevertheless, all three studies find wheat/barley and canola to be substitutes in production.

2.7.4   *Partial Responsiveness to Non-Price Variables*

From Table 2.4, the acreage allocations for wheat, barley and canola are positively related to the production of wheat, barley and canola; the estimated coefficients 0.589, 1.17 and 0.842 respectively. The estimates for barley and canola are statistically significant asymptotically. These findings are not surprising since crop production depends on acreage planted.

Regarding the effects of cross-acreage allocations, signs on the elasticity estimates are mixed. For example, the estimate on acreage seeded to barley is positive (0.271) in the wheat production equation but the estimate on land allocated to wheat in the barley production equation is negative (-0.247). However, there is consistency in the sign on estimates for cereal grain (wheat and barley) production with respect to acreage allocation to canola. The supply elasticity of wheat with respect to canola acreage allocation is –0.231, and the supply elasticity of barley with respect to acreage allocation to canola is –0.171. Both estimates are statistically significant, which reaffirms the substitutability between cereal grains and canola production indicated earlier. Farmland allocated to summer-fallow is negatively related to the production of wheat, barley and canola. The estimates are negative and statistically significant asymptotically with values of –0.869, -0.684, and –0.8 respectively. This result probably reflects competition among crop enterprises and the farming practice of summer-fallow for farmland. Acreage allocated to tame hay is positively related to the production of wheat, barley and canola.

For livestock, cattle production is positively related to cattle inventory with an estimate of 0.658 and hog production is positively related to pig inventory with an estimate of 0.148 (Table 2.4). The estimate of cattle inventory is statistically significant asymptotically. Cattle production is also positively related to acreage allocated to tame hay acreage but negatively related to acreage allocated to wheat, barley, canola, and summer-fallow. This result is expected since hay production is a major component (i.e. input)of cattle production enterprises in western Canada. The estimate of cattle production with respect to tame hay acreage is 0.347. Hog production is positively related to area allocated to barley and tame hay with estimates of 0.35 and 0.843 respectively (Table 2.4). The production of hogs is, however, negatively related to acreage allocated to wheat, canola, and summer-fallow. The effect of interest rate (the price of capital) on

commodity production is quite low on all commodities with estimates ranging from –0.009 to 0.011. All estimates are statistically insignificant asymptotically.

2.7.5   *Total Price Responsiveness*

The total elasticity measure expresses the change in supply induced by a price change as well as the change in supply associated with reallocation of farmland in response to the price change (see Appendix 2b). Total elasticity measures of price changes on production are reported in Table 2.6. Of the 25 estimated elasticity measures, 9 are deemed statistically asymptotically significant. All own-price elasticity measures have signs that are consistent with the results reported in Table 2.4. These own-price elasticity measures of production, shown on the diagonal of Table 2.6, have positive signs. A positive total own-price elasticity implies that production increases in response to increases in price, even when land allocations are allowed to change. The production of wheat and hog production is price-elastic in terms of total effects. Hog production is the most price elastic in production among the five commodities with a total own-price elasticity measure of 1.204. Canola production is the least elastic in production with a total own-price elasticity measure of 0.614 which is consistent with the partial own-price elasticity results in Table 2.4. In terms of the size of own-price estimates, total own-price elasticity measures are larger in size than are the partial own-price elasticity measures reported in Table 2.4. For example, the partial and total own-price elasticity measures for wheat are 0.449 and 1.058 respectively; barley, 0.498 and 0.741 respectively; canola, 0.064 and 0.411 respectively; cattle, 0.123 and 0.614 respectively and hogs, 0.830 and 1.204 respectively.

Regarding total cross-price elasticity measures, there are no prior theoretical empircal expectations in terms of signs (see formulations in Appendix 2b). In Table 2.6, most commodities appear as complements in production. There are positive total cross-price elasticity measures, except for wheat production with respect to canola price.

2.7.6   *Tests of Non-jointness in Production*

Various tests of non-jointness in production are performed using equation (2.16). Non-jointness in production implies that both the cost and profit functions of the multi-commodity enterprises are the sum of the single-commodity cost and profit functions (Chambers 1988, p. 293). Hence, the test of non-jointness may be regarded as a test of independence in production (null hypothesis). First, non-jointness is tested in the production of all enterprises. Then, non-jointness in production of only the three-crop enterprises is tested in each of the crop equations. The third test of non-jointness involves production of only the two-livestock enterprises and the final test involves non-jointness in production between barley and hogs. Formulations for the parametric tests of non-jointness are presented in Appendix 2c. Results of these tests are reported in Table 2.7. The second, third and fourth tests of non-jointness are more intuitive and are commented on below.

Consistent with Shumway et al. (1987), joint production of grains and oilseed is evident from the second test. The hypothesis of non-jointness of production of wheat, barley and canola is rejected at the 5% level in each of the crop equations (Table 2.7, column 3). This implies that the production of individual grains/oilseed in western

Canada is not independent of one another. Jointness in production of the three crops wheat, barley and canola may be due to technical interdependence and/or to the presence of allocatable farmland or rotational limitations. All three crops are commonly planted on the same farm in a given year in western Canada. Thus, they often compete for the same land, labour and managerial resources. Differences in the relative importance of technical interdependence and allocatable inputs may result in the nature of the economic interdependence between any pair of production activities being either complementary or competitive in production (Shumway et al. 1987).

The null hypothesis of non-jointness in the production of cattle and hogs is not rejected at the 5% level in any of the livestock equations (Table 2.7, column 4). Non-jointness in production of cattle and hogs is likely due to technical independence in the production process. In western Canada, cattle production and hog production are independent as each production process requires different husbandry and managerial skills. The null hypothesis of non-jointness in the production of barley and hogs is rejected at the 5% level suggesting that barley production is not independent of hog production. That seems to suggest that the barley and hog industries are closely tied together. Barley is a major input into hog production.

2.8   Summary and Conclusions

The objective of this section of the study was to specify and estimate the supply response of western Canadian agriculture. The study examined a model of three crop (wheat, barley and canola) and two livestock activities (cattle and hogs) which incorporated farmland allocation in the production of wheat, barley, canola and tame hay, as well as land allocation to summer-fallow. Previous regional studies have ignored farmland allocation to tame hay and summer-fallow in their analyses and have not examined the crops and livestock sectors simultaneously. Supply functions derived from the Generalized Leontief profit function were specified and estimated simultaneously for the crops and livestock sectors using annual data from 1960 to 1997. The study assessed the extent of substitution/complementarity in production among the five commodities and the effects of price changes on production resulting directly from changes in price as well as indirectly from farmland reallocation. The statistical and economic implications of the models were assessed.

The results indicate significant economic interrelationships in the western Canadian agricultural sector. The partial and total effects of price changes on production are examined and these results show that the quantity supplied of each of the commodities examined is positively related to its own price. Hog production is the most price-elastic among the five commodities examined suggesting that inventory of animals can be reduced readily for slaughter with high market prices. Canola production is the least price-elastic. Wheat production and barley production appear as complements but canola production appears to be a substitute to wheat production. Hog production is positively related to the prices of wheat, barley and canola. Cattle production is positively related to the price of barley. A chi-square test of non-jointness in production indicates jointness in the production of grains and oilseeds, non-jointness in the production of cattle and hogs and jointness in the production of hogs and barley. These findings provide insights into the potential effect of increased value added activities in the processing

sector on the farm sector. Insights are also gained into the potential effects that changes in the economic conditions of one commodity may have on other commodities.

Future research on estimation of western Canadian commodity supply functions may improve the present study in a number of ways. First, it may be desirable to expand the number of commodities for study. Although the five commodities examined in the present study are considered to be major commodities, several other commodities are increasingly becoming popular, particularly 'speciality crops.' Second, the specification and inclusion of input demand functions for agricultural inputs such as chemicals, machinery, and labour may improve the overall specification and estimation of the models.

Figure 2.1: Canadian Slaughter Cattle Numbers and Average Carcass Weight (1960 to 1997)
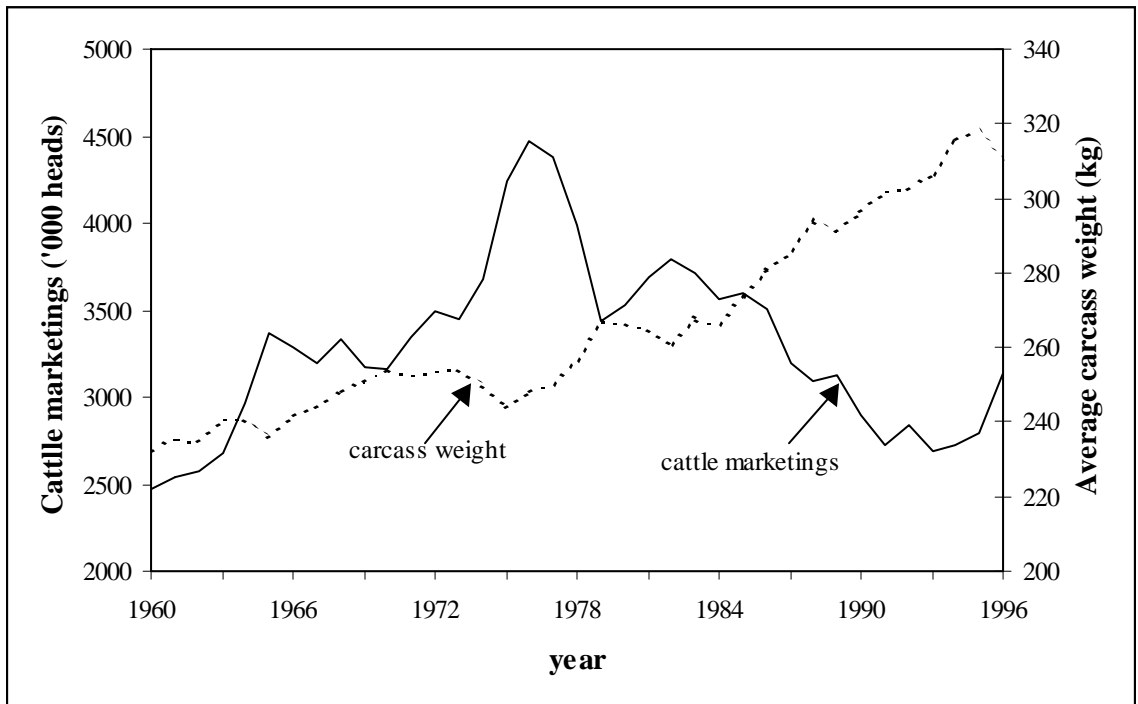
Source: Agriculture and Agri-Food Canada, Livestock Market Review

Figure 2.2:   Canadian Slaughter Hog Numbers and Average Carcass Weight (1960-1997)
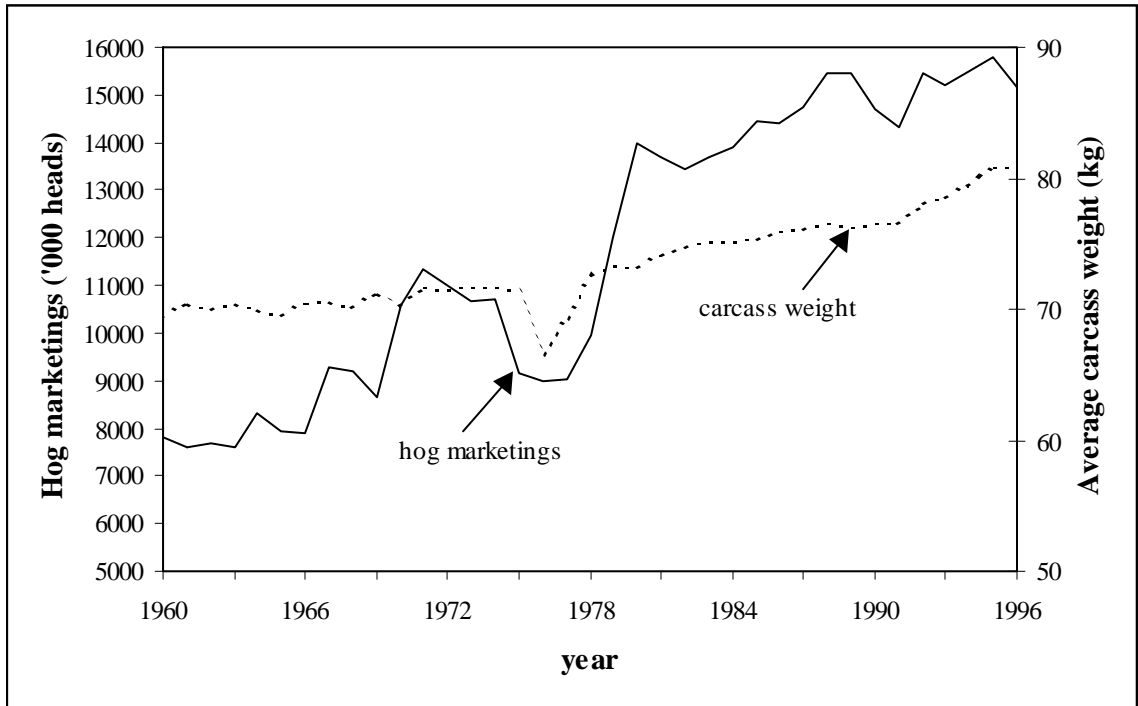
Source: Agriculture and Agri-Food Canada, Livestock Market Review.

Table 2.1:   Farm Sector Variables: Definition and Sources of Data (1960-1997)[1]

Variable	Definition	Source
Wheat production	Product of yield per hectare and area harvested in hectares.	CANSIM D216079 & D216083
Barley production	Product of yield per hectare and area harvested in hectares.	CANSIM D216204 & D216208
Canola production	Product of yield per hectare and area harvested in hectares.	CANSIM D216577 & D216581
Slaughter cattle production[2]	Cold dressed weight equivalent of slaughter cattle.	*Livestock Market Review* and CANSIM D226062
Slaughter hogs production[2]	Cold dressed weight equivalent of slaughter hogs.	*Livestock Market Review* and CANSIM D226377
Farmland Price	Farmland values	Farm Credit Corporation, Regina (Saskatchewan)
Wheat acreage	Area seeded in hectares.	CANSIM D216055 & D216059
Barley acreage	Area harvested in hectares.	CANSIM D216183 & D216187
Canola acreage	Area seeded in hectares.	CANSIM D216565 & D216569
Summer-Fallow	Summer-fallow areas in the prairie provinces.	CANSIM D216740
Tame Hay	Area seeded in hectares.	CANSIM D216635 & D216639
Beef cattle inventory	Total beef cattle numbers from annual livestock surveys.	D226005, D226008, D226014, D226017, D226023, D226026, D226032, D226035
Pig inventory	Total number of pigs from annual livestock surveys.	D236796, D236782, D236810, D236824
Wheat price	1 CWRS Final realised price ($)	Canadian Grain Council
Barley price	1 CW Final realised price ($)	Canadian Grain Council

Continued on next page

Table 2.1 continued

Variable	Definition	Source
Canola price	Weighted average price (see Appendix 2a)	CANSIM D216583 & Canadian Grain Council
Slaughter cattle price[3]	Weighted average price (Lethbridge / Southern Alberta)	*Livestock Market Review*
Slaughter hogs price[3]	Weighted average price (Edmonton / Alberta)	*Livestock Market Review*
Farm input price index	Aggregate input price index for western Canadian agriculture	CANSIM D641800
Interest rate	90-day commercial paper rate	Bank of Canada
Exchange rate	The equivalent of Canadian dollar to one American dollar	Bridge Information Systems, Chicago.
Corn price	No. 2 Yellow, Cash Basis – Chicago	Bridge Information Systems, Chicago.
Soybeans	No. 1 Yellow, Cash Basis – Central Illinois	Bridge Information Systems, Chicago.

[1] The data series are presented in Appendix 2d.

[2] Total Canadian beef (pork) production divided by total Canadian slaughter cattle (hogs) gives the average weight per animal. Beef (pork) production in Western Canada is obtained by multiplying the average weight per animal by total slaughter cattle (hogs) in Western Canada.

[3] Slaughter cattle (hog) prices are quoted in $/cwt. (100 lb. weight). This is converted into $/tonne.

Table 2.2:   Unit Root Tests

Variable	Test statistic	Number of lags	Variable	Test statistic	Number of lags
Wheat production	-2.62	2	Canola/cattle price ratio	-2.11	5
Barley production	-2.79	2	Hog/cattle price ratio	-2.42	2
Canola production	-1.26	5	Hog price	-1.95	3
Cattle production	-1.40	0	Wheat/hog price ratio	-3.05	4
Hog production	-3.45*	0	Barley/hog price ratio	-2.64	5
Land price	-3.58*	1	Canola/hog price ratio	-3.34*	2
Wheat price	-1.71	2	Cattle/hog price ratio	-2.37	2
Barley/wheat price ratio	-2.79	5	Wheat acreage	-2.36	0
Canola/wheat price ratio	-2.72	5	Barley acreage	-2.71	0
Cattle/wheat price ratio	-2.21	2	Canola acreage	-2.81	2
Hog/wheat price ratio	-3.25*	2	Fallow	-2.23	1
Barley price	-1.98	3	Tame hay	-2.40	0
Wheat/barley price ratio	-2.87	5	Cattle inventory	-2.36	1
Canola/barley price ratio	-2.62	5	Hog inventory	-2.84	2
Cattle/barley price ratio	-2.22	5	Interest rate	-1.68	0
Hog/barley price ratio	-3.41*	2	Wheat price	-2.36	4
Canola price	-1.71	2	Barley price	-1.00	4
Wheat/canola price ratio	-2.71	5	Canola price	-2.00	2
Barley/canola price ratio	-2.52	5	Cattle price	-1.03	2
Cattle/canola price ratio	-2.18	5	Hog price	-0.86	3
Hog/canola price ratio	-3.33*	2	Wheat acreage	-3.38*	0
Cattle price	-1.93	0	Barley acre/wheat acre	-2.33	0
Wheat/cattle price ratio	-2.57	0	Canola acre/wheat acre	-2.76	2
Barley/cattle price ratio	-2.21	5	Fallow acre/wheat acre	-2.87	1
			Hay acre/wheat acre	-3.36*	0

* Indicates the value is significant at the 10% level therefore, the null hypothesis of unit root is rejected.
Note: asymptotic critical value at 10% significance is –3.13.

Table 2.3: Estimated Coefficients of the Commodity Supply Response Models

Independent Variable	Wheat Production	Barley Production	Canola Production	Cattle Production	Hog Production	Farmland Value
			Dependent Variable			
Intercept	0.238	0.097	1.075^b	1.957^a	1.110	1.101^a
Wheat price	0.037	0.203	-0.054	-0.031	0.294^b	0.419^b
Barley price	0.203	0.183	-0.151	0.023	0.240	0.005
Canola price	-0.054	-0.151	0.212^b	-0.152	0.209	-0.007
Cattle price	-0.031	0.023	-0.152	0.320^a	-0.037	0.296^a
Hog price	0.294^b	0.240^b	0.209	-0.037	0.124	-0.062
Wheat acreage	0.589	-0.247	-0.255	-0.609^a	-0.532	-1.753
Barley acreage	0.271	1.170^a	0.099	-0.241^a	0.350	0.581^a
Canola acreage	-0.231^b	-0.171^a	0.842^a	-0.221^a	-0.055	0.221
Summer-Fallow	-0.869^a	-0.684^a	-0.800^a	-0.922^a	-0.712	1.139
Hay acreage	0.839^b	0.563^a	0.051	0.347	0.843	-1.114^b
Cattle inventory	-0.101	-0.031	0.097	0.658^a	-0.982^a	0.724^a
Pig inventory	-0.282^b	-0.309^a	-0.185^b	-0.061	0.148	-0.576^a
Interest Rate	0.011	0.007	-0.005	-0.010^b	-0.009	0.008
R-square	0.86	0.96	0.99	0.94	0.88	0.96
Variance of estimates	0.010	0.003	0.005	0.004	0.019	0.007
D-W statistic	1.9	2.3	2.2	1.1	1.9	1.5

[a] indicates asymptotic significance at the 5% level.
[b] indicates asymptotic significance at the 10% level.

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Table 2.4:   Estimated Measures of Partial Supply Elasticities[1]

	Wheat Production	Barley Production	Canola Production	Cattle Production	Hog Production
with respect to					
Wheat price	0.449	0.203	-0.054	-0.031	0.294[b]
Barley price	0.203	0.498[a]	-0.151	0.023	0.240[a]
Canola price	-0.054	-0.151	0.064	-0.152	0.209
Cattle price	-0.031	0.023	-0.152	0.123	-0.037
Hog price	0.294[b]	0.240[b]	0.209	-0.037	0.830[a]
Wheat acreage	0.589	-0.247	-0.255	-0.609[a]	-0.532
Barley acreage	0.271	1.170[a]	0.099	-0.241[a]	0.350
Canola acreage	-0.231[b]	-0.171[a]	0.842[a]	-0.221[a]	-0.055
Summer Fallow	-0.869[a]	-0.684[a]	-0.800[a]	-0.922[a]	-0.712
Hay acreage	0.839[b]	0.563[a]	0.051	0.347	0.843
Cattle inventory	-0.101	-0.031	0.097	0.658[a]	-0.982[a]
Pig inventory	-0.282[b]	-0.309[b]	-0.185[b]	-0.061	0.148
Interest Rate	0.011	0.007	-0.005	-0.010	-0.009

[1] Partial elasticity measures express the change in supply induced by a change in price holding allocatable land constant.
[a] indicates asymptotic significance at the 5% level.
[b] indicates asymptotic significance at the 10% level.

Table 2.5: **Comparison of Partial Supply Elasticity Estimates with Estimates from Selected Studies of Western Canadian Agriculture**

	This Study	Coyle (1993b)	Meilke & Weersink (1991)	Horbulyk (1990)	Coleman & Meilke (1988)
Sample period	1960-1997	1961-1984	1972-1988	1983-1987[a]	1972-1982[b]
Commodity					
Wheat	0.449	0.159	0.617		
Barley	0.498	0.273	0.788		
Canola	0.064	0.448	1.546		
Cattle	0.123			1.998	0.24
Hogs	0.830				1.36
Wheat / Barley price	0.203	-0.096	-0.196		
Wheat / Canola price	-0.054	-0.006	-0.213		
Barley / Wheat price	0.203	-0.062	-0.430		
Barley / Canola price	-0.151	-0.253	-0.209		

[a] Data are cross-sectional.
[b] Data are quarterly.

Table 2.6:   Estimated Total Supply Elasticities[1]

	Wheat Production	Barley Production	Canola Production	Cattle Production	Hog Production
With respect to					
Wheat price	1.058	0.446	0.293	0.460	0.668^b
Barley price	0.210	0.741^a	0.196	0.514^b	0.614^b
Canola price	-0.064	0.092	0.411	0.372	0.583
Cattle price	0.400	0.266	0.195	0.614^b	0.338
Hog price	0.203	0.483^b	0.556^b	0.488^b	1.204^a

[1] Total elasticity measures express the change in supply induced by a change in price as well as a change in allocatable land due to the price change.
[a] indicates asymptotic significance at the 5% level.
[b] indicates asymptotic significance at the 10% level.

Table 2.7:   Chi-squared Test Results for Non-Jointness in Production

	Test of non-jointness (independence in production) includes			
	all 5 enterprises[a]	Only crop enterprises[b]	Only livestock enterprises[c]	barley and hogs[d]
	$\chi^2_{df=13}$ statistic	$\chi^2_{df=11}$ statistic	$\chi^2_{df=2}$ statistic	$\chi^2_{df=3}$ statistic
Equation				
Wheat Production	143.48	123.41		
Barley Production	328.81	260.00		140.89
Canola Production	575.77	526.07		
Cattle Production	105.45		2.56	
Hog Production	50.65		2.11	11.70
Test Outcome	Independence in production is rejected in each equation	Independence in production is rejected in each equation	Independence in production is not rejected in each equation	Independence in production is rejected in each equation

[a] the critical values at the 5% level of significance for $\chi^2_{df=13}$ = 22.362

[b] the critical values at the 5% level of significance for $\chi^2_{df=11}$ = 19.675

[c] the critical values at the 5% level of significance for $\chi^2_{df=3}$ = 7.815

[d] the critical values at the 5% level of significance for $\chi^2_{df=2}$ = 5.991.

Appendix 2a: **Canola Price Series**

Statistics Canada (CANSIM) provided a weighted average price per tonne for the period 1960 to 1984 (P_{c1}) while the Canadian Grains Council (Canadian Grains Industry Statistical Handbook) provided cash prices (Winnipeg) from 1972 to 1996 (P_{c2}). The overlapping period between the two series is 1972 to 1984 (13 data points). Ordinary Least Squares (OLS) regression of P_{c2} on P_{c1} through the origin produced the following results:

$$\hat{P}_{c2} \quad = \quad \underset{(0.01658)}{1.1108\, P_{c1}} \qquad\qquad\qquad R^2 \quad = \quad 0.9419$$

The standard error of the estimate is reported in brackets.

The estimated coefficient is multiplied by the P_{c1} series from 1960 to 1971 to generate an estimated price series that is consistent with the P_{c2} series. The generated series (1960 to 1971) and the P_{c2} series (1972 to 1996) are used in the study.

Appendix 2b: **Elasticity Formulations**

Due to the wide variation in the values of variables, all variables were divided by their respective mean values. Consequently, the mean values of the data from 1960 to 1997 are unity. Using equation (2.18), the partial own-price elasticity of supply is calculated as:

$$\frac{\partial q_i}{\partial w_i}\frac{w_i}{q_i} = \Xi_{ii} = \alpha_i + \sum_j \alpha_{ij} \qquad i \neq j$$

The partial cross-price elasticity of supply is calculated as:

$$\frac{\partial q_i}{\partial w_j}\frac{w_j}{q_i} = \Xi_{ij} = \alpha_{ij} \qquad i \neq j$$

The partial elasticity of supply with respect to reallocation of farmland is calculated as:

$$\frac{\partial q_i}{\partial z_k}\frac{z_k}{q_i} = \Xi_{ik}^z = \delta_{ik}$$

The partial elasticity of supply with respect to changes in quasi-fixed variables is calculated as:

$$\frac{\partial q_i}{\partial d_t}\frac{d_t}{q_i} = \Xi_{it}^d = \lambda_{it}$$

Using equations (2.12) and (2.19), the total elasticity of supply is calculated as:

$$\frac{\partial q_i(w,z,d)}{\partial w_j}\frac{w_j}{q_i} = \frac{\partial q_i}{\partial w_j}\frac{w_j}{q_i} + \sum_i \sum_k \frac{\partial q_i}{\partial z_k^i}\frac{z_k^i}{q_i} \left(\frac{\partial z_k^i}{\partial w_j}\frac{w_j}{z_k^i}\right)$$

$$\Xi_{ij}^T = \Xi_{ij} + \sum_i \Xi_{ik}^z \qquad \delta_{kj}\Big/ \beta_{kl}$$

Total Elasticity of Supply		Partial Price Elasticity of Supply		Partial Elasticity of Supply with respect to Farmland Allocations	Elasticity of Acreage Allocation with respect to Price
	=		+		

Appendix 2c: **Formulations for Testing Non-jointness in Production[11].**

1. Test for non-jointness in the production of all five commodities involves testing the following in each supply equation (2.18);

    $$\alpha_{ij} = \delta_{ik} = \beta_{kl} = 0 \qquad\qquad \forall \quad i \neq j; \quad k \neq l$$

2. Test for non-jointness in production of grains/oilseed involves testing the following in equation (2.18) relating to the supply of wheat, barley and canola;

    $$\alpha_{ij} = \delta_{ik} = \beta_{kl} = 0$$

    for $i, j = 1,2,3; \quad k, l = 1,...,5; \quad i \neq j; \quad k \neq l$

3. Test for non-jointness in production of livestock involves testing the following in equation (2.19) relating to the supply of cattle and hogs;

    $$\alpha_{ij} = 0 \qquad\qquad \text{for} \qquad i, j = 4,5; \quad i \neq j$$

4. Test for non-jointness in production of barley and hogs involves testing the following in equation (2.18) relating to the supply of barley and hogs;

    $$\alpha_{ij} = \delta_{ik} = \beta_{kl} = 0 \qquad \text{for} \quad i, j = 2,5; \quad k, l = 2; \quad i \neq j$$

---

[11] The index i,j = 1,…,5 represents the production of wheat, barley, canola, cattle and hogs respectively; k,l = 1,…,5 represents hectares of wheat, barley, canola, tame hay and summer fallow respectively; and t,u = 1,…,3 represents cattle inventory, hog inventory and interest rate respectively.

3. ANALYSIS OF DOMESTIC DEMAND FOR FARM OUTPUT

Initiatives taken by the government on value adding activities are focussed on encouraging and promoting projects that contribute to the economic development of the agricultural industry. Government initiatives in value adding include funding programs that encourage research and development into the commercialization of value-added products. With such programs, it is hoped that the food-processing sector will undertake structural adjustments that may eventually result in increased utilization of primary agricultural commodities.

Agricultural and food-processing industries in Canada and the United States have become increasingly concentrated, often resulting from mergers and acquisitions (Green 1985). The trend toward fewer and larger firms has continued since the 1960s, which could raise concerns about potential market power and its exploitation. In particular, if increasing concentration allows firms to exploit the domestic market for farm commodities, then farmers will be affected if the food processing firms are able to use their power to hold commodity prices at artificially low levels. However, prior studies have shown the positive relationship between efficiency and plants size in the food-processing industries when production structure characteristics such as cost economies and technical change are incorporated into the analysis (Hazeldine 1991; Goodwin and Brester 1995; Holloway and Goddard 1988; Paul 199b). In these circumstances increased import and export competition may modify market power. In Canada, a significant proportion of primary agricultural products particularly grains and oilseeds is exported, suggesting that, with export competition, food-processing firms may not be able to exercise any market power in the domestic market for farm outputs.

This portion of the study examines aggregate demand in the processing sector for wheat, barley, canola, slaughter cattle and hogs in order to assess potential market power exploitation. An alternative index for measuring industry-wide market power is developed for use in the analysis. The procedure used here differs from previous studies in that conjectural marginal input cost is explicitly incorporated into a profit function allowing a system of factor demand and output supply equations to be estimated. With this procedure and sufficient data, policy analyses can be conducted by assessing the conduct of the industry over time in response to certain changes. This framework is applied to four Standard Industrial Classification (SIC) food-processing industries in Canada including the meat and meat products industry (excluding poultry), the cereal grain flour industry, the livestock feed industry and the vegetable oil industry (excluding corn oil). These are the major food processing industries for Western Canadian agricultural outputs.

The following section reviews some of the approaches that have been utilized in previous studies to assess market power in the market for farm output. This is followed by an outline of the theoretical foundation of the model used here to measure the degree of oligopsony power. Duality theory is applied with the incorporation of a profit function that explicitly incorporates a price "mark-down" factor to assess possible non-competitive behaviour in the market for farm outputs. The models are applied to aggregate annual data from four Canadian food industries for the period 1974 to 1996. The results are then presented and discussed and some conclusions are drawn from this

component of the study. The final section summarizes the findings and discusses limitations.

3.2 Review of Past Derived Demand Studies

A common approach adopted in studies that examine derived demand relationships and market power involves applying the theory of the firm. A behavioural assumption of short run profit maximization or costs minimization is made for the processing firm. From the solution of the first-order conditions for the maximization or minimization problem, output supply and input demand schedules for the marketing firm are obtained. This approach has been applied in many studies to examine demand relationships under different market structures. Most of these studies analyse a firm's conduct through the estimation of conjectural elasticities. These are measures of the firm's expectation of the percentage change in industry output (input) in response to its own output (input) change. Unfortunately, the panel data on firm level input and output necessary to estimate these elasticities are frequently unavailable due to confidentiality concerns. This limitation has led analysts to assume that conjectural elasticity measures are identical across firms. This particular assumption allows conjectural elasticity measures to be applied at the industry level in the form of indices of market power in output and input markets (Appelbaum 1982; Azzam and Pagoulatos 1990). However, changing consumer preferences, corporate mergers, strategic alliances of firms and acquisitions of firms have changed the structure of the food industry and consequently, it may be expected that the aggregate values of the conjectural elasticities have changed.

Appelbaum (1979, 1982) used the theory of the firm to provide a general framework to examine non-competitive behaviour in a processor's output market. The framework developed by Appelbaum has been extended to the processor's input market (e.g., Azzam and Pagoulatos 1990; Chen and Lent 1992; Durham and Sexton 1992; Huang and Sexton 1996; Schroeter and Azzam (1991); Sexton 1990; Wann and Sexton 1992).

Given a perfectly competitive market structure, processing firms are assumed to be price takers in the market for farm commodities and have no influence in setting purchase prices. The assumption of a perfectly competitive market structure has sometimes been applied in welfare analyses of the impacts of agricultural policies. Studies of derived demand that have assumed perfectly competitive farm commodity markets include Dunn and Heien (1985); Martin and Alston (1994); Mullen et al. (1988); Kinnucan et al. (1996); and Wahl et al. (1992).

If agricultural markets are not perfectly competitive, the welfare implications may differ from those derived assuming a perfectly competitive structure. Consequently, some studies have examined derived demand relationships under an assumption of imperfect competition in the processors' input markets (e.g., Chen and Lent 1992; Durham and Sexton 1992; Huang and Sexton 1996; Hyde and Perloff 1994; Just and Chern 1980; Sexton 1990). Further extensions of this general modelling framework are found in the literature. For example, Azzam and Pagoulatos (1990), Dryburgh and Doyle (1995), Schroeter (1988), Schroeter and Azzam (1991), and Wann and Sexton (1992) have investigated non-competitive behaviour in both the output and input markets.

Some of the studies cited above focus on investigating comparative statics in imperfect competitive market situations, while others investigate the implications for

market equilibrium of exogenous shocks in supply and demand. Issues that have been examined in the context of non-competitive markets include the impact of agricultural policy, government programs, research, advertising and promotion. The implications of policy or exogenous factors are not the focus of this part of the study. However, results obtained from the models will be used to simulate the likely impact on the farm sector of value adding initiatives in the processing sector.

3.3   Theoretical Framework

3.3.1   Preliminary Outline

It is postulated that the behaviour of a firm is determined by its production technology and by the economic environment in which it operates, both of which act as constraints on the firm's decision making. Assuming profit maximization as the goal for a primary processing industry that is using a homogenous technology g(.) to produce a retail good, the production function for the industry may be expressed as:

$$ x = g(q, v, z) \tag{3.01} $$

where $x = \sum x^j$, is the sum of all outputs produced by the j firms in the industry; q is a vector of farm commodity inputs; v is a vector of marketing inputs; and z is a vector of quasi-fixed factors.

For simplicity, assume there is only one farm commodity input and one marketing input. Short run variable cost, c, for the jth firm is expressed as:

$$ c^j = wq^j + mv^j \tag{3.02} $$

where q^j and v^j are the farm commodity and marketing input used by the jth firm in the production process and w and m are the respective prices. If p is the price of the industry output faced by all firms in the market, then in the short run (when z is fixed), the profit function for the jth firm is:

$$ \Pi^j(p, w, m, z^j) = \max[px^j - wq^j - mv^j - r'z^j; \quad g^j(q^j, v^j, z^j)] \tag{3.03} $$

where r is the price of the quasi-fixed input. Equation (3.03) is an expression of the maximum level of profit (i.e., revenue minus cost) given the exogenous factors and the fixed input. Given standard assumptions for the underlying technology, the profit function of equation (3.03) has the properties of being positive (monotonicity), non-decreasing in p, non-increasing in w, convex and continuous in p and w[12]. Consequently, the first-order conditions (*Hotelling's lemma*) for (3.03) provide a system of short run output supply and factor demand equations for the firm expressed as:

$$ x^j = \frac{\partial \Pi^j(p, w, m, z^j)}{\partial p} \tag{3.04} $$

$$ q^j = -\frac{\partial \Pi^j(p, w, m, z^j)}{\partial w} \tag{3.05} $$

$$ v^j = -\frac{\partial \Pi^j(p, w, m, z^j)}{\partial m} \tag{3.06} $$

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[12] The assumption is that the input requirement set (i.e., all input combinations capable of producing output level x) is convex, closed and non-empty for all $x > 0$.

where x^j is output supply function for firm j; q^j is farm commodity input demand function for firm j; and v^j is marketing input demand function for firm j. An assumption in the above formulation is that firms in the industry are price takers in the output and input markets. The properties of the profit function of equation (3.03) imply that:

$$\frac{\partial x^j}{\partial p} \geq 0; \qquad\qquad \frac{\partial q^j}{\partial w} \leq 0; \qquad\quad \text{and} \quad \frac{\partial v^j}{\partial m} \leq 0 \qquad (3.07)$$

$$\frac{\partial x^j}{\partial w} = -\frac{\partial q^j}{\partial p}; \qquad \frac{\partial x^j}{\partial m} = -\frac{\partial v^j}{\partial p}; \qquad \text{and} \quad \frac{\partial q^j}{\partial m} = \frac{\partial v^j}{\partial w} \qquad (3.08)$$

The expressions in (3.07) are the direct consequences of the convexity of the profit function and the expressions in (3.08) are reciprocity or symmetry relationships. These expressions represent a set of conditions on smoothly differentiable supply and factor demand functions that ensure these functions can be "integrated" to capture the underlying technology that generated the profit function (Chambers 1988, p. 131). These expressions or conditions are useful for validating estimated models.

3.3.2   Modelling Non-Competitiveness

Non-competitive behaviour is characterized by firms possessing some control in determining their input and/or output prices. For example, firms having oligopsony power are able to influence their input prices. The extent of influence depends on the conjectures of other firms in the industry. In modelling oligopsony power, these conjectures are taken into consideration.

Consider the situation of the processing firm that has some influence (i.e., market power) over prices for farm commodities but is a price taker for its own output and other non-farm inputs. The objective function (3.03) becomes:

$$\Pi^j(p,w,m,z^j) \quad = \quad \max[px^j - w(q)q^j - mv^j - r'z^j] \qquad (3.09)$$

The first order condition for profit maximization with respect to the farm commodity input is:

$$p\frac{\partial x^j}{\partial q^j} \quad = \quad w + q^j \frac{\partial w(q)}{\partial q}\frac{\partial q}{\partial q^j} \qquad (3.10)$$

The expression on the left side of (3.10) is the value of marginal product (VMP) for farm commodity input. The term on the right side is the effective marginal cost (EMC) to the firm (an oligopsonist). Using algebraic manipulation (see Appendix 3a), the EMC term can be expressed in elasticities as follows:

$$p\frac{\partial x^j}{\partial q^j} \quad = \quad w(1 + \frac{\theta^j}{\varepsilon}) \qquad (3.11)$$

where θ^j is the firm's conjectural elasticity in the farm commodity market; and ε is the supply price elasticity for the farm commodity. θ^j shows the jth firm's perception of the percent change in the purchases by all firms in the industry in reaction to a one percent change in its own purchases. Thus, θ^j with values in the [0,1] interval can be interpreted as an index of processor market power for the affected farm commodity. This parameter is comparable to Appelbaum's (1982) conjectural elasticity term for the output market. Chen and Lent (1992) refer to the right side of (3.11) as the processor's conjectural marginal input cost (CMIC) and suggest that this is useful for testing the degree of

monopsony/oligopsony power held by the processor. Azzam and Pagoulatos (1990) suggest that in equilibrium θ^j is invariant across firms, that is:

$$\theta^1 = \theta^2 = ... = \theta^n = \theta \qquad (3.12)$$

Azzam and Pagoulatos (1990) also suggest that the ratio θ^j/ε is an industry–wide index of oligopsony power in the farm commodity market. The index represents the degree to which processing firms can set input price below the value of marginal product (i.e., price "mark-down"). With observations for the farm commodity price w, the conjectural marginal input cost can be estimated with knowledge of the market elasticity ε. From equation (3.11) if the index equals zero, a perfectly competitive market exists for the affected farm commodity. If the index does not equal zero, the farm commodity market is not perfectly competitive. By rearranging the expression in (3.11), Hyde and Perloff (1994) suggest that the price "mark-down". μ_q, can be expressed as:

$$\mu_q \;\; = \;\; \frac{p}{w}\frac{\partial x^j}{\partial q^j} \;\; = \;\; (1+\frac{\theta^j}{\varepsilon}) \qquad (3.13)$$

If $\mu_q=1$, the industry-wide index equals zero and the value of marginal product of the processor's farm commodity input equals the farm commodity price. If $\mu_q \neq 1$, the index is not zero. The expression for price "mark-down" (3.13) can be expressed alternatively as (see Appendix 3b):

$$\mu_q \;\; = \;\; \frac{\xi_q}{\varpi_q} \qquad (3.14)$$

where ξ_q is the firm's elasticity of output with respect to the farm commodity input, and ϖ_q is the cost of the farm commodity input relative to value of supply (i.e., farm commodities input cost share of value of supply). From (3.13) the conjectural marginal input cost of the farm commodity input is equal to $w\mu_q$.

Appelbaum (1979) suggests ways that non-competitive behaviour may be incorporated into (3.03). Following Appelbaum and substituting for $CMIC$ ($=w\mu_q$) the profit function for the oligopsonist has the form:

$$\Pi^j \;\; = \;\; \Pi^j[p,w,\mu_q,m,z^j] \qquad (3.15)$$

The first-order conditions for profit maximization from (3.15) give the short run output supply, farm commodity input demand and marketing input demand functions respectively as:

$$x^j \;\; = \;\; \frac{\partial \Pi^j[p,w,\mu_q,m,z^j]}{\partial p} \qquad (3.16)$$

$$q^j \;\; = \;\; -\frac{\partial \Pi^j[p,w,\mu_q,m,z^j]}{\partial w} \qquad (3.17)$$

and $\qquad v^j \;\; = \;\; -\frac{\partial \Pi^j[p,w,\mu_q,m,z^j]}{\partial m} \qquad (3.18)$

The output supply and factor demand functions (3.16) to (3.18) are homogenous of degree zero in p and w, i.e., only relative price changes affect supply or demand. The second-order conditions of (3.15) are similar to (3.07) and (3.08) and are useful for validating (3.16) to (3.18).

Based on the development of these expressions, specification of a functional form for (3.15) allows us to derive estimable supply and demand functions to test for the significance of μ_q, the price "mark-down". Thus, we can test for non-competitive behaviour in the market for farm commodities.

3.3.3   *Aggregation Issues*

The model outlined above is a firm-level model. As is often the case in empirical work, firm-level data for prices and quantities are not available because of confidentiality restrictions. To apply the firm-level formulations to the industry, the common assumption that is applied in empirical work is linear aggregation of output and profits for the firms in the industry, that is:

$$x \;=\; \sum_{j=1}^{n} x^{j} \tag{3.19}$$

and
$$\Pi \;=\; \sum_{j=1}^{n} \Pi^{j}[p, w, \mu_q, m, z^{j}] \tag{3.20}$$

where x is the industry output and Π is the industry profit. Any functional form capable of incorporating (3.19) and (3.20) is a candidate for an industry profit function (Chambers 1988 p. 183). The first-order condition of (3.20) with respect to output price p, is:

$$\frac{\partial \Pi}{\partial p} \;=\; \sum_{j=1}^{n} \frac{\partial \Pi}{\partial \Pi^{j}} \frac{\partial \Pi^{j}}{\partial p} \;=\; \sum_{j=1}^{n} \frac{\partial \Pi^{j}}{\partial p} \qquad \text{since} \qquad \frac{\partial \Pi}{\partial \Pi^{j}} = 1 \tag{3.21}$$

Thus,
$$\frac{\partial \Pi}{\partial p} = \sum_{j=1}^{n} \frac{\partial \Pi^{j}}{\partial p} \tag{3.22}$$

The assumption of linear aggregation of output and profits across firms allows the firm-level formulation to apply to the industry. The problem with the aggregation assumption is that from the aggregate perspective, it is irrelevant which firm produces which units of output. Equation (3.22) implies that the sum of each firm's level of output equal aggregate output.

3.4   Application and Empirical Specifications

The imperfect competition formulation outlined above is applied to each of the four food processing industries; the meat and meat products industry (excluding poultry), the cereal grain flour industry, the livestock feed industry and the vegetable oil industry (excluding corn oil). The procedure outlined above differs from the cited previous studies in two major ways. The conjectural marginal input costs for farm commodity inputs are explicitly incorporated into the oligopsonist's profit function and the resulting system of factor demand and output supply equations is estimated. None of the cited studies have estimated factor demand and output supply functions of the form (3.16) to (3.18)[13]. This permits the evaluation of the direct effect of farm commodity input prices as well as the

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[13] Most studies investigating market power use a variant of (3.10) and specify this as a behavioural function. For example, (3.10) may be specified as a factor demand function (e.g., Azzam and Pagoulatos 1990). A similar derivation for an oligopolist may be specified as a supply function (e.g., Schroeter 1988; Wann and Sexton 1992).

effect of any price "mark-down." This approach is particularly important because the existence of a price "mark-down" represents a depression of the price that farmers receive and this may result in resources being diverted away from the production of the affected farm commodity.

Now consider a firm producing any of the industrial products being considered; that is meat and products (excluding poultry), cereal grain flour, livestock feed, or vegetable oil (excluding corn oil). It is assumed that, in terms of farm commodity inputs, the meat products industry uses cattle, the wheat flour industry uses wheat, the livestock feed industry uses barley; and the vegetable oil industry uses canola. In addition to farm commodity input, all firms are assumed to use labour, capital, and energy as other inputs.

The profit function of the firm is specified using a Translog functional form (Christensen et al. 1973), expressed as:

$$
\begin{aligned}
\ln \Pi = {} & b_0 + b_x \ln p + b_q \ln w + b_q^* \ln \mu_q + b_v \ln m + 0.5 b_{xx} (\ln p)^2 + b_{xq} \ln p \ln w \\
& + b_{xq*} \ln p \ln \mu_q + b_{xv} \ln p \ln m + 0.5 b_{qq} (\ln w)^2 + b_{qq*} \ln w \ln \mu_q \\
& + b_{qv} \ln w \ln m + 0.5 b_{q*q*} (\ln \mu_q)^2 + b_{q*v} \ln \mu_q \ln m + 0.5 b_{vv} \ln m \ln m
\end{aligned}
\tag{3.23}
$$

where p is retail price output; w is price of the farm commodity; μ_q is the price "mark-down" of the farm commodity; m is labour wage; and the bs are parameters to be estimated.

The translog function is a flexible functional form that permits examination of comparative statics without imposing arbitrary cross-equation restrictions. From *Hotelling's lemma*, and substituting for $\mu_q = \xi_q / \varpi_q$, the share equations of short run output supply, farm commodity input demand and labour input demand are obtained from (3.23) respectively as:

$$
\frac{\partial \ln \Pi}{\partial \ln p} = s_x = b_x + b_{xx} \ln p + b_{xq} \ln w + b_{xq*} \ln \left(\frac{\xi_q}{\varpi_q} \right) + b_{xv} \ln m
\tag{3.24}
$$

$$
\frac{\partial \ln \Pi}{\partial \ln w} = s_q = -\left[b_q + b_{xq} \ln p + b_{qq} \ln w + b_{qq*} \ln \left(\frac{\xi_q}{\varpi_q} \right) + b_{qv} \ln m \right]
\tag{3.25}
$$

and
$$
\frac{\partial \ln \Pi}{\partial \ln m} = s_v = -\left[b_v + b_{xv} \ln p + b_{qv} \ln w + b_{vq*} \ln \left(\frac{\xi_q}{\varpi_q} \right) + b_{vv} \ln m \right]
\tag{3.26}
$$

where $s_x = \dfrac{p\,x}{\Pi}$ is the value of shipment of output to total profit,

$s_q = \dfrac{w\,q}{\Pi}$ is the cost of the farm commodity input to total profit and

$s_v = \dfrac{m\,v}{\Pi}$ is the cost of labour input to total profit.

All variables are defined as previously.

Assuming standard properties for the processing technology, equation (3.23) satisfies the following conditions: monotonicity and convexity in prices; symmetry; and homogeneity. Appropriate restrictions on the parameters can be imposed on (3.24) to (3.26) during estimation so that the profit function satisfies the properties of symmetry and linear homogeneity in prices.

Monotonicity and convexity are not general properties of the translog function. These properties cannot be conveniently imposed with linear restrictions on parameters in (3.24) to (3.26) (Holloway and Goddard 1988; Fulginiti and Perrin 1993; Lau 1978). Instead, the consistency of the estimated share equations with these properties must be evaluated after estimation. To satisfy the monotonicity condition, the shares fitted from the estimated parameters must be positive. The implications are that processors do not accept negative profits if all inputs are perfectly variable and input costs are not less than zero. To be convex in prices, the Hessian implied by the estimated price parameters must be positive semi-definite (Chambers 1988; Fulginiti and Perrin 1993). The implication is that for outputs, all own-price effects are positive and for inputs, all own-price effects are negative, as expressed by (3.07). The hypotheses of monotonicity and convexity in prices of the estimated functional forms are tested in this study. In addition, non-competitive behaviour in the domestic market for farm commodities is tested through estimation of the price "mark-down" as discussed above.

3.4.1 *Responsiveness and Elasticity Measures*

The dependent variables in (3.24) to (3.26) are shares that do not allow easy interpretation with respect to the effects of prices on supply quantities. In this case processors' responsiveness to price changes may be appropriately measured by elasticities. The elasticity measures of interest in this study are own-price elasticities of supply and demand as well as the elasticity of demand for farm commodity inputs with respect to own-price "mark-down". The elasticity formulations specified below are derived from Fulginiti and Perrin (1993). The formulation for own-price elasticity of output supply is:

$$E_{xx} = \frac{b_{xx} + s_x^2 - s_x}{s_x} \tag{3.27}$$

From (3.07) it is expected that output supply will respond positively to output price changes; that is output supply will increase with an increase in output price ($E_{xx} \geq 0$). This will be an affirmation of the basic economic theory relating to supply in that supply curves are expected to be upward sloping.

Own-price elasticity of demand for farm commodity input is:

$$E_{qq} = \frac{b_{qq} + s_q^2 - s_q}{s_q} \tag{3.28}$$

From (3.07) it is also expected that own-price elasticity of demand will be negative (i.e., $E_{qq} \leq 0$) reflecting a negatively sloped demand curve for farm commodities. A similar sign is expected for own-price elasticity of demand for labour, which may be expressed as:

$$E_{vv} = \frac{b_{vv} + s_v^2 - s_v}{s_v} \tag{3.29}$$

Appropriate signs for all own-price effects are a confirmation of the convex nature of the profit function from which the functions were derived.

Following Fulginiti and Perrin (1993) the existence of substitution and/or complementarity between a farm commodity and labour in the production process is assessed using the cross-price elasticity formulation:

$$E_{ij} \quad = \quad \frac{b_{ij} + s_i s_j}{s_i} \qquad i, j = q, v; \quad i \neq j \qquad (3.30)$$

The sign of E_{ij} depicts the technical relationship between a farm commodity input and labour in production. A positive sign implies that labour and farm commodities are technical (i.e. $\frac{\partial MPP_i}{\partial x_j} < 0$) substitutes while a negative sign implies that the inputs are complements (i.e. $\frac{\partial MPP_i}{\partial x_j} > 0$). Initially we would expect the two inputs will be complementary in the food production process such that an increase in commodity usage induces an increase in labour usage.

Expressions similar to (3.30) are used to calculate the elasticity of supply with respect to factor prices and the elasticity of factor demand with respect to output price. Economic theory provides no prior expectations about the sign of these elasticities. From equation (3.08) supply response to changes in w, and factor demand response to changes in p are expressed, respectively, as:

$$\frac{\partial x^j}{\partial w} = \left\{ \frac{\partial x^j(p, q^{j*})}{\partial q^j} \right\} \left\{ \frac{\partial q^j}{\partial w} \right\} \qquad (3.31)$$

and

$$\frac{\partial q^j}{\partial p} = \left\{ \frac{\partial q^j(w, \mu_q, x^{j*})}{\partial x^j} \right\} \left\{ \frac{\partial x^j}{\partial p} \right\} \qquad (3.32)$$

where "∗" indicates optimal levels. The direction of change in the expressions in the second set of brackets of (3.31) and (3.32) can be predicted using (3.07). However, economic theory does not suggest a particular direction of change in the expressions in the first set of brackets of (3.31) and (3.32). The expressions in the first set of brackets represent a change in output (input) to changes in input (output). For example, in the production process, increasing output may require an adjustment of the input mix but the extent to which individual inputs adjusts is determined by how input demand in turn responds to changes in output (Chambers 1988, p.133).

Regarding the effect of the price "mark-down", the parameter ξ_q in (3.24) to (3.26) is a local measure that measures the effect on output within the immediate of farm commodity input space. The sum of all elasticity measures of output with respect to variable inputs ξ_is, is termed the *elasticity of scale* (i.e., $\sum_i \xi_i = \xi$, Chambers 1988). Decreasing (constant) returns to scale implies that each ξ_i is less than (less than or equal to) unity since their sum must be less than (equal to) unity. The elasticity measure of output with respect to each input is unknown. However, assuming that the profit function satisfies the aggregation property of (3.19), the production technology implied in the production process is quasi-homothetic and therefore a constant-returns technology (Chambers 1988, p. 184)[14]. This assumption implies that the parameter ξ equals unity. For the purposes of this study, the parameter ξ_q (elasticity of supply with respect to farm commodity input) is set at 0.5 to allow the evaluate changes in the price markdown.

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[14] Quasi-homothetic production functions have expansion paths that are straight lines that do not necessarily emanate from the origin.

Assuming that the parameter ξ_q is constant over the sample period, equation (3.14) implies that:

$$\mu_q \quad = \quad (0.5)\frac{px}{wq} \quad = \quad (0.5)\frac{s_x}{s_q} \tag{3.33}$$

Any variations in the price "mark-down" μ_q will be attributed to the ratio of the optimal shares of the value of output and the value of farm commodity. From the above expression, $\partial s_q/\partial \mu_q < 0$ and $\partial s_x/\partial \mu_q > 0$. This implies that a higher price "mark-down" results in a lower share of farm commodity and a higher share of the value of output. Empirically therefore, two conditions suggest non-competitive behaviour in the farm commodity market. These are; (1) a statistically significant and positive estimate of the coefficient on μ_q in the output equation and (2) a statistically significant and negative estimate of the coefficient on μ_q in the farm commodity equation. Regarding the signs of the associated elasticity measures, the elasticity of demand for a farm commodity with respect to a price "mark-down" is expected to be positive because a high price "mark-down" depresses commodity price, resulting in increased quantity demanded for the farm commodity. This is expressed as:

$$E_{qq}^* \quad = \quad \frac{b_{qq^*}}{s_q} \tag{3.34}$$

Similarly, the elasticity measure of supply with respect to farm commodity price "mark-down" is expected to be positive because with more farm commodity input, more output will be produced. This is also expressed as:

$$E_{xq}^* \quad = \quad \frac{b_{xq^*}}{s_x} \tag{3.35}$$

3.5 Data and Estimation Procedure

Data used are annual time series for the period 1974 through 1996. The definitions and sources of the data series are summarized in Table 3.1. Four food processing industries are considered in the study; the meat and meat products industry (excluding poultry), the cereal grain flour industry, the livestock feed industry and the vegetable oil industry (excluding corn oil). These industries constitute part of the Canadian 1980 Standard Industrial Classification (SIC) and are identified respectively as SIC 1011, SIC 1051, SIC 1053 and SIC 1061[15].

Variables used in the estimation process include the price index of industry output, the price of the farm-commodity, the price of labour (wage), the price of energy, capital, and the generated commodity price "mark-down" variable (equation 3.33). Data on capital could not be obtained for the specified industry subdivisions. Consequently, following Bradley et al. (1993) and Holloway and Goddard (1988), operating surplus of the industry is used as a proxy for capital. Input prices and all nominal variables are

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[15] SIC 1011 refers to establishments primarily engaged in abattoir operations and/or in meat packing operations. SIC 1051 refers to establishments primarily engaged in milling flour from wheat, corn, buckwheat, rye and other cereal grains. SIC 1053 refers to establishments primarily engaged in manufacturing balanced feeds and pre-mixes or feed concentrates. SIC 1061 refers to mill establishments primarily engaged in crushing, expressing, oxidizing, dehydrating or otherwise processing oil seeds.

deflated by the consumer price index. This implicitly imposes the homogeneity property in the supply and demand functions. With the data used, the disturbances in equations (3.24) to (3.26) are assumed to be linearly dependent because of the endogeneity of the price "mark-down" term and inaccurate measurement of capital. The system of equations is therefore estimated for each industry using the three-stage least squares (3SLS) procedure in the "SHAZAM" software program (White 1978). The consumer price index and the interest rate are used as additional predetermined variables in the estimation. Symmetry conditions (3.08) are imposed during the estimation procedure.

Preliminary results indicated the existence of multicollinearity. Therefore, all right-hand side variables used in the estimation were divided by the price of energy. Since the price of energy is not explicitly included as an explanatory variable, the equation for energy is not included in the system. For each industry, the system has three equations; output supply, farm commodity demand and labour demand. The dependent variables are the output and input shares. The full model for each industry comprising output supply, farm commodity demand and labour demand has 23 observations and 15 estimated parameters.

While the properties of homogeneity and symmetry are imposed, monotonicity is tested using the estimated parameters to predict shares at each data point. The monotonicity property is satisfied when predicted shares are positive at each data point. For convexity in prices, all own-price elasticities should have the expected signs; that is, positive for output supply and negative for input demand (Chambers 1988). Convexity in prices can also be checked using the sign definiteness of the Hessian of the sub-matrix of price coefficients (Holloway and Goddard 1988; Fulginiti and Perrin 1993). The sub-matrix of price coefficients should be positive semi-definite.

3.6   Results and Discussion

3.6.1   Model Diagnostics

Estimates of parameters, values of R-squared, Durbin-Watson (D-W) statistic, and variance of the estimates (σ-squared) for the various industry models are presented in Table 3.2. The R-squared statistic reported here is the square of the correlation coefficient between the observed and predicted dependent variable[16]. Generally, there is a reasonable level of fit for the individual equations given the values of the R-squared statistic. The values range from 0.54 for the labour demand equation in the livestock feed industry model, to 0.96 for the meat supply equation in the meat and meats products industry model. The D-W statistic values are measures of first-order serial correlation in the estimated models. The D-W statistic values obtained suggest that serial correlation is not a problem in the models. The variance of the estimates, which is a measure of the difference between observed variation and predicted variation in shares, is also used to validate the models. Variance estimates are generally low ranging from 0.000 in the labour demand equation in the vegetable oil industry model, to 0.099 in the flour demand

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[16] This R-squared is not the goodness-of-fit measure which is calculated as one minus the ratio of the residual variance over the variance of the left-hand side (unexplained portion of the total variance). In 3SLS estimation, the goodness-of-fit measure of R-squared is not well defined (Berndt 1991, p. 468; Judge et al. 1988, p. 650)

equation in the cereal-flour industry model. Low variance estimates are indications of good predictive abilities of estimated models.

3.6.2   Model Validation

In addition to model diagnostics, a more general approach to ascertaining the validity of the estimated model is to check whether the model satisfies the theoretical properties of the function from which it is derived. Homogeneity and symmetry are imposed in the estimation process but monotonicity and convexity are not. All fitted shares are positive implying that the translog profit function satisfies the property of monotonicity. In an economic sense, this implies there are no negative profits for processors when inputs are perfectly variable. The property of convexity in prices is ascertained using the eigen value test of sign definiteness. Convexity requires that all eigen values of the sub-matrix of estimated price coefficients be non-negative and that at least one should be zero for positive semi-definiteness. Eigen values obtained are: 0.341, -0.025, 0.100 for the meat products industry model; 0.426, 0.059, -0.583 for the cereal-flour industry model; -0.328, 0.018, -0.240 for the livestock feed industry model; and 0.105, -0.024, 0.495 for the vegetable oil industry model. Eigen values from the meat industry and vegetable oil industry models appear to satisfy the condition for positive semi-definiteness. A convex profit function implies that processors can always keep output and cost constant but still increase profit with an increase in output price.

3.6.3   Test of Non-Competitive Behaviour

As illustrated in section 3.4.2, if there is non-competitive behaviour in the farm commodity market, the price "mark-down" is expected to be positive in the supply equation but negative in the farm commodity demand equation. From Table 3.2, these sign conditions are satisfied in the livestock feed industry and vegetable oil industry models. The two estimated parameters for supply and commodity demand are respectively, 5.67 and –2.431 in the feed industry model, and 3.416 and –1.036 in the vegetable oil industry model. However, the estimated parameters are not statistically significant asymptotically. Statistical significance of the parameters would have suggested the presence of non-competitive behaviour (market power) in the market for barley and canola. Nevertheless, the signs on the parameters appear to suggest that there is a limited ability or potential for the two industries to exert some market power in the market for the two commodities. In the meat products industry and cereal flour industry models, the sign conditions for the estimated parameters on the price "mark-down" are not satisfied. In both models, estimated parameters are positive in the supply and farm commodity equations. This suggests the absence of market power and absence of the potential to exert some power by these particular industries.

This finding (i.e. absence of market power in commodity markets) may be attributed to a number of factors. First, the markets for feed barley and canola are unregulated and may be considered as reasonably competitive. For wheat, the Canadian Wheat Board (CWB) controls international and domestic sale of the commodity and it appears that prices are negotiated between the board and the grain milling industry. For slaughter cattle, animals are marketed through auction or private treaty, particularly in western Canada. Such market structures do not facilitate non-competitive behaviour.

Second, a substantial proportion of cereal grains and canola is exported and barley is used as a major feed ingredient in livestock production. Thus competition in the primary commodity market probably limits the ability of processors of these commodities to exert market power. Competition in the output market of the food-processing sector may also be relevant. Obligations to the General Agreement on Tariffs and Trade (GATT) have resulted in reduced tariffs on food products of the food processing industries assessed in the study. Increased cross-border trade of processor outputs also limits processors' market power.

Third, it has been speculated that firm concentration does not necessarily lead to market power, particularly when scale economies, technical change and trade factors are taken into account. For example, the US food industry has experienced increasing consolidation yet some researchers find limited or no indications of market power when cost economies, technical change, and competitiveness are considered (e.g., Azzam 1997; Azzam and Schroeter 1995; Durham and Sexton 1992; Paul 1999a, 1999b). Martin et al. (1998) report that the costs of hog processing in Canada have been affected by scale and quality of plant and equipment, number of shifts, wage costs, capacity utilization and size of animals.

3.6.4 Elasticity Measures of Price Change

The effects of price on output supply and input demand are evaluated using elasticity measures. From an inspection of the elasticity formulation for the translog model in section 3.4.2, it is apparent that the magnitude of the elasticity measures will vary depending on the evaluation point (i.e., as the value of shares change). Therefore it is of interest to look at the elasticity measures implied by the estimated models at points other than the mean point. The elasticity estimates evaluated at the mean of the sample period 1974-1996 are reported in Table 3.3. The estimates evaluated at the mean of the period 1991-1996 are reported in Table 3.4. To estimate the asymptotic significance of elasticity estimates, share values are treated as constants, so that the asymptotic normal statistic can be formed (Holloway and Goddard 1988; Fulginiti and Perrin 1993).

It is expected that the sign on output supply elasticity measures will be positive. This is satisfied in all the industry models. From Table 3.3, own-price elasticity measures of output supply evaluated at the sample mean values for the meat, flour, feed and oil industries are respectively, 0.586, 0.625, 0.588, and 0.385. All estimates are statistically significant asymptotically at the 5% level. From Table 3.4, own-price elasticity measures output supply evaluated at the 1990s mean values for the four industries are respectively, 1.223, 1.436, 1.256, and 1.116. This indicates that the supply curve for each food industry is upward sloping. The supply function in the 1990s for the various industry products of meat, flour, feed and oil all appear to be relatively price elastic. The industry is apparently able to respond to changes in consumer demand.

Regarding factor demand elasticity estimates, there is an *a priori* expectation that the signs on the own-price elasticity measures of input demand are negative. All 8 of the estimated own-price elasticity measures of factor demand have the appropriate negative sign with one exception. The elasticity of wheat demand, evaluated at the sample mean, is 0.193 (Table 3.3). In the meat products industry model, the own-price elasticity for cattle demand is –0.172 and own-price elasticity for labour demand is –0.922. In the cereal flour industry model, the own-price elasticity for labour input demand –1.166. In

the livestock feed industry model, own-price elasticity measure for barley input demand is –0.117 and the own-price elasticity measure for labour input demand is –1.629. Own-price elasticity measures of factor demand in the vegetable oil industry model are also negative. The corresponding own-price elasticity measures of factor demand, evaluated at the mean values for the 1990s, are all negative (Table 3.4). A negatively sloped input demand function implies that processors demand less of the factor inputs as factor price increases. This also implies that the implicit cost function underlying the profit function is concave and continuous in input prices (Chambers 1988, p. 138). It appears that own-price factor demand elasticity measures tend to become larger in absolute value when evaluated at the 1990s share values than at the sample means. The translog functional form applied in the study permits the measurement of elasticity for different sample periods. Therefore it is not entirely clear whether the elasticity measures evaluated at the mean of the 1990s are more useful for policy analysis than are elasticity measures evaluated at the sample mean.

The findings of positive elasticity measures of supply and negative elasticity measures of factor demand satisfy the conditions in equation (3.07). This finding is consistent with results from the convexity property of the profit function and confirms the findings from the eigen values obtained earlier.

Table 3.3 provide cross-price elasticities evaluated at sample mean, These values suggest a particular relationship between farm commodities and labour used in agri-food processing. In all of the farm commodity equations, the elasticity measures for demand of a farm commodity with respect to labour wage are negative, being -0.124 for cattle demand, -0.097 for wheat demand, -0.055 for barley demand, and –0.044 for canola demand (Table 3.3). All estimates are statistically significant, asymptotically. The implication is that labour and farm commodities are complements in food processing. In contrast, the elasticity estimates of demand for labour input with respect to farm commodity prices, while nonsignificant, are positive. The elasticities of labour demand are with respect to cattle price, wheat price, barley price and canola price are 0.032, 0.238, 0.809 and 0.644 respectively (Table 3.3). The positive signs are counter-intuitive in suggesting substitution between labour and farm commodities, but most of these estimates are statistically insignificant, asymptotically.

From Table 3.4 (elasticity measures evaluated at 1990s mean) all estimates of cross-price effects are negative and most are statistically significant, asymptotically. Labour and farm commodities appear as complements to each other in the respective demand equations. For example, the elasticity measures of labour demand with respect to the prices of farm commodities are –1.741 for cattle price, -1.174 for wheat price, -1.43 for barley price and –2.017 for canola price (Table 3.4). Similarly, the elasticity measures of demand for farm commodities with respect to wage are –0.186 for cattle demand, -0.171 for wheat demand, -0.107 for barley demand and –0.05 for canola demand (Table 3.4). Labour and farm commodities are complementary in the food production process.

The finding of complementarity between farm commodities and labour leads to expectations about the effect of commodity price "mark-down" on labour demand. With complementarity between labour and farm commodities, we would expect a positive relationship between labour demand and farm commodity price "mark-down". A higher price "mark-down" reflects a depressed commodity price and processors may consequently purchase more of the affected farm commodity. With a depressed farm

commodity price and increased quantity demanded, we should expect that the demand for labour would increase as well since the two inputs are complements. From Tables 3.3 and 3.4, there is a positive relationship between labour and farm commodity price "mark-down" in all industries except for the livestock feed industry where this relationship is negative. In Table 3.3, the elasticity estimates of labour demand with respect to cattle, wheat and canola price "mark-downs" are 0.925, 0.888 and 3.321 respectively. The same elasticity measures evaluated at the mean of the 1990s' series of the data are 0.599, 0.596 and 2.745 respectively (Table 3.4).

Regarding the effect of input prices on output supply and the effect of output price on factor demand, as pointed out in section 3.4.2, there are no prior expectations,. From equations (3.31) and (3.32) the effect in either case is determined by technology and by the extent to which input adjusts as output changes and vice versa. All that can be said about these elasticity measures is that from equation (3.08), the direction of the effect of a change in factor price on supply should be opposite to the direction of the effect of output price on factor demand. This condition is satisfied in all the models. In Table 3.3 for example, the elasticity measure of meat supply with respect to cattle price is 1.195 and the elasticity measure of cattle demand with respect to the price of meat products is – 1.496. The elasticity measure of meat supply with respect to wage is –0.002 and the elasticity measure of demand for labour with respect to meat product price is 0.032. In each of the industry models in Tables 3.3 and 3.4, the direction of the effect of a change in factor price on supply is opposite to the direction of the effect of output price on factor demand.

In summary, the results from the estimated models are generally consistent with theoretical expectations as well as economic intuition. The translog functional form applied in the study is used to approximate the profit function of food processors. The elasticity measures are the results that are probably of most interest for policy analysis. As pointed out earlier, it is not clear which of the elasticity measures are more useful for policy analysis given the variation in absolute value from Tables 3.3 and 3.4.

3.7   Summary and Conclusions

The purpose of this component of the project was to examine the processing sector's demand for farm commodities and the potential presence of non-competitive behaviour (market power) in the domestic market for farm commodities. Four food industries were examined; the meat and meats products industry (excluding poultry), cereal grain flour industry, livestock feed industry and vegetable oil industry (excluding corn oil). The profit function for each industry was specified as a translog functional form and one output supply and two factor demand models were estimated for each industry.

The results suggest that the supply curves for meat and meat products, cereal grain flour, livestock feed and vegetable oil are upward sloping. The results also indicate that the demand curves for slaughter cattle, wheat, feed barley, canola and labour are downward sloping. Own-price elasticity measures evaluated at the mean of the period 1991-1996 are larger in absolute value than estimates that are based on the sample mean which covers the period from 1974-1996. The results portray labour and farm commodities as complements in the food production process. The elasticity measures have signs that make economic sense and may be of interest for policy analysis. Regarding the issue of the existence of market power held by processors, there is no

evidence of non-competitive behaviour in any of the commodity markets. The absence of non-competitive behaviour may be attributed to the structure of the commodity markets as well as other factors such as the increased competition from world trade that has accompanied technical change, and increased scale of food processing operations. In conclusion, it should be pointed out that the approach employed in the study may be useful in other empirical evaluations of potential imperfections and distortions in the domestic market for farm commodities.

Future research concerning the operations of the Canadian food processing industry may improve the present study in a number of ways. First, the sample period used in the study may not be long enough to evaluate any significant changes in the operations of the Canadian food processing industry. It is preferable to have more and better data in empirical research. Second, it may be desirable to enhance the database of the processing sector, especially as this relates to the disaggregation of farm commodities and the inputs used and output produced by these industries. The database as it now exists and used here is highly aggregated. With a relatively less aggregated data, estimation of output supply and factor demand functions could be accomplished in order to examine non-competitive behaviour in both output and input markets.

Table 3.1:   Processing Sector Variables: Definition and Sources of Data

Variable	Definition	Source
Value of output		
SIC 1011	Value of manufactured goods	CANSIM D907976 & D662312
SIC 1051	"	CANSIM D910352 & D662389
SIC 1053	"	CANSIM D910703 & D662411
SIC 1061	"	CANSIM D912836 & D662422
Cost of farm commodity		
All industries	Cost of manufacturing materials	Statistics Canada cat # 31-203
Cost of labour		
All industries	Production workers wages	Statistics Canada cat # 31-203
Cost of energy		
SIC 1011	Cost of fuel & electricity	CANSIM D907974 & D662314
SIC 1051	"	CANSIM D910350 & D662391
SIC 1053	"	CANSIM D910701 & D662413
SIC 1061	"	CANSIM D912834 & D662424
Industry Product price		
SIC 1011	Industry Product Prices Indexes	CANSIM P1608
SIC 1051	"	CANSIM P1611
SIC 1053	"	CANSIM P1612
SIC 1061	"	CANSIM P1606
Farm commodity price		
SIC 1011 (slaughter cattle)	Calgary/Southern Alberta price.	Agriculture Canada)
SIC 1051 (wheat)	"1 CWRS" Final realized price[1]	Canadian Grain Council
SIC 1053 (barley)	"1 CW" Final realized price[2]	Canadian Grain Council
SIC 1061 (canola)	"1 Canada" price	Canadian Grain Council
Wage		
SIC 1011	Average production workers wage	Statistics Canada cat # 31-203
SIC 1051	"	"
SIC 1053	"	"
SIC 1061	"	"
Energy price		
All industries	Consumer price index for energy	CANSIM P100288

[1] CWRS is an abbreviation for Canada West Red Spring
[2] CW is an abbreviation for Canada West.

Table 3.2:   Estimated Coefficients for the Processing Sector Models[1].

	Meat & Meat Products Industry Model			Cereal Grain Flour Industry Model			Livestock Feed Industry Model			Vegetable Oil Industry Model		
	Meat Supply	Cattle Demand	Labour Demand	Flour Supply	Wheat Demand	Labour Demand	Feed Supply	Barley Demand	Labour Demand	Oil Supply	Canola Demand	Labour Demand
Intercept	-12.036^a	11.55^a	3.778^a	-1.207	3.271	1.061	-2.149	2.964	0.567	2.196	-0.961	0.009
Wage	-0.183^a	-0.009	-0.210^a	-0.256	0.037	-0.270	-0.190	0.030	-0.203	-0.079	-0.010	-0.047
Capital	1.038^a	-0.953^a	-0.329^a	0.316	0.402	-0.149	0.441	-0.405^b	-0.110	0.112	-0.113	-0.013
Meat price	0.075	0.050	0.183^a									
Cattle price	-0.050	0.068	-0.009									
Flour price				-0.117	0.348^a	0.256						
Wheat price				-0.348^a	0.251^a	0.037						
Feed price							0.023	0.134	0.190			
Barley price							-0.134	0.120^b	0.030			
Oil price										-0.228^a	0.260^a	0.079
Canola price										-0.260^a	0.232^a	-0.010
Cattle-PMD[2]	2.054^b	0.019	0.108									
Wheat-PMD				3.505^a	0.379	0.118						
Barley PMD							5.670^a	-2.431	-0.230			
Canola PMD										3.416	-1.036	0.121
R-squared	0.96	0.94	0.74	0.77	0.54	0.65	0.82	0.78	0.54	0.94	0.93	0.84
σ-squared	0.012	0.009	0.001	0.099	0.048	0.001	0.068	0.040	0.001	0.018	0.013	0.000
D-W statistic	2.9	2.8	2.9	1.4	1.4	1.7	2.2	2.2	2.2	2.1	2.1	1.4

[1] 'a' indicates asymptotic significance at the 5% level and 'b' indicates asymptotic significance at the 10% level.
[2] PMD refers to price "mark-down".

Estimated Elasticity Measures for the Processing Sector Evaluated at 1974-1996 Mean[1].

	Meat & Meat Products Industry Model			Cereal Grain Flour Industry Model			Livestock Feed Industry Model			Vegetable Oil Industry Model		
	Meat Supply	Cattle Demand	Labour Demand	Flour Supply	Wheat Demand	Labour Demand	Feed Supply	Barley Demand	Labour Demand	Oil Supply	Canola Demand	Labour Demand
Meat price	0.586^a	-1.496^a	0.032									
Cattle price	1.195^a	-0.172^a	-1.309^a									
Flour price				0.625^a	-1.362^a	0.238^b						
Wheat price				0.841^a	0.193^b	-0.767^a						
Feed price							0.588	-1.463^a	0.809			
Barley price							1.131^a	-0.117^a	-0.841^a			
Oil price										0.385^a	-1.334^a	0.644
Canola price										1.130^a	-0.120^a	-1.583^a
Cattle-PMD[2]	1.336^b	0.015	0.925									
Wheat-PMD				2.068^a	0.362	0.888						
Barley PMD							3.604^b	-2.000	-2.883			
Canola PMD										2.227	-0.875	3.321
Wage	-0.002	-0.124^a	-0.922	-0.019	-0.097^a	-1.166	-0.041	-0.055^a	-1.629	-0.015	-0.044^a	-0.318

[1] 'a' indicates asymptotic significance at the 5% level and 'b' indicates asymptotic significance at the 10% level.

[2] PMD refers to price "mark-down".

Table 3.4:   Estimated Elasticity Measures for the Processing Sector Evaluated at 1991-1996 Mean[1].

	Meat & Meat Products Industry Model			Cereal Grain Flour Industry Model			Livestock Feed Industry Model			Vegetable Oil Industry Model		
	Meat Supply	Cattle Demand	Labour Demand	Flour Supply	Wheat Demand	Labour Demand	Feed Supply	Barley Demand	Labour Demand	Oil Supply	Canola Demand	Labour Demand
Meat price	1.223^a	-2.159^a	-1.174^a									
Cattle price	1.665^a	-0.648^a	-1.741^a									
Flour price				1.436^a	-2.227^a	-1.174^a						
Wheat price				1.222^a	-0.178^a	-1.174^a						
Feed price							1.256^a	-2.165^a	-0.727			
Barley price							1.609^a	-0.597^a	-1.430			
Oil price										1.116^a	-2.072^a	-0.419
Canola price										1.665^a	-0.652^a	-2.017^a
Cattle-PMD[2]	0.928^b	0.011	0.599									
Wheat-PMD				1.412^a	-0.279	0.596						
Barley PMD							2.525^b	-1.457	-1.837			
Barley PMD										1.540	-0.637	2.745
Wage	0.096^a	-0.186^a	-0.348	0.095	-0.171^a	-0.562	0.041	-0.107^a	-0.749	0.008	-0.050^a	-0.103

[1] 'a' indicates asymptotic significance at the 5% level and 'b' indicates asymptotic significance at the 10% level.
[2] PMD refers to price "mark-down".

Appendix 3a: Converting Effective Marginal Cost into Elasticity Measures

The first order condition of the profit function (3.09) with respect to q^j is expressed as:

$$\frac{\partial \Pi^j}{\partial q^j} = p\frac{\partial x^j}{\partial q^j} - w + \left[q^j \frac{\partial w(q)}{\partial q}\frac{\partial q}{\partial q^j}\right] = 0$$

Multiplying the expression in parenthesis by $\dfrac{w}{w}\dfrac{q}{q}$ and rearranging, we obtain:

$$p\frac{\partial x^j}{\partial q^j} = w + \left[w\left(\frac{\partial w}{\partial q}\frac{q}{w}\right)\left(\frac{\partial q}{\partial q^j}\frac{q^j}{q}\right)\right]$$

In elasticity form the above expression becomes:

$$p\frac{\partial x^j}{\partial q^j} = w\left(1 + \frac{\theta^j}{\varepsilon}\right)$$

where $\quad \theta^j = \dfrac{\partial q}{\partial q^j}\dfrac{q^j}{q} \quad$ and $\quad \varepsilon = \dfrac{\partial q}{\partial w}\dfrac{w}{q}$

Appendix 3b: **Expression for the Oligopsonistic Price "Mark-Down."**

Following Hyde and Perloff (1994), the expression for the oligopsonist's price "mark-down" factor (3.13) is:

$$\mu_q \;=\; \frac{p}{w}\frac{\partial x}{\partial q}$$

Multiplying the expression on the right hand side by $\dfrac{x}{x}\dfrac{q}{q}$ and rearranging, we obtain:

$$\mu_q \;=\; \left(\frac{p\,x}{w\,q}\right)\left(\frac{\partial x}{\partial q}\frac{q}{x}\right)$$

In elasticity form the above expression becomes:

$$\mu_q \;=\; \frac{\xi_q}{\varpi_q}$$

where $\quad \xi_q = \dfrac{\partial x}{\partial q}\dfrac{q}{x} \qquad$ and $\qquad \varpi_q = \dfrac{w\,q}{p\,x}$

4.   THE IMPACT OF VALUE-ADDING ON THE FARM SECTOR USING

DUAL MODELS: A Simulation Analysis

Most of Canada's grains/oilseeds production and much of the livestock output originates in the prairie provinces of Alberta, Saskatchewan and Manitoba. Much of the grains/oilseeds and pork products is destined for the export market. Domestic demand for agricultural and food products is relatively stable. Thus, apart from influences due to weather and technological factors, variations in farm prices and farm incomes are predominantly determined by situations in the international market. Such situations have caused a renewed interest in the concept of "post-farm-gate value adding" by the federal and provincial governments and by the agriculture industry. Consequently, substantial investment has been made in value-added initiatives in the post-farm-gate sector.

Agricultural economists have expended much effort toward evaluating the economic benefits from cost-reducing research in agriculture. Some economic research has generally been carried out by assessing a multi-stage production system in a partial-equilibrium framework. Studies have focused on the distribution of economic benefits from government policy such as investment in research and development (e.g., Dryburgh and Doyle 1995; Holloway 1991; Huang and Sexton 1996; Mullen et al. 1989; Voon and Edwards 1991). Other studies have examined the benefits from investments in commodity promotion and advertising (e.g., Cranfield et al. 1995; Kinnucan et al. 1996; Wohlgenant 1993).

The literature provides important insights into the effects of different types of exogenous factors on commodity prices and quantities as well as the effects on welfare of particular groups in the food production system. For example, typically the effects of promotion and/or advertising are evaluated under the assumption that promotion and/or advertising shift the retail demand curve. In the case of research, the effects are evaluated under the assumption that research shifts the farm input supply curves. While this multi-stage approach is equally applicable to estimating the effects of value adding investment, no attention as yet has been given to economic research on this particular issue. This component of the project extends the literature on distribution of gains in a multi-stage production system to include gains/losses from investment in value adding in the post-farm-gate sector.

This portion of the study follows and adapts the work of Martin and Alston (1994) who measure the impact of a technological change that shifts the supply curve of farm commodities. This study is concerned with the impact of investment in value added processing that may shift the derived demand curve for farm commodities. Five commodities are examined; wheat, feed barley, canola, slaughter cattle and slaughter hogs. Functional equations representing the supply and demand for the commodities are applied in experiments based on the assumption of increased demand for the commodities. Results from the experiments should provide insights into the effects of investment in value adding on prices, quantities and farmers' welfare.

The following section of the study illustrates a conceptual model capable of assessing the likely impact of value added investments in the processing sector. Following this, sections dealing with the empirical specification of the models, parameterization of the models, solution algorithm for the models, validation of the

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models, and measurement of changes in farmers' welfare are presented. The simulation results are then presented and discussed. Finally some conclusions are drawn from the simulated results.

4.2   Conceptual Model

Figure 4.1 provides a simplified diagram illustrating the impact of value-added investment on western Canadian farmers. It is assumed that value-adding activities would increase quantities of farm commodities demanded for domestic processing. From Figure 4.1, the world market determines the domestic price for commodity **q**. Assuming that government investments in value adding act as a subsidy that applies to purchasers of the commodity, the effective domestic market demand for **q** shifts vertically from **D** to **D'.** The vertical shift is equal to the magnitude of the subsidy as more of q is demanded at each market price. One of the effects of this increase in domestic market demand is to shift the excess supply function inwards, from **ES** to **ES'**. The magnitude of this horizontal shift at each price is the same as the horizontal movement from **D** to **D'**.

The effect of these shifts in domestic market demand and excess supply function on western Canadian farmers depends on the nature of the excess demand function **ED** as perceived by Canada. In panel [A], the excess demand function is downward sloping but almost infinitely elastic, indicating that Canada has a small but positive amount of power on the world market to influence the price of **q**. Thus, with a shift in the domestic market demand for **q** and the resulting contraction in the excess supply, the domestic price of **q** increases from w_0 to w_1. In terms of welfare, the gain by producers from the price increase is the shaded area.

In panel [B], the excess demand function that Canada faces is infinitely elastic (horizontal), indicating that Canada has very minimal or no power to influence the price of **q** in the world market. The price of **q** is exogenous to Canada. The contraction in the supply of **q** on the world market does not translate into any change in the price of **q**. Consequently, there is no welfare gain by producers from the shift of the domestic market demand from **D** to **D'**.

4.3   Empirical Model

The modelling procedure employed in the current study to evaluate the effects of value-added investment lends itself directly to applications of full general equilibrium models but attention focuses on only a few commodity sub-sectors. All of the functional relationships specified previously in Chapters 2 and 3 are combined in a partial equilibrium framework and used to simulate the effects of changes in domestic demand for commodities.

The production functions for the farm commodities were derived from a Generalized Leontief profit function (see Chapter 2). From section 2.1 (Chapter 2), the supply functions are represented as:

$$q_i(w) \;=\; \frac{\alpha_i}{w_i^{0.5}} + \alpha_{ii} + \sum_{j=2}^{5} \alpha_{ij} \frac{w_j^{0.5}}{w_i^{0.5}} \quad i \neq j \quad \& \quad i,j = 1,...,5 \qquad (4.1)$$

where q_i is the quantity of commodity i supplied; and w_i is the price. The subscripts i,j are indexed 1=wheat, 2=canola, 3=slaughter cattle, 4=slaughter hogs and 5= feed barley.

Equation (4.1) differs from equation (2.18) in that the constant term α_{ii}, in (4.1) subsumes the effects of the fixed and quasi-fixed factors.

Similarly, the demand functions for the farm commodities were derived from a Translog profit function (see Chapter 3, section 3.4). The demand functions are represented as:

$$s_i = \frac{w_i q_i^d}{\Pi} = -(b_i + b_{i*} \ln p_k + b_{ii} \ln w_i) \qquad i = 1,...,4 \qquad (4.2)$$

where s_i is the cost of the commodity to total profit; Π is the processor profit; q_i^d is the quantity of the commodity demanded domestically; and p_k is the price of the output k produced from commodity i.

It is assumed that feed barley is used primarily as a livestock feed. Consequently, the demand function for barley ($i=5$) is specified as a linear function of the price of slaughter cattle, slaughter hogs and barley:

$$q_5^d = \sigma_0 + \sum_j \sigma_{ij} w_j \qquad j = 3,...,5 \qquad (4.3)$$

where q_5^d is the quantity of barley demanded and the σ's are parameters.

Regarding output from the processors, the following correspondence is made between commodities and output: Wheat is used to produce wheat flour, canola is used to produce canola oil, and slaughter cattle and slaughter hogs are used to produce meat products[17]. Thus, from the processor profit function, the supply functions for processor output are represented by:

$$s_k = \frac{p_k x_k}{\Pi} = b_k + b_{k*} \ln p_k + b_{ki} \ln w_i \qquad k = 1,...,3 \qquad (4.4)$$

where the subscript k is indexed as 1=wheat flour, 2= canola oil, and 3=meat[18]. Equations (4.2) and (4.4) differ from equation (3.24) and (3.25) in that the intercept terms b_i and b_k subsume other intermediate and marketing inputs such as labour and energy. Other variables are defined as before.

Initially the retail demand was incorporated into the model. The demand for processors' output was represented by the linear version of the almost ideal demand system. The share equations for the products are expressed as:

$$c_k = \alpha_k + \sum_l \alpha_{kl} \ln p_l + \beta_k \ln(\frac{M}{P^*}) \qquad k,l = 1,...,4 \qquad (4.5)$$

where c_k is the share of product k in consumer expenditure $(p_k x_k^d / M)$; x_k^d is the quantity of product k demanded on the domestic market; M is total expenditure; and P^* is Stone's price index. In equation (4.5) the subscripts k and l are indexed 1=wheat flour, 2=canola oil, 3=beef, and 4=pork. The α's and β_k are parameters. The following relationship is used to link the output of meat products and the retail products of beef and pork:

$$x_{meat} \equiv \theta + x_3^{ex} + x_4^{ex} + x_3^{ex} + x_4^{ex} \qquad (4.6)$$

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[17] The meat processing industry output data obtained from Statistics Canada are aggregated and include abattoir operations and meat packing operations.

[18] The equation for meat products includes the price of both slaughter cattle and slaughter hogs.

where x_k^{ex} is the quantity of beef and pork exported; and θ is a parameter that captures other livestock products other than beef and pork (e.g., veal and mutton). Similarly, the price of meat products is linked to the price of beef and pork as follows:

$$p_{meat} \equiv \pi_0 + \sum_{k=3}^{4} \pi_k p_k \qquad (4.7)$$

where the π's are parameters.

To complete the model market closing identities (i.e., market equilibrium conditions) and other price linkages need to be established. The commodity market closing identities are represented as:

$$q_i \equiv q_i^d + q_i^x \qquad i = 1,...,5 \qquad (4.8)$$

where q_i^x is export of commodity i. For feed barley, q_i^x is denoted by a parameter that accounts for stocks. The product market closing identities are represented as:

$$x_k^d \equiv \lambda_0 + \lambda_k x_k^{d*} + x_k^x \qquad k = 1,...,4 \qquad (4.9)$$

where x_k^{d*} is the retail demand for product k; x_k^x is the quantity of product exported; and the λ's are parameters. The parameter λ_0 subsumes stocks of the product k and λ_k is a technical conversion factor. For example, beef and pork are converted from carcass weight to retail weight using λ_k=0.73 and λ_k=0.76 for beef and pork respectively (Veeman and Peng 1997). The market closing identities of equations (4.8) and (4.9) ensure that total supply equals total demand.

For wheat, canola, slaughter cattle and slaughter hogs, export supply functions are specified as functions of own price; that is,

$$q_i^x = \phi_0 + \phi_1 w_i \qquad i = 1,...,4 \qquad (4.10)$$

where the ϕ's are parameters.

Other price linkage equations involve relationships between processor output price (p_k) and farm commodity price (w_i). These are specified as:

$$p_k = \delta_0 + \delta_1 w_i \qquad i,k = 1,...,4 \qquad (4.11)$$

where the δ's are parameters.

The complete model consisted of 34 variables and 36 equations and the solution method followed to solve the model was to treat the model as a collection of linear and non-linear algebraic equations. The system of equations was then solved using GAMS (General Algebraic Modelling System) and the CONOPT solver (Brooke et al. 1996). The process involved the following steps:

1. Solve the system of equations to obtain optimal solutions for the variables (base case).
2. Validate the model by introducing a shock of a 50% increase in grain/oilseed prices and resolve the system of equations to obtain new solutions for prices and quantities.
3. Conduct other shock experiments by increasing domestic demand of each commodity by 20% and resolve the system to obtain new solutions for prices and quantities other than the fixed demand levels.
4. For each solution, calculate the changes in quantity, price and farmers' welfare.

Unfortunately, the solution for the system of equations contained some infeasibilities and required reparametrization. Moreover, the complete model failed one or more validation tests. Therefore, the supply and demand functions for processor

output were eliminated from the system. The resulting model used in the study consisted of 22 variables and 22 equations (see Appendix 4a).

4.4   Model Parameterization

With the model specification as above, the next step is to determine the values of the model parameters that appear in the equations. In the literature, two procedures are used to obtain the parametric values; by stochastic procedure and/or by a deterministic procedure. With the stochastic procedure, the equations of the system are estimated simultaneously by econometric techniques using time series data (e.g., Kinnucan et al. 1996; Wahl et al. 1992; Weerahewa 1996). This procedure has the advantage of allowing statistical tests on the estimated parameters. In addition, the parameters are calculated on the basis of average relationships exhibited between the dependent and independent variables over a period of time. Thus, out of sample projections would be more accurate. In spite of the advantages of the stochastic procedure, a major problem is infeasibility because of problems with degrees of freedom. Moreover, in such multi-stage models where market-clearing conditions are included, the likelihood function of the system of equations is not be well defined since there are restrictions on parameters (Rodriguez and Kunkel 1974).

The alternative deterministic procedure is followed in this study. It involves calibrating the equations to a base period using elasticity estimates from the literature and occasionally by econometric estimation to fix the values of certain parameters (e.g., Adilu 1998; Dryburgh and Doyle 1995; Holloway 1991; Martin and Alston 1994; Wohlgenant 1993). For the present study, elasticity estimates from chapters 2 and 3 are used to calibrate the supply and demand relationships of equations (4.1) to (4.5)[19]. Econometric estimates are used to calibrate the relationships in equations (4.7), (4.10) and (4.11). One implication of calibration is that the model cannot be statistically tested since the parameters are chosen in a deterministic way. In addition, a fundamental assumption in calibration is that the market is in equilibrium in the base period. Hence, the model can be used to perform different comparative static analyses from changes in exogenous variables.

4.5   Model Validation

Model validation is important in empirical analysis particularly, for predictive analysis. Validation refers to exercises that determine whether the model behaviour is sufficiently close to real world behaviour (McCarl and Spreen 1984). Where stochastic procedures are used to parameterize the model, the most commonly used validation statistics are the Correlation coefficient, Root Mean Square Error, and statistics obtained by regressing actual on predicted values. The purpose of examining the statistics is to ascertain how well the simulated values predict the actual data.

Where deterministic procedures are applied to parameterize the model as in this study, models are frequently validated using historical events. Models are constructed and validated or justified in one of several ways:
1. The right procedures are followed where the modelling approach is consistent with industry, previous research and/or theory and that data are specified using reasonable

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[19] Additional elasticity estimates from Quagrainie (2000) were used as required for processor demand..

scientific estimation and accounting procedures (e.g., Cranfield et al. 1995; Martin and Alston 1994).

2. Trial results indicate the model is behaving satisfactorily and does not contradict perceptions of reality (e.g., Kinnucan et al. 1996; Wahl et al. 1992).

3. The data are set up in a manner so that the real world outcome is replicated (e.g., Adilu 1998; Benirschka et al. 1996).

A review of the various model validation procedures reveals that the process of validation is fundamentally subjective (McCarl and Spreen 1984). Modellers choose the validity tests, the criteria for passing those tests, which model outputs to validate, which setting to test in, which data to use, etc. Nonetheless, validation exercises improve model performance and provide insights into the issues being examined. In this study, two procedures of validation by model construction are followed:

1. The modelling approach in this study utilizes functional relationships that are derived from duality approaches in economic theory rather than the ad hoc linear relationships specified in the literature (e.g., Cranfield et al. 1995; Wahl et al. 1992). The modelling approach is also consistent with industry structure and previous research (e.g., Martin and Alston 1994).

2. Trial results from this study indicate the model behaves satisfactorily and does not contradict perceptions of reality. This is accomplished using the behaviour of commodity prices, which are known to move together (Bewley et al. 1987; Burt and Worthington 1988; Coyle 1993; Shumway et al. 1987). A sharp increase in the price of one commodity results in corresponding increases in the price of other commodities.

4.6   Welfare Measures

The economic welfare measure depicted in Figure 4.1 applies to linear demand and supply relations involving a single commodity. The system of equations derived and applied in the present study involves more than one commodity. Thus, changes in the quantity demanded of one commodity result in changes in the price of other commodities. Just et al. (1982, p. 337-343) provide procedures for evaluating welfare associated with multiple price changes. In the farm commodity market, this procedure involves evaluating producer (processor) surplus by integrating with respect to commodity prices above (below) the commodity supply (demand) curve. This approach consists of first differentiating the profit functions with respect to price(s) and then integrating with respect to the same price(s). The profit function must be expressed as the integral over all of the supply functions with respect to prices, with integration undertaken one price at a time (Just et al. 1982, p. 340). This need for integration with respect to all prices makes the calculation of economic surplus difficult to undertake. Consequently, producer welfare is evaluated in this study using changes in producer profit. Producer profit (Π^f) is calculated as:

$$\Pi^f \quad = \quad 2\sum_{i=1}^{5}\alpha_i w_i^{0.5} + \sum_{i=1}^{5}\sum_{j=1}^{5}\alpha_{ij} w_i^{0.5} w_j^{0.5} \qquad i,j = 1,...,5 \qquad (4.12)$$

All variables are defined as previously. The α's identified in equation (4.1) are used to parameterize equation 4.12.

4.7   Results and Discussion

The analysis of the effects of value adding investment follow the nature of the model. The base solution represents the initial market equilibrium conditions. Exogenous shocks to the system affect the initial equilibrium causing imbalances in the market. The variables then adjust to establish a new market equilibrium. From economic theory, it is assumed that changes in the price variables trigger changes in quantity variables and/or vice versa. Thus the model solution illustrates price and quantity responses and cross-commodity substitutions. The changes that occur in the variables contain both direct and indirect effects of the introduced shocks but it is difficult to distinguish between the two effects. However, it may be assumed that the direct effects are relatively larger than the indirect effects. This ensures the stability of the system.

4.7.1   Effects of Increases in Commodity Prices

Table 4.1 reports the effects of a 50% increase in the price of commodities. The values reported in the table are percentage changes from the base solution. The purpose of these experiments is to verify whether prices of commodities move together. This is one means of validating or justifying the performance of the model for predictive policy scenarios. Since commodity prices are known to move together, it is expected that with a shock in one commodity price, other prices will move along in the same direction. For example in 1973, a sudden increase in demand for wheat on the world market resulted in sharp increases in commodity prices, particularly for wheat, and a significant increase in the export of wheat from Canada. Consequently, assessing the effect of a 50% increase in the price of wheat can be used to validate the model used in this study as the model solution is compared to the real world results.

4.7.1.1   Effects of a 50% Increase in Wheat Price

This experiment was conducted by introducing a 50% increase in the price of wheat. The model solution is presented in Table 4.1. All commodity prices increased from the base solution except the price of hogs, which declined by 4.35%. The price of barley increased by 28.65%, the price of canola by 117.73% and the price of slaughter cattle by 3.98% (Table 4.1). The rise in the price of wheat triggered a response in supply with wheat production increasing by 12.55%. Production of barley and canola did not respond to the rise in the prices. Canola production declined by 5.57%. These effects may be attributed to substitution effects in production from increased wheat production.

The increase in grain/oilseed prices resulted in a decline in domestic demand for the commodities. Domestic demand for wheat decreased by 86.1% while canola demand decreased by 77.12%. Regarding exports, there are significant increases in wheat and canola exports. Exports of wheat and canola increased by 40.8% and 438% respectively.

In the livestock sector, with a 50% increase in the price of wheat, the price of hogs decreased by 4.35%. Nonetheless, hog production increased by 179.17% and domestic demand also increased by 145.14%. With a relatively high domestic demand for hogs compared to production, exports of live hogs decreased by 39.02%. Cattle price increased by 3.98%, probably causing the observed decline in domestic demand (13.3%). Production also declined by 8.29%. With a low domestic demand for cattle, exports

increased by 123.53%. In terms of farmers' welfare, total profits increased by 327.77% resulting in making farmers being significantly better off than for the base solution.

4.7.1.2   Effects of a 50% Increase in Barley Price

A second experiment was conducted where the price of barley was increased by 50% to observe the effects on prices and quantities. Results from that scenario are also presented in Table 4.1. All commodity prices increased except the price of hogs, which decreased by 4.53%. The price of wheat, canola, and cattle increased by 45.2%, 100.45% and 3.98% respectively. With a rise in the price of barley, there was a consequent increase in production by 11.3%. The production of wheat remained fairly constant while canola production declined by 5.57%. These effects may also be attributed to substitution in production between the commodities since it is implicit in the functional specifications that land allocation is fixed. The increase in wheat and canola price resulted in a decrease in domestic demand for the commodities. Domestic demand for wheat declined by 86.1% and domestic demand for canola fell by 72.45%. Wheat exports increased by 40.73%, and canola exports by 362%.

Regarding the effects on livestock, the price of hogs declined by 4.53% and yet production increased by 187.5%. Domestic demand for hogs also increase by 152.57% probably resulting in the observed decline in hog exports. In the cattle industry, there was a rise in price but production and domestic demand declined. However cattle exports increased. In terms of welfare, farmers were better off, with total profit increasing by 407.82%.

4.7.1.3   Effects of a 50% Increase in Canola Price

This experiment involved introducing a 50% increase in the price of canola. The model solution is also presented in Tables 5.1. All commodity prices increased from the base solution except the price of hogs. The price of wheat increased by 29.38%, the price of barley by 14.89% and the price of slaughter cattle by 2.18% (Table 4.1). The increase in the price of canola triggered a response in supply with canola production increasing by 30.31%. Production of wheat and barley did not respond significantly to the rise in the prices. These effects may also be attributed to substitution effects in production.

The increase in commodity prices resulted in a decline in domestic demand for the commodities. Domestic demand for wheat decreased by 65.07% while canola demand decreased by 50.05%. Regarding exports, there are significant increases in wheat and canola exports. Exports of wheat and canola increased by 40.57% and 140% respectively.

In the livestock sector, the price of hogs decreased by 4.35% but cattle price increased by a modest . The production of hogs increased by 95.83% and domestic demand also increased by 185.71%. With a relatively high domestic demand for hogs compared to production, exports of live hogs decreased by 21.14%. Domestic demand for cattle declined by 6.82%. Production also declined and with the low domestic demand, cattle exports increased by 67.65%. In terms of farmers' welfare, total profits increased by 180.44% again resulting in farmers being better off than under the base scenario.

In summary, it can be observed that an increase in the price of one of the grains/oilseed commodities caused a significant increase in the price of other

grains/oilseed but not the price of livestock. An increase in the price of a grains/oilseed commodity resulted in an increase in production and either constant or declining production for the others. This effect may be attributed to substitution between commodities in production. An implicit assumption underlying the models is that land is fixed. Hence, there is competition for the land resource in production. Thus, the model solution illustrates price and quantity response and cross-commodity substitutions. Consistent with economic theory, changes in price variables triggered changes in quantity variables.

High prices also caused domestic demand to fall and increased exports, particularly for wheat and canola. Farmers' welfare increased significantly with an increase in the price of grains/oilseed.

4.7.2   Effects of an Increase in Domestic Demand for Commodities

Table 4.2 reports the effects of a 20% increase in domestic demand for grains/oilseed and livestock. The values reported in the table are percentage changes from the base solution. These experiments were conducted to verify the effects of government projections of domestic demand for commodities through increased value adding activities in the processing sector.

4.7.2.1   Effects of a 20% Increase in Domestic Demand for Wheat

With an increase in domestic wheat demand, the prices of wheat and barley declined by 9.04% and 2.81% respectively. There was however an increase in canola price. With the decline in prices, wheat and barley production experienced some decline in production. Canola production declined as well. The decline in barley price did not result in an increase in domestic demand for this grain. The increase in the price of canola caused the domestic demand for this oilseed to fall by 4.19%. Canola exports increased by 60%, which probably explains the increase in canola price. Wheat exports also increased by 10.78%. This volume of export was not enough to result in a rise in wheat price. The changes in wheat and canola exports appear to be more pronounced than the changes in production of the commodities. The effects on barley were minimal. Although the price of barley declined by 2.81%, domestic demand declined and production did not increase. This solution may appear counter-intuitive but considering the fact that barley is used as feed for the livestock industry, we observe that the production of cattle and hogs did not increase (Table 4.2). Therefore, this result may not necessarily be counter-intuitive. Changes in the hog industry were modest and it appears that the cattle industry was not affected by the increase in domestic wheat demand.

In terms of welfare, producer profits declined by 5.77%, which may be attributed to the unrealized increase in farm prices, particularly for the grains. Wheat and barley production is very significant in western Canada. The findings from this scenario underscore the fact that variation in farm prices (particularly in the price of grain and oilseed) and variation in farm incomes are predominantly determined by conditions in international markets.

4.7.2.2   Effects of a 20% Increase in Domestic Demand for Canola

From Table 4.2, a 20% increase in the domestic demand for canola caused a 5.45% increase in the price of canola but also a decline in the price of wheat and barley. With an increase in price, canola production increased by 21.06%. The production of wheat and barley declined which may be attributed to the decline in price and to substitution effects in production with canola. Exports of canola increased by 50%. The decline in wheat price however, caused a 21.69% increase in domestic demand for wheat. In view of the results given in section 4.7.1 above, it is difficult to explain why wheat exports in this scenario increased by 49.61% and yet the price of wheat fell. The effect on barley was not pronounced. Unlike wheat, a significant amount of canola is processed locally. Thus, the finding of an increase in canola price and production with an increase in domestic demand may be in order.

An increase in the domestic demand for canola resulted in an increase in hog price but a decrease in cattle price. Nonetheless, the production of both cattle and hogs decreased by 0.32 and 11.11 respectively. The domestic demand for the two commodities also declined and for exports, hogs exported increased by 3.25% while export of cattle decreased by 5.88%.

4.7.2.3   Effects of a 20% Increase in Domestic Demand for Cattle

Table 4.2 also reports the effects of a 20% increase in domestic demand for slaughter cattle and hogs. With a 20% increase in domestic cattle demand, the price of cattle declined by 1.14% instead of increasing. The price decline appears contrary to expectation, nevertheless there was a 16.9% increase in cattle production, suggesting a positive net effect for the cattle industry. Exports of cattle decreased by 64.71%. The price of hogs fell by 0.18% but hog production increased by 4.86%. However, the decrease in hog price resulted in an increase in the domestic demand for hogs by 42.86%. Exports of hogs decreased by 1.63%.

Changes in the prices and production of the crops were modest but significant in the quantities exported. The price of barley was unchanged yet production and domestic demand decreased. This solution appears counter-intuitive to the increased production of cattle and hog production. It was expected that an increase in the production of cattle and hogs would result in an increase in domestic demand for barley.

In terms of producer welfare, total profits increased by 5.09%. The significant increase in the production of cattle and hogs coupled with the relatively stable livestock prices, may have contributed to the increase in farmers' welfare. This solution may suggest that farmers will be better off with increased investments and capacity-expansions in the domestic cattle slaughtering industry.

4.7.2.4   Effects of a 20% Increase in Domestic Demand for Hogs

Generally, a 20% increase in domestic demand for slaughter hogs resulted in price increases for all five commodities, ranging from 0.09% to 1.13% (Table 4.3). The price increases did not cause much change in commodity supply except in hog production. The production of hogs increased by 2.78%. There was no change in hog exports. With a

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price increase, the domestic demand for wheat, canola and cattle decreased. The quantity of canola and cattle exported increased by 20 and 2.94% respectively. The effects on barley were minimal.

In terms of producer welfare, total profits increased by 4.72%, which may be attributed to the resulting increases in commodity prices. This solution is consistent with the solution from the cattle scenario above, in which farmers may be better off with capacity expansions in the domestic meat processing industry.

In summary, an increase in the domestic demand of commodities resulted in a very small effect on commodity prices. As a result, the increase in farmers' profits is also minimal. Changes in quantity variables did not trigger changes in price variables suggesting that in Canada, commodity prices are exogenously determined by conditions in international market. Consequently, farmers' incomes are also determined predominantly by international market conditions. This suggests that the belief that increasing domestic demand for commodities due to value adding investments would boost commodity prices and farmers' incomes may not be necessarily realized in the short term.

4.8   Summary and Conclusions

This portion of the project attempted to evaluate the impact of value-added investment in the post-farm-gate sector on prices, quantities and welfare of western Canadian farmers. The model used in these analyses consisted of a system of commodity supply and demand relationships, market equilibrium conditions and price linkage relationships. The system of equations was first solved for initial equilibrium conditions. Then shocks were introduced to destabilize the system and the system resolved to obtain new equilibrium conditions.

Research investment in value added processing is assumed to enhance demand for primary commodities through improvement in product quality and production of new and alternative products causing an outward shift in the demand curve for farm commodities. The resulting effects would include price and quantity responses as well as cross-commodity substitution in production. Overall, the various simulation results allude to the expectations that farmers will be better off with increased prices of grains/oilseed. However, the results indicate that increases in commodity prices cannot be realized in the short term from increased domestic demand for commodities. Currently, commodity prices appear to be exogenously determined. Nonetheless, results suggest that, to a smaller extent, increased domestic demand for cattle and hogs may increase farmers' welfare. Value-added investment in the livestock and canola processing industries appears to provide some short-term returns in contrast to value-added investment in the wheat milling industry.

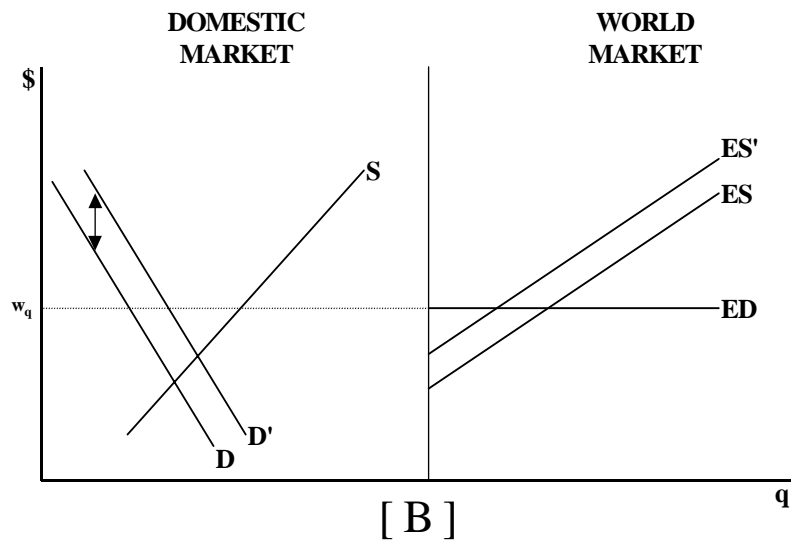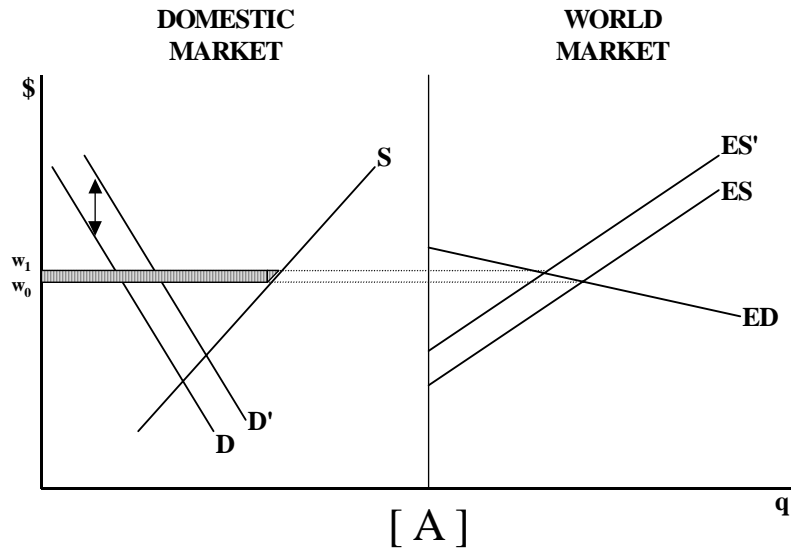**Figure 4.1:   Hypothesised Effects of Value Added Investments**

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Figure 4.1:   Hypothesised Effects of Value Added Investments

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Table 4.1   Effects of 50% Increase in Commodity Price

Percentage change (%) from base solution

Variable	50% increase in wheat price	50% increase in barley price	50% increase in canola price
Wheat production	12.55	1.78	4.06
Barley production	0.54	11.30	0.27
Canola production	-5.57	-5.57	30.31
Cattle production	-8.29	-6.57	-4.09
Hog production	179.17	187.50	95.83
Wheat price	50.54	45.20	29.38
Barley price	28.65	50.69	14.89
Canola price	117.73	100.45	50.00
Cattle price	3.98	3.98	2.18
Hog price	-4.35	-4.53	-2.36
Flour price	29.76	25.46	16.69
Oil price	130.22	111.51	55.40
Meat price	-0.21	-0.31	-0.10
Wheat demand	-86.10	-86.10	-65.07
Barley demand	1.12	2.06	0.57
Canola demand	-77.12	-72.45	-50.05
Cattle demand	-13.30	-11.51	-6.82
Hogs demand	145.14	152.57	185.71
Wheat export	40.80	40.73	40.57
Cattle export	123.53	123.53	67.65
Hogs export	-39.02	-40.65	-21.14
Canola export	438.00	362.00	140.00
Producer profit	327.77	407.82	180.44

Table 4.2   Effects of 20% Increase in Domestic Demand for Commodities

Percentage change (%) from base solution

Variable	20% increase in domestic demand for wheat	20% increase in domestic demand for canola	20% increase in domestic demand for cattle	20% increase in domestic demand for hogs
Wheat production	-4.09	-3.12	0.68	-1.80
Barley production	-0.06	-0.02	-0.19	0.01
Canola production	-3.59	21.06	-1.89	-1.04
Cattle production	0.00	-0.32	16.90	-0.11
Hog production	-0.69	-11.11	4.86	2.78
Wheat price	-9.04	-6.21	2.26	1.13
Barley price	-2.81	-1.40	0.00	0.28
Canola price	2.73	5.45	1.36	0.91
Cattle price	0.00	-0.19	-1.14	0.09
Hog price	0.09	0.36	-0.18	0.18
Flour price	-5.40	-3.71	1.18	0.51
Oil price	2.88	6.12	1.44	0.72
Meat price	0.00	0.00	-0.84	0.00
Wheat demand	19.99	21.69	-6.34	-2.61
Barley demand	-0.12	-0.04	-0.40	0.01
Canola demand	-4.19	20.11	-2.19	-1.24
Cattle demand	0.00	-0.11	20.00	-0.22
Hogs demand	-9.52	-95.24	42.86	19.05
Wheat export	10.78	49.61	49.70	0.01
Cattle export	0.00	-5.88	-64.71	2.94
Hogs export	0.81	3.25	-1.63	0.00
Canola export	60.00	50.00	30.00	20.00
Producer profit	-5.77	-1.42	5.09	4.72

Appendix 4a: Empirical Model

Structure	Equation[*]	Commodity
Farm Supply	$q_i(w) \;=\; \dfrac{\alpha_i}{w_i^{0.5}} + \alpha_{ii} + \sum\limits_{j=2}^{5} \alpha_{ij} \dfrac{w_j^{0.5}}{w_i^{0.5}} \quad i \neq j \quad \& \quad i,j = 1,...,5$	Wheat, Canola, Barley, Cattle and Hogs
Processor Demand	$s_i \;=\; \dfrac{w_i q_i^d}{\Pi} \;=\; -(b_i + b_{i*} \ln p_k + b_{ii} \ln w_i) \qquad i = 1,...,4$	Wheat, Canola, Cattle and Hogs
	$q_5^d \;=\; \sigma_0 + \sum\limits_{j} \sigma_{ij} w_j \qquad j = 3,...,5$	Barley
Processor Output	$s_k \;=\; \dfrac{p_k x_k}{\Pi} \;=\; b_k + b_{k*} \ln p_k + b_{ki} \ln w_i \qquad k = 1,...,3$	Wheat flour, canola oil, and meat
Farm Market Closing Identities	$q_i \;\equiv\; q_i^d \;+\; q_i^x \qquad i = 1,...,5$	Wheat, Canola, Barley, Cattle and Hogs
Export Function	$q_i^x \;=\; \phi_0 \;+\; \phi_1 w_i \qquad i = 1,...,4$	Wheat, Canola, Cattle and Hogs

[*] The subscripts i,j are indexed 1=wheat, 2=canola, 3=slaughter cattle, 4=slaughter hogs and 5= feed barley; and the subscript k is indexed as 1=wheat flour, 2= canola oil, and 3=meat

5. THE IMPACT OF VALUE-ADDING ON THE FARM SECTOR: A

Simulation Analysis Using the Canadian Regional Agricultural Model

It is useful to assess the validity of the results obtained from the partial equilibrium model in the previous chapter. In this chapter, these results are compared to those obtained from modeling value-added scenarios using the Canadian Regional Agricultural Model (CRAM). CRAM is a spatial equilibrium model that has been previously validated for use in policy analysis related to the Canadian agricultural sector. The remainder of this chapter is divided into two parts. First, a brief overview of CRAM, in terms of its structure, is provided. Secondly, the results of alternative value-added scenarios are presented and discussed. The focus of the discussion is on the degree to which these results concur with those determined and discussed in Chapter 4.

5.1   An Overview of the Canadian Regional Agricultural Model[20]

The Canadian Regional Agricultural Model (CRAM) is a regional, multi-sector, comparative static, partial equilibrium mathematical programming model of Canadian agriculture. It simulates the production, consumption and transportation of the major agricultural commodities produced in Canada. The model solves for the quantitative levels of agricultural activities which maximize a modified welfare function - the sum of consumer surplus and producer surplus less processing and transport costs. The model optimizes production of these commodities for a single year subject to a set of linear constraints that reflect agricultural resources and final demands for producers (Klein and Stennes 1993). In CRAM, five disaggregated geographical levels are used to represent agricultural activities in Canada: the national level, eastern and western Canada, the provincial level, crop regions in the Prairies, and export/shipping points. Currently, there are 10 provinces, 29 crop producing regions and two export ports (i.e., Vancouver and Thunder Bay) in the model. The model has approximately 2300 variables and 1300 equations (Horner et al. 1992).

　　　　CRAM was developed in 1985-86 at the University of British Columbia by Webber et al. (1986). Originally programmed in FORTRAN, the model was made more accessible and portable to a wider range of potential users when it was converted to the GAMS system (Brooke et al. 1988) in 1991.

　　　　CRAM has been used extensively to examine policy issues in international trade, domestic agricultural programs and economic benefits of research. For example, MacGregor and Graham (1988) examined the impact of the 1985 US Food Security Act on the Canadian grains sector and Graham et al. (1990) used CRAM to examine the implications of the Canada-US Trade Agreement (CUSTA), and the Multi-lateral Trade Negotiations. Regarding the use of CRAM to examine government programs, Webber et. al (1989) examined the effects of direct government assistance programs on the beef and hog sectors and Klein et al. (1991) examined regional implications of the Western Grain Transportation Act (WGTA). More recently, Klein et al. (1996) employed CRAM to determine the rate of return to yield-increasing research on wheat for the period 1962 to 1991.

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[20] A more detailed discussion of CRAM is provided by Horner et al. (1992).

Three major types of equations can be identified in CRAM: resource constraint equations, commodity balance equations, and ratio equations. Resource constraint equations specify opening and closing livestock numbers for livestock and land availability. Two major sets of production activities are defined in the model – those dealing with crop (or forage production) activities and those dealing with livestock. The crop production section in the model represents Canada's 29 crop regions producing wheat, barley, flax, canola, corn, soybeans, hay, pasture and other crops. Livestock production is modeled at the provincial level for beef, hog, dairy and poultry. Shipments of livestock, livestock products and grains occur to meet provincial demand levels. Opening inventories of livestock herds and poultry flocks are adjusted through incorporation of retention functions responding to own prices and feed grain price effects. Trade in red meats, grains, dairy and poultry products requires that export and import prices be established (Horner et al. 1992).

Commodity balance equations deal with supply utilization for each of the demanded commodities in each region and ensure that demand does not exceed supply. CRAM also has a set of transportation equations to simulate the inter-provincial trade for most of the crops, some live animals (e.g., slaughter cattle, feeders, and hogs) and some processed dairy products (e.g., cheese and butter). The domestic sales balance constraints determine the level of the commodity demanded and the prices for crop, livestock, and dairy products. These prices and quantities are then used to calculate consumer and producer surplus, which are added into the objective function. Some products are specified as eastern or western Canadian sales (e.g., dairy products); others are treated at a national level without regional disaggregation (Horner et al. 1992).

Ratio equations define certain biological relationships in the beef, pork, and dairy sectors. This block also defines some technical ratios, such as the components (e.g., butterfat) required per unit of each dairy product. Ratio equations also allocate national demand for some commodities to the provincial level according to population.

Canadian agricultural production activities are divided into two major groups in CRAM: crop production and livestock production. Products in the crop section include grains, oilseed and forages. The livestock section, includes beef, dairy, hogs, and poultry. Among these commodities, crops and beef are "linked" to the dairy sector and will be discussed in more detail. Each of these groups, has three general categories of activities modelled in CRAM: production, demand, and transportation.

5.1.1   Crop Sector

The cropping part of CRAM is used to further illustrate the structure of the model. Crop production activities can be split into two parts: regional crop production activities and activities that transfer the crops produced to the provincial level where they can be used for livestock feed, domestic consumption, or shipped to a export port.

Positive Mathematical Programming (PMP) is used in the cropping section of the model to calibrate a regional crop's specific supply function against a set of base data on prices, costs, yield, and area.[21] CRAM specifies crop production as Positive Mathematical Programming (PMP) activities that allow crop area to be a function of the

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[21] Positive Mathematical Programming is a method by which empirical observations are used in mathematical programming models to improve model calibration. Further discussion of this methodology is provided by Howitt (1995).

observed area, the marginal value of production and the marginal cost of production. This permits the derivation of non-linear cost functions from the base year data and from the demand supply elasticities. The PMP formulation calibrates the model by equating marginal costs with marginal returns for all crops in each region, at the cropping levels that were observed in the base year. This assumes that producers had chosen the combination of crops to maximize their economic profits in the base year.

In order to model crop production in CRAM, the following elements are necessary:

- Resource limitations to specify resource (e.g., land) requirements and availability.
- Summer-fallow ratio of land for each region to dictate the minimum amount of land that must be summer-fallowed each year.
- Cropping pattern constraints to specify historical cropping ratios within each crop production region.
- Crop production costs for fertilizers and chemicals, machinery repair and fuel, seed, insurance, and utilities.
- Crop yields to define the output of crop production based on different inputs. The yields employed are based on historical average yields. Those crops that are used for feed have production specified at the provincial level.

All regional production of wheat, barley, flax, canola, and corn grain is first transferred to the provincial level. Shipments to other provinces are taken from the provincial supply. To allow the shipment of crops between province, unique transportation costs are associated with each transfer activity.

5.2.   Methodology

In this study, CRAM was used to assess the impacts of value-added activities for western Canadian agricultural. Specifically, two case situations were analyzed:

- The domestic demand for each of the commodities, wheat (high quality), beef (high quality), and pork was increased by 5% and by 10% and
- The domestic demand for all four commodities was increased simultaneously by 5% and by 10%.

A baseline solution was obtained by solving CRAM, using the base year information , in this case 1991. Each of the value-added scenarios above is then modelled assuming that value-added initiatives will create additional domestic demand for commodities. The policy-run results are compared to the baseline results to assess any changes.

5.3.   Results and Discussion

The results obtained were generally consistent with those from the dual model used in Chapter 4 and the discussion on the CRAM model results is limited to a brief analysis. . An increase in the domestic demand for individual commodities did not result in any appreciable change in the relevant variables. Therefore, this scenario is not discussed.

Table 5.1 presents a summary of the results from the second set of policy runs, in which the domestic demand for high quality wheat, high quality beef and pork were simultaneously increased first by 5% and then by10% . the results from these scenarios

suggested that in each case, producer and consumer welfare declined, but by less that 1%. Within the revised solutions, increases in domestic demand were all accounted for from export demand by the rest of the world. This may have resulted in the decline in welfare. Specifically, with a 10% increase in production, a 1.79% decline in world demand for high quality wheat, 14.46% decline in world demand for heifers and steers, a 3.1% increase in world demand for low quality dressed beef, and a 3.77% decline in export demand for pork were all observed.

There was no significant change in production levels for any of the commodities resulting from the value-added scenarios. Any changes in production were less than 1% from the base results. For beef, however, an increase in domestic demand resulted in an increased in beef slaughter in Alberta. In the case of a 5% increase in domestic demand, there was a 2% increase in Alberta beef slaughter; specifically, a 2.4% increase in the slaughter of heifers and steers. With a 10% increase in domestic demand, there was a 4% increase in Alberta beef slaughter. Other minor changes that are observed particularly with a 10% increase in domestic demand are changes in production and input use (fertilizer, chemicals and fuel).

Table 5.1:   Estimated Economic Surpluses at 1991 prices (CRAM Policy Runs).

	Producer and Consumer Surpluses
Policy Run	**Percentage Change from Base Line**
5% increase in domestic demand of all commodities	-0.007
10% increase in domestic demand of all commodities	-0.031

6.   GENERAL DISCUSSION AND CONCLUSIONS

6.1   Introduction

The objective of this study is to assess the impacts of post-farm-gate value added activities on western Canadian agriculture. Value adding activities in the form of research and development projects in the post-farm-gate sector are assumed to result in increased demand for primary commodities produced in western Canada. The hope is that value-adding activities will contribute to economic development, sustained prosperity, and adaptation in the changing agricultural environment. Thus, the study provides an assessment of the effects of value adding on the production and price of primary commodities in the Canadian prairie region and on the welfare of farmers in the region. Primary commodities that are considered in the project include wheat, barley, canola, slaughter cattle and slaughter hogs.

The procedure adapted to achieve the objectives of the project was first, to establish the type of relationships among the commodities considered in the study. Second, the nature of the market for these primary commodities was assessed and finally, experiments were conducted to provide insights into the effects of the assumed increased demand for commodities resulting from post-farm-gate value adding activities. The effects assessed are changes in prices, quantities and producer welfare in the form of profits.

6.2   Results

The results indicate significant economic interrelationships among wheat, barley, canola, slaughter cattle and slaughter hogs at the farm level. The supply for each of the commodities is positively related to its own price. Wheat production and barley production appear as complements but canola production appears to be a substitute to wheat production. The results also indicate jointness in the production of grains and oilseeds. Hog production is positively related to the prices of wheat, barley and canola. Cattle production is positively related to the price of barley. The results indicate non-jointness in the production of cattle and hogs and jointness in the production of hogs and barley. Policies encouraging increases in the beef industry and the hog industry simultaneously can be successful since historically, production in the beef industry is not strongly related to the pork industry. However, expanding the livestock industry will impact on the barley production sector.

The results from the assessment of the market for farm commodities indicate that the demand curves for slaughter cattle, wheat, feed barley, canola and labour are downward sloping. Labour and the five farm commodities are found to be complements in the food production process. On the issue of the existence of market power held by processors, there is no evidence of non-competitive behaviour in any of the commodity markets examined. The absence of non-competitive behaviour may be attributed to factors such as the structure of the commodity markets, increased competition from world trade, technical change, and cost economies of food processing operations.

Results from the simulation exercises corroborate the earlier finding that production of commodities is positively related to the price, and that substitution and complementary relationships exist among the commodities. The results indicate that an

increase in the price of one commodity results in an increase in the production of the commodity and a fairly constant or decline in the production of others. An implicit assumption underlying the simulation model is that land is fixed. Hence, there is competition for the land resource in production. Thus, the model solution illustrates price and quantity response and cross-commodity substitutions. Increased commodity prices cause domestic demand to fall and exports to increase, particularly for wheat and canola. Farmers' welfare increases significantly with an increase in the price of grains/oilseed.

Experiments conducted by increasing the quantity of commodities demanded in domestic markets result in a very small effect on commodity prices. As a result, the increase in farmers' profits is also minimal. Changes in quantity variables do not trigger changes in price variables suggesting that in Canada, commodity prices are exogenously determined and predominantly by conditions in international markets. Consequently, farmers' incomes are also determined predominantly by international market conditions. The belief that increasing domestic demand for commodities (through increased value adding) would boost commodity prices and farmers' incomes may not be realized in the short term. Thus, there are no immediate benefits to farmers from the funding that governments have spent on value added investments. Any anticipated benefits to farmers would require significant marketing strategies, policy shifts in the agricultural sector and/or structural changes in the agricultural industry.

Increasing the quantity of major primary agricultural commodities processed in Alberta, will have minimal impact at the farm gate. Local prices for commodities will remain relatively unchanged from world prices. Farm incomes, assuming that farm size remains unchanged, will also remain relatively unchanged with increased processing of commodities in Alberta or Canada. Major shifts in the mix of commodities produced may occur depending upon the source of demand. Land area devoted to crops and livestock is a constraint. The final product mix under different scenarios was mixed. Initial increases in demand for one product such as wheat could lead to an overall reduction in wheat production due to complex interactions with other commodities.

6.3   Recommendations

It is clear from the results that the volume of Canadian agricultural commodities traded on the world market is too small to permit Canada to influence world price[22]. On an individual commodity basis however, Canada may be able to influence the price that farmers receive. As illustrated in Figure 4.1, shifts in the domestic demand of a commodity can result in a price increase provided the excess demand function that Canada faces on the world market is downward sloping. Figure 4.1 and the results from the simulation exercises indicate increased commodity prices do result in improved farmer welfare. Therefore, there is the need for strategies directed at specific markets to enhance a rise in price. In foreign markets, strategies could be directed at increasing market share. Canada's average market shares in the world market for wheat and barley from 1988 to 1997 are approximately 18% and 19%, respectively (Canadian Wheat Board 1999; Food and Agriculture Organization 1999; International Grains Council

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[22] Over the period from 1992 to 1997 total Canadian agricultural products exports made up, on average, 3% of total world agricultural products exports (Food and Agriculture Organization –FAO 1999).

1999). Canada's share of the world market for canola is approximately 48%. However, this would not lead to a larger economic sector devoted to further processing.

Canada's potential to influence prices on the world market depends critically on the world demand for commodities, which is erratic. Consequently, domestic value-added processing has been seen as an opportunity for guaranteed markets that would facilitate high prices of commodities. Adding value to enhance the price of commodities will be effective when an appreciable proportion of domestic production is processed domestically and a smaller proportion of the commodity is exported. The current development of new value-added processing opportunities in the prairie region (e.g., canola crushing plants and livestock slaughter facilities) will provide some economic activity in the prairies. However, these activities will not enhance the price of commodities at the farm gate, which will continue to be set by the world price, less transportation cost. The loss of direct support from the government means that farmers will continue to face the full impact of downturns in agricultural commodity prices. Increasing the value of processing and related activities to $20 billion will have minimal direct impact on the welfare of primary agriculture producers who are engaged in producing the typical commodities such as wheat or beef.

If primary agricultural producers are to benefit directly from increased processing in Alberta and Canada, then these producers will have to participate directly in value-adding industries. Primary producers will have to invest directly in processing plants either through direct ownership or through cooperatives. Alternative structures may be alliances between various players in the sectors or primary agricultural producers may have to move into niche markets where current demand exceeds the supply. However, typically, niche markets, unless consumer demand is growing rapidly, are often rapidly saturated and any "excess profits" at the farm gate will soon be removed.

Although farmer involvement in processing can take many forms, the formation of new structures of co-operation and vertical co-ordination in the food chain must be given special attention. New management structures are required to meet the challenges of the new agricultural economy. The "New Generation Co-operatives" (NGCs) initiated in the US in North Dakota and Minnesota provide a potential model to follow. New Generation Co-operatives integrate farmers into domestic processing activities, with focus on vertical integration between these levels. Such arrangements provide farmers with a set price for their primary commodities as well as earnings from the processing and value adding activities. Thus, NGCs may have the potential with respect to first, their inherent ability to compete in value-added products market and second, providing ways of generating and sustaining producers' revenues from the marketplace.

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