REMOVING THE CWB AS A SINGLE DESK GRAIN MARKETER: ASSESSING THE INITIAL EFFECTS ON THE CANADA–US FEED BARLEY MARKET

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In the Department of
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ABSTRACT

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Removing the CWB as a Single Desk Grain Marketer: Assessing the Initial Effects on the Canada–US Feed Barley Market
Thesis Supervisor: Dr. James F. Nolan

Key Words: barley, Canadian Wheat Board, market integration, spatial price transmission, cointegration.

This thesis examines some of the economic effects associated with the elimination of single desk marketing on Canadian feed barley exports. It focuses on the interactions between Canadian and US spot feed barley markets in transition after this policy change in Canada.

A brief introduction about world and regional barley markets is provided. The role of the CWB single desk and its role in Canadian barley marketing are discussed to motivate analysis about the effects of its absence.

This study postulates there should be no significant change in Canada–US regional feed barley markets, based on conclusions from previous studies. This postulate is broken down into three testable hypotheses under the framework of spatial price analysis. With respect to the Canada–US regional feed barley market as single desk marketing was eliminated in Canada;

(1) There should not be a significant structural break in the feed barley prices;

(2) There should not be a significant change in market integration;

(3) There should not be a significant change in the direction of price transmission.

To test these hypotheses, the study employs econometric tests on Canadian and US prices spot prices for substitutable feed barley. The hypotheses are tested using a structural break test, a cointegration test, a Granger causality test, and associated impulse response functions. Since structural break tests do not find significant breakpoints in the data, the first hypothesis cannot be rejected. Next, the sample is split into two subsamples at the date when single desk was eliminated. An Engle-Granger procedure and the Johansen procedure are used to test cointegrating relationships between the variables. The results do not allow us to reject the second hypothesis of no significant change in market integration. In contrast, the third hypothesis is rejected, as a significant change is uncovered using the Granger causality test. Simulated impulse responses are also consistent with this finding.

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LIST OF ABBREVIATION

ADF	Augumented Dickey Fuller (test)
AIC	Akaike information criterion
ARIMA	Autoregressive Integrated Moving Average
CANSIM	Canadian Socioeconomic Database from Statistics Canada
CAP	Common Agricultural Policy
CBM	Continental Barley Market
CUFTA	Canada-US Free Trade Agreement
CWB	Candadian Wheat Board
CWB I	Canadian Wheat Board before August 1, 2012
CWB II	Canadian Wheat Board after August 1, 2012
cwt	Centum weight
DF	Dickey Fuller (test)
EEP	Export Enhancement Program
ERS	Economic Research Service of United States Department of Agriculture
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAS	Foreign Agricultural Service of United States Department of Agriculture
HQC	Hannan-Quinn criterion
ICE	IntercontinentalExchange
KPSS	Kwiatkowski-Phillips-Schmidt-Shin (test)
LIFFE	London International Financial Futures and Options Exchange
LM	Lagrange Multiplier
LOP	Law of one price
MCA	Monetary Compensatory Amounts
MT	Metric Ton
NAFTA	North American Free Trade Agreement
NASS	US National Agricultural Statistics Services
OLS	Ordinary Linear Square
PPP	Purchasing Power Parity
SC	Schwarz criterion
STE	State Trading Enterprise
TRQ	Tariff Rate Quota
URAA	Uruguay Round Agreement on Agriculture
US	United States
USDA	United States Department of Agriculture
VAR	Vector Autoregressive
VECM	Vector Error Correction Model

CHAPTER ONE

INTRODUCTION

1.1 Problem Statement

Bill C–18, the Marketing Freedom for Grain Farmers Act[1], announced an end to single desk control by the Canadian Wheat Board (CWB) over Western Canadian feed barley exports. Producers could opt to still deliver to the CWB pool or to any commercial grain handler, but the single desk status of the CWB was terminated. Starting with the 2012/13 crop year, Western Canadian feed barley exports are no longer controlled through the CWB, and the marketing channel is expected to be characterized with multiple sellers instead of a single seller.

This structural change in the Canadian barley marketing chain is intended to give producers more alternatives for selling their products. The domestic livestock sector is not the only major area where feed sales can enter a marketing channel with multiple sellers. Growth of US biofuel production combined with drought in its major corn production zones in 2012 has resulted in high feed grain prices and tightening stocks. For the time being, an integrated North American feed grain market with US livestock producers purchasing feed barley from Canada is likely to emerge.

Previous studies have forecast that multiple–seller marketing for Western Canadian barley would lead to a shift in the western barley price. In a series of studies, researchers (Gray et al. 1993; Schmitz and Furtan 2000; Schmitz et al. 2005) described the price premium of western malting barley as well as the CWB's practice of price discrimination. These authors postulated that a multiple–seller market would lead to a significant decrease in Western Canadian malting barley price, coupled with a slight decrease in the domestic feed barley price in Canada. Schmitz and Gray (2000) also found that the flow of Western Canadian feed barley to the US was likely to increase in a multiple–seller market.

Since single desk selling for feed barley export has now been eliminated from the Western Canadian region, there is a need to test these predictions on pricing behavior *ex post*, using current market data. Given what Schmitz and Gray (2000) predicted, this thesis posits that

[1] *An Act to Reorganize the Canadian Wheat Board and to Make Consequential and Related Amendments to Certain Acts*, ascent on December 15, 2011.

the market prices of Western Canadian feed barley should not significantly change between the previous and the current marketing structure. In effect, there are three basic questions that this study will address;

(1) Is structural change in the Canadian barley sector associated with a significant change in Western Canadian feed barley prices relative to US feed barley prices?

(2) Is the Canadian feed barley market becoming more interactive or tied to the US feed barley market after single desk was removed?

(3) Has the importance of Canada in the Canada–US regional feed barley market been reduced since single desk was removed?

By addressing these questions, this thesis will provide insight into the workings of the Western regional feed barley market during the transitional period. Ultimately, the primary contribution of this thesis is that it analyzes a topical agricultural issue about market changes, using up–to–date data for evaluation.

Owing to the fundamental change in the CWB's role in Canadian grain and barley marketing, for the rest of the thesis "CWB I" is defined as the CWB and its actions before August 1, 2012, while "CWB II" is defined as the CWB and its actions after August 1, 2012.

1.2 Objectives and Hypothesis

The objective of the thesis is to examine economic effects associated with the removal of CWB single desk marketing on price movements in the Western Canadian feed barley sector. Using an appropriate US market price as a comparison, this thesis focuses on testing for changes in price integration and transmission within this Canada–US regional feed barley market as it passes through transition.

Based on previous work, this thesis also presumes that CWB I was not able to significantly influence the domestic feed barley market. Subsequently, I postulate that the removal of single desk powers should not lead to measurable structural change in this regional Canada–US feed barley market, and also that such a change should not manifest though a shift in relative price movements or a significant change in the direction of price transmission. Conversely, under the alternative, as the price discipline of a single desk exporter is removed across this regional market, it could be that a higher degree of market integration and a significant change in price transmission direction occured.

1.3 Structure of the Study

Chapter 2 provides a discussion of the regional Canada–US barley market for general use. It covers the trade of barley in both global and relevant regional markets and also describes the Western Canadian barley sector. Since the status of Canada in the world barley market changed and was strongly influenced in the past by the single desk marketing function, this chapter also discusses the role of single desk in the western barley sector prior to its removal. Furthermore, for a better understanding of the western barley sector across the transitional period, relevant literature that has evaluated the performance of CWB I is also reviewed. Owing to the linkages between malt barley and feed barley, the market power of the CWB I might have indirectly influenced domestic feed barley prices prior to the removal of single desk. This effect needs to be discussed to help establish the research questions that this thesis will address.

Chapter 3 develops a theoretical framework in order to establish testable hypotheses about this policy change. I use the concepts of market integration and spatial price transmission to frame the potential effects associated with the removal of CWB single desk powers in this market. Relevant literature about these concepts is reviewed in order to help identify a methodology to conduct the analysis. In particular, these concepts as applied to grain, other agricultural commodities, as well as non–agricultural commodities are highlighted in the literature review of Chapter 3.

Chapter 4 describes the data and motivates the choice of empirical model to test hypotheses about integration and price transmission in this market. Since the data are a time series of prices, certain key properties including stability, stationarity, and the structure of cointegration need to be examined before proceeding with the analysis. For example, the results from my stability tests are in fact consistent with both Schmitz and Gray's (2000) and Clark's (1995) predictions that there should not be significant changes in the price levels of western feed barley with the establishment of a multiple–seller market.

Owing to the non–stationary characteristics of the data subsamples, a vector autoregressive (VAR) model is estimated to analyze movements and co-movements among variables in the data. Chapter 4 motivates this methodology showing VAR–based econometric tests, including the Johansen procedure and Granger causality testing. Subsequently, based on the VAR estimates impulse response functions simulate the reactions of barley prices in the markets to an exogenous shock. This process will provide information about the dynamic stability of the estimated price system. The time series results are presented and interpreted in detail in Chapter 5. Finally, Chapter 6 provides a summary and concludes the study, while I also discuss various limitations and provide suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW: BARLEY MARKETS

This chapter provides a brief introduction to barley marketing. To supplement a general understanding of the Western Canadian barley sector and its status in the world market, some up–to–date market statistics are also illustrated in this chapter. Historically, CWB I and the single desk function played an important role in the marketing chain for Western Canadian barley. The literature examining market power as exercised by CWB I is reviewed in this chapter.

2.1 Global Barley Market

2.1.1 Production of Barley

Barley is grown for two purposes. Malting barley is generally used for human consumption while feed barley is used mainly for livestock. The factor that distinguishes barley for malting from barley for feed is its use in the brewing process for beer (Kendall 1993). Malting barley varieties are bred to achieve desirable properties, such as a lower protein level (usually lower than 15%) to produce malt for beer production (Taylor et al. 2012). Malting barley is usually priced at a premium and gives higher added value than feed barley (Kendall 1993). Feed barley varieties seek a comparatively high protein level and high yield, both of which are not suitable for brewing and are generally used as livestock feed (Taylor et al. 2012). Feed barley accounts for the majority of world barley production (Kendall 1993). In turn, if malting varieties have undesirable properties such as thin kernels or other factors, they can be downgraded to feed and sold at a lower price. However, feed barley in general cannot be used for malting unless feed barley quality is marginal enough to produce malt.

There are so-called two row and six row malting varieties, as well as feed varieties. Two row varieties have one kernel on each node, which shows two rows of kernels. Six row varieties have three kernels on each node, or six rows. This characteristic results in two row varieties having greater plumpness and therefore higher bushel weight, relative to the six row varieties in general (Pearson 2013). For malting use, the two row varieties also yield more malt per bushel for malters than the six row. However, the six row varieties have a higher tolerance for disease and humidity (Buschena et al. 1998).

Barley is planted worldwide, and its production is often concentrated in areas where growing conditions are less suitable for other grains (Kendall 1993). In any case, production is concentrated among just a few countries. As of 2012/13, the European Union (EU–27[2]), Russia, Ukraine, Canada and Australia are the largest barley producers (Figure 2.1) in the world market. Production in Europe, mostly from the EU–27, Russia and Ukraine, accounts for about 60% of the total world production of barley.

The total production of barley across the world, however, has gradually declined in the past two decades, as Figure 2.2 shows. In 2011, aggregated world barley production was approximately 134 million MT, which was 80% of production in 1991. Competition from high yield feed grains is likely the reason for this decline in feed barley production (Taylor et al. 2012). Downward consumption of beer is the main reason for declining production in malting barley (Taylor et al. 2012).

[2] From January 1, 1993, the EU-27 members include Belgium, Greece, Luxembourg, Denmark, Spain, Netherlands, Germany, France, Portugal, Ireland, Italy, United Kingdom, Poland, Czech Republic, Cyprus, Latvia, Lithuania, Slovenia, Estonia, Slovakia, Hungary, Malta, Bulgaria, Romania.

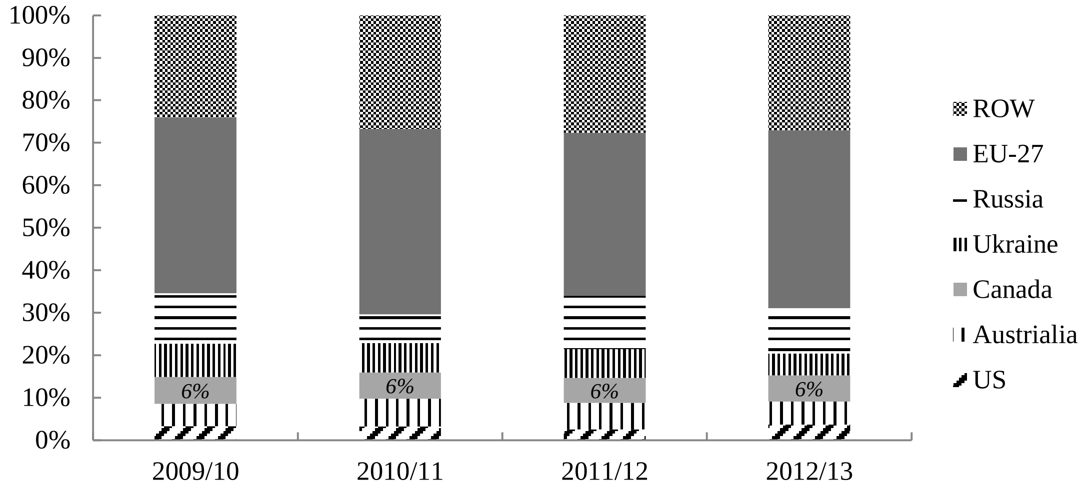

Figure 2.1: Percentage Shares of Major Countries in World Barley Production, 2009/10 – 2012/13

Source: Adapted from Foreign Agricultural Service of USDA (FAS). World Agricultural Production: Table 05 Barley Area, Yield, and Production. http://www.fas.usda.gov/psdonline/psdreport.aspx?hidReportRetrievalName=BVS&hidReportRetrievalID=885&hid hidReportRetrievalTemplat=1.

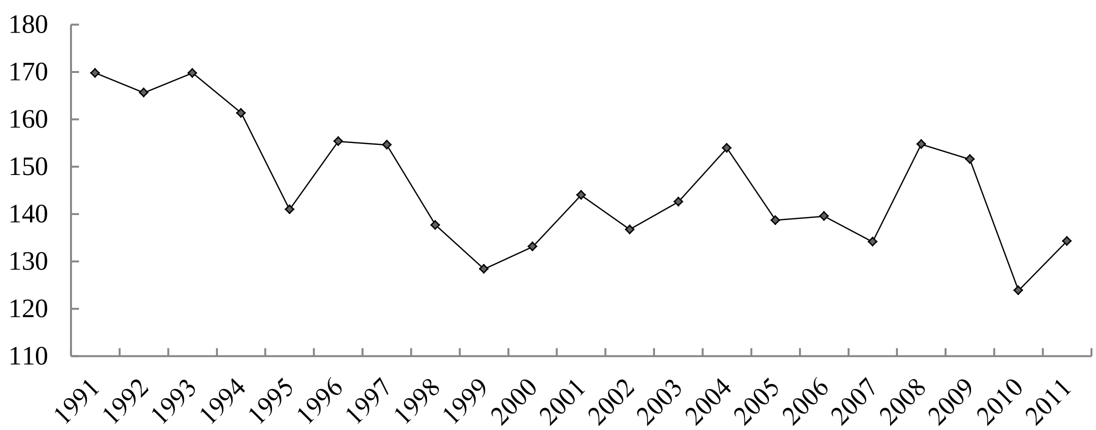

Figure 2.2: World Barley Production, 1991–2011 (million MT)

Source: Adapted from Food and Agriculture Organization of the United Nations (FAO) Statistics. Food and Agricultural Commodities Production. http://faostat.fao.org/site/339/default.aspx.

2.1.2 Barley Trade

Global trading for barley is concentrated within a limited number of players. The few major barley exporters account for over 80% of world barley exports (Figure 2.3), while more than 60% of this barley is imported by just three nations – Saudi Arabia, China and Japan (Figure 2.4).

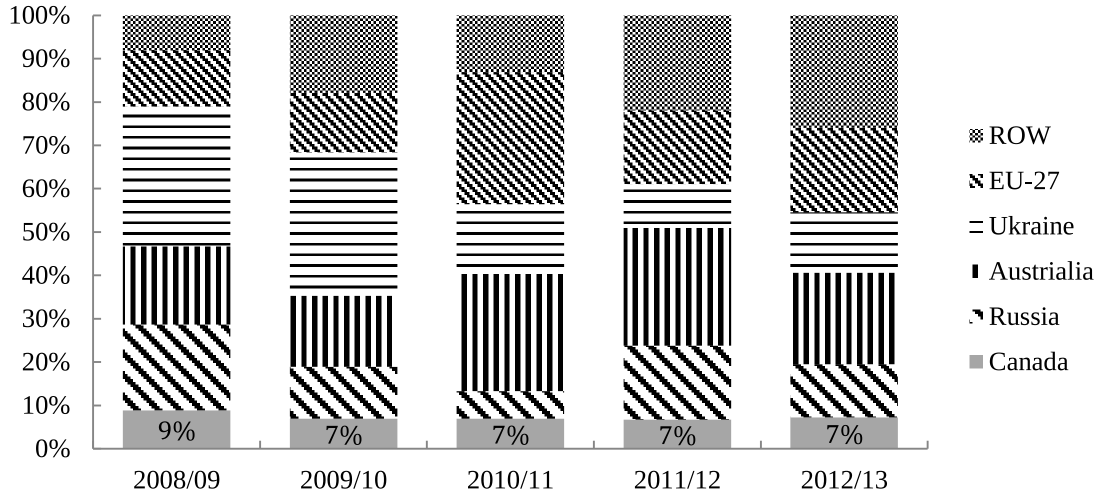

Figure 2.3: Percentage Shares of Major Countries in World Barley Export, 2008/09 – 2012/13

Source: Adapted from FAS. May, 2013. Production, Supply and Distribution Online: World Barley Trade. http://www.fas.usda.gov/psdonline/
Statistics by Trade Year; 2012/13 data updated till January 2013.

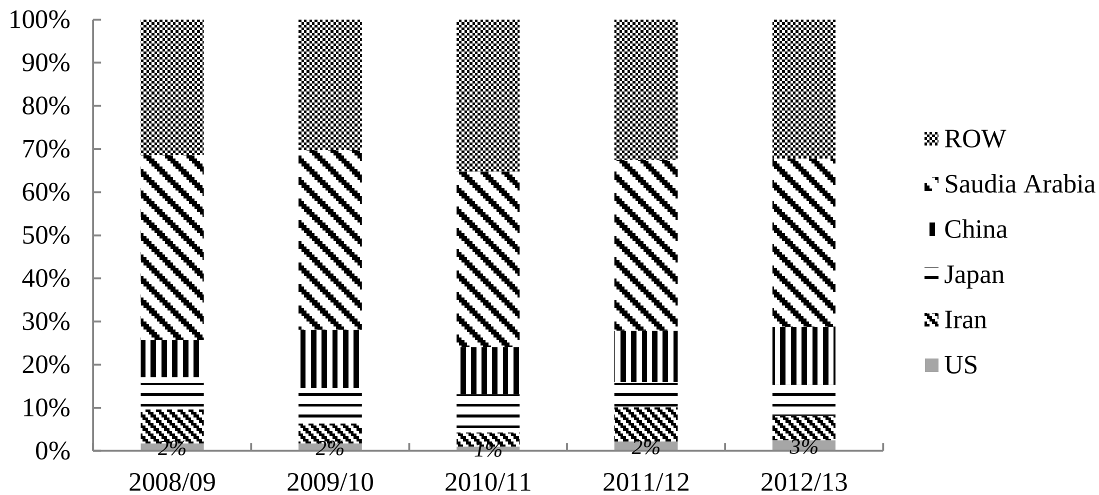

Figure 2.4: Percentage Shares of Major Countries in World Barley Import, 2008/09 – 2012/13

Source: Adapted from FAS. May, 2013. Production, Supply and Distribution Online: World Barley Trade. http://www.fas.usda.gov/psdonline/
Statistics by Trade Year; 2012/13 data updated till January 2013.

The price level of traded barley has been relatively stable over the last two decades, except for the period of the so-called food crisis, centered around 2008. The US biofuel initiatives also contributed to high food prices, which helped lead to the food crisis. As Figure

2.5 shows, the per unit price of world barley exports peaked at USD$358.85/MT in 2008, which was over three times greater than the lowest price (USD$111.61/MT) in 1999. Although the price level fell again after 2008, prices for most grains including barley remained at a higher level than before.

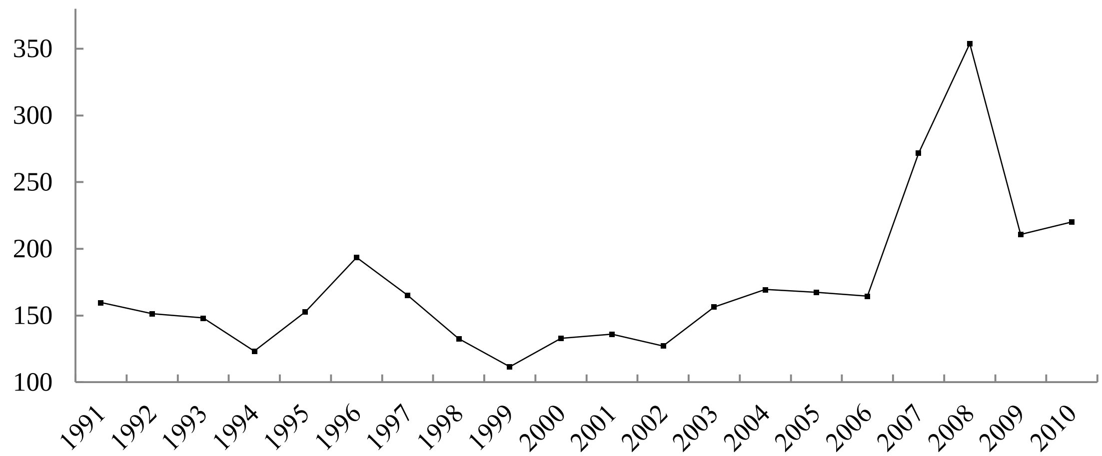

Figure 2.5: Price Level of World Barley Export, 1991 – 2010 (USD$/MT)

Source: Adapted from FAO Statistics. Trade. Calculated by dividing total export value by total export volume. http://faostat.fao.org/site/342/default.aspx.

2.2 US Barley Market

The US is an influential player in the barley trade with Canada owing to its regional proximity and linkage with the Canadian market. The US is neither a major barley producer nor seller, but its consistent demand for malting barley and the potential increase in feed demand cannot be neglected when considering the behavior of the barley market in Canada.

2.2.1 US Barley Production

Barley ranks third behind corn and sorghum in feed grain produced in the US, but production has been declining over time (Taylor et al. 2012). As Figure 2.6 shows, barley production in the US has decreased in the most recent two decades. Production increased slightly around 2008, but has been mostly declining in the time interval shown here. Note that total production quantity in 2011 was approximately one–third of the production in 1991.

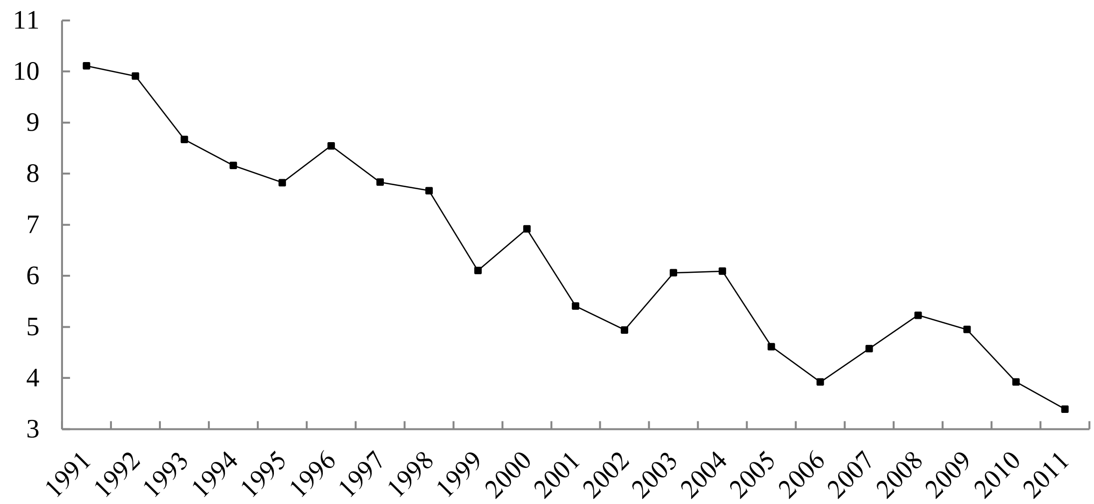

Figure 2.6: US Barley Production Quantities, 1991–2011, million MT

Source: Adapted from FAO Statistics. Food and Agricultural Commodities Production. http://faostat.fao.org/site/339/default.aspx.

This decline in barley production has been due mostly to the adoption of shorter–season corn varieties as substitutes for feed barley. In recent years, the decline in barley production is attributable to the US biofuel program, along with the wide use of distiller feed grains coupled with drought in the main feed grain production areas in recent years (Taylor et al. 2012).

US barley production is concentrated in the Great Plains, mostly adjacent to the US–Canada border. Production in the states of North Dakota, Idaho, and Montana accounted for over 60% of total US production in 2011. Most of the region, including the Dakotas, Minnesota and part of Idaho, has adopted six–row barley varieties because the two–rowed varieties are not suitable for the climate and soil conditions in this region. The rest of the region, including parts of Idaho, along with Montana, Colorado, Wyoming, Washington, Oregon and California, produced mainly the two–row varieties (Taylor et al. 2012; Buschena et al. 1998).

Most barley production in the US is for human consumption while the remainder is for animal feed. Demand for malting barley has stayed at a consistent level in the domestic market, but domestic demand for feed barley has been continuously declining. As Figure 2.7 shows, from the 1991/92 to 2011/12 marketing year, domestic production of barley in the US consistently declined, characterized by falling consumption of feed barley but relatively consistent consumption of barley for non–feed use.

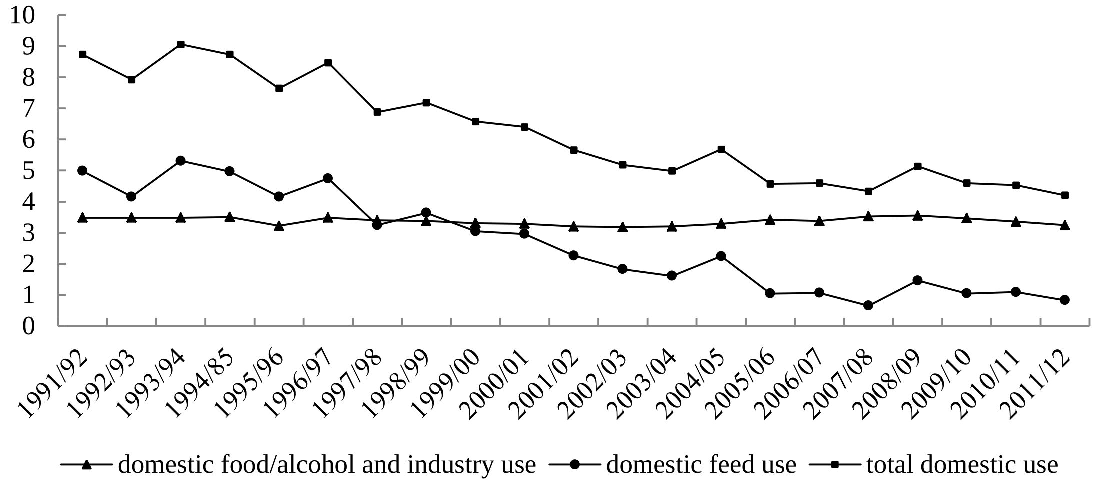

Figure 2.7: US Barley Consumption, 1991/92– 2011/12, million MT

Source: Economic Research Service (ERS) of USDA. April 2013. Feed Grain Database. http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-custom-query.aspx#.UbPiCtg3inI.

2.2.2 US Trade of Barley

As mentioned, the US is a minor player in world barley trade. On average, from 2005/06 to 2011/12, it has annually exported 0.39 million MT and imported 0.37 million MT of barley. As Figure 2.8 shows, exports have declined from 2007/08. By way of a breakdown, in 2011 the US exported around 0.73 million MT of malting barley to Canada and Mexico, and approximately 0.93 million MT of feed barley to Tunisia, Morocco and Japan. Note that Japan is historically the dominant buyer of US feed barley.

Figure 2.8: US Barley Export Quantities, 2005/06 – 2011/12, million MT

Source: Economic Research Service (ERS) of USDA. April 2013. Feed Grain Database. http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-custom-query.aspx#.UbPiCtg3inI.

Imports of barley to the US have also declined in recent years. Figure 2.9 shows that the imported quantity from 2005/06 to 2011/12 peaked in 2007/08 and 2008/09 (around the 2008 food crisis) and decreased up to the 2010/11 crop year. However, current US barley imports have begun to increase again in 2011/12. In addition, most of the US imports come from Canada.

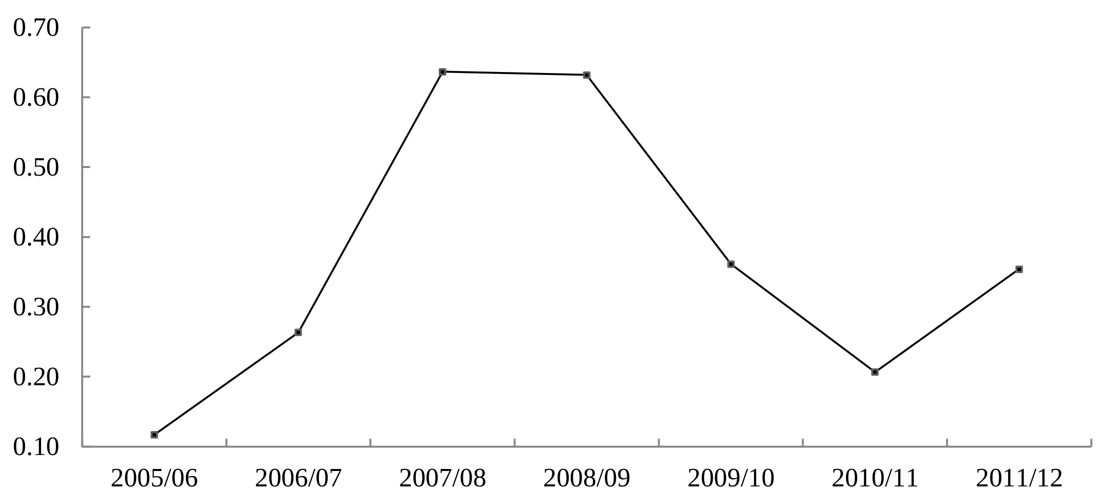

Figure 2.9: US Barley Import Quantities, 2005/06 – 2011/12, million MT

Source: Economic Research Service (ERS) of USDA. April 2013. Feed Grain Database. http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-custom-query.aspx#.UbPiCtg3inI.

2.2.3 US Trade Barriers in the Regional Barley Market

Although the US is not an influential barley exporter in terms of market share, a range of support programs for barley production and exports have affected the trade of barley in the broader North American regional barley market, especially regarding trade with Canada. For instance, from 1995 to 2011, subsidies to barley production and exports in the US totaled USD$2.7 million (Environmental Working Group 2013). The main support programs include product flexibility contracts, direct payments, market loss assistance, loan deficiency, and crop insurance premium subsidies (Environmental Working Group 2013).

Under the Canada-US Free Trade (CUFTA) and North American Free Trade Agreements (NAFTA), the US eliminated import tariffs on barley that originated from Canada. However, the US export of barley to Canada was historically subject to quantitative restrictions, import license requirements, and tariff rate quota (TRQ), owing to the higher level of support in the US than was available in Canada (Economic Research Service 2000). On August 1, 1995, Canada converted the import license requirements on imports of US barley into the TRQ, in accordance with its obligations in the Uruguay Round Agreement on Agriculture (URAA). As the calculated Canadian supports were no longer below the calculated US supports, Canada suspended the TRQ on the imports of US barley in order to facilitate two-way trade between the two countries (Economic Research Service 2000).

2.3 Canadian Barley Market

Canada is one of the most important barley producers and exporters in the world. Most of the barley produced in Canada is from the Prairies and marketed as Western Canadian barley or western barley. The marketing chain of western malting barley and the export channel of western feed barley was governed by CWB I through single desk marketing. With the removal of this ability, the marketing channel for western barley is currently in a transitional period from the former single-seller market to the new multiple-seller market.

2.3.1 Canadian Barley Production

Over 90% of Canadian barley is produced in the Prairie Provinces. According to Statistics Canada, Alberta accounted for the largest portion at 43%, while Saskatchewan accounted for 34% over the most recent two decades. The rest was produced in Manitoba. From

1991 to 2012, the quantity of barley produced totaled 10.3 million MT on average across the three Prairie Provinces. However, this total has been dropping over the last two decades. As Figure 2.10 shows, although the quantity of barley produced on the prairies fluctuates over time, in general it declined after the 2008 food crisis. Over 1991 to 2011, production on the prairies peaked at 14.5 million MT (1996), but bottomed out in 2002 with a quantity of just 6.25 million MT. By comparison, barley production for 2012 was approximately 7.43 million MT.

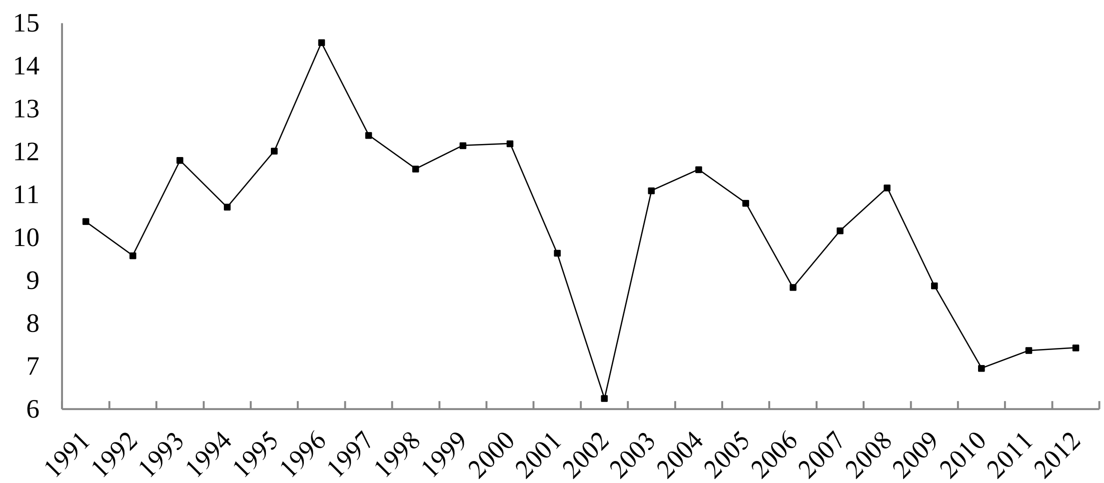

Figure 2.10: Barley Production Quantities, the Prairies, 1991–2011 (million MT)

Source: Adapted from Canadian Socioeconomic Database from Statistics Canada (CANSIM), Table 001–0010: Estimated areas, yield, production and average farm price of principal field crops, in metric units. http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0010010&tabMode=dataTable&srchLan=-1&p1=-1&p2=9.

In terms of feed barley, the Lethbridge area in Alberta has the highest concentration of producers and end users in Canada (ICE Futures 2011). As Figure 2.11 indicates, the region from Central/Southern Alberta to US border is the main barley production zone in Canada. This area is also characterized by a high concentration of livestock related industries.

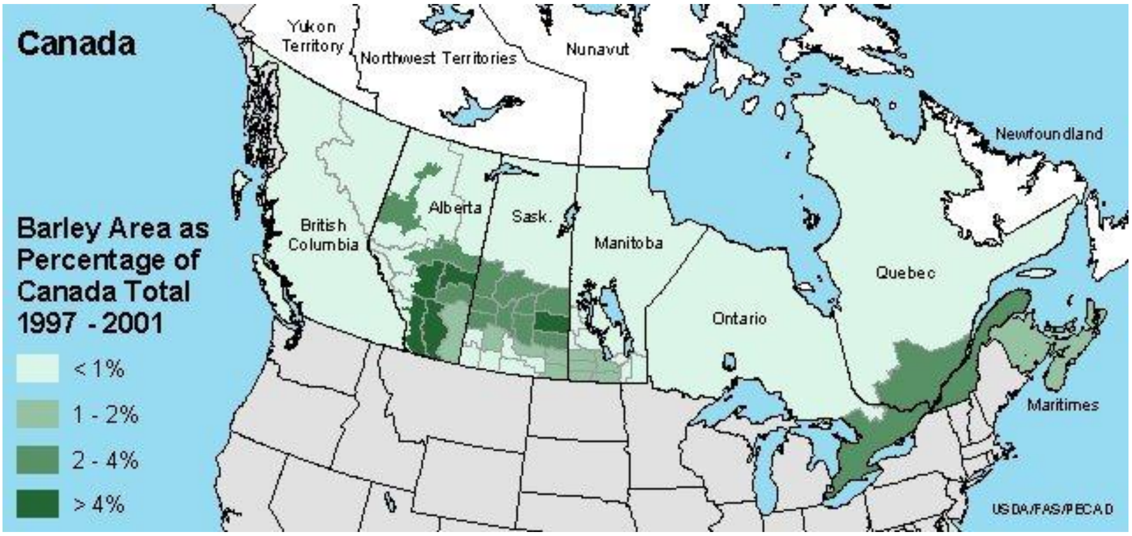

Figure 2.11: Barley Area Distribution in Canada, 1997–2001

Source: Production Estimates and Crop Assessment Division from FAS of USDA; agricultural region outlines from: Agriculture Division, Statistics Canada. Canada Barley Facts: Map of Barley Area Distribution in Canada. http://www.fas.usda.gov/remote/Canada/can_bar.htm.

Canadian barley varieties are mostly the two–row type. Most of the six–row varieties found in Western Canada are planted in Manitoba due to the province's proximity to the Minneapolis market, one of the major grain exchange market in North American, as well as growing conditions in the province (Buschena et al. 1998).

Premiums from malting barley make the malt varieties preferable for producers in Canada. However, it turns out that only a small proportion of producers can typically meet the protein and associated requirements for malting use. This means most barley production ends up being sold for domestic feed use (Canadian Wheat Board 2011). However, there is a portion of barley produced in Western Canada that can be used for both malting and feed. This barley is marginal in quality, and can be sold as low quality malting when buyers reduce their specifications on malting barley. At some margin, feed barley can be substituted for malting. It is worth noting that CWB I also had a direct influence over the selection rate of malting barley (Schmitz and Gray 2000).

2.3.2 Trade of Western Barley

In the global barley market, Canada remains one of the key players in the market among a handful of barley exporters. Recalling Figure 2.3, we see that in the period between the 2008/09 – 2012/13 trade years, Canada ranked fifth among global barley exporters with a market share of 7% on average. In the 2010/11 crop year, under single desk marketing, two–row western malt barley was largely exported to countries in Asia, the Americas and South Africa, while six–row western malt barley was sold to domestic beer brewers, and to the US and Mexico (Canadian Wheat Board 2011).

Comparatively, for global feed barley exports, Canada is not as significant a player as it is in malting. According to CWB data, Canada annually accounts for about 4% of world feed barley export (compared to a 27% average of world malting barley exports from 1997–2001) (Edney and Brophy 2004). Japan and Saudi Arabia were the largest buyers of Western Canadian feed barley in the 2010/11 crop year (Canadian Wheat Board 2011).

2.3.3 The Historical Role of the CWB in Western Barley Marketing

Single desk refers to the singular seller status of CWB I in Canadian wheat, durum and barley for human consumption, as well as feed wheat and barley for export (Schmitz and Furtan 2000). Single desk status was created to provide a mechanism for the capture of rents, on behalf of Western Canadian grain producers, from the sales of their products (Veeman et al.1998). With single desk, CWB I was perceived by many outside Canada to be a State Trading Enterprise (STE) or a producers' export market board (Carter 1993; Veeman et al. 1998; Alston and Gray 2000; Schmitz et al. 2005). The historical role of CWB I in Western Canadian barley marketing is briefly reviewed in this section. The economics of CWB I single desk marketing power will be discussed in Section 2.4.

Before single desk control over grain marketing was eliminated in 2012, Western Canadian barley marketing featured CWB I as the sole malting barley marketer and feed barley exporter. The stated goal of CWB I marketing through single desk was to maximize returns to producers (Canadian Wheat Board 2011).

In fact, a dual market for Western Canadian feed barley was active from 1975/76 through the 2011/12 crop years. Under this dual market, compulsory grain marketing through CWB I was replaced by a system under which producers could deliver feed barley to either the CWB I pooled price market for export, or to a domestic cash market (Schmitz and Furtan 2000). The primary objective of establishing this dual market was to equalize feed grain prices across Canada and to be competitive with US (feed) corn prices in Eastern Canada (Schmitz and Furtan 2000). Producers faced two prices in this dual market: a price based on CWB payments and a cash price from spot markets where there was almost no CWB involvement (Schmitz and Furtan 2000).

However, in Western Canadian malting barley markets, CWB I had been the sole marketer before the 2012/13 crop year. This meant it was compulsory for producers to deliver malting barley to the CWB I pool. The initial and final payments to producers were adjusted during the pooling period on the basis of returns to the pool (Schmitz and Furtan 2000).

CWB I played a significant role in the downstream marketing chain of Western Canadian barley through contracts to coordinate with producers, buyers, processors and the Canadian railways. As Figure 2.12 illustrates, CWB I managed the domestic and international marketing chain for western malting barley and the export channel for western feed barley through a series of collaborations as well as effective coordination.

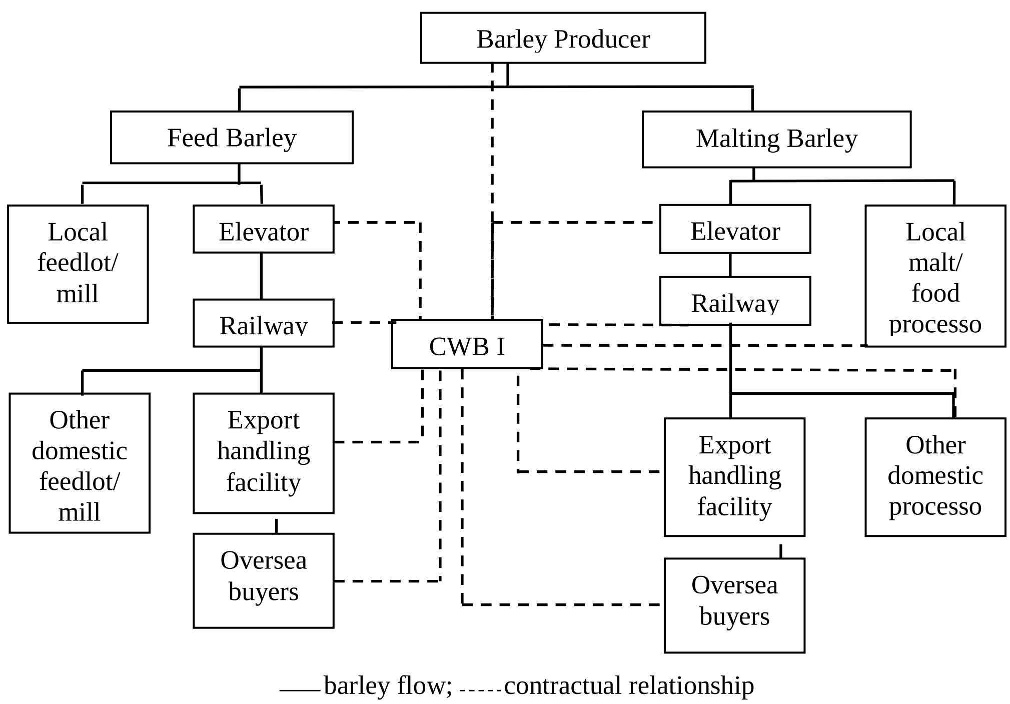

Figure 2.12: Marketing Chain of Western Barley with the CWB I

Source: Adapted from Edney and Brophy. 2004. Barley: Grading and Marketing." In Encyclopedia of Grain Science, by Colin Wrigley, Harold Corke and Charles Walker, 49–57. Oxford: Elsevier Science, 2004.

In effect, CWB I reduced the information costs for buyers and farmers owing to its ability to coordinate market development activities with sales functions and with supply predictions (Young and Hobbs 2000). It maintained connections by providing the two parties with information about each other in direct sales contracts. According to Young and Hobbs (2000), owing to its information base provided by a number of internal departments that contributed to its market intelligence, CWB I could more readily perceive a buyer's opportunistic behavior if the buyer failed to honor a contractual commitment. In long–term agreements, buyers were notified of the quantities and qualities of grain that CWB I would supply during the course of a specified period (Schmitz and Furtan 2000).

Historically, CWB I developed and maintained high quality standards and credibility for domestic and worldwide buyers in western malting barley sales as well as western feed barley exports. In contracts with farmers, CWB I guaranteed an initial payment (which would be announced in July) prior to the next crop year. The initial payment was based on the estimated pool return and was financially backed by the federal government. Throughout the pooling period, the CWB adjusted the payment according to the realized return to pool. Eventually, farmers received a final payment, which was based on the final return to pool, with operational costs deducted at the end of each crop year (Schmitz and Furtan 2000).

However, feed barley for domestic use was not included in the pool of CWB I and therefore was sold as non–CWB barley. As long as the domestic price offered for feed barley was higher than the expected CWB payments, rational producers would sell feed barley in the domestic market. Any price differentials between the CWB pooling price and the domestic market price for Western Canadian feed barley are due to this effect.

The sole barley exporter status of CWB I was challenged with the (brief) establishment of a continental barley market (CBM) in 1993. The creation of the CBM effectively allowed Canadian producers to ship malt barley directly to the US. However, that legislation was withdrawn after 41 days of practice because of resistance from farmer marketing pools in Saskatchewan, Alberta and Manitoba. Since a different government with different priorities won the subsequent 1993 federal election, the CBM issue was set aside at that time (Schmitz and Furtan 2000).

One of the goals of CWB I barley marketing was to achieve the highest possible prices for producers. This made CWB I focus on maximizing total return to pools in western barley sales. With this goal, when allocating barley across pools CWB I would tend to sell more malt barley in the designated pool for malt barley where market price was higher. In practice, when there was barley with marginal quality in the pools, CWB I would sell it as malt if there was market demand (Schmitz and Gray 2000). Although confidential information is not available to definitively verify this practice, it is evidenced by examining the transacted quantities of malting and feed barley through CWB I, as shown in Table 2.1. For instance, in the five consecutive years up to 2011, note that the pooling quantity of designated malting barley was significantly higher than the total quantity in Pool A and Pool B for feed. Compared to the amount of feed that was exported through the single desk process, malting barley had a significant proportion of the CWB I's barley business. Lower transacted amounts of western feed barley export could be attributable to the lower price that feed barley could be sold, compared to the price of malting barley.

Table 2.1: CWB Receipts of Barley from Producers (million MT)

Crop Year	Designated (Malting) Barley	Feed Pool A	Feed Pool B	Difference*
2006/07	1.85	0.147	0.0198	1.6842
2007/08	2.45	0.375	0.0418	1.9944
2008/09	2.41	0.193	0.0116	2.3801
2009/10	1.45	N/A	N/A	N/A
2010/11	0.68	0.299	0.153	0.2991

Source: CWB. 2011. The Bottom Line: 2010–11 Annual Report. CWB. Winnipeg.
*Difference=Amount of Designated Barley – Pool A – Pool B.

Since CWB I was able to adjust the transacted amounts between malt and feed varieties, this implies that as long as it could meet the required agronomic standards, barley in the feed pools could often be exported as malting barley when supply was comparatively tight and a higher market price for malting barley (Schmitz and Gray 2000). In this thesis, such interaction and adjustment between malting and feed export amounts is assumed to have been the process by which CWB I may have (indirectly) affected the domestic non–CWB feed barley price.

2.4 CWB Market Power in Western Barley Marketing

With respect to the world barley market, although CWB I had control over western malt barley marketing and western feed barley exports, it is unclear whether CWB I's market power in those markets affected the domestic non–CWB feed barley market, due to the inherent linkages between malt and feed varieties. Assessing the influence of CWB I in world barley marketing, prior research examined CWB I's capacity to price discriminate in western malt and feed barley marketing, as well as measuring price premiums associated with this potential market power. This research provides some insight to help understand the related effects of single desk marketing.

Many postulate that exploiting market power through price discrimination and consequently increasing producer revenue is one of the key rationales as justification for single desk marketing under CWB I (Ryan 1994; Carter and Loyns 1996). In turn, this justification is based on the theory of imperfect competition and market segmentation in the world barley market.

The economics of market power and firms' pricing behavior are reviewed here to gain further insight into CWB I's operations before the recent process of deregulation in grain marketing. A set of studies that examined western barley prices and single desk price discrimination behavior are reviewed to help develop basic hypotheses on pricing behavior that will be tested with current data later in this thesis. Other relevant issues related to the efficiency of single desk marketing by CWB I are also discussed in this section.

2.4.1 Theory of Market Power

The issue of market power is one of the key issues in the long-term debate about CWB I. A firm possessing market power is defined as being able to raise price above its marginal cost and garner economic rent (Church and Ware 2000). In other words, unlike the paradigm of a firm in a competitive market, a firm possessing market power can influence the price it receives by its choice of output decision.

In the field of industrial organization, the so-called Lerner index is often used as an indicator of firm market power (Church and Ware 2000). The index is defined as the ratio of a firm's economic profit margin (the market price of the product minus the firm's marginal cost) to the market price of the product. In a market with homogeneous goods, the Lerner index varies inversely with the price elasticity of demand. In other words, the more inelastic is market demand, the greater market power any single firm can exert in the market. If more elastic demand existed for a given product, consumers could easily switch to substitute products when price increases. Conversely, inelastic demand for a product implies a relative scarcity of substitutes for consumers (Samuelson and Nordhaus 2004).

With respect to agricultural product marketing, the goal for an individual farmer is to render the demand curve more inelastic, as well as increasing demand. One way farmers can achieve these goals is by marketing collectively and eliminating substitutes (Hobbs 2011). The establishment of marketing boards and implementation of product differentiation characteristics are common marketing practices that help to achieve these goals.

As a marketing board, CWB I could affect market power for Western Canadian producers in the historical western barley marketing chain. First of all, CWB I was the single seller of western malting barley from as early as 1949, as well as the sole exporter of western feed barley from 1974. Given this, without entry of other competing sellers, the CWB I's perceived demand curve was more inelastic in the domestic malt barley market as well as the western malt and feed barley export channel. Entry of any type would have necessarily increased the demand elasticity faced by CWB I, meaning its perceived demand curve could have been affected so as to reduce its market power (Church and Ware 2000). In addition, by aggregating each individual farmer's output into pools and marketing collectively, CWB I increased the market share of western malt and feed barley in each of these accessible markets. The latter is also how collective marketing could increase producers' bargaining power in these markets (McMillan 1964). In addition, CWB I rendered demand more inelastic through product differentiation. As an example, in the identity preserved production and marketing system for grain in Canada, when buyers requested identity preservation for specific varieties to meet certain quality needs (Kennett et al. 1998), CWB I played a critical role in assuring this because of its single seller status (Smyth and Phillips 2002).

However, there is no such consensus regarding CWB I's situation in the world barley market. Schmitz et al. (2005) stated that CWB I was clearly not a monopolist because it was not the sole seller of barley within the global marketplace. But since it was the sole supplier of Western Canadian barley that entered into the international grain market, it was only a monopolist over Western Canadian barley in the world market (Schmitz et al. 2005). The authors also stressed that overall, CWB I was not a monopoly because it could not restrict the supply of grain marketed by its competitors internationally. They did acknowledge that the influence of CWB I was significant on western malt barley prices.

Regardless of arguments about market power, Schmitz et al. (1997) and Schmitz and Furtan (2000) asserted that even if CWB I was instead a monopolistic competitor, it could still exercise some influence on prices and earn more revenue from western barley sales than it could do in a perfectly competitive market.

CWB I's actual market position was refined in other studies of world grain markets. McCalla (1966) used a Canada–US duopoly model with a competitive fringe to analyze the structure of the international wheat market from 1956 to 1965. Goldberg and Knetter (1997) and Carter et al. (2001) found that under the former US Export Enhancement Program (EEP)[3], Canada was in fact a fringe player, along with Australia (following the US) in the Japanese wheat market in the 1990s.

In the remaining sections of this chapter, I will outline CWB I behavior assuming that CWB I could have acted as a dominant firm competing with fringe firms in the US feed barley market. In this market, the CWB I is also assumed to have had a significant market share and could also practice price discrimination across barley markets. The latter assumption is based on the fact that most US barley imports were done through CWB I, so CWB I was a large player in barley by any measure. By extension, I assume the US did not produce a large volume of feed barley. Finally, US demand for Western Canadian feed barley is assumed to be relatively inelastic.

Figure 2.13 depicts the situation in which CWB I acts as dominant firm that competes with fringe firms ("the fringe"). At different price level, the total market demand is $Q^M(p)$. Given the fringe's supply S^F and the total market demand D, the dominant firm confronts a residual demand D^D. The residual demand curve is derived from the total demand D by subtracting the aggregate supply of the fringe firms S^F. Before the dominant firm enters the market, the market will reach equilibrium when the fringe's supply intersects with the total demand. Therefore, P^{max} is the maximum price that the dominant firm can charge, because at any price higher than P^{max}, the total market demand equals the total supply of the fringe, which implies that D^D will be zero. Similarly, P^0 is the minimum price that the dominant firm would charge in this market because at any price lower than P^0, there will be no fringe, and the dominant firm's demand will become the total market demand D. Its marginal revenue falls to

[3] "The Export Enhancement Program is designed to help US farm products meet competition from subsidizing countries"… "Under the program, the US Department of Agriculture pays cash to exporters as bonuses, allowing them to sell US agricultural products in targeted countries at prices below the exporter's costs of acquiring them. The major objectives are to expand US agricultural exports and to challenge unfair trade practices." — Foreign Agricultural Service, 2006.

$MR^D = MR$ (where MR is derived from total market demand D). Ideally, between the extremes of P^{max} and P^0, the dominant firm prices to maximize its profit, and this occurs at the point where its MR^D intersects with its marginal cost MC^D, as shown in the diagram. Thus, the dominant firm's output Q^D should equal its profit–maximizing output Q^*. This profit-maximizing output Q^* determines the price P^* at which the dominant firm obtains maximum profit given these market conditions, and also the total output of the fringe $Q^F(P^*)$ at P^*. The dominant firm's profit is highlighted as the shaded rectangle in Figure 2.13. With respect to the hypotheses examined later in this thesis, the removal of the single desk function would mean an end to this profit level. This in turn could generate significantly altered relative movements of Canada–US feed barley prices, particularly in the period after the end of the single desk function.

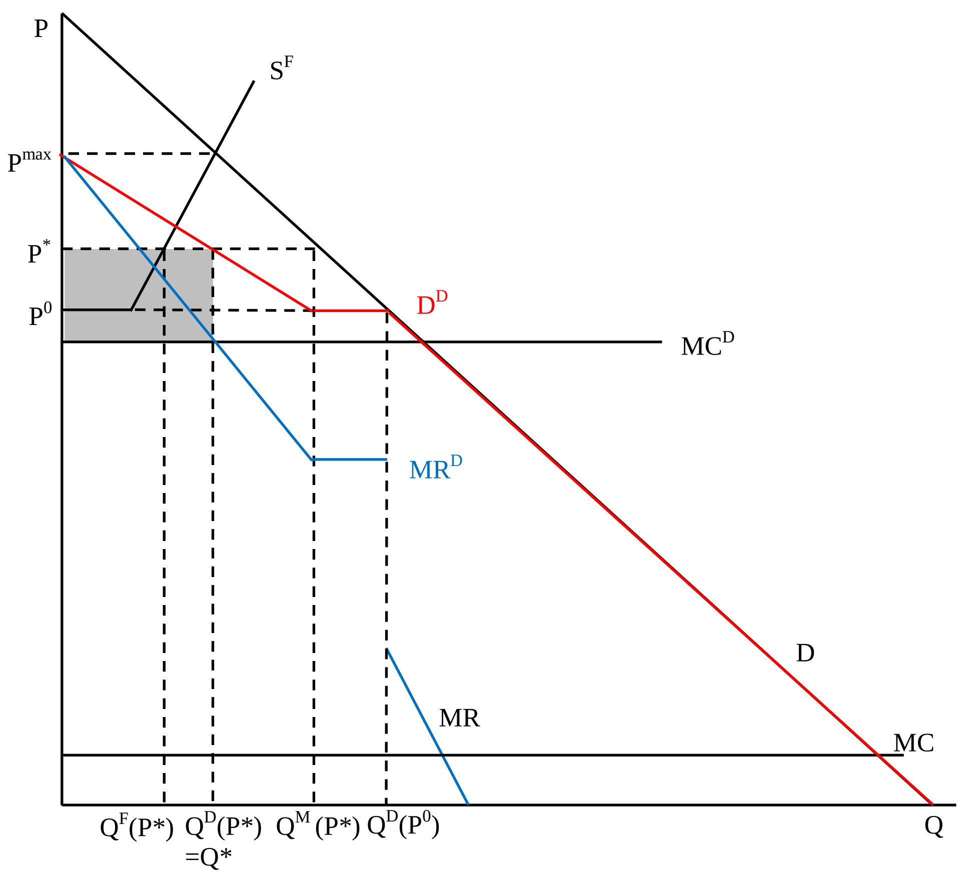

Figure 2.13: Pricing Behavior of the CWB I: Dominant Firm with Competitive Fringe

Source: Adapted from Church and Ware, 2000. Industrial Organization: A Strategic Approach. New York: McGraw–Hill, 2000. 127.

Note that market power and prevention of arbitrage (resale between buyers) are two necessary conditions for price discrimination (Church and Ware 2000). Under these conditions, a dominant firm can exercise price discrimination to maximize its profit across markets. From a pricing perspective, CWB I is assumed to be have been able to practice third–degree price discrimination in the relevant markets.

Under third–degree price discrimination, groups of buyers are segmented in some fashion that prohibits arbitrage between the different groups. The price discriminating firm is aware of the separate demand functions of each individual group, but not necessarily demand within a group. It charges the same price within a group but differentiates prices between the groups. In a two–group example, the firm's pricing behavior under third–degree price discrimination is depicted in Figure 2.14. Consumers in Group 1 have a relatively lower and more elastic demand D_1; consumers in Group 2 have a relatively higher and less elastic demand D_2. To maximize profits across the two markets, the firm will set its marginal revenue equal to the marginal cost in each market. Therefore, it will sell q_1 to Group 1 and q_2 to Group 2. It charges p_1 and p_2 for consumers in Group 1 and 2 respectively. The total profit that the firm acquires is equal to the sum of the profits across both markets.

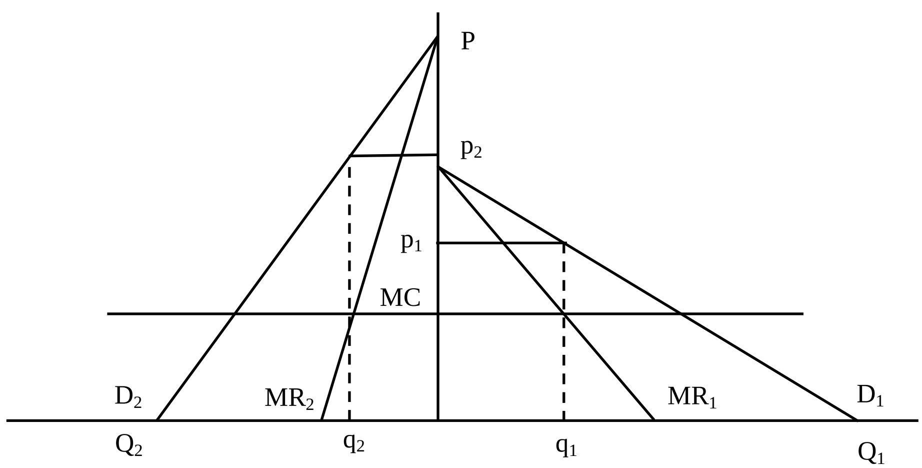

Figure 2.14: Market Segmentation and Third–Degree Price Discrimination

Source: Church and Ware, 2000. Industrial Organization: A Strategic Approach. New York: McGraw–Hill, 2000. 165.

Given its dominant role in the North American barley market, in this thesis I also assume that CWB I had the potential to exercise market power as well as price discrimination in multiple markets as described above. With this market power, it would charge higher prices in the markets where demand was more inelastic, and lower prices in markets where demand was more elastic (Ryan 1994, Carter and Loyns 1996). From a pricing perspective, the structure of the testable hypotheses in this thesis regarding the relative movements of feed barley prices through time and space are founded on these assumptions about the pricing behavior of CWB I in barley markets.

2.4.2 Pricing of Western Canadian Barley

It is generally accepted that Canadian malt barley producers marketing through CWB I received higher prices than producers in competing countries (Schmitz and Furtan 2000; Gray et al. 1993; Carter 1993). For example, previous studies have found that compared with farmers in the US, Canadian farmers earned a relative premium from malting barley. Schmitz and Furtan (2000) compared CWB final realized prices with equivalent US prices. According to their study, through the period from 1981/82 to 1991/92 Canadian malting barley on average achieved premiums of $36.03/MT[4] for the six–row variety and $45.77/MT for the two–row variety over US malting barley.

Gray et al. (1993) offered that the price premiums for Canadian malting barley were attributable to the superior management function of CWB I. According to Gray et al. (1993), CWB I ensured that it exported better quality malting barley, and also the CWB I's capacity for reallocation reduced the uncertainty of quality consistency faced by barley buyers. Using this logic, malting buyers must have been willing to pay a premium to reduce transaction costs in purchases for the guaranteed high quality of products and services. These authors also pointed out that by gathering all prairie barley producers together as a single marketing entity, CWB I increased the negotiation power of producers in trade. The upshot is that removal of the mandatory single seller status of CWB I had the potential to reduce those historical premiums for producers that were gained through single desk marketing (Gray et al. 1993).

Regarding export prices of Western Canadian feed barley, there is evidence that historically western feed barley tended to get lower price premiums than malting barley. Gray et al. (1993) showed that from 1981/82 to 1990/91, the 10–year average CWB pooling prices for feed barley were $6.61/MT lower than Minneapolis cash prices and $2.20/MT lower than US

[4] All prices in the remainder of the thesis, unless specified, are measured in Canadian dollars.

National Agricultural Statistics Services (NASS) prices. Performing a similar comparison, Schmitz and Furtan (2000), found that from 1981/82 to 1991/92 the average historical CWB final realized prices for feed barley were around \$1.10/MT lower than the average price received by US producers. Additional comparisons done by Carter (1993) indicated that from 1975 to 1992, the CWB feed barley price was 4 percent lower than equivalent Minneapolis prices.

These comparisons were made between export feed prices paid by CWB I with feed prices received by the US producers. However, very few studies have examined domestic feed prices in Canada. One study by Carter and Loyns (1996) compared US–Canada farm gate prices for feed barley and found that from 1988/89 to 1994/95, Lethbridge No. 1 Canada West (No. 1 CW) feed price was \$30/MT lower than the Great Falls (Montana) feed price on average. Carter (1993) also noted that the yearly average Alberta non–board feed barley price was 3 percent lower than the average CWB feed price from 1975 to 1992. From a behavioral perspective, these latter results seem reasonable. As mentioned earlier, if producers in the prairies were rational and CWB I performed its marketing function as described, producers would sell feed barley through CWB I only if the expected export price was higher than the domestic price.

2.4.3 Price Discrimination and the CWB

Price discrimination is an important concept in the examination of barley markets in Canada because the capacity of an agricultural marketer to exercise price discrimination has been used to assess the market power of state trading enterprises (STEs) in the global grain trade (Carter 1993; Schmitz et al., 1997; Schmitz and Gray 2000; Gray et al. 1993; (Schmitz et al. 1993)). As described in Section 2.4.1, if CWB I could exercise third–degree price discrimination, it could potentially divide markets into several different demand groups and charge the grouped consumers different prices for essentially the same or at least substitutable products, depending on the structure of their demands. With respect to historical grain marketing in Canada, the potential to price discriminate is the key distinction between the single desk function as compared to a market with multiple competitive firms (Schmitz et al., 1997).

Carter (1993) developed a series of empirical models to test the ability of CWB I to price discriminate within the North American market of barley for general use. His study postulated that CWB I did not possess market power in the world barley market due to its small relative market share. To test this latter supposition, Carter used structural econometric models that were based on Krugman (1987) and Knetter (1987) to test the effect on export prices of Canadian barley to four importing countries — US, Japan, Former Soviet Union, Saudi Arabia — using control factors including export destinations, time, and the importing countries' exchange rates. The hypothesis that CWB I did not possess market power in world markets could not be rejected. However, Carter did find that the US Export Enhancement Program (EEP) might have had influence on Canadian barley exports at that time. In fact, he found that CWB I was able to obtain higher prices in non–EEP markets than it did in EEP markets. This suggests that barley market discrimination or segregation over the time of the study might have been due to explicit US policy rather than any inherent market power exercised by CWB I. Since he found no evidence of CWB I price discrimination in the first model, he then developed a structural test based on Canadian barley exports to the US, since Canada was virtually the only barley exporter to the US (Carter 1993). This latter model tested relationships for Canadian barley export prices to the US, using factors that might affect export quantity to the US, including US domestic barley production quantity, number of livestock, and US barley stocks. The latter results also indicated that CWB I did not exercise market power and further, could not benefit by restricting sales in the US barley market.

Alternatively, Schmitz et al. (1997) found that CWB I had in fact acquired market power over barley exports, and also that the elimination of its single marketer status would ultimately decrease returns to Canadian barley producers. The authors constructed two econometric models to evaluate the degree of CWB price discrimination as well as measure the resulting benefits to western barley producers. They assumed that CWB I's objective function was to maximize the total revenue across markets for feed barley internationally, and for malting barley both domestically and internationally. It is worth noting that Japanese feed barley demand was separated from other off–shore importing markets because CWB I obtained a significantly higher premium in this market over the test period from 1980/81 to 1994/95 (the difference between the price to Japan and that to the rest of the world averaged $20.73/MT, since Japan was typically a market demanding much higher quality). A comparison was made between the two scenarios, given domestic demand elasticity for feed in Canada and excess demand elasticity for western feed barley in non–Japanese offshore markets. They concluded that the returns from CWB I were significantly higher than those possible with a multiple seller market.

Schmitz and Gray (2000) concluded that in general, prices for western Canadian feed and malting barley varieties would fall with a multiple seller market, and this drop in prices would lead to a loss in producer revenue. Additionally, these authors estimated changes in trade flow in a multiple seller market. Overall, they found that the export quantity of feed barley to the US would decrease, while that of malting barley would increase.

Finally, in terms of feed barley exports it is worth mentioning again the study that was conducted by Gray et al. (1993) acknowledging CWB I's capacity to practice price discrimination. The authors grouped the four major markets in a world trade model for Canadian feed barley as follows: US domestic, Canadian domestic, Japanese import demand and import demand from the rest of the world. The markets were segmented this way as a consequence of the US EEP policy rather than market power of CWB I, while Japan was again treated as an individual market because it was not subsidized under the EEP. Using estimated supply and demand elasticity for feed in the four markets as well as an assumption of a perfectly inelastic supply of Canadian feed barley, they concluded that only a slight decline in total revenue to Canadian barley producers would occur if a single (or continental) barley market was enacted. In turn, the measured loss in their study was assumed to stem from a decrease in price premiums for Canadian barley since CWB market power would be eliminated.

In sum, research has widely acknowledged that CWB I was able to price discriminate to some degree among the segmented barley markets in an attempt to maximize returns to Canadian producers. In several instances, market power was also found from the price premiums that CWB I earned from malting barley sales. However, comparisons made in previous studies also show that although CWB I obtained higher prices in western malting barley sales, domestic non–board feed barley prices were lower than US feed barley prices.

CHAPTER THREE

CONCEPTUAL FRAMEWORK

Previous studies have generally acknowledged that CWB I could generate premiums in Western Canadian malt barley sales. However, domestic non–CWB feed barley prices in Canada were lower than the CWB I feed barley prices and the feed barley prices for substitutable grades in comparable regional markets. CWB I might have been able to manipulate prices in Western Canadian malt barley sales and Western Canadian feed barley exports, but its indirect influence on domestic feed barley prices was not well understood.

Drawing upon conclusions made in previous studies, this thesis hypothesizes that if CWB I was not able to affect domestic non–board feed barley prices, the removal of its single desk power would not cause any change in price integration or price transmission between the Canadian domestic feed barley market and the US feed barley market. To support this supposition, in this chapter a conceptual framework is developed to explain market integration and price efficiency in the Canada–US regional feed barley market in order to develop testable hypotheses. This particular conceptual framework is based mostly on Fackler and Goodwin's (2001) study on spatial market integration. To motivate the analysis, a series of related empirical studies are reviewed to help describe the empirical tests used in this thesis.

3.1 Price Transmission and Market Integration

3.1.1 Market Integration

The notion of spatial market integration is derived from the concept of Law of One Price (LOP) in international trade (Viju et al. 2006). As Marshall (1890) asserted, in a perfect market, the same price would be paid for homogeneous products if the cost of transportation was zero. Samuelson (1949) in his study on international factor prices raised this concept in trade and showed that frictionless trade would lead to equalization of the ratios of both commodity and factor prices between two countries. Thus, spatial markets are considered to be integrated if LOP holds across markets (Fackler and Goodwin 2001).

The idea of market integration has also been adopted as a measure of the efficiency of price transmission across distant markets. As Fackler and Goodwin (2001) demonstrate, market integration could be a measure of the degree to which demand and supply shocks arising in one region are transmitted to another region. In other words, for identical goods, if a price shock is perfectly transmitted from one spatial market to another, these markets are said to be perfectly integrated. Conversely, if there is little or no effect of price signal from one market to another, the markets are distinct or separated.

According to Fackler and Goodwin (2001), perfect market integration or LOP are rarely achieved in real world transactions. Unavoidable frictions, such as transaction costs and transportation costs across markets, are the main causes of differential price movements in real–life transactions between spatially separate markets for the same good.

In spite of the unavoidable costs, market power can also hinder the realization of perfect market integration (Conforti 2004). Market power of firms in the production and/or marketing chain can be transmitted vertically in the production process and therefore affect factor prices (Conforti 2004). Hence, differentials between the prices of the end products can be a consequence of the unequal market power in the production and marketing chain (Conforti 2004). Moreover, product differentiation, defined as the degree of product substitutability between markets, is another obstacle to perfect market integration (Conforti 2004). The neoclassical assumption of product homogeneity does not often hold in agricultural markets due to the variation of product qualities and consumer preferences across markets.

In addition, non–economic factors can also affect trade flows and therefore market integration within a geographic region. When discussing the widely–adopted gravity model for trade policy analysis, Ivus and Strong (2007) stressed the effects of non–economic factors on the cost of bilateral trade. Even considering conventional non-economic factors such as relative size and distance between trading regions, they argue that language, history, laws and currency also affect trade and should be taken into consideration in the study of trade flows. While Canada and the US are very close trading partners, it is possible that some of these non–economic factors generate barriers in the regional Canada–US feed barley trade and affect the realization of pure LOP or market integration.

3.1.2 Price Transmission

Like market integration, perfect price transmission is rare in agricultural commodity trade, and some argue that this is primarily due to border policies (Moodley et al. 2000). With respect to this thesis, data show that when CWB I was the monopoly exporter, trade flow of Western Canadian feed barley was limited and only a very small amount was sold through the CWB pool for feed barley into the world market (Table 2.1). Demand for western feed barley from the international market might have been suppressed over this time because exports had to be made through CWB I. However, CWB pooled payments, based on forward pricing contracts, lagged behind price signals in the spot markets. Thus, domestic feed barley prices in Canada prior to the removal of single desk might not precisely reflect the actual supply and demand for western feed barley in the domestic and world market. Ultimately, these issues will make it challenging to identify market price transmission effects in the context of this study.

Although sometimes imperfect, price information can, to some extent, be transmitted across borders through arbitrage activities. Fackler and Goodwin (2001) state that the extent to which price signals in one spatial market can be transmitted across to other markets is an indicator of the level of price transmission efficiency, and therefore a proxy for market integration. Effectively, co–movements of commodity prices across spatially–separated markets imply that the markets are reacting to the price signal in a similar manner even if the exact market prices are not equal (when corrected for factors such as exchange rates and transportation costs) (Fackler and Goodwin 2001).

Over time, a lead or lag in price transmission may also appear because a certain length of time is usually required to conduct arbitrage of visible tradable goods (Fackler and Goodwin 2001). The existence of a time element in price transmission across markets corresponds to the period that the price "follower" waits before reacting to the price signal or information that is transmitted from the price "leader". Prices in such a situation will move together across spatial markets and are often necessarily lagged through time (Fackler and Goodwin 2001).

In addition, price signal transmission across spatial markets can be represented as a dynamic system, where linkages and feedback between prices represent information transmission across markets as well as the level of market integration. The latter has become a factor for recent research about market integration, which offer that short–run price differences may exist, but a one–to–one correspondence of price changes across integrated markets must be the case in the long run (Fackler and Goodwin 2001). Alternatively, Fackler and Goodwin (2001) state that if price changes or shocks in one location do not have an immediate effect on related prices at other locations, there must exist some informational inefficiency across the markets.

3.2 Studies of Market Integration in Commodity Markets

Previous related studies on market integration have focused on testing spatial integration through price transmission across markets. Earlier work (Mohendru 1937, Jasdanwalla 1966, Cummings 1967, cited in Fackler and Goodwin 2001) examined correlations between prices of a commodity across markets using simple static regression models. As techniques for analyzing price integration and transmission have evolved, dynamic econometric models are now being used to examine pricing relationships in time–series data.

Within the set of possible empirical testing approaches, three econometric methods will be used in this study to examine the structure of feed barley prices in this regional market. First, cointegration tests will be used to identify the existence of market integration between spatially separated markets. Next, Granger causality tests will be developed to uncover the existence of key lead/lag relationships between variables and markets. Finally, impulse response functions derived from a vector autoregression model will simulate price changes and help identify complex dynamic linkages and feedback between the spatial markets.

In this section, related studies that employ these methods are reviewed to help motivate the empirical framework to be used in this thesis. More precise descriptions and explanations about the econometric methods will be given in Chapter 4.

3.2.1 Studies of Grain Markets

A statistical or econometric framework for the study of price transmission through space and time has been applied to grain prices across spatially separated markets to test the extent of price transmission and market integration. The results from such analyses have been used to assess policy changes and the level of regional market integration.

Clark (1995) used tests of structural break as well as cointegration analysis for selected feed grain prices in order to test the effects of the Continental Barley Market (CBM) on Canadian feed grain market integration. Using a sample of cash market prices for feed wheat, barley and oats, he conducted tests to identify structural breaks in the price series for the CBM. He developed his hypotheses on the basis of prior information contained in work from the CWB (1993, cited in Clark 1995), along with Schmitz et al. (1993), and Gray et al. (1993). Clark also incorporated discrete variables corresponding to the established breakpoints in time associated with the CBM. In his paper, tests for structural break (either assumed or using an unknown breakpoint) did not find evidence that significant breakpoints in the price data occurred at or around the establishment of the CBM. The null hypothesis of no structural break in Canadian feed grain prices associated with the brief introduction of the CBM could not be rejected.

Alternatively, Clark set up cointegration tests to identify a long–run equilibrium relationship among the selected feed grain prices. In other words, if some kind of complex structural break in feed grain prices occurred, this should have generated measureable changes in the cointegrating relations in the data. Two related test procedures were used, the Hansen L_C and the Park J_1 test. The L_C test was developed by Hansen (1992, cited in Clark 1995), while the J_1 test was developed by Park (1990, cited in Clark 1995). Both procedures test the null hypothesis that there exists a cointegrating relationship among unit root variables. Unfortunately, the tests yielded two different conclusions - the L_C test tended to support the existence of cointegrating relationships among the price variables, while the J_1 test did not yield consistent cointegration results.

Clark concluded that there appeared to be a "single stable relationship among the feed wheat, feed barley, and oat prices" in the North American barley market (Clark 1995). He also offered that his test results showed that the elimination of single desk marketing for Western Canadian barley (albeit briefly) did not significantly affect feed prices over the duration of the data.

While Clark's research is closest to the scope of the research done in this thesis, it is worth noting that other studies have also used time series analysis to identify possible market power and assess the integration of commodity price series across spatially distinct markets.

One recent study tried to evaluate the consequences of common policies within EU agricultural markets. Viju et al. (2006) compared pre– and post–EU prices of selected agricultural commodities (rye, wheat, and barley) for three recently included EU countries (Austria, Finland and Sweden). The authors assumed that the law of one price should necessarily hold under free trade, while regional market power in some form could offset any tendency towards price integration among these spatially separated countries. In this light, they hypothesized that in these countries in the pre–EU period, there should exist no cointegrating vectors in the sample commodity price pairs. The reason for this was that within the EU, the selected commodities were supported by the Common Agricultural Policy (CAP), while exports were subsidized through the Monetary Compensatory Amounts (MCA) policy, and that the CAP and MCA were not applicable to countries outside the EU.

The authors then searched for cointegrating relationships between the commodity prices in the sample countries and those in a representative EU country (Germany) using an error correction procedure. Their findings indicated that the prices of these commodities were not cointegrated in the pre–EU era, at a time when the agricultural sector was highly subsidized in the sample countries before they joined the EU. However, in the post–EU period, they found rye and barley markets were integrated for all three countries, whereas wheat markets were integrated in Austria and Sweden, but not in Finland. Clearly, EU policies contributed to a higher degree of market integration as predicted, but this effect was not consistent across space or commodity.

Another study by Dawson et al. (2006) evaluated the price effects of another set of agricultural policies related to market integration in feed grain futures, and also motivated methodologies to identify price cointegration as well as potential structural breaks in the data. The authors hypothesized that the international feed barley and feed wheat futures market was integrated on Euronext, through the London International Financial Futures and Options Exchange (LIFFE). They postulated that a cointegrating relationship should exist between these commodity prices so long as the commodities are strong substitutes for each other.

Using a system-based analysis on futures prices for feed barley and feed wheat with a designated structural break, they found that both feed barley and feed wheat futures prices were statistically integrated (i.e. integrated of order 1, or I(1)), and that wheat futures possessed a significant structural break around the reform of CAP on July 1, 2000[5]. To check for market integration, they also performed a cointegration test and concluded that the two commodity price series were in fact cointegrated. Finally, impulse response functions were computed from the model parameters to simulate the interactions of the commodity data and assess the structure of dynamic price transmission. They found that as one price series was shocked in this manner, the other price moved similarly over the long run and that this effect was permanent. This indicated the existence of a measurable price transmission relationship between the LIFFE feed barley futures market and the feed wheat futures market.

[5] I(1) processes will be explained in details in Chapter Four.

3.2.2 Related Studies of Other Agricultural Markets

Similar time series analyses of prices have been employed to examine market integration and associated dynamics across both international and regional markets for a number of agricultural products. Since Granger causality is a sufficient but not necessary condition for cointegration, in some studies, tests for the former have been set up to complement those for the latter. Even if spatially separated prices are not found to be cointegrated, there could still be asymmetric price transmissions if uni– or bi–directional Granger causality is detected (Conforti 2004). In particular, some researchers offer that uni–directional causality indicates some kind of informational inefficiency in markets (Fackler and Goodwin 2001).

Gupta and Mueller (1982) used Granger causality to examine price efficiency among German hog slaughter markets. They argued that Granger causality would manifest as a lead or lagged interrelationship between the spatially separate markets. In this case, if the price in one market leads the prices in the other markets, then the information set from the former market is said to "Granger cause" the latter price changes in the other markets. Gupta and Mueller (1982) also examined the relationships between prices that West German hog producers received from slaughter houses across three regional markets in the country. An autoregressive integrated moving average (ARIMA) model based on the Box and Jenkins (1970) approach was used to perform the analysis. The latter estimates showed that the coefficients at zero lag were all significant. The authors concluded that the three markets were pricing efficiently, meaning that price signals were being transmitted across markets without measurable lag.

Williams and Bewley (1993) utilized a cointegration test, a Granger causality test, and impulse response function analysis to identify arbitrage opportunities in selected cattle auction markets in Queensland, Australia. Within four cattle auction markets, cointegrating relationships were detected and there were also lags in price transmission - the latter was seen as an opportunity for arbitrage. To measure the speed of price adjustment, the authors estimated impulse response functions by simulating the path of price movements under the influence of an exogenous shock. They found a two-week delay in Townsville's response to the shock from the Rockhampton market, while prices in the other markets showed a "relatively muted reaction to a shock in the price at Townsville" as the impulse responses of the other market prices were relatively weak. Given this, they concluded that there existed non-trivial arbitrage opportunities in the Queensland cattle auction market.

Finally, research by Conforti (2004) applied Granger causality tests to agricultural price series data from the FAO database to examine the patterns of price transmission in selected markets among a set of countries. By analyzing the broad pattern of results from the sample, he concluded that incomplete price transmissions characterized many African markets as compared to similar Latin American or Asian markets, likely owing to the amount of available information (or lack thereof) in African countries.

3.2.3 Studies of Non–agricultural Markets

The conceptual econometric framework analyzing movements of price series for evidence of market integration and the structure of market price transmission has also been used for analysis in non–agricultural industries. Especially when arbitrage in many markets now readily takes place around the globe, comparable prices from vastly separated spatial markets have been used to test for international market integration.

Siliverstovs et al. (2005) applied the methodology to natural gas prices in Europe, Japan and North America between 1990 and 2004 to assess the degree of integration in the natural gas market across these regions. Using cointegration analysis, the authors concluded that natural gas prices across Europe and North America moved together, as did prices in Europe and in Japan. However, North American and Japanese prices did not move together, highlighting the limits of global arbitrage in natural gas.

For the coal industry, Wårell (2006) implemented cointegration testing to identify levels of international market integration. Using internationally traded steam coal and coking coal data from 1980 to 2000, error–correction based cointegration testing on coal price series from Europe and Japan revealed that a globally integrated market existed for the two respective grades of coal. Their study also used time series price analysis to estimate the effects of a merger and acquisition trend in the coal mining industry (during the 1980s) with respect to enhancing market power of the merged coal companies, and expanding global integration into what has become a very concentrated international coal market.

Voronkova (2004) examined equity market integration between Central Europe and other global markets, using price indices from 1993 to 2002 in emerging Central European markets (the Czech Republic, Hungary, and Poland), three developed European stock markets, and the US. The testing period featured increasing foreign investment flows, which were expected to encourage the Central European markets to become more integrated with global markets. The authors implemented cointegration tests on the data, finding that there was a cointegrating relationship within the Central European market and also between the Central European market and the other markets (the developed European stock market and the US stock market). The author concluded that there were also significant long–run relationships between the emerging Central European markets within the region and globally.

Finally, Moodley et al. (2000) assessed the effect of the Canada–US Trade Agreement (CUSTA) on market integration through an analysis of the convergence of price indices in Canada and the US. Using producer price indices from January 1974 to January 1996, the authors examined the impact of CUSTA on the movement of the two countries' purchasing power parity (PPP). They first tried to locate any significant structural breaks in the data associated with the beginning of CUSTA in 1989. A significant structural break was found for January 1989, the same month when CUSTA came into effect. Their cointegration test (a Johansen procedure) suggested that price indices were cointegrated in both the pre–CUSTA (before January 1989) period and the post-CUSTA (after January 1989) period. The authors concluded that there were equilibrium price relationships between the two countries, but CUSTA was not the cause.

While not typically identifying idealized LOP situations, empirical studies of agricultural and non–agricultural market prices have focused mostly on testing the efficiency of price transmission across markets and/or the level of spatial market integration. Methodologically, time series analysis using cointegration analysis, Granger causality, and in some cases, impulse response function analysis are the prevailing analytical approaches for the study of structural changes and resulting price dynamics within spatially separated yet potentially interrelated markets.

3.3 Developing Market Integration Tests – Description of the Hypotheses

In August 2012, the CWB single desk marketing system was eliminated from the Western Canadian feed barley export market. The basic null hypothesis of this thesis is that the policy switch should not have led to significant changes in the relationship between feed barley spot markets in Canada and the US. To this end, time series analysis of the respective spot market prices are used to evaluate changes in this transitioning regional feed barley market.

Conversely, identifying a significant change in the cointegrating relationship between feed barley prices constitutes rejection of the null hypothesis. In the latter situation, rejection implies that removal of the single desk powers of CWB I generated significant changes in the Canada–US regional feed barley market with respect to transmission of price information as well as market integration.

Motivated by the related empirical literature, the thesis will examine the level of price transmission and market integration between current Canadian and US feed barley markets through the analysis of the respective price series. By comparing the degree of market integration across CWB I and CWB II periods, price effects attributable to the single desk regime may also be inferred.

Similar to the work of Clark (1995) regarding the short–lived CBM, econometric tests of feed barley price cointegration are developed to identify changes in the degree of market integration between Canadian and US feed barley markets during the latest transitional period. A cointegration test is the primary test used here because it allows consistent inferences to be drawn in situations when the individual price series are non–stationary (Fackler and Goodwin 2001). To this end, I assume that there are two critical test periods for CWB I and CWB II, with the latter referring to the era after the removal of single desk marketing. In sum, one of three situations will need to be considered with respect to econometric testing of the price series;

CASE I. The price series are cointegrated in both test periods. If this is the case, we conclude that the spatial feed barley markets are integrated, and through arbitrage the markets have achieved long run equilibrium. Further, this result implies that the existence of the single desk and the export constraint on western feed barley did not prevent the Canada–US feed barley market from realizing price integration.

CASE II. The barley price series are not cointegrated in either of the test periods. If this occurs, we conclude that these regional feed barley markets were not inter-related or integrated before single desk power was removed, and no measureable change can be detected in the market relationship using current data. This result would imply that under single desk, the Canadian and US feed barley markets were never integrated, nor have the markets become integrated since the policy change in Canada.

CASE III. The price series are not cointegrated through the CWB I period, but are found to be cointegrated in the CWB II period. This would imply that the removal of single desk marketing has led to increased market integration between the Canadian and US feed barley markets. Furthermore, as other barriers (i.e. the export constraint) have gradually been eliminated, improved regional price transmission has moved these feed barley markets toward a higher level of integration.

In addition, within the test periods defined in the data, I will also perform Granger causality tests to detect any significant changes in the direction of market price transmission. This testing is done to complement the set of cointegration tests. With respect to Granger causality, the three cases of interest are:

CASE A. If there is unidirectional causality between the price series, then asymmetric price transmissions are happening. This may be evidence of the existence of continued asymmetry in price transmission between the Canadian and US feed barley markets, implying one market "signals" or transmits price information more accurately than the other.

CASE B. Bidirectional Granger causality implies a greater degree of price transmission between the markets than CASE I.

CASE C. If no Granger causality is identified between the feed barley price series, no measurable price transmission is occurring between these regional markets. In this case, we can say these feed barley markets are fundamentally independent of one another with respect to pricing.

From a VAR analysis of the price series, impulse response functions can be estimated to examine dynamic issues related to spatial market integration (Fackler and Goodwin 2001). Impulse responses will be used to complement the cointegration testing and Granger causality testing since the impulse responses indicate the speed of price adjustment (Williams and Bewley 1993). In this case, with a system of n regional prices, a set of impulse responses reflects the effects of exogenous shocks to prices in each of the n markets and expresses the (simulated) prices as a function of current and lagged shocks, providing additional inference regarding the dynamics of price adjustments (Fackler and Goodwin 2001).

Due to the spatial nature of this analysis, impulse response functions will be generated to provide information about price transmission across the markets. Comparing the changes in plotted impulse responses for Canadian and US markets to simulated price shocks, the responses reflect the pattern of price reactions within each market. Furthermore, if the impulse responses of Canadian and US prices follow the same broad pattern, we will conclude that a high level of price transmission exists across the markets. In contrast, if the two price series react in different ways, we will conclude that the degree of price transmission is low across these markets. An overview of this approach and interpretation will be reviewed in detail in the next chapter.

In summary, this thesis will develop and interpret cointegration tests, Granger causality tests and associated impulse response functions in the context of examining historical and current linkages across the Canada–US spot market for feed barley. Comparisons of these results across both CWB I and CWB II test periods allows the identification of any changes in the degree of market integration and price transmission through the recent transition period, a period during which the regional feed barley market has adjusted to the removal of single desk marketing power in Canada.

CHAPTER FOUR

EMPIRICAL MODEL STRUCTURE

In this chapter, a set of econometric tests and models are developed as an application of the conceptual framework. The time series analysis will consist of cointegration and Granger causality tests on feed barley price series across comparable spatial markets in Canada and the US. The data come from the transitional period after the single desk marketing function of CWB I was removed. Based on certain properties of the data, the actual econometric model is specified as a general vector autoregressive process or VAR. On the basis of these VAR estimates, impulse response functions will be simulated to generate price movements and reactions across this market.

4.1 Data Description

The data sample consists of secondary data. These are daily cash market prices of feed barley in Canada and the US, starting from August 4, 2009 to May 1, 2013. To this end, the daily bidding price of No. 1 CW in Lethbridge, Alberta as well as the daily elevator bidding price of US No. 2 feed barley in Great Falls, Montana are used to represent feed barley prices in Canada and the US, respectively. As described by ICE Futures Canada (Giesbrecht 2013), the Lethbridge No.1 CW feed barley cash price reflects transactions from buyers and sellers for spot delivery in Lethbridge. The Great Falls price, according to the USDA Agricultural Marketing Service expresses average prices of US No. 2 feed barley in the Great Falls area. Without question, the Lethbridge–Great Falls area is one of the major feed barley and livestock production zones in North America.

There are two good reasons that render the price series comparable and therefore suitable to the conceptual framework. First, the two spot market locations chosen for feed barley are geographically close. Such proximity, even across a major international border, means these locations essentially constitute a continuous market for feed barley so that prices in each market are comparable. Second, the selected commodities in these two cash markets are somewhat comparable for end use in terms of quality. Table 4.1 shows the official agronomic standards for both No. 1 CW and No. 2 US feed barley, and shows the standards for the two grades of feed barley are comparable in terms of test weight, foreign material, soundness and broken kernels.

According to the Alberta Feedlot Management Guide (Ramsey 2011), the difference between each feed barley variety on feedlot performance is insignificant. The only major difference between the two grades of feed barley as generally accepted by feed buyers is test weight (Pearson 2013), with the higher test weight of No. 1 CW the primary reason for its higher price. Given their overall similarities, in this thesis the feed barley associated with each market is assumed to be substitutable for feed use.

Table 4.1: Comparisons of Selective Quality Standards, No. 1 CW and No. 2 US Feed Barley

	No. 1 CW[6]	No. 2 US[7]
Test Weight (g/L)	606	579
Foreign Material	2.5%	2%
Soundness	Reasonably sweet, may be frost–damaged, weather–stained or otherwise damaged	94% of sound barley that kernels and pieces are not damaged
Broken Kernels[8]	15%	8%

Source: CGC and Grain Inspection, Packers and Stockyards Administration of USDA.

The sample of prices contains 903 observations. The Lethbridge price is tracked and released by Intercontinental Exchange (ICE) Canada, while the US price is obtained from the USDA market news on Montana Elevator Cash Grain Prices. Figure 4.1 plots the movements of each series in the study time horizon, where the Lethbridge price is measured in CAD$/MT ($/MT). Note that both series trend upward across the full sample period, with the Lethbridge price peaking at $295/MT on April 4, 2013. The Great Falls price is recorded in USD$/cwt[9] and is converted into CAD$/MT by adjusting with the Canada/US exchange rate for the same date (using daily noon exchange rates from the Bank of Canada, see Figure 4.2). The Great Falls price plateaus from early April to early September in 2011 and peaks at $235/MT on September 20, 2011, the latter occurring during the major US drought of 2011/12.

[6] Modified, July 29, 2011.
[7] Effective since June, 1997.
[8] CGC defines broken kernels as pieces that are less than three-quarters of a whole kernel and kernels with the germ end broken off. The USDA defines broken kernels as barley kernels that have one-third or more of the hull removed, or that the hull is loose or missing over the germ, or broken kernels that have a part or all of the germ missing.
[9] 1 cwt = 100 lbs.

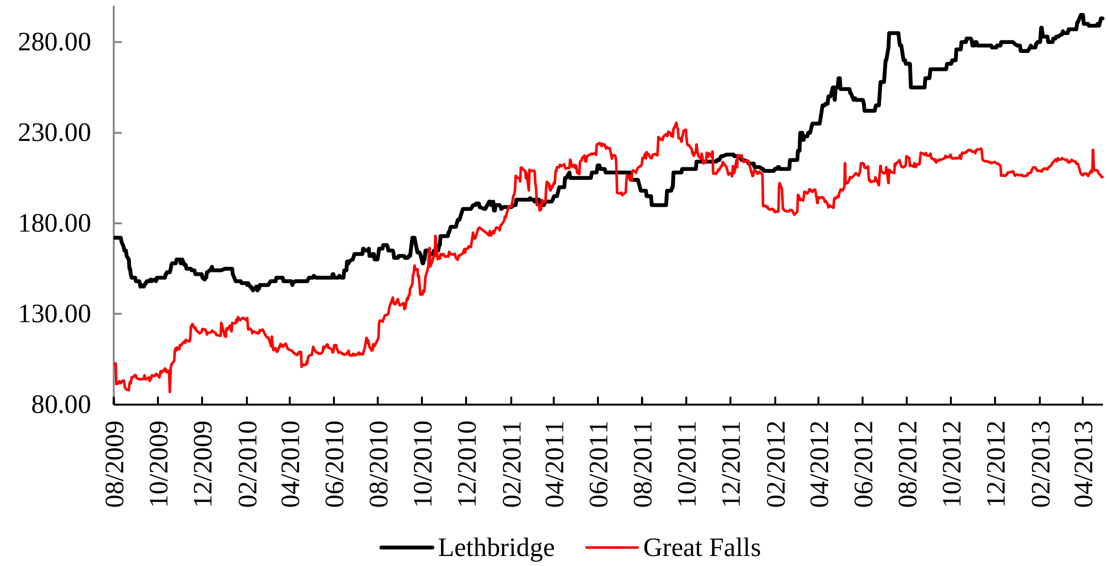

Figure 4.1: Feed Barley Prices, Lethbridge and Great Falls (August 4, 2009 to May 1, 2013, $/MT)

Source: ICE, Canada; USDA, Agricultural Marketing Service Marketing News.

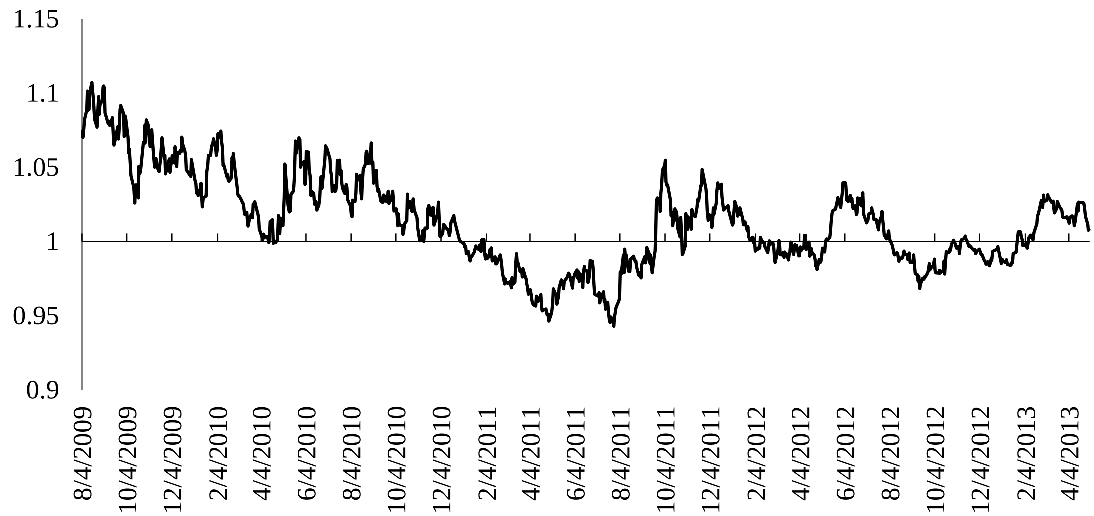

Figure 4.2: Daily Noon Exchange Rate (USD to CAD, August 4, 2009 to May 1, 2013)

Source: Daily noon exchange rate, Bank of Canada.

Table 4.2 contains descriptive statistics of the selected feed barley prices over the sample period. The average of the Lethbridge prices is $30.64/MT higher than the average of the Great Falls prices. Figure 4.3 illustrates the price differentials between the two price series. For most of the sample, the Lethbridge price is greater than the Great Falls price, but the converse holds true during the 2011 drought period in the US.

Table 4.2: Descriptive Statistics

Price	Observations	Mean	St. Dev
No. 1 CW barley in Lethbridge cash market	903 [August 4, 2009; May 1, 2013]	206.68 $/MT	47.14
No. 2 US barley price in Great Falls	903 [August 4, 2009; May 1, 2013]	176.04 $/MT	44.89

Source: Author calculation.

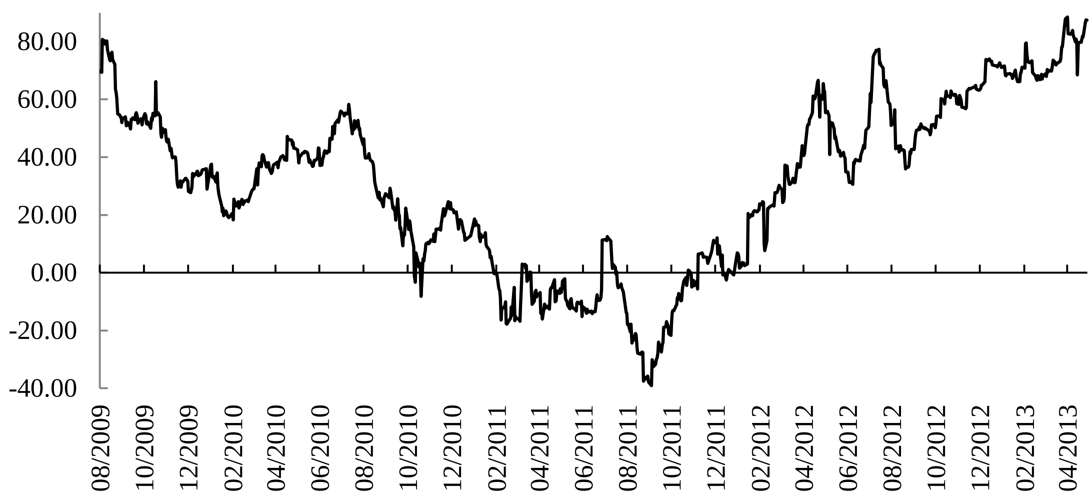

Figure 4.3: Price Differential between Lethbridge and Great Falls Feed Barley Prices, (August 4, 2009 to May 1, 2013, $/MT)

Source: Author calculation.

4.2 Time Series and Data Properties

Time series data on commodity prices are often characterized by non–stationarity as well as structural breaks (Nelson and Plosser 1982). These two characteristics affect the performance of certain econometric tests and could generate misleading results if not handled properly. Perron (1989, 1990) highlights the importance of identifying both stationarity and structural stability of data before implementing conventional time series tests.

In this section, selected stability and stationarity tests are reviewed and then applied to the feed barley data. Some interesting and relevant characteristics of the data are identified from the results.

4.2.1 Structural Stability

In this section, structural stability tests that were developed by Chow (1960), and Andrews (1993) and Andrews and Ploberger (1994) are reviewed and carried out to identify the overall structural stability of the feed barley data.

4.2.1.1 Structural change and test performance

As discussed in Perron (1989, 1990), if structural breaks exist in time series data, conventional unit root tests for stationarity can produce misleading results. For example, a standard Dickey–Fuller (DF) unit root test may under–reject the null hypothesis of unit root if the data is fundamentally unstable (Perron 1989, 1990). Thus, if a structural break can be found in the time series, the power of DF unit root tests will fall. If this is the case, we say that stationary data is mistakenly being treated as non–stationary data. It is therefore necessary to identify structural stability in the data at the beginning of this kind of testing process.

Chow (1960) developed the well-known Chow breakpoint test for data stability. The test is applicable to stationary variables with one known structural break τ in the entire series t on a linear regression model. This analysis starts by performing a Chow test under the null hypothesis of no structural break, which means an equal estimated structural coefficient in the model before and after the break[10]. Under the F distribution, if the null hypothesis can be rejected, the hypothetical breakpoint is said to be a significant structural break in the regression series of the variables.

However, a major limitation of the Chow test is that it is only valid for testing known breaks but it cannot be used to search for unknown breakpoints. For this reason, the Chow test does not provide sufficient evidence to identify the stability of data if there are unknown breakpoints in the series.

Expanding upon this, Andrews (1993) and Andrews and Ploberger (1994) developed a test to overcome the limitations of the Chow test. Their technique implements the Chow test for $t-1$ times between every two observations in the series, effectively searching for any unknown

[10] For more detail, see Chow (1960).

breakpoints. The test looks for an unknown break at $t = m$, and the null hypothesis of no breakpoint at t implies that the estimated model coefficients both before and after t are equal. To this end, supremum Wald, exponential average Wald and average Wald statistics are employed to test the null of no structural break, under a set of regularity conditions[11].

The general stability test developed by Andrews (1993) and Andrews and Ploberger (1994) can be employed to search for any significant but unknown breakpoints in time series. If there are multiple breakpoints uncovered by this method, ideally the sample can be split by the identified breakpoints. In doing this, one can maintain the accuracy and reliability of conventional DF–type unit root tests even when the data is structurally unstable.

Critically, these stability tests are applicable only to stationary economic data. Since a large amount of economic data also features the problem of a unit root (as noted by Nelson and Plosser, 1982), and without prior information about the stationarity of the series, time series data should typically be first–differenced before conducting stability tests.

4.2.1.2 Data stability and subsample statistics

Using this sample, I hypothesize that there are two possible breakpoints that could be associated with legislation concerning the removal of single desk. The first possible breakpoint would occur on December 15, 2011 when Bill C–18 was assented, and the second one would occur on August 1, 2012 when the single desk function for the CWB was officially removed.

To conduct my stability test, the Lethbridge price series, P_t^C, and the Great Falls price series, P_t^U, are transformed into logarithms, and then first differenced into series called ΔP_t^C and ΔP_t^U respectively. Subsequently, a Chow test is estimated twice using Ordinary Linear Squares (OLS) to test the two null hypotheses of no structural break on December 15, 2011, and no structural break on August 1, 2012 separately.

Table 4.3 shows the result of the Chow tests. The table shows that neither of the two hypothesized breakpoints are statistically significant. At 5% level of significance, the probabilities of the null hypotheses of no breakpoints on the test dates December 15, 2011 and August 1, 2012 are greater than 5%. Therefore, the null hypotheses cannot be rejected.

[11] See Andrews (1993) and Andrews and Ploberger (1994) for details about this test.

Table 4.3: Chow Test Results (df=2)

Test Breakpoints	December 15, 2011	August 1, 2012
F–statistic	0.4389	0.8992
Prob. F (2, 898)*	0.6449	0.4073
Log likelihood Ratio	0.8813	1.8046
Prob. Chi–square*	0.6436	0.4056

*5% level of significance.
Source: Table generated by author utilizing Eviews 6.0.

Given these results, the entire series is partitioned into two subsamples around the August 1, 2012 date to compare the market data across the CWB I period and the CWB II periods and also to help search for any underlying breakpoints in the series. The first subsample, Subsample I, contains 722 observations over a period of approximately two crop years, from August 4, 2009 to July 31, 2012. The data in Subsample I captures the Western Canadian feed barley cash market price in the CWB I period. The second subsample, Subsample II, includes 181 observations in the CWB II period (to the most recently available data), from August 1, 2012 to May 1, 2013.

Table 4.4 shows the descriptive statistics of the data within the subsamples. The mean of P^C is higher than the mean of P^U in both subsamples. Within Subsample I, the mean of P^C is $22.24/MT higher; within Subsample II, this difference has grown to $64.12/MT.

Within Subsample I, the observations of P^C are dispersed closer to its mean than the observations of P^U, because the standard deviation of P^U is higher than the standard deviation of P^C. Conversely, within Subsample II, P^C's standard deviation is higher. This measures the higher variance of Canadian feed barley prices in the transitioning CWB II period.

Table 4.4: Descriptive Statistics of P^C and P^Uwithin in the Subsamples

Subsample	Variable	Observations	Mean	St. Dev.
I	P^C	722 [August 4, 2009; July 31, 2012]	189.04 $/MT	34.63
	P^U	722 [August 4, 2009; July 31, 2012]	166.80 $/MT	45.71
II	P^C	181 [August 1, 2012; May 1, 2013]	277.05 $/MT	10.19
	P^U	181 [August 1, 2012; May 1, 2013]	212.93 $/MT	4.39

Source: Author calculation.

Following the Chow test, the Andrews (1993) and Andrews and Ploberger (1994) test is implemented within the subsamples to search for other underlying breakpoints in the series. Eviews V6.0 is used to carry out this test. An almost identical test to the Andrews (1993) and Andrews and Ploberger (1994) test is actually used in the E-Views software, and it is known as the Quandt–Andrews test. However, for the latter test, as a default each subsample for the test needs to be symmetrically trimmed to avoid the occurrence of the breakpoint at the head and the tail of the series.

Table 4.5 shows the results of the Quandt–Andrews test. At a 5% trimming level, the first 2.5% and the last 2.5% of the observations are removed. The trimmed Subsample I covers a test period from September 5, 2012 to July 31, 2012; the trimmed Subsample II covers a test period from August 16, 2012 to April 18, 2013. The null hypothesis of no breakpoint within the subsamples cannot be rejected at a 5% level of significance in both of the testing periods. Therefore no other significant breakpoints are identified by the Quandt–Andrews test within the trimmed subsamples.

Table 4.5: Quandt–Andrews Test Result

Statistic	Subsample I		Subsample II	
	Value	Prob.*	Value	Prob.*
Maximum F–statistic	7.6870	0.3341	6.0231	0.5570
Exp F–statistic	1.6022	0.3058	0.5585	0.8898
Ave F–statistic	2.3317	0.2942	0.6181	0.9880

*5% level of significance.
Source: Table generated by author utilizing Eviews 6.0.

In sum, the results of the two Quandt-Andrews stability tests on the subsamples do not allow rejection of the null hypothesis of no significant structural change in spot feed barley prices across the Canada–US regional feed barley market, even in the period since the CWB single desk marketing powers were removed.

4.2.2 Stationarity

In this section, statistical tests pertaining to stationarity of the data are reviewed and then applied to the subsamples. The test results provide information about model selection in the latter sections of the thesis.

4.2.2.1 Non–stationary data and test performance

Spurious or false positive interpretation problems may occur in regressions of two non–stationary variables. According to Granger and Newbold (1974), spurious regression can be identified by a high value for the coefficient of determination even if the variables are independent of each other. When a spurious regression problem is present, most conventional test statistics will not retain good statistical characteristics, making regression models unreliable with respect to hypothesis testing (Granger and Newbold 1974). While misleading regression models typically produce results like a high R^2 combined with a low Durbin–Watson statistics, Granger and Newbold (1974) also found that in a spurious regression, the rejection frequency of null hypotheses on the variable coefficients increases even as the sample size grows. Phillips (1986) also showed this effect over asymptotic samples.

As mentioned in Section 4.2.1, the performance of standard unit root tests is affected by data stability. Perron (1989) found that structural breaks in testing variables could cause an under–rejection problem of the null hypothesis. In other words, when there are structural breaks in data, an I(0) or stationary process may be mistakenly categorized as an integrated of order one or I(1) (first differenced stationary) process. Also, Leybourne et al. (1998) found that if the data series was a true I(1) process, structural breaks in the series would lower the power of unit root tests. They found that, for instance, if the break occurred early in the series, Dickey–Fuller (DF) tests could lead to spurious rejection of the null hypothesis. In this analysis, since stability of the data was shown in Section 4.2.1, the chance of producing such a distorted result is minimized with respect to the unit root tests on the subsamples.

Amongst a variety of unit root tests, the so-called augmented Dickey–Fuller (ADF) test is favored over the regular DF test in this instance. Since the null DF hypothesis functions under the assumption that errors are not serially correlated, the DF test is inappropriate when the series is actually an autoregressive process (Greene 2003). The ADF test overcomes this limitation in the DF test by including p lagged terms of the dependent variable as an autoregressive process in the test mode. In this test, the t-statistic is employed to test the significance of the null hypothesis of non–stationarity. Also, certain information criteria are used to determine the optimal test lag length p.[12]

[12] Ch. 20 "Econometric Analysis", 5th ed. by Greene, see pp 643.

Like conventional DF–type tests, the ADF test also lacks statistical power (Hassler and Wolters 1994). To resolve this problem, Kwiatkowski et al. (1992) suggested exercising the test on the null of stationarity instead of on unit root. To this end, they developed the so-called Kwiatkowski–Phillips–Schmidt–Shin (or KPSS) test to data stationarity.

In fact, applied researchers have often used the KPSS test as a complement to the ADF test. The null hypothesis of stationarity with KPSS is formulated as zero variance of the residual from an autoregressive process on the variable so that under the null, the variable is stationary. In fact, a modified Lagrange Multiplier statistic is employed to test the significance of this null.[13]

Considering the two tests, variables could be I(1) processes only when the ADF null of I(1) is not rejected, coupled with the KPSS null of I(0) being rejected at the same time. If the KPSS null cannot be rejected, and even if the ADF null is not rejected, the variables could still be I(0) or fractionally integrated. Regarding the latter, when variables are fractionally integrated, the integrated orders of the variables are fractions, instead of being integers meaning that long memory models would be needed to establish the order of integration (Greene 2003). This will be discussed along with the test results in Section 4.2.2.2.

4.2.2.2 Data Stationarity

In this section, the ADF test and KPSS test are used to check for stationarity of the variables. The tests are implemented separately on P^C and P^U in the subsamples.

Previous studies (Clark 1995; Thoma and Wilson 2007; Wårell 2006) examining time–series price data in a similar manner apply unit root tests to the data in level form. This approach takes the cases of I(1) and I(0) into consideration but neglects a situation where the variables could be fractionally integrated. Fractionally integrated data must be treated differently from I(1) or I(0) processes (Niquidet and Sun 2012). Long memory models, which accommodate the effect of very long term autocorrelation and its persistent response to shocks need to be used for fractionally integrated data, instead of conventional regression models for I(0) data or VAR models for I(1) data (Greene 2003). In this analysis, for completeness the case of fractionally integrated data will also be considered to ensure I select an appropriate model and data generating process.

[13] See Kwiatkowski et al. (1992) for details.

Two procedures will be considered to avoid misidentifying the type of stationarity in the data. First, I will test the null hypothesis of unit root and stationarity in the data series utilizing the ADF test and KPSS test. Note again, that if the null hypotheses in each of the two tests are rejected, the variables may actually be fractionally integrated (Niquidet and Sun 2012). Following this first step, I will implement the tests on both level data and first–differenced data. Since the first–differenced values of true I(1) data must be I(0), a finding of difference stationary data will show that the variables are actual I(1) processes.

Table 4.6 shows the results of unit root tests on the feed barley price data in level form. In Subsample I, the results show that both P^C and P^U might contain a unit root. The ADF test is implemented, in which an assumed constant is the only exogenous variable and the lag length is specified as zero by the Schwarz criterion[14]. In fact, the null hypothesis of unit roots in the data series cannot be rejected in either series, since the ADF test statistics are greater than the critical values at 5% significance. In addition, the KPSS test is performed on the same model. The null of stationarity is rejected, since the KPSS statistics for both the variables are greater than the listed critical values at a 5% level of significance.

For Subsample II, my test results also show that P^C and P^U could be I(1) variables. The ADF null of a unit root cannot be rejected for either variable, since the ADF statistics are greater than the critical values at a 5% level of significance. And the KPSS null hypothesis of stationarity can be rejected for both of these variables, since the KPSS test statistics are greater than the critical values at the 5% level.

In summary, my results from the unit root tests on the data in levels indicate that P^C and P^Umay be I(1) processes in both Subsample I and Subsample II.

Table 4.6: Unit Root Test Results on Data in Level

		ADF Test		KPSS Test
Subsample	Variable	T–Statistic	Prob.*	LM–Statistic**
I	P^C	0.9698	0.9964	2.9992
	P^U	-1.2137	0.6703	2.7649
II	P^C	-0.7021	0.8424	1.4012
	P^U	-1.8043	0.3776	0.6644

*5% level of significance. **Asymptotic critical value at 5% level of significance is 0.4630.

[14] For more detail on information criterion, see Greene (2003).

Source: Table generated by author utilizing Eviews 6.0.

Next, Table 4.7 shows the results of the ADF test and the KPSS test on the data, but done in first differences. The results confirm that the first–differenced price variables are stationary in the subsamples, as expected. At a 5% level of significance for both variables in both of the subsamples, the ADF null hypothesis on the variables can be rejected while the KPSS null of stationarity cannot be rejected. These results are consistent with the prior results from the tests on the level data.

Table 4.7: Unit Root Test Results on Data in First Difference

Subsample	Variable	ADF T–Statistic	Prob.*	KPSS LM–Statistic**
I	P^C	-25.7839	0.0000	0.2798
	P^U	-30.7679	0.0000	0.1544
II	P^C	-13.4167	0.0000	0.0926
	P^U	-16.2790	0.0000	0.0969

*5% level of significance. **Asymptotic critical value at 5% level of significance is 0.4630.
Source: Table generated by author utilizing Eviews 6.0.

As the overall test results on the price variables in level and in first difference indicate, these variables can be treated as I(1) processes. Instead of a conventional regression model or a long memory model, econometric models that are designed for non–stationary I(1) analysis will be used to carry out the testing in the remainder of this chapter.

4.2.3 Cointegration

In this section, cointegrating relations between the feed barley price series are considered as a characteristic of the data since the variables are integrated at the same order. A conceptual testing procedure developed on the basis of Engle and Granger’s (1987) definition of cointegration is used in the first stage of this analysis to examine the nature of cointegration between the variables in a preliminary fashion. These results are used to help select the model that will be used to carry out the additional empirical tests.

4.2.3.1 A Model of Cointegration

According to Engle and Granger (1987), two variables that are integrated at the same order are cointegrated if the time series of the residuals from their linear combination is stationary. In other words, in a linear regression model,

$$\boldsymbol{Y_t = \beta_0 + \beta_1 X_t + \varepsilon_t} \qquad 4.\ 1$$

with $\boldsymbol{Y_t}$ and $\boldsymbol{X_t}$ assumed to be two I(d) processes (d≥1). If the estimated residuals, $\boldsymbol{\hat{\varepsilon}_t}$**,** are stationary (an I(0) process), then $\boldsymbol{Y_t}$ and $\boldsymbol{X_t}$ are said to be cointegrated.

The definition of cointegration literally focuses on the differentials between the variables (Fackler and Goodwin 2001). Applicable to this thesis, finding a cointegrating relationship between the feed barley price series in spatially separated markets implies that the residuals from their linear combination have a zero–mean equilibrium error (Kennedy 2008). In other words, in the long run, these prices, according to Fackler and Goodwin (2001), will converge toward common behavior. In turn, this means that the markets will likely reach equilibrium, presumably through a process like arbitrage. Therefore, although a finding of cointegration between price series is not definitive proof of perfect market integration or market efficiency, it is strongly indicative of the existence of some level of price or information transmission across the spatial markets (Fackler and Goodwin 2001).

4.2.3.2 Engle–Granger cointegration test

Since $\boldsymbol{P^C}$ and $\boldsymbol{P^U}$ were identified as I(1) processes in Section 4.2.2, in fact there could potentially be a cointegrating relationship between them. In this case, cointegration can be tested in a conceptual way. According to Engle and Granger's (1987) definition of cointegration as applied to this study, if the series of the estimated residuals, $\boldsymbol{\hat{\varepsilon}_t}$, from the regression of $\boldsymbol{P^C}$ and $\boldsymbol{P^U}$**,**

$$\boldsymbol{P_t^C = \beta_0 + \beta_1 P_t^U + \varepsilon_t} \qquad 4.\ 2$$

is I(0), then the I(1) variables $\boldsymbol{P^C}$ and $\boldsymbol{P^U}$ are cointegrated.

Various related research interprets time series cointegration as a condition for which the prices of a single commodity across two distinct markets should converge in a long–run equilibrium (Fackler and Goodwin 2001). For this reason, cointegration tests have been employed to investigate market integration and price transmission in various industries, as was reviewed in Section 3.2.

Here, cointegration tests on the feed barley price series are used to investigate the structure of the transition within this regional Canada–US market after single desk marketing in Canada was eliminated. Referring again to Fackler and Goodwin's (2001) work, this thesis postulates that if the cash market prices of feed barley in Canada and the US have reached equilibrium in the long run, then prices in the regional market will be econometrically integrated to some extent. Under the alternative hypothesis, if CWB I was in fact able to prevent Canadian and US feed barley markets from being better integrated, under CWB II, the degree of market integration in the region should be significantly enhanced, assuming no other exogenous influence. But under the null hypothesis assumed here, and based on conclusions from Schmitz and Gray's (2000) and Clark's (1995) studies, suggest that although single desk power was removed from the Western Canadian barley marketing in 2012, it is possible that the Canada–US regional feed barley market would not show any significant change in the degree of market integration over the new CWB II era. To test the hypothesis, an Engle–Granger procedure is used to broadly examine the significance of the policy change on cointegrating relations. A system–based cointegration test is conducted in Section 4.4 after an appropriate model is specified for the data.

4.2.3.3 Engle–Granger cointegration test results

Here, the Engle–Granger approach is used to test for cointegration between the relevant price series. This starts with a linear regression model, where simple regressions of P^C and P^U are estimated using OLS within each subsample. An ADF test is then used to test the stationarity of the residuals from the OLS regressions. In addition, the test is done on two test equations. The first equation includes an intercept, while the second equation includes both an intercept and a trend term.

Table 4.8 shows the statistics from the estimation of the first equation with just the intercept for each subsample. It indicates that the series of the residuals are I(1) processes for both of the subsamples. The t–statistics for the residuals from Subsample I and Subsample II are both greater than the critical values at a 5% level of significance. This implies that the ADF null hypothesis of unit root cannot be rejected at the 5% level, which in turn indicates that P^C and P^U may not be cointegrated in both subsamples.

The ADF test results stem from estimation of a simple linear equation with both an intercept and a trend. These show that P^C and P^U are not cointegrated in both subsamples, where the results are reported in Table 4.9. Since the ADF null hypothesis cannot be rejected at the 5% level, the series of residuals from this latter regression are likely to be non–stationary. Note that this finding is consistent with the prior results found estimating the equation with just the intercept.

Table 4.8: ADF Test on Residuals from Estimation on Equation with Intercept

Subsample	T–Statistic	Prob.*
I	-2.0051 (-2.8654)	0.2655
II	-1.1998 (-2.8776)	0.6743

*5% level of significance.
Source: Table generated by author utilizing Eviews 6.0.

Table 4.9: ADF Test on Residuals from Estimation on Equation with Intercept and Trend

Subsample	t–Statistic	Prob.*
I	-3.0728 (-3.4161)	0.1137
II	-2.1742 (-3.4353)	0.5006

*5% level of significance.
Source: Table generated by author utilizing Eviews 6.0.

This result showing no cointegration in fact suggests that a vector autoregressive (VAR) model should be used over a vector error correction model (VECM) in order to carry out the remaining time series analysis. However, it is worth noting one weakness of the Engle–Granger procedure when a DF–type unit root test is used to test the stability of the estimated errors, or a cointegrating vector in this case. First of all according to Greene (2003), DF–type test tables are inappropriate for the estimated errors when errors are autocorrelated. But even if some augmented approach is used to address the autocorrelation problem, a rejection of the null of I(1) does not necessarily prove that the variables are cointegrated (Greene 2003). Therefore, the Engle–Granger results only yield a somewhat "blurred" image of the true cointegrating relations between the variables. Furthermore, Greene (2003) concludes that in using the Engle–Granger procedure, studies "will proceed as if the finding had been affirmative". To address this latter issue, a system–based Johansen cointegration test will be estimated (Section 4.4) as a complementary test to the basic Engle–Granger procedure.

4.3 Vector Autoregressive Model

Since we found that the price variables are both I(1) but are non–cointegrated processes through both of the subsamples, a VAR system estimation is favored over conventional single–equation regression models. This model is introduced here. Most importantly, a VAR needs to be specified with an optimal length order for the data.

4.3.1 Overview of VAR

The autoregressive integrated moving average (ARIMA) model, developed by Box and Jenkins (1970) was the predecessor of related VAR–type models. Designed for non–stationary time series data analysis, an ARIMA model requires I(1) data to be first–differenced in order to become stationary. The ARIMA model is a hybrid, consisting of an autoregressive process for the regressors and a moving average process for the errors. Unlike traditional regression models, this approach reduces the form of the model and attempts to identify relationships from the past behavior of the data. Although the ARIMA approach was an innovation for time–series data analysis, it was complex and inevitably biased since it required the researchers' own judgment to help identify the model (Kennedy 2008).

The class of so-called VAR models evolved from the early ARIMA models. Removing the moving average dimension from ARIMA models, a VAR model has the general form,

$$\boldsymbol{Y_t} = \boldsymbol{\mu} + \sum_{\boldsymbol{i=1}}^{\boldsymbol{p}} \boldsymbol{A_i Y_{t-i}} + \boldsymbol{\varepsilon_t} \qquad 4.3$$

with all operators as listed previously. In the VAR model to be estimated in this analysis, $\boldsymbol{Y_t} = [\boldsymbol{P_t^C}\ \boldsymbol{P_t^U}]'$, where $\boldsymbol{\mu}$ and $\boldsymbol{A_i}$ are matrices of parameters to estimate, p is the pre–identified lag length and $\boldsymbol{\varepsilon_t}$ is the residual or error term.

As an improvised and simplified ARIMA approach, VAR has been used to analyze and model non–stationary time series data (Kennedy 2008). In effect, VAR models are able to illustrate interrelationships between variables using reduced form equations. This gives VAR modeling advantages in revealing the dynamics within data as compared to structural models (Kennedy 2008).

4.3.2 Model Specification

A VAR model needs to be specified over an optimal lag length selection (Greene 2003). This can be done by testing the null hypothesis that the lag coefficients in each equation in the VAR model are jointly zero, using a likelihood ratio test to test the null. The number of non–zero lag coefficients is the appropriate lag length that is selected through this process[15].

4.4 Market Integration: Cointegration Testing in VAR

As discussed in Section 4.2.3, the Engle–Granger procedure has certain known weaknesses and in for my purposes, I will perform a system–based Johansen cointegration test as a complement to the Engle-Granger procedure.

4.4.1 Johansen Procedure for Cointegration Testing

Johansen (1988, 1992) developed a system–based cointegration test for VAR. Greene (2003) summarizes the procedure as follows. The Johansen procedure starts from a simple VAR,

$$\boldsymbol{y_t} = \boldsymbol{\Gamma_1 y_{t-1}} + \boldsymbol{\Gamma_2 y_{t-2}} + \cdots + \boldsymbol{\Gamma_p y_{t-p}} + \boldsymbol{\varepsilon_t} \qquad 4.\ 4$$

Here, a null hypothesis of r or fewer cointegrating vectors is tested. The matrix trace statistic developed by Johansen (1988, 1992) is the test statistic employed;

$$\text{Trace Statistic} = -T\sum_{i=r+1}^{M} ln[1-(r_i^*)^2]$$

Recall M is the number of variables, T is the number of the available observations, and r_i^* is the correlation of the ith canonical variates. As detailed by Greene (2003), this test statistic can be represented by a the chi-square distribution with $M - r$ degrees of freedom, or to alternative significance tables given by Johansen and Juselius (1990) and Osterwald–Lenum (1992). The procedure starts from $r = 0$ and continues until the null hypothesis is rejected[16].

Specifically, if a cointegrating relationship is discovered using this testing procedure, a vector error correction model (VECM) needs to be estimated to examine short–run and long–run causality between the chosen variables. Conversely, if the chosen variables are not found to be

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[15] Ch. 19 "Econometric Analysis", 5th ed. by Greene, see pp 564 for details.
[16] Ch. 20 "Econometric Analysis", 5th ed. by Greene, pp 657 for details.

cointegrated, the VAR(p) model as specified in 4.4 must be used to examine the structure of the data.

4.5 Price Transmission: Causality Testing

In this section, the concept of Granger causality is reviewed, and an appropriate test procedure for the data in this study is illustrated. For this thesis, this test is used to examine the significance of changes in the direction of price transmission between P^C and P^U over both CWB I and CWB II periods.

4.5.1 Definition of Granger Causality

Granger (1969) developed the concept of causality in time series by focusing on the lead/lag relationship in data. Accordingly, variable Y_t is said to be Granger caused by variable X_t if the historical values of the latter help to predict the current values of the former (Greene 2003). This sort of causality also seems to depict the economic reality that price movements in separate markets do not usually occur simultaneously, because a delay on a price decision is inevitable in any commodity arbitrage (Fackler and Goodwin 2001). Therefore it is sufficient for cointegration analysis (Hassapis et al. 1999) that if P^C and P^U are cointegrated, there must be significant Granger causality between them.

In this study, the general VAR (4.3) takes a form depicting a bivariate VAR(p) process;

$$\begin{bmatrix} \boldsymbol{P}_t^C \\ \boldsymbol{P}_t^U \end{bmatrix} = \sum_{i=1}^{p} \begin{bmatrix} \boldsymbol{\alpha}_i^{C1} & \boldsymbol{\alpha}_i^{C2} \\ \boldsymbol{\alpha}_i^{U1} & \boldsymbol{\alpha}_i^{U2} \end{bmatrix} \begin{bmatrix} \boldsymbol{P}_{t-i}^C \\ \boldsymbol{P}_{t-i}^U \end{bmatrix} + \boldsymbol{u}_t \qquad 4.5$$

where P_t^U is not Granger–causing for P_t^C, if $\alpha_i^{C2} = 0$, where $i = 1,2, \dots, p$. This description covers the null hypothesis of Granger non–causality. Compared with typical coefficient tests in regression, this concept of causality boils down to testing whether the relevant variable coefficients are zero or not and provides a way for interpreting the VAR model in terms of the strength of relationships between the variables (Kennedy 2008). Once again, it is worth noting that the test can only be implemented on stationary variables using either chi–square or F–statistics, based on a Wald test (Kennedy 2008).

4.5.2 Granger Causality Test for Non–stationary Data

While significant Granger causality is sufficient to conclude that there is cointegration between variables, in fact Granger causality is not only able to identify movements in the price data but also to identify any asymmetric price transmission processes between markets (Fackler and Goodwin 2001). What this means is that although there may not be significant cointegrating relations found between variables, there may still exist uni– or bi–directional Granger causality between prices in the two markets.

A finding of Granger causality between the two markets analyzed in this study would indicate that strong price signals are being transmitted across the Lethbridge–Great Falls regional feed barley market. And recall that according to its definition, if one price Granger causes another, the latter can be predicted not only from its own historical performance but also from the historical performance of the former.

We must also improvise our Granger causality tests since the test is only valid for stationary data. When the data is not stationary, the Wald statistic that is typically used in Granger causality testing is not asymptotically distributed as a chi–square distribution (Toda and Yamamoto 1995). Therefore, Toda and Yamamoto (1995) developed a technique to render conventional Granger causality tests appropriate for non–stationary data. They improved the test by adding extra lags as exogenous variables into the VAR model. They also showed that the number of extra lags should equal the maximum integration order of the variables.

In this analysis, since the data series are I(1), one more lagged value of the variables can be added as an exogenous variable into the model,

$$\begin{bmatrix} \boldsymbol{P}_t^C \\ \boldsymbol{P}_t^U \end{bmatrix} = \sum_{i=1}^{p} \begin{bmatrix} \boldsymbol{\alpha}_i^{C1} & \boldsymbol{\alpha}_i^{C2} \\ \boldsymbol{\alpha}_i^{U1} & \boldsymbol{\alpha}_i^{U2} \end{bmatrix} \begin{bmatrix} \boldsymbol{P}_{t-i}^C \\ \boldsymbol{P}_{t-i}^U \end{bmatrix} + \begin{bmatrix} \boldsymbol{\alpha}_{p+1}^{C1} & \boldsymbol{\alpha}_{p+1}^{C2} \\ \boldsymbol{\alpha}_{p+1}^{U1} & \boldsymbol{\alpha}_{p+1}^{U2} \end{bmatrix} \begin{bmatrix} \boldsymbol{P}_{t-p-1}^C \\ \boldsymbol{P}_{t-p-1}^U \end{bmatrix} + \boldsymbol{u}_t \qquad 4.6$$

After the VAR(p+1) model (4.6) is estimated, Toda and Yamamoto (1995) ensure that the null hypothesis of $\boldsymbol{\alpha_i^{C2} = 0}$ or $\boldsymbol{\alpha_i^{U1} = 0}$ can be tested using the usual Wald test with p degrees of freedom under the null, if the error term $\boldsymbol{u}_t$ is not autocorrelated.

If significant Granger causality is discovered between the price variables, this implies that the price signals are being transmitted from one market into the other but with p periods of lag. If true, the presence of measurable Granger causality means that the history of the feed barley price series in one market can help improve predictions on the movement of the feed barley price in the other market.

4.6 Simulation of Price Reactions: Impulse Response Functions

Once a model form is established, price transmissions between P^C and P^U in a dynamic market can be simulated through the estimation of an impulse response function on the system (Fackler and Goodwin 2001).

The impulse response function, as noted by Greene (2003), is essentially a conceptual experiment in disturbing an estimated system in equilibrium. In a VAR model, dynamic stability is achieved if the characteristic roots of the estimated coefficient matrix have modulus less than one (Greene 2003). Accordingly, if a system is stable, the equilibrium relationships can be found with the final form of the system. Following this concept, the impulse response function allows us to examine how P^C and P^U would react to a (hypothetical) exogenous shock in the regional market, including showing us how long the markets take to return to equilibrium after the shock. For example, if demand for feed barley in one market increases by a few dollars, the other market price may well react in a significant manner to this shock over a given time horizon.

On basis of the VAR (4.5) estimations on Subsample I and Subsample II, the relative dynamic stability of these two bivariate systems can be visualized using this method. Given the information contained in the estimation results, the impulse response functions simulate the reactions of P^C and P^U to an exogenous shock and show the differential between the current values of the variables and the long-run estimated equilibrium[17].

A plot of the impulse response functions is a useful way to observe the dynamic stability of the system (Greene 2003). Since the plot of an impulse response function is a combination of the calculated differentials from the simulated shock, if the values of the function converge to a constant amount, we can say that the system is relatively stable. Conversely, if the values of the calculated functions diverge, we can say that the system is relatively unstable. These interpretations will be useful in describing the behavior of the feed barley price series over both space and time in this regional market.

[17] Ch. 19 "Econometric Analysis", 5th ed. by Greene, pp 593 for details.

CHAPTER FIVE

RESULTS

5.1 Vector Autoregressive Model Specification

To begin, the optimal lag order must be selected for the unrestricted VAR (4.4), with $\boldsymbol{Y_t} = [\boldsymbol{P_t^C}\ \boldsymbol{P_t^U}]'$, and $\boldsymbol{P^C}$ and $\boldsymbol{P^U}$ are the endogenous variables. Either the Akaike information criterion (AIC), the Schwarz criterion (SC), or the Hannan–Quinn criterion (HQC) are used to choose the optimum lag order for VAR (4.4), based on the data. While the AIC is often used as a reference criterion because it tends to overestimate the order, here the SC and HQC are preferred because they consistently estimate the lag order (Greene 2003), Also, the optimal lag order should ensure that the residuals from the VAR estimation are not auto–correlated. Recall that one key assumption of the Toda–Yamamoto Granger causality test is that the error term cannot be autocorrelated. As a general rule, for the purpose of simplifying the model a lower order is preferred.

Table 5.1 presents these results for Subsample I and Subsample II. For Subsample I, SC selects the lowest lag order of one, while AIC and HQC select two periods of lag. SC, HQC, and AIC select one lag for Subsample II. More details about these lag selection criteria can be found in Greene (2003).

Table 5.1: System–wide Lag Order Selection

Subsample	Lag	AIC	SC	HQC
I	0	-1.5201	-1.5073	-1.5151
	1	-11.8499	-11.8115*	-11.8351
	2	-11.8695*	-11.8055	-11.8448*
II	0	-8.8322	-8.7957	-8.8174
	1	-14.6737*	-14.5644*	-14.6293*

* Optimal lag order selected by the criterion.
Source: Table generated by author utilizing Eviews 6.0.

To confirm optimal lag order for the VAR models on the subsamples, I also conducted a VAR residual test on autocorrelation, a process that ensures the VAR residuals are not autocorrelated for the Toda–Yamamoto Granger causality test. Table 5.2 shows the results from this VAR residual test for the subsamples when one lag is selected for the model. The result for

Subsample I indicates that if one lag is selected for the VAR model, the null hypothesis of residual non-autocorrelation can be rejected at the 5% level of significance. For the data in Subsample I, although a single lag gives the VAR model a simpler structure, I find that a two–lag specification is preferred in order to avoid the problem of residual autocorrelation. However, as Table 5.2 shows, one lag is the optimal lag length for the VAR model on Subsample II, where the null hypothesis of residual non-autocorrelation cannot be rejected at 5%.

Table 5.2: VAR(1) Residual Autocorrelation Test

Subsample	Lag	LM-Stat	Prob.*
I	1	20.8375	0.0003
	2	3.9267	0.4160
II	1	6.1403	0.1889
	2	0.7607	0.9436

*5% level of significance.
Source: Table generated by author utilizing Eviews 6.0.

Accordingly, the specified VAR (4.4) should include values of the independent variables for two lag periods in Subsample I, and one lag period for Subsample II. With two lags, VAR (4.4) has the following form for Subsample I,

$$\boldsymbol{P_t^C = \alpha_1 + \beta_1^{C1} P_{t-1}^C + \beta_1^{C2} P_{t-2}^C + \beta_1^{U1} P_{t-1}^U + \beta_1^{U2} P_{t-2}^U + \varepsilon_t^C} \quad 5.1.1$$
$$\boldsymbol{P_t^U = \alpha_2 + \beta_2^{C1} P_{t-1}^C + \beta_2^{C2} P_{t-2}^C + \beta_2^{U1} P_{t-1}^U + \beta_2^{U2} P_{t-2}^U + \varepsilon_t^U} \quad 5.1.2$$
5. 1

With one lag, VAR (4.4) has the following form for Subsample II,

$$\boldsymbol{P_t^C = \alpha_1 + \beta_1^C P_{t-1}^C + \beta_1^U P_{t-1}^U + \varepsilon_t^C} \quad 5.2.1$$
$$\boldsymbol{P_t^U = \alpha_2 + \beta_2^C P_{t-1}^C + \beta_2^U P_{t-1}^U + \varepsilon_t^U} \quad 5.2.2$$
5. 2

These specifications (VAR (5.1) and VAR (5.2)) are used to carry out a system–based cointegration test, a Granger causality test, and also to generate and plot associated impulse response functions for Subsample I and Subsample II respectively.

5.2 Market Integration: System–based cointegration test results

As described, the VAR–based Johansen procedure is applied individually to the two models to achieve more accurate results. Each is differentiated by the form of their cointegrating equations. One cointegration equation includes an intercept, while the other includes an intercept as well as a linear trend. The Johansen procedure continues to test the null hypothesis that the cointegration rank equals r until the null can be rejected. If the trace statistic (Section 4.4.1) exceeds the given critical value at a 5% level of significance, then the null can be rejected.

Table 5.3 presents the results of the Johansen cointegration test. Tests on Equation I and Equation II show that there is no cointegrating equation to be found in either of the subsamples. The null hypothesis of $r = 0$ cannot be rejected for each of the subsamples. The trace statistics, in a form of a likelihood ratio test, are not greater than given critical values as quoted from MacKinnon et al. (1999),while we note that the latter differ sligtly from the original tables found in Johansen and Juselius (1990). In sum, these results are consistent with the results derived from the Engle–Granger procedure in Section 4.2.3.

Table 5.3: Johansen Cointegration Test Results on Subsamples (Lag Interval: 1 to 1)

Subsample	Hypothesized No. of CE(s)	Trace Statistics (critical values)	
		Equation I: Intercept	Equation II: Intercept and Linear Trend
I	None	5.3362 (15.4947)	14.5700 (18.3977)
	At most 1	0.0225 (3.8415)	1.3974 (3.8415)
II	None	7.6387 (15.4947)	20.1167 (18.3977)
	At most 1	0.9931 (3.8415)	5.2691 (3.8415)

Source: Table generated by author utilizing Eviews 6.0.

To interpret, the Johansen statistics indicate that the Lethbridge and Great Falls feed barley markets do not exhibit significant change over the sample period with respect to market integration. The two spot markets were not integrated over the CWB I era, and given up-to-date data, they are not integrated over the CWB II era either. Simply put, the elimination of single desk marketing in the Canadian barley market appears to have had no effect on market integration in the region. This particular finding accords with the prior conclusions of Schmitz and Gray (2000), and Clark (1995), and corresponds to the testable proposition of CASE II in Section 3.3.

5.3 Price Transmission: Granger Causality Test Results

VAR (5.1) and VAR (5.2) are modified to carry out a Granger causality test for non–stationary data for both Subsample I and Subsample II. The test is used to identify price transmission directionality between the Lethbridge and Great Falls markets.

Considering the Toda–Yamamoto procedure described earlier, one additional lagged value of each variable is added as an exogenous variable into VAR (5.1) and VAR (5.2). The modified VAR model for the Toda-Yamamoto Granger causality test for Subsample I is,

$$\boldsymbol{P_t^C = \alpha_1 + \beta_1^{C1} P_{t-1}^C + \beta_1^{C2} P_{t-2}^C + \beta_1^{U1} P_{t-1}^U + \beta_1^{U2} P_{t-2}^U + \gamma_1^C P_{t-3}^C + \gamma_1^U P_{t-3}^U + \varepsilon_t^C} \quad 5.3.1$$

$$\boldsymbol{P_t^U = \alpha_2 + \beta_2^{C1} P_{t-1}^C + \beta_2^{C2} P_{t-2}^C + \beta_2^{U1} P_{t-1}^U + \beta_2^{U2} P_{t-2}^U + \gamma_2^C P_{t-3}^C + \gamma_2^U P_{t-3}^U + \varepsilon_t^U} \quad 5.3.2$$

5. 3

and for Subsample II,

$$\boldsymbol{P_t^C = \alpha_1 + \beta_1^C P_{t-1}^C + \beta_1^U P_{t-1}^U + \gamma_1^C P_{t-2}^C + \gamma_1^U P_{t-2}^U + \varepsilon_t^C} \quad 5.4.1$$

$$\boldsymbol{P_t^U = \alpha_2 + \beta_2^C P_{t-1}^C + \beta_2^U P_{t-1}^U + \gamma_2^C P_{t-2}^C + \gamma_2^U P_{t-2}^U + \varepsilon_t^U} \quad 5.4.2$$

5. 4

In these equations, $\boldsymbol{\gamma}$ is the coefficient matrix of the exogenous lagged values of the variables. Once again, this specification ensures that given the situation where degrees of freedom equal the specified lag interval, the Wald statistics should have an asymptotic chi–square distribution (Toda and Yamamoto 1995).

For the specified VAR models, a Granger causality test is implemented on the endogenous lagged values of the variables individually in the subsamples. In equation (5.3.1), under the null hypothesis of Granger non–causality, $\boldsymbol{\beta_1^{U1} = \beta_1^{U2} = 0}$, this means that the lagged values of P^U **(**from the previous two periods) are not helpful in predicting the value of P^C in the current period. Similarly, in equation (5.3.2), the null hypothesis of Granger non–causality is $\boldsymbol{\beta_2^{C1} = \beta_2^{C2} = 0}$. In this case, a rejection of the null means P^U Granger causes P^C and that the relevant market prices are in fact linked through time. Similarly, the null hypotheses concerning Granger non-causality, based on VAR (5.4), are $\boldsymbol{\beta_1^U = 0}$ and $\boldsymbol{\beta_2^C = 0}$.

Table 5.4 lists the results of the Toda–Yamamoto Granger causality test within the subsamples. For Subsample I, the null hypothesis of no Granger causality cannot be rejected for equation (5.3.1), while the null is not accepted (rejected) for equation (5.3.2) at a 5% level of significance. Taken together, these imply uni–directional Granger causality in Subsample I - P^U does not Granger cause P^C, but P^C Granger causes P^U. The economic interpretation of these findings is that through CWB I, the Lethbridge market was the price leader in this regional market. This possibility is listed as CASE A in Section 3.3, further implying that price transmission in the regional market is asymmetric.

For Subsample II, the null hypothesis cannot be rejected in both of the equations at the 5% level of significance. This implies that since the removal of single desk, the Lethbridge price is no longer Granger causing the Great Falls price. Given this finding, this thesis speculates that in a post single desk world, Lethbridge may have lost its price leadership status in the regional feed barley market. In addition, a specific price transmission direction cannot be identified in this new feed barley market. This possibility is listed as CASE C in Section 3.3, implying that currently, there are no informative price transmissions between the spatial markets and the markets appear to have become more distinct then previously.

Table 5.4: Granger Causality Test Results

	H_0: P^U Granger not causes P^C		H_0: P^C Granger not causes P^U	
	chi–sq Stat.	Prob.	chi–sq Stat.	Prob.
Subsample I	1.6885 (df=2)	0.4299	7.9622 (df=2)	0.0187
Subsample II	2.2642 (df=1)	0.1324	0.2744 (df=1)	0.6004

*Probability not to reject the null at 5% level of significance.
Source: Table generated by author utilizing Eviews 6.0.

5.4 Simulation of Market Price Reactions: Impulse Response Function Plots

While the modified time series causality test detected some price transmission directionality, the pattern of price transmission can also be simulated as a dynamic system. To examine these dynamics, impulse response functions are calculated on basis of the VAR (5.1) and VAR (5.2) models. Economically, when there is a price shock in one market, the reaction of prices in the other market can be examined through the lagged structure of the VAR models. An impulse response function, according to its definition, measures the reaction of a variable to the shock by comparing its current value under the effect of the shock to its equilibrium value (Greene 2003). As reviewed in Section 4.6, the IRF allows one to evaluate the relative dynamic stability of the price system.

The impulse response functions of the VAR (5.1) and (5.2) estimation for Subsample I are calculated by E-Views 6.0 and plotted in Figure 5.1. Each panel of Figure 5.1 presents the simulated responses of the price in one market to a shock from the other market over a 90–day time horizon. Note that the variables exhibit the same pattern of movement, given the exogenous shocks. The left panel shows that as there is a shock in Great Falls, the price in Lethbridge increases. This implies a potential price transmission mechanism, which the Granger causality test in Section 5.3 did not detect, moving from Great Falls to Lethbridge in the CWB I period, but I note that the size of the impulse response of P^C is quite small. Similarly, the right panel shows that as there is a shock in Lethbridge price, the price in Great Falls increases, which indeed accords with a previous finding in this study, that the Lethbridge price likely Granger causes the Great Falls price in the CWB I period.

The simulated responses of P^U to P^C also indicate that the shocks will have permanent effects on the prices in the other market, based on the Subsample I estimation. This effect may in fact be due to market stagnation caused by the CWB pool payment mechanism. Before August 1, 2012, the CWB pool payment, which was based on forward contract and price adjustments over the entire crop year, is the only representative price for Western Canadian feed barley exports. Since the Lethbridge price tended to lead the regional market, these lagged CWB pooling prices might have generated slow price adjustment speeds. Ultimately, I find that the Subsample I system is not stable for forecasting as the simulated values do not converge back to their equilibrium in the long run.

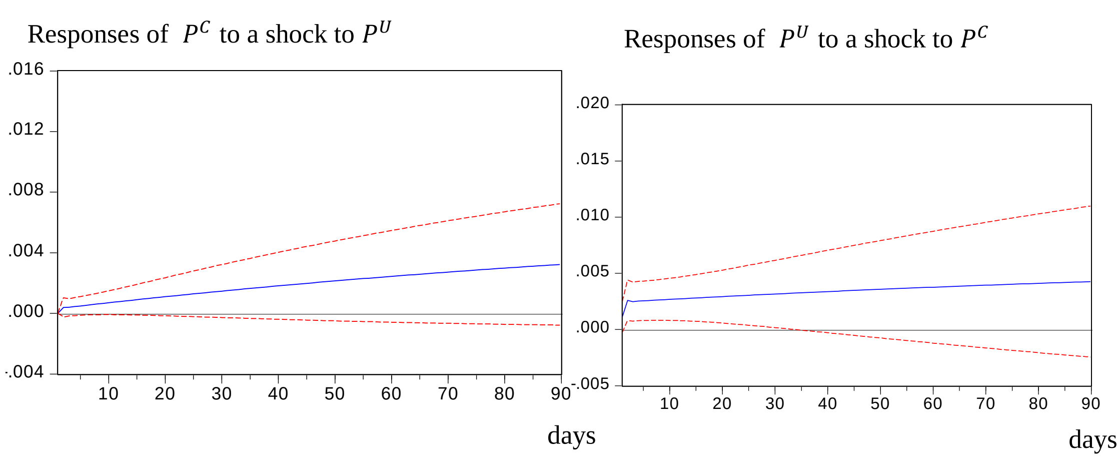

Figure 5.1: Responses to Exogenous Shocks (Subsample I Estimation)

The solid lines are impulse response functions; the dashed lines are asymptotic standard deviation.
Source: Plotted by Eviews 6.0.

Figure 5.2 presents the responses of the variables in the system from Subsample II estimation over a 90–day horizon. The two prices behave in different ways when exogenous shocks are introduced to the system. It shows that as there is a shock in Great Falls, the price in Lethbridge (the left panel) increases, but with a shock in Lethbridge, the price in Great Falls (the right panel) will decrease.

Theoretically, if price signals are being transmitted between the two markets, similar response patterns for the prices in the spatially separated markets should be observed as one integrated regional market, as Figure 5.1 shows. However, the simulated negative response of P^U to the shock in P^C does not follow the same pattern as P^C's response to the shock in P^U. A potential change in the price transmission mechanism may be one explanation. The different pattern in the responses of the prices may constitute evidence of a lesser level of price transmission efficiency. As different responses of P^U to the price signal from Lethbridge are simulated from the Subsample II estimation, the influence of the Lethbridge market may be declining over the CWB II period. This mirrors the result from the Granger causality test on Subsample II in Section 5.4. However, it is also worth noting that since the size of P^U's negative response is very small (a maximum of 0.0020), this does not represent strong evidence of a change in the price transmission pattern.

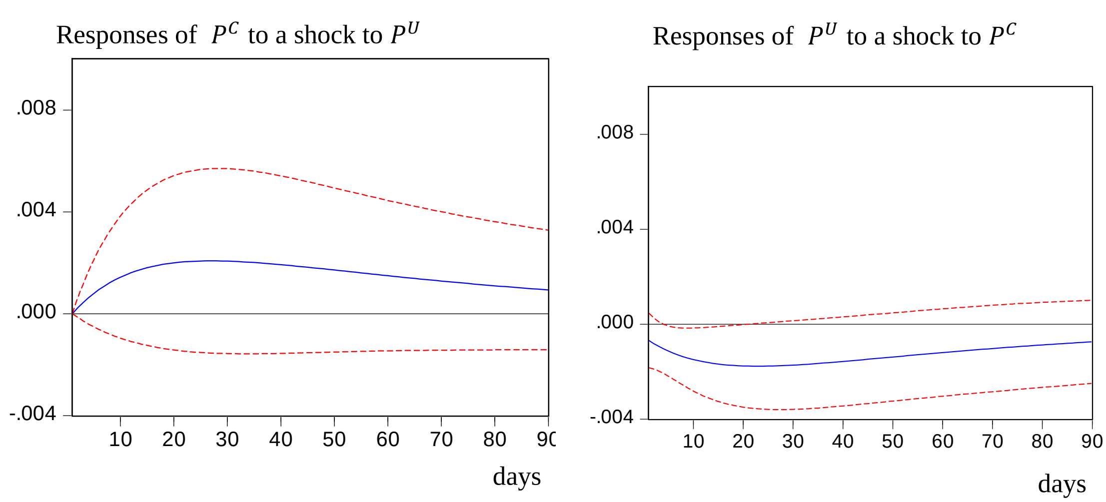

Figure 5.2: Responses to Exogenous Shocks (Subsample II Estimation)

Left panel: Response of P^C to a shock to P^U; right panel: Response of P^U to a shock to P^C.
The solid lines are impulse response functions; the dashed lines are asymptotic standard deviation.
Source: Plotted by Eviews 6.0.

The comparison between the impulse response functions for the two VAR systems provides insight about how the price in one market reacts to price signals from the other market in a simulated dynamic system. From the CWB I period to the CWB II period, a change was detected in the response of P^U to a shock in P^C. One legitimate concern about these results is the lower level of price transmission efficiency from the Lethbridge market to the Great Falls market through the transition period. However, without further analysis, the root cause of this finding is unknown at this time. However, the finding is somewhat consistent with the Granger causality test results.

However, taking into account the relatively small size of the impulse responses (less than 0.4%) into account, the differences in the impulse responses pattern between Subsample I and Subsample II may not be significant. This is not enough evidence to draw a conclusion that the removal of the CWB single desk led to a significant change in spatial price transmission within this market.

5.5 Interpretation of the Econometric Results

The removal of CWB single desk marketing brought an end to the singular exporter status of CWB I for Western Canadian feed barley export. Under the null hypothesis of this thesis, I argued that there would not likely be any significant changes in the Canada–US regional feed barley market after the policy change. To test this hypothesis, Lethbridge and Great Falls feed barley market prices were used, while various econometric tests including a cointegration test, a Granger causality test, and the development of impulse response functions from a VAR estimation were used to identify any significant changes in this market between the CWB I period (before August 1, 2012) and the CWB II period (after August 1, 2012). Furthermore, these tests are interpreted in terms of market integration, price transmission, and price reactions between the spatially separated markets.

From cointegration testing, I find no evidence supporting integration between the Lethbridge and Great Falls feed barley markets in either of the sample periods. This also implies that when single desk marketing was the policy for Canadian feed barley, the Lethbridge market was not integrated with the Great Falls market, and this relationship did not change after single desk powers were removed in Canada. Therefore, from the perspective of market integration, the

Lethbridge–Great Falls regional feed barley markets have not become integrated through the recent CWB II era.

The Granger causality tests also provided information about changes in price transmission direction in the regional market. In the CWB I period, the Lethbridge feed barley price was found to likely Granger cause the Great Falls feed barley price but not vice versa. This verifies the existence of unidirectional price transmission because only price transmission from Lethbridge to Great Falls was statistically significant before the single desk was removed. However, no significant price transmission was discovered in the CWB II period. As of August 1, 2012, the Lethbridge feed barley price is still not Granger caused by the Great Falls feed barley price, but in addition it no longer Granger causes the Great Falls price. The change in Granger causality through the two sample periods implies that the influence of the price signal from Lethbridge has become weaker in the regional feed barley market in the CWB II period than it was in the CWB I period. Therefore, in terms of price transmission, the Lethbridge feed barley market appears to have been rendered less influential in determining prices in this Canada–US regional feed barley market during the CWB II period.

A simulated price change between the Lethbridge and the Great Falls markets is also examined using impulse responses. In the CWB II period, as a shock occurs in the Lethbridge market, the simulated feed barley price in Great Falls declines, which is very different from the response in the CWB I period. However, this does support the findings from the Granger causality analysis, emphasizing that role of the Lethbridge feed barley market has likely been weakened in the CWB II period. However, the underlying reason for this effect is unknown and will require further analysis.

In summary, the null hypothesis of no significant impact on the Canada–US feed barley market cannot be rejected from the econometric analysis conducted in this thesis. However, changes in the interactions between the selected prices were detected from the Granger causality tests and the impulse response functions. The results from the Granger causality tests provided evidence of imperfect price transmission and the declining importance of the price signals from the Lethbridge market in the overall regional market. From the plotted impulse responses, there was an unusual reaction of the Great Falls price to the shock in the Lethbridge market in the CWB II testing period. This may yet support the finding from the Granger causality test but determining the underlying reason needs further analysis.

In terms of price transmission, the Granger causality result shows the declining importance of the Canadian price in leading the US price in feed barley. Also, the simulated reactions of the prices from impulse response functions have shown a difference in the response patterns of the prices to exogenous shocks in the market. However, the evidence does not show that the difference is statistically significant. Ultimately, the additional hypothesis that there would not be a significant change in price transmission across the Canada–US regional feed barley market as the CWB single desk was eliminated can be rejected based on the results of the Granger causality test. The plotted impulse response functions also weakly supported this result, but the evidence was not significant enough to draw further conclusions.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

This chapter includes a summary of the study, the conclusions drawn from the econometric tests, limitations of the study, and suggestions for further research on relevant topics.

6.1 Summary and Conclusions

The Western Canadian feed barley marketing was characterized by a dual market mechanism and is currently an open market. Under the dual market regime, producers were given options to sell feed barley in the domestic cash market, but the CWB pool was the only conduit to both foreign and domestic malting markets. Since the dual market was terminated as of August 1, 2012, feed barley has become an open market in which the CWB pool is no longer mandatory for Western Canadian feed barley export. At the same time, the CWB also lost its single seller status in Western Canadian malting barley marketing.

Although there were concerns about the negative effects on profits in western malting barley, the structural change in the market does not seem to have led to significant changes in feed barley sales. Previously, Schmitz and Gray (2000) and Clark (1995) examined the effects of removing the CWB single desk on the Canada–US barley market. Neither of those studies predicted significant changes in the Western Canadian feed barley sector with the removal of the CWB as single desk marketer.

As the CWB lost its singular exporter status, there arose a need to examine some of the economic effects of this change on the Western Canadian feed barley market using ongoing market data. The objective of this thesis is to examine the effects and reveal any significant changes in Western Canadian feed barley markets. The thesis established a hypothesis that the removal of the CWB single desk function would not lead to a significant change in Western Canadian feed barley prices or price dynamics, based on conclusions from Schmitz and Gray (2000) and Clark (1995).

Focusing on Western Canadian feed barley exports, I used spot prices for substitutable US feed barley as a market comparison. After a brief review of the Canada–US barley market, I selected feed barley prices from Lethbridge, AB and Great Falls, MT as the comparative sample. I also broke down the sample into two periods: the CWB I period in which the CWB was the single exporter of western feed barley, and the CWB II period in which the CWB does not own a monopoly seller status in Canadian grain marketing. Given this, there are three basic questions that this thesis attempts to answer:

(1) Is structural change in the Canadian barley sector associated with a significant change in Western Canadian feed barley prices relative to US feed barley prices?

(2) Is the Canadian feed barley market becoming more linked to the US feed barley market in the CWB II period after single desk was removed?

(3) Given the ability of CWB I to price discriminate in barley markets, has Canada lost its leadership in the Canada–US regional feed barley market through the CWB II period?

Based on these three queries, this thesis tests hypotheses with respect to structural breaks, market integration, and price information transmission. To help answer these questions, I construct a conceptual framework based on the ability of CWB I to price discriminate, in addition to analyzing the market from a spatial and temporal perspective. A series of relevant econometric tests are motivated by this framework.

The first question is answered by implementing stability tests on the data in a single equation regression model. Using a Chow breakpoint test, I find that the two proposed breakpoints likely associated with the removal of the single desk are not statistically significant. Given this, I break the sample down using the August 1, 2012 date to compare the feed barley price data before and after the removal of the single desk function. Note that even though August 1, 2012 was not identified as a significant structural break point in the series, I offer that there should still be changes detectable in the linkages and interactions between the prices from CWB I to CWB II.

A time series cointegration test is used to answer the second question. Based on the prior conceptual work of Fackler and Goodwin (2001), if prices of one commodity from spatially separated but related markets are in fact cointegrated, these markets can potentially reach a stable equilibrium in the long run. To check for this situation, the Engle–Granger procedure is initially used to identify some preliminary cointegration information that will help to correctly select an econometric model for more detailed analysis. The results of the tests show that feed barley prices are not cointegrated in either CWB I or CWB II periods. Given this, a VAR model is used to carry out a system cointegration test. The results of the Johansen cointegration test confirm that the feed barley price series are not cointegrated. I infer that the selected feed barley markets in this region were not integrated in the CWB I period, and there is no evidence to show that they have somehow become integrated in the more recent CWB II period.

The last question was addressed using a Granger causality test. In CWB I when the CWB could price discriminate, the Lethbridge feed barley market was found to be a price leader as the test showed that the Lethbridge price was likely to Granger cause the Great Falls price, but not vice versa. In CWB II, the test showed that the Lethbridge market has lost its price leader status in the regional market. I conclude that the direction of price transmission in the market changed after the single desk function in Canada was removed, because the price signal from the Lethbridge market became less influential on the Great Falls price.

In addition to the Granger causality test on price transmission direction, I also examined simulated responses of the market prices to exogenous shocks, based on the VAR estimations. Impulse response functions were generated and plotted separately for the two subsamples. The Great Falls feed barley price series in Subsample II exhibited an unusual and negative response to a price shock from Lethbridge. While this result was consistent with reduced importance of the Lethbridge price signal over time, developing a detailed explanation about what this finding might imply for the market in the future is beyond the scope of this work.

Overall, my findings do not allow rejection of the primary hypothesis that the removal of the CWB single desk function did not have a significant effect on this Canada–US regional feed barley market. However, I found that price transmission directionality was altered after the single desk function was removed. The latter in turn implies that Lethbridge lost its former price leadership status in this regional feed barley market.

6.2 Limitations of the Study

Using daily data, this thesis provides some insight about changes in the Canada–US regional feed barley market through a recent period of transition. However, there are a number of limitations to this analysis that could be addressed moving forward.

To start, my spatial price analysis was developed on a bivariate basis only because of a lack of broader and reliable data for this regional market. In addition, one of my assumptions was that the selected spot market prices constitute a good representation of Canadian and US feed barley prices. This assumption is likely to be somewhat incorrect, since the spot market prices do not embody all the variance in this entire Canada–US regional feed barley market. Ideally, more spot market prices or country level data should be used in further related studies.

The small sample of available observations after the removal of the CWB in the feed barley market is also a limitation in this study. Relative to the CWB I period, Subsample II contains many fewer observations and therefore may not embody enough useful time series information about the market after August 1, 2012. My analysis on Subsample II probably accurately represents the current market, but does not allow good inference about this market over the longer term.

This analysis focuses on identifying changes in market integration and price transmission across this Canada–US regional feed barley market, but like many similar studies, I cannot in every case explain the reasons behind some of these identified changes. My conclusions could also fall into causal fallacy if the changes were said to be the sole and absolute consequence of the removal of the single desk function. This particular weakness is embodied in the thesis because other exogenous factors and their effects on the market prices should ideally be included in a more complete and structural empirical analysis.

I hope the reader agrees that these points comprise the major limitations in this thesis and constitute the key issues that any future studies of this market will need to address.

6.3 Suggestions for Further Research

Further research will need to be conducted to reassess the economic effects of the changes in this market owing to the limitations inherent in this thesis. For example, to improve representativeness, more spot markets in this regional market or even country level data should be incorporated to broaden the analysis. Considering an effective price discovery mechanism, more relevant market price data will also contain information from feed barley spot markets across the country. Results from an econometric analysis using more complete data will provide better explanatory details about this transitioning market.

The sample size of the CWB II period needs to be enlarged, and certainly more observations will become available as time passes. More notable changes in market integration and price transmission might be revealed with a longer time horizon for the post single desk era data. Any conclusions would necessarily be more convincing if tests were applied to a larger sample of observations that would more fully represent the feed barley market in the CWB II period.

Finally, a more thorough analysis of this market would add other dominant feed grains into the analysis of feed price changes. US corn prices, as the basis of US feed grain prices, likely play some role in determining or influencing feed barley prices even in this regional market. The significant leadership that the US has in corn prices is likely being transmitted to some extent into this feed barley market, since feed barley is a substitute for corn. The latter omission could help explain some of the anomalous findings in this thesis, and is worthy of further analysis.

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