ECONOMIC ANALYSIS OF THE REGIONAL EFFECTS OF GRAIN-BASED ETHANOL PRODUCTION ON THE COMPETITIVENESS OF FED CATTLE PRODUCERS IN EASTERN AND WESTERN CANADA

A Thesis

Presented to

The Faculty of Graduate Studies

of

The University of Guelph

by

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In partial fulfillment of requirements

for the degree of

Master of Science

September, 2011

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ABSTRACT

ECONOMIC ANALYSIS OF THE REGIONAL EFFECTS OF GRAIN-BASED ETHANOL PRODUCTION ON THE COMPETITIVENESS OF FED CATTLE PRODUCERS IN EASTERN AND WESTERN CANADA

Alex DeJong
University of Guelph, 2011

This thesis investigates the regional impacts that increased grain based ethanol production has the competitiveness of fed cattle producers in Eastern and Western Canada. A simulation model solves for the price of feed grains in Eastern and Western Canada and the United States. Fed Cattle Producer Surplus values are calculated as a baseline by which scenario results are compared.

Two scenarios are tested by the model, both applying increased ethanol production to the 2002 base year. Results show that 2008 ethanol production increases the price for feed grains in all three regions of the model by between 95% and 100%. Applying the projected ethanol production for 2015 to the model produces feed grain increases of greater than 200%.
Acknowledgements

I would like offer my sincere thanks to my advisors Dr. Glenn Fox and Professor Jim Fisher. Your patience, guidance, and insight were invaluable.

Thank you as well to the staff and faculty in the department of Food, Agriculture and Resource Economics; an incredibly gifted group of individuals who made my experience at Guelph richer and more complete.

Also, thank you to the Beef Research Council (BRCR) and the Advancing Canadian Agriculture and Agri-Food (ACAAF) program for the funding support for this project. It is the financial contributions of these groups, as well as countless others, which allow graduate students to pursue their academic goals.

A special thanks as well to my fellow students. The experiences we shared together will stay with me for a lifetime.

To my parents, your unending support is more than any son could ask. Thank you so much for all you have done. Kristen, Natalie, and Joselyn, a huge thank you for everything. Nothing will keep a young man humble and grounded like three wonderful and successful sisters like you three.

And finally to Jessica; whom none to of this would have been possible without. Through the good days and bad ones, and plenty of late nights, your encouragement and unwavering confidence have been my rock. Your work ethic is inspiring. You know more about corn than any city girl should. Thank you.
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Chapter 1

Introduction

1.1 Background

The increase in North American ethanol production is one factor that influences the price of agricultural commodities. More specifically, the increased quantity demanded for grain corn pushes the market price for many crops upwards (Simpson et al. 2008).

At the same time that ethanol production in North America is growing, the prices for many grains and oilseeds have also increased. Futures prices on the Chicago Board of Trade for corn, soybeans, wheat and oats have all increased by more than 100 percent, in nominal terms, between 2002 and 2011.

This increase in grain and oilseed prices is increasing the cost of feeding cattle for meat in North America (Kruse et al. 2007). One particularly eye opening assessment completed in 2007 (Warner 2007) estimated that in the five months between October of 2006, and February 2007 the feed costs of the United States livestock industry increased by close to 30 percent.

The question raised by the simultaneous increases in ethanol production and the cost of feeding cattle is whether the increase in ethanol production has had a measurable impact on the cost of production for cattle producers. If there is in fact an impact, what is the magnitude of that impact, what consequences might those impacts have?
1.2 Economic Problem

The economic problem faced in both Canada and the United States with regard to ethanol production and the red meat industry is the question of how increasing grain based ethanol will impact the cost of feeding cattle. There is considerable debate among both academics and industry leaders in regards to how the increasing scale of North American ethanol production will influence these costs, and what the long term impacts may be. While some within agriculture view ethanol as a great danger to the meat production industry, others insist that the meat and ethanol industries can successfully coexist. Both meat producers and the industry associations that represent them are eager to understand how increased ethanol production will affect their industries. Producers recognize the need to understand the role that ethanol will play in the changing cost structures of meat production. Producer groups must understand the influence that ethanol policy has on their constituencies in order to best represent their needs. Government and policy makers require accurate assessment of the longer term and wider impact of the policies that they enact.

1.3 Economic Research Problem

The economic research problem addressed in this study is that it is not known currently, the extent to which the expansion of ethanol production has increased feedgrain prices in Canada, and subsequently adversely influenced the competitiveness of the cattle feeding industry.
As well, the study will examine whether any such impacts vary regionally across Canada; do cattle feeders in western Canada experience a price and cost effect that is different from any impact that is being experienced by cattle feeders in Eastern Canada?

1.4 Purpose and Objectives

Purpose

The purpose of this study is to assess the impact that increasing ethanol production in Canada and the United States will have on the costs and competitiveness of the Canadian Beef industry, and to measure any regional discrepancies within these impacts.

Objectives

1. To develop a multi level simulation model that includes North American trade, in order to illustrate the relationships between the corn production, ethanol production and the production of fed cattle.

2. To determine the role that the scale of ethanol production may play in the evolving cost structures of beef production in North America.

3. To determine whether any such impact(s) in cost structure vary regionally across Canada and the United States.

4. To communicate the resulting data and information to the interested parties and stakeholders, among them the Canadian Cattlemen’s Association.
1.5 Chapter Outlines

- Chapter One Introduction
  The first chapter will introduce the background issue surrounding the project. As well the economic and economic research problems, the purpose and objectives, an overview of the methods, and chapter outlines will be provided.

- Chapter Two Policy and Literature Review
  This second chapter will critically assess the importance and contributions of previous literature related to the beef industry, ethanol production, and the estimated impacts that ethanol production has had on the price of feed grains in Canada and the United States.

- Chapter Three Conceptual Framework
  Chapter three will focus on developing and presenting the theoretical basis for the model.

- Chapter Four Empirical Model
  Chapter Four presents the calibration and validation of the model. As well, the impact of ethanol production on the calibrated results is examined.
• Chapter Five Results and Discussion

The fifth chapter will present the results of the both the base model and the two scenarios that have been imposed on the model. Policy shocks and their outcomes related to the beef industry will be of particular interest. As well, the results of sensitivity testing is reviewed.

• Chapter Six Summary and Conclusion

The final chapter of the thesis will relate the results of the research back to the original purpose of the project. The main findings will be highlighted, and policy impacts will be addressed. As well, opportunities for future research will be discussed.

1.6 Summary

This introductory chapter has touched on the background of ethanol production in North America, as well as the interplay between ethanol fuel and the meat industries in both Canada and the United States. The economic and economics research problem, as well as the purpose and objectives of the study have been presented, and the methods and outlines section address how I have chosen to approach the research problem. The remaining chapters will follow the outline as it has been presented, culminating in the presentation of results in chapter five and summary and conclusion in chapter six.
Chapter 2

Ethanol History and Policy Review

2.1. Introduction

This chapter reviews the nature of biofuels in general, as well as an overview of the ethanol industry in the United States, followed by a similar review of the Canadian ethanol industry. Following that is a review of the literature pertaining to the impact of ethanol production on the price of corn and grains in North America.

2.2 Biofuels

Biofuels are energy sources that have been derived from organic materials such as plant matter that is only recently deceased. Fossil fuels, such as crude oil, by comparison, are fuels that are sourced from long deceased organic material (Gardner & Tyner, 2007). The term biofuel is used commonly in the media in reference to ethanol, but more accurately is employed in the science and academic literature in reference to a host of energy sources that are derived from recently living organic matter. Table 2.1 lists the various energy sources referred to by the term biofuels, categorizing them by generation and providing details and examples.

While it is clear from the Table 2.1 that there is more to the term biofuels than just ethanol, the scope of this research project is limited to the potential impacts of just one of these many biofuels, first generation non-cellulosic ethanol. The following sections will examine the history of ethanol production in Canada and the United States, including both past and present policy measures that have as influenced the development of the ethanol industry.
Table 2.1 Description of Biofuels by Type and Generation

By generation and fuel type

<table>
<thead>
<tr>
<th>Generation</th>
<th>Fuel Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Generation</td>
<td>Vegetable Oil</td>
<td>Low grade, non edible vegetable oil is processed to reduce the viscosity and make the oil applicable to older model diesel engines.</td>
</tr>
<tr>
<td></td>
<td>Biodiesel</td>
<td>Typically derived from either animal or plant fats, biodiesel is mixed with conventional mineral diesel and used widely in commercial fleets, and public transportation vehicles.</td>
</tr>
<tr>
<td></td>
<td>Bioalcohol</td>
<td>Ethanol is the most common bioalcohol, others include propanol and butanol. Derived from plant starches, common feed stocks include grain and sugar cane.</td>
</tr>
<tr>
<td></td>
<td>Biogas</td>
<td>Captured as a by-product of anaerobic digestion of organic materials. High levels of methane are used as a gas.</td>
</tr>
<tr>
<td></td>
<td>Syngas</td>
<td>Produced by the partial combustion of biomass, a more efficient energy source then the complete combustion of biomass itself</td>
</tr>
<tr>
<td></td>
<td>Solid biofuels</td>
<td>Wood, grass, manure etc. are all solid biofuels that produce heat energy as they are combusted.</td>
</tr>
<tr>
<td>Second Generation</td>
<td>Cellulosic Ethanol</td>
<td>Bioalcohols produced by converting the fibrous plant cellulose into glucose by way of various enzymes. The glucose sugar is converted in bioalcohol. Not in commercially viable operation.</td>
</tr>
<tr>
<td>Third Generation</td>
<td>Algae Fuel</td>
<td>Produced using the oil extracted from algae. Still very much in development.</td>
</tr>
</tbody>
</table>

Source: (Solomon, Barnes, & Halvorsen, 2007)
2.3 The History of Ethanol as Fuel

The development of fuel alcohol has been experimented with for as long as the combustion engine has been a part of western society. As early as the 1900’s engineers were experimenting with alcohol fuels as the input into the internal combustion engines of the day (Dimitri & Effland, 2007). Even as gasoline evolved into the dominant fuel source for combustion engines, the interest in ethanol with regards to the fuel industry remained. Periodic spikes in the price of oil, such as the prices increases during World War I and the 1970’s Oil Crisis, would inevitably lead to renewed interest in ethanol as either a fuel on its own, or more commonly as a cost efficient blending agent within a gasoline mix. Ethanol was even considered to be the preferred fuel additive to reduce engine knock prior the industry decision to remedy the problem with the introduction of leaded gasoline in 1920’s and 30’s (Dimitri & Effland, 2007).

Ethanol reentered the transportation fuel conversation in the 1970’s as the potential answer to the increasing price of oil. Oil exports to the United States from the Arab member countries of the Organization of Petroleum Exporting Countries (OPEC) were reduced for global political reasons and oil prices across the western world rose sharply as a result. The answer to such a supply deficit and price increase, as viewed by governments in Canada, the United States and Europe, was an increase in non oil based fuels. While Brazil had fostered a domestic ethanol industry employing sugar cane as the major feed stock for decades, much of the western world had only small scale ethanol production capacity (Gardner & Tyner, 2007). In order to jump start their domestic ethanol industries governments in both Canada and the United States provided funding for not only ethanol research and development, but also production.
2.4 Ethanol Production and Support Programs in the United States

The United States 1978 Energy Tax Act (ETA) defined gasohol as a blend of gasoline and at least 10 percent non fossil fuel based ethanol. The ETA officially exempted gasohol from the 1.1c/gal (3.8 c/l) excise tax on gasoline, which at a 10 percent level acted as a 10.1 c/gal (38.0 c/gal) subsidy for ethanol. This excise tax increased to as large as 15.8c/l (60.0c/gal) in the late 1980’s before the tax exemption was to reduced to a maximum of 13.4c/l(51.0 c/gal) of ethanol in the Energy Policy Act of 2005 (Solomon, Barnes, & Halvorsen, 2007). Further growth in the ethanol industry through the 1980’s was limited by severely decreased oil prices and an industry preference for Methyl Tertiary Bethel Ether (MTBE) as opposed to Ethyl Tertiary Bethel Ether (ETBE) as an octane booster.

Following the 1992 United States Energy Policy Act, much of the United States Government car fleet, as well as various State and Municipal car fleets, were required to transition to vehicles compatible with a fuel blend that contained 85 percent ethanol (E85). Even with such policies in place increased ethanol use was hampered by low gasoline prices and increased corn prices through much of the 1990s. Ethanol production and use began to grow much more quickly beginning in 2001, as presented in Figure 2.1, as restrictions on the use of MTBE increased. ETBE entered fuel blends as many states banned the use of MTBE in transportation fuels (Solomon, Barnes, & Halvorsen, 2007).
Notes.
1. Production refers to quantity of fuel grade ethanol produced in plants in the United States in a given year

Sources
1. USDA Economic Research Service. Ethanol fact sheet
The policy supports for the production and use of ethanol shifted again in 2004 with the introduction of the Volumetric Ethanol Excise Tax Credit (VEETC). This tax credit eliminated many of the restrictions that were previously in place regarding specific blend rates and instead focused the support measures on the amount of ethanol produced and blended. This was followed in 2005 with the Energy Policy Act that contained the original Renewable Fuel Standard that has become synonymous with biofuel support today. Table 2.2 is a breakdown of the current ethanol support programs in place in the United States. Details of the updated 2009 Renewable Fuel Standards are included in Table 2.3 as a schedule of the annual renewable fuel requirements.

The policies described in Table 2.2 are the most current versions of the host of support policies targeted towards the U.S. ethanol industry. In addition to these domestic support measures the United States also imposes an import tariff of $0.14 US$/l ($0.54 US$/gal) on Brazilian ethanol imports. Given that with the expectation of the United States Brazil is the largest and lowest cost ethanol producer in the world, such tariffs serve to protect the United States ethanol industry from its single largest competition (Solomon, Barnes, & Halvorsen, 2007). Motivations for such extensive support include job creation, energy independence, environmental protection, and support of the agricultural industry.
Table 2.2  Summary of U.S. Federal and State Ethanol Support Programs

<table>
<thead>
<tr>
<th>Program</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Excise tax exemption (1978), replaced with the VEETC (2004)</td>
<td>• Renewed until 2010 at $0.13 US$/l ($0.51/gal)</td>
</tr>
<tr>
<td></td>
<td>• Replaces the original fuel excise tax exemption, blenders credit and pure alcohol fuel credit</td>
</tr>
<tr>
<td>Small Producer tax credit (1990)</td>
<td>• Production credit of $0.026 US$/l ($0.10 US$/gal) for up to 15 Mgal for producers with annual production capacity of less than 60 Mgal.</td>
</tr>
<tr>
<td>Renewable Fuel Standard (2005). Update in 2009</td>
<td>• See Table 2.3 for updated annual schedule of renewable fuel requirements</td>
</tr>
<tr>
<td>Cellulosic ethanol production incentive (2005)</td>
<td>• In addition to the VEETC, current magnitude is undetermined</td>
</tr>
<tr>
<td>State incentives (variable across 36 states)</td>
<td>• Including, but not confined to; excise tax exemptions, producer credits, producer payments, property tax exemptions, grants, loans, financing assistance.</td>
</tr>
<tr>
<td>10% ethanol blend mandates</td>
<td>• Minnesota, Hawaii, Montana, Missouri, and Washington have all mandated E10 as the State standard for transportation fuel</td>
</tr>
<tr>
<td>MTBE bans (20 states since 2004)</td>
<td>• MTBE Bans in California, Connecticut, and New York</td>
</tr>
<tr>
<td></td>
<td>• Major transportation fuel consuming states</td>
</tr>
</tbody>
</table>

Sources
1. Table sourced from (Solomon, Barnes, & Halvorsen, 2007).
<table>
<thead>
<tr>
<th>Year</th>
<th>Cellulosic biofuel requirement</th>
<th>Total Advanced biofuel requirement</th>
<th>Maximum first generation ethanol inclusion</th>
<th>Total renewable fuel requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>n/a</td>
<td>n/a</td>
<td>0.00</td>
<td>9.00</td>
</tr>
<tr>
<td>2009</td>
<td>n/a</td>
<td>0.60</td>
<td>10.50</td>
<td>11.10</td>
</tr>
<tr>
<td>2010</td>
<td>0.10</td>
<td>0.95</td>
<td>12.00</td>
<td>12.95</td>
</tr>
<tr>
<td>2011</td>
<td>0.25</td>
<td>1.35</td>
<td>12.60</td>
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</tr>
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<td>2012</td>
<td>0.50</td>
<td>2.00</td>
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<td>2013</td>
<td>1.00</td>
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<td>2014</td>
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<td>16.00</td>
<td>21.00</td>
<td>15.00</td>
<td>36.00</td>
</tr>
</tbody>
</table>

**Sources**

All figures sourced from the U.S Federal Environmental Protection Agency 2009 Renewable Fuel Standard Update

**Notes**

1. The updated Renewable Fuel Standard was released through the U.S Federal Environmental Protection Agency in May 2009 as an update to the original 2005 Renewable Fuel Standard

2. Cellulosic biofuel is ethanol produced by converting the fibrous cellulose found in plant matter into glucose by way of various enzymes.

3. Total Advanced biofuel requirement consists of cellulosic and other second generation biofuels

4. Maximum first generation ethanol inclusion is the maximum quantity of first generation (grain based) ethanol that can be counted against the yearly total renewable fuel requirement. A quantity greater then that amount may be incorporated into the fuel system, but will not be counted against the total renewable fuel requirement.

5. The total renewable fuel requirement is the minimum annual quantity of renewable fuel that must be incorporated into U.S. transportation fuel.
2.5 Ethanol Production and Support Programs in Canada

The developing Canadian ethanol industry has not experienced a level of government support comparable to the industry of the United States. While the first operational commercial scale ethanol plant in Canada came online in 19811 and ethanol gasoline blends were available across the western provinces by the mid 1980s, federal ethanol support programs did not come into existence until the early 1990s. These supports consisted of excise tax exemptions and investment incentives provided by the federal government, As well, the National Biomass Ethanol Program was launched as a way to protect investors from the impacts that changes in ethanol support may have on the security of their investments (Lann, Litman, & Steenblik, 2009). A number of provincial support measures similar to the federal programs were introduced by the mid 1990s; Alberta, British Columbia, Manitoba and Ontario were among the provinces introducing such policies.

The landscape of government support for ethanol production shifted again in 2003 with the introduction of the Ethanol Expansion Program. This federal program pledged $100 million CDN$ in negotiable repayment loans in order to increase ethanol capacity towards a national goal of more than one billion litres annually. Following this introduction, several provinces launched similar programs to foster investment in production capacity through loan guarantees and other measures. Such programs prompted increased private investment in ethanol production in the years following, culminating in large increase in annual production capacity beginning in 2005. Figure 2.2 on the following page illustrates these increases in annual ethanol production.

---

1 The Husky Energy Inc plant in Minnedosa Manitoba, producing 10 million litres annually.
Figure 2.2 Canadian Annual Fuel Ethanol Capacity

Notes:
1. Capacity refers to the total plant capacity of all fuel ethanol plants as reported by plant managers

Sources
1. (Lann, Litman, & Steenbil, 2009)
production capacity, as well as the yearly annual ethanol capacity that existed between 1980 and 2008.

The most recent evolution in Canadian government support came in 2008 with the enactment of federal legislation that allows the government to establish mandates for minimum renewable fuel mixtures. Similar to the renewable fuel standards mandated in the United States by the Environmental Protection Agency, the mandate for renewable fuel mixtures allows the federal government to set annual minimum renewable fuel blend levels. This federal mandate overlaps with a number of provincial mandates that were in existence prior to this federal program, as well a number of programs that have been introduced since then. Table 2.3 lists the most current version of these mandates as well as the estimated volume of ethanol required to meet them.

In addition to the renewable fuel mandates, there are also a number of per litre producer subsidies employed to both federally and provincially in order to increase ethanol production. These policies vary in both value and duration and are detailed in Table 2.4

Finally, there is also a border protection measure included in Canadian support for ethanol. A tariff of CDN$ 0.0492 per litre is applied to all ethanol imported into Canada from any country that is not included in any Canadian trade agreement. This includes potential ethanol imports from Brazil, but does not include any ethanol imported from the United States.
### Table 2.3 Canadian Federal and Provincial Ethanol Mandates

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Mandate level</th>
<th>Estimated ethanol requirements for 2012¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal</td>
<td>5 percent beginning in 2010</td>
<td>2,145</td>
</tr>
<tr>
<td>Alberta</td>
<td>5 percent beginning in 2010</td>
<td>290</td>
</tr>
<tr>
<td>British Columbia</td>
<td>5 percent beginning in 2010</td>
<td>250</td>
</tr>
<tr>
<td>Manitoba</td>
<td>8.5 percent beginning in 2010</td>
<td>135</td>
</tr>
<tr>
<td>Ontario</td>
<td>5 percent beginning in 2007</td>
<td>830</td>
</tr>
<tr>
<td>Quebec</td>
<td>5 percent cellulosic beginning in 2012</td>
<td>445</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>7.5 percent beginning in 2007</td>
<td>125</td>
</tr>
</tbody>
</table>

**Notes**

1. Estimated ethanol required based on the total sales of all grades of transportation fuel in Canada in 2008, assuming one percent annual increase (litres).

**Sources**

1. Table and data sourced from (Lann, Litman, & Steenblik, 2009)
Table 2.4 Canadian Federal and Provincial Per-Litre Ethanol Producer Subsidies

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Subsidy level</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal</td>
<td>Maximum of CDN$ 0.10 per litre. Decline to 0 by 2017</td>
<td>2008-2017</td>
</tr>
<tr>
<td>Alberta</td>
<td>Between CDN$0.09 and CDN$ 0.14 per litre depending on producer size</td>
<td>2006-2011</td>
</tr>
<tr>
<td>Manitoba</td>
<td>CDN$ 0.20 for the first two years, CDN$ 0.15 per litre for the next three years, CDN$ 0.10 for the final three years</td>
<td>2008 – 2015</td>
</tr>
<tr>
<td>Ontario</td>
<td>Up to CDN$ 0.11 per litre based on the market prices for petroleum, corn and ethanol</td>
<td>2007 – 2016</td>
</tr>
<tr>
<td>Quebec</td>
<td>Up to CDN$ 0.185 per litre when crude oil is under US$ 65 per barrel, CDN$ 0.0 otherwise</td>
<td>2006 onwards</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>CDN$ 0.15 per litre</td>
<td>2007 onwards</td>
</tr>
</tbody>
</table>

Sources
1. Table and data sourced from (Lann, Litman, & Steenblik, 2009)
2.6 Literature Review

This section reviews academic literature and research that addresses the question of how the production of ethanol has impacted the price of feedgrains. Specifically, a recent review by Koto (2011) found 11 papers published between 2004 and 2011 that addressed this issue. Publications were found from the following sources; *Canadian Journal of Agricultural Economics, Review of Agricultural Economics*, papers listed on Agecon, reports by the United States Congressional Budget Office, the George Morris Centre, and the Food and Agricultural Policy Research Institute. The remainder of this section summarizes the findings of Koto (2011).

Using the increase in the price of oil as a proxy for an increase in the demand for ethanol, Tokgoz, *et al* (2007) showed that in an increase in the price of oil from $75 per barrel to $85 per barrel resulted in a 40% increase in the price of corn. The initial price for corn was $3.15 per bushel and the final price was $4.42 per bushel. The authors associated the rise in the price of oil with an increase in the demand for ethanol, but were not clear on how much of the 40% increase was directly due to corn based ethanol production. Pimental and Patzeck (2005) were similarly vague in arguing that beef producers could expect increased prices for corn because roughly 70% of grain corn is fed to U.S. livestock. They did state how large that increase might be. Cassman and Adam (2007) suggested that expanding ethanol production in the United States was responsible for the 82% increase in the price of corn in the two years between January 2005 and December 2006.

In research targeting Canadian producers, Mussel *et al* (2007) partially attributed 20 to 30 percent increases in the monthly average prices for corn and wheat between 2002
and 2007 to ethanol production in Canada and the United States. These changes represented only the basis effect on the prices, and they did specify just how much of those 20 to 30 percent gains were the result of ethanol production.

Randall and Park (2008) used equations representing corn supply, feed demand, export demand, food alcohol and industrial demand and corn price to develop a price dependent reduced form equation to isolate ethanol production’s impact on the price of corn. They estimated that in the short run corn supply had a 0.16 price elasticity with respect to the production of ethanol. Calculating in increase in the average price of corn of 32 percent between the first quarter of 2006/2007 and the first quarter of 2007/08, Randell and Park (2008) reported that 41 cents or 16 percent of the increase was due to increased ethanol production. Their conclusion was although ethanol production did have a significant positive effect on the price of corn, it was not the sole reason for the increases observed between 2006 and 2008.

Examining the impact of United States biofuel policy on commodity prices, The Food and Agricultural Policy Research Institute (FAPRI)(2008) estimated that three policies; the Renewable Fuels Standard, the blender’s tax credit, and the import tariff on imported ethanol increased the price of corn by 16 percent in the long run. Their research focused on only federal policies and used a set of stochastic models. Using a stochastic model based on the FAPRI model Thomson et al (2009) used shocks to the crude oil and corn markets to estimate an implied elasticity of change in oil price on corn price to be 0.17 with the Renewable Fuels Standard in effect, and 0.31 without it. Approaching the question from the opposite side, McPhail and Babcock (2008) reported that the removal
of all United States federal biofuel policies would result in a 14% decrease in the prices of corn in 2008/2009.

The United States Congressional Budget Office (2009) suggested that U.S. ethanol production was responsible for 50 to 80 cents per bushel (15-24%) of the $1.75 per bushel increase in the price of corn between April 2007 and April 2008. Babcock and Fabiosa (2011) examined a longer time frame from 2006 to 2009. They conclude that of the 80 percent increase in the price of corn over that time, $0.14 (8 percent) was directly attributable to ethanol studies, while another 45 cents (27%) could be the result of market-based expansion of the corn ethanol industry. As a whole then, they found that 35% of the 80% increase in the price of corn between 2006 and 2009 could be attributed to ethanol subsidies and market-based ethanol expansion.

In a similar review to the one by Koto (2011), Daynard and Daynard (2011) examined public information addressing the effect of Canadian and global biofuel production on food prices, as well as on the environment and world hunger during the periods of 2007-2008 and 2010-2011. Examining prices in the United States, they acknowledged that biofuel production resulted in between a 20 and 40% increase in the price of corn in 2008. As well, they concurred with the findings of other studies that removing United States ethanol support programs would result in a 15% decrease in the price of corn.

Focusing on Canadian results, they found that between 2001 and 2007 Ontario corn prices increased 29 cents relative to the corn price in Michigan. Considering that in 2001 the average price for corn in Ontario was $2.10 per bushel, $0.29 works out to a 13% increase. It should be noted that this increase in only the basis increase, not the total
price increase. For users of corn in Ontario and Alberta the move from an export market to an import market means the total price increase for corn is made up of two parts; the increase in the price of corn in the United States, and the additional basis impacts on top of that.

After reviewing the literature summarized above, Koto (2011) conclude that the debate is no longer about if ethanol promoting programs increase the price of corn, but the debate is now by how much these programs have contributed to the increase in the prices of grains in Canada and the United States. Studies examining the price of corn in the United States estimate effects as high as 82% (Cassman and Adam (2007)) and as low as 16% (Randal and Park (2008)). Work addressing the same question in Canada suggest effects as high as 30% (Mussel et al. (2007)) and as low as 13% (Daynard and Daynard (2011)).

The results of this study will be compared to ranges cited above at the conclusion of Chapter 5.

2.7 Summary

This chapter has examined ethanol production and support in Canada and the United States as an important step to understanding the context of this research. While this chapter is by no means a complete and exhaustive review of the history of ethanol policies and production in both countries, it is sufficiently detailed to give the work that follows and the results that are produced a broader sense of meaning.
Chapter 3

Conceptual Framework

3.1 Introduction

This chapter will detail the development of the conceptual framework of the research model. An overview of the model will be followed by subsections that address specific levels of the model. A brief summary will follow at the end of the chapter.

In order to measure the impact of ethanol production on the cost structure and competitiveness of Canadian beef producers a means of comparing their competitiveness with and without ethanol production is required. Calculating and comparing the producer surplus of a producer group or industry is a common method of making this type of comparison within agricultural economics (Just, Heuth, & Schmitz, 1982). This research follows that lead.

The model developed in this study calculates base model producers’ surplus values for corn producers and fed cattle producers, as well as producers’ surplus values for each of the scenarios imposed on the model. These calculations allow for the comparison of the welfare of the beef producers across different scenarios.

Using the measurement of changes in producers’ surplus levels to quantify changes in competitiveness of beef producers requires the construction of a model that is not only theoretically sound, but also grounded in empirical data (Currie, Murphy, & Schmitz, 1971). This chapter focuses on the first of those two requirements; the development of the conceptual framework.
3.2.1 Conceptual Model

The architecture of the model is based on a three region breakdown of Canada and the United States. Canada is divided into eastern Canada (Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland and Prince Edward Island) and western Canada (British Columbia, Alberta, Saskatchewan, Manitoba and the Territories) while the United States is represented as a single region. This breakdown of the Canadian markets reflects both the agricultural and geographical disparities (number of heat units, precipitation levels, soil type, etc.) that exists between the two areas, as well the research question that has motivated this study; the potential for regional variation within the impacts of ethanol production on Canadian beef producers.

The model contains representations of the markets for oil, ethanol, feed grains, and fed cattle industries in both Canada and the United States. The following sub sections will address each of the smaller models and lead through to the complete framework.

3.2.2 The Oil and Ethanol Market

The oil, gasoline, and ethanol markets are the first level the model. Linking the oil and gasoline markets in Canada and the United States with the ethanol and agricultural markets is the first step in the development of the model. Of particular importance is the use of oil in the supply of transportation fuel, and how increasing ethanol production fits into this supply process.

As explained in Chapter 2, ethanol programs in both Canada and the United States are tied to transportation gasoline production through the use of a blend mandate. The blend mandate requirement sets a minimum percentage of ethanol fuel that must be used
by fuel blenders in processing transportation fuel. Graphically, this relationship between the amount of transportation fuel processed, and the amount of ethanol fuel required in order to meet the blend mandate is shown in Figure 3.1. Given a constant required blend rate ($\delta$), the amount of ethanol ($Q_E$) required to meet the blend mandate will increase or decrease with changes in the amount of transportation fuel processed ($Q_{TF}$).

$$Q_E = Q_{TF} \times \delta$$

This blend mandate is captured in the model by modeling the relationship between the price of oil and the price of ethanol’s major feed stock, grain corn. Grain corn is the most widely used feed stock in North American ethanol production, though several ethanol plants in western Canada do use wheat as their major feed stock (Canadian Renewable Fuels Association - Statistics), (Renewable Fuels Association - Statistics, 2009). This grain requirement for the production for ethanol allows for the estimation of a maximum bid price for corn by ethanol producers. Following work done by the Department of Agriculture and Consumer Economics at the University of Illinois (Department of Agricultural and Consumer Economics, University of Illinois, November 2007), the world prices for oil and ethanol co-products, the standard ethanol and co-product yields from corn, as well as the value of current ethanol supports are employed to estimate the maximum bid price for corn by an ethanol producer.
Figure 3.1 Mandated Ethanol Disappearance as a Function of Equilibrium Transportation Fuel Consumption

\[ \delta \] represents the mandated blend rate
The world price for oil is transformed into the retail price of gasoline by dividing the price of oil by a factor of 28.9, the historic price factor between oil and retail gasoline (CARD Briefing Paper 06-BP49, November 2006). This price for gasoline is then transformed to an energy equivalent price for fuel ethanol by being divided by a factor of 0.667, which is the energy value of ethanol relative to standard regular gasoline (Department of Agricultural and Consumer Economics, University of Illinois, November 2007). This energy equivalent price of ethanol can then be used to estimate a bid price for a bushel of corn by ethanol producers by incorporating the yields for ethanol and co-products from that bushel of corn. The ethanol price is multiplied by the ethanol yield from a bushel of corn, (2.8 U.S. gallons/bushel), in order to calculate the ethanol value of a bushel of corn. Added to this value the co-product value of a bushel of corn processed to ethanol; calculated as the co-product yield from a bushel of corn (17.75 lbs per bushel) multiplied by the market value of these co-products. The resulting value is the revenue that is associated with a bushel of corn that is used to produce ethanol.

Subtracting the estimated non-corn variable costs of production associated with ethanol production ($1.50 US$/U.S. gallon as estimated by the Department of Agricultural and Consumer Economics, University of Illinois, November 2007) from the per bushel revenue of ethanol production leaves the maximum price a ethanol producer could bid for corn, while still covering its variable costs in the short run. Add to this price the value of ethanol support measures in place and the ending value is the estimated maximum bid price for grain corn by ethanol processors (See Appendix 2.0 for more detailed description and calculations). This estimated bid price becomes the floor price for grain corn in the representative corn market developed in the next section.
Ethanol production in Canada and the United States is also influenced by an annual production guideline. As discussed in Chapter 2 and described in Tables 2.3 and 2.4, each country has set a schedule of minimum amounts of ethanol fuel that must be produced and used each year. These schedules act as a quantity floor, regardless of the amount of ethanol required to meet the minimum blend mandate (Energy and Independence and Security Act, 2007).

Graphically, such a quantity floor may be represented on a standard supply and demand graph for ethanol as a vertical line at a set quantity amount. The combination of these two ethanol supports is represented graphically in Figure 3.2; the vertical line representing the annual ethanol quantities required by the renewable fuel standard and the horizontal line representing the break even bid price for corn by ethanol producers.

3.2.3 The Corn and Feed Grains Markets

As explained in the previous section, the oil and ethanol markets are linked to the corn and feed grains markets in both Canada and the United States through the use of corn as the major feed stocks for first generation ethanol. The need for feed grains to fuel increasing ethanol production has lead to additional demand for both corn and other feed grains beyond the traditional demand by livestock, poultry feeders, and food processors. (Mussel, Hedley, & Hedley, January 2009). These increases in demand lead to upward pressure on the prices of many of the grain crops grown in North America. As well, the growth of ethanol production influences the trade dynamics of corn in North America. For most of the past 25 years Ontario has produced more corn than it requires for feed and further processing. This led to an exporting of Ontario corn and generally a negative price basis. As Ontario ethanol production has grown faster than Ontario corn production the
Figure 3.2 Corn market including Floor Price and Minimum Quantity Demanded by Ethanol

- Minimum Quantity of corn required to meet ethanol volume mandate
- Floor price for corn as set by the maximum bid price for corn by ethanol blenders
gap between the amount of corn that is grown in Ontario and the amount of corn that is used in Ontario has narrowed. The result is a shrinking of the negative basis, and an increase in the price of corn in Ontario relative to the Chicago market price.

While the grain corn market in Canada and the United States bears much of the direct weight of increased demand from ethanol, the markets for the other feed grains do not go without impact. Ethanol plants in western Canada that use wheat as their feedstock have introduced additional demand for feed grains. As well there is the influence that the corn market has over all feed grains markets in North America. Corn remains the dominant row crop in both the United States and Ontario and Quebec, consuming roughly one quarter of annual planted acreage. This disparity is a result of a number of factors, most notably that corn remains one of the most profitable large scale field crops, and its production is suited to a wide range of US and Central Canadian climates. Such an uneven balance in production between grain corn and the remaining row crops leads to the strong influence that the corn market has over the remaining field crop markets. Other crops must compete with grain corn for acreage, and given the profit based decision making of producers, therefore must compete with corn for profitability. This leads to the reality that the price of corn influences the price of the other major field crops. This is a result of the fact that, in order to ensure that there are enough acres of other crops planted each year, the price of those crops must reflect the choice that producers have with regard to planting decisions. If that price for other crops is too low, relative to the price of corn, then other crop acres will be transitioned to corn acres and the resulting supply of other crops will fall.
The model uses a representation of the U.S. grain corn market. Figure 3.3 is a graphical demonstration of this market for corn in the United States. The supply function denoted $QS^c_i$ is the supply function of grain corn in the United States. This function is written as:

$$QS^c_i = a^c_i (P^c_i - b^c_i)^{c^c_i}$$  \hspace{1cm} (3.1)

Where $QS^c_i$ is the quantity of corn supplied in the United States each year

- $a$ is a multiplicative scaling factor
- $P$ is the price of corn in the United States
- $b$ is the shutdown price of corn production in the United States
- $c$ is an elasticity coefficient
Figure 3.3 Representative Grain Corn Market
The demand for corn in the United States is represented by the demand curve marked \( QD^c \), and is be expressed as;

\[
QD^c = g^c + d^c P^c f^c
\]

Where \( QD^c \) is the total quantity of corn demanded in the United States, including ethanol and non-ethanol uses.

\( g^c \) is the amount of grain corn required to meet ethanol production mandates. This quantity does not respond to the price of corn.

\( d^c \) is a multiplicative scaling parameter

\( P^c \) is the price of corn

\( f^c \) is the elasticity of demand coefficient for corn for non-ethanol use

The market clearing price for grain corn in the United States is solved for in the model as the equilibrium price of these two equations.

The equilibrium price for grain corn in Eastern Canada is obtained by applying the adjusted basis level from the calibration year to the U.S. price of grain corn, measured in Canadian dollars. The resulting price is the price of grain corn in Eastern Canada as a function of the price of grain corn in the United States and the adjusted basis level between the two regions. This calculation is expressed as;

\[
P^c_{ec} = P^c_{us} + CB^c_{ec}
\]

Where \( P^c_{ec} \) is the price of grain corn in Eastern Canada
\( P_{us}^c \) is the equilibrium price of grain corn in the United States

\( CB_{ec}^c \) is calibration basis level between the price of grain corn in Eastern Canada and the price of corn in the United States. This value is taken as the difference between the average price for grain corn in the United States and the average price for grain corn in Ontario in 2002 on a per bushel value. This difference can be thought of as the transportation costs between the two regions.

In Western Canada, feed barley is the main feed stock for the production of fed cattle. The equilibrium price for feed grade barley in Western Canada is calculated as the function of U.S. price of grain corn, the historical relationship between the U.S. prices for grain corn and barley and the calibration year adjusted basis level between the U.S. price of feed barley and the Western Canadian price of feed barely. This price function for Western Canadian feed barely is written as:

\[
P_{wc}^{fb} = P_{us}^c \times PR_{us}^{fb} + CB_{wc}^{fb}
\]

(3.4)

Where \( P_{wc}^{fb} \) is the price of feed grade barley in Western Canada

\( P_{us}^c \) is the equilibrium price of grain corn in the United States

\( PR_{us}^{fb} \) is the historical price ratio between the price of grain corn and the price of feed barley in the United States

\( CB_{wc}^{fb} \) is calibration basis level between the price of feed barley in Western Canada and the price of feed barley in the United States. This
value is taken as the difference between the average price for feed barley in the United States and the average price for feed barley in Alberta in 2002 on a per bushel value. This difference can be thought of as the transportation costs between the two regions.

This first level of the model solves for the equilibrium price of the two main feed sources for fed cattle; grain corn and feed barley. The next level of the model integrates these equilibrium prices into the regional supply functions for fed cattle.

3.2.4 The Fed Cattle Market

The fed cattle markets across the three regions of the model are similarly structured, with the most notable differences being related to the size and scale of production within each region. While eastern Canada supports a greater percentage of smaller mixed farms that incorporate fed cattle as a component of the overall farming operations, western Canada and the United States support a greater percentage of large and very large dedicated feedlots (Brocklebank, Hobbs, & Kerr, 2008).

These fed cattle producers are linked to the growing ethanol industry in North America by their competing demand for corn and associated feed grains. The process of finishing cattle typically requires a high energy ration that most often includes either corn or barley, both of which are feed stocks for first generation ethanol (Brocklebank, Hobbs, & Kerr, 2008).

The supply functions for fed cattle in each region are linked to the corn and feed grains market through the inclusion of the regional price for the major grain component in each region, grain corn in Eastern Canada and the United States, and feed barley in
Western Canada. The supply of fed cattle in each of the three regions is represented by the curve marked $QS_{i}^{fc}$ where $i$ refers to the region, and can be expressed as,

$$QS_{i}^{fc} = h_{i}^{fc} (P_{i}^{fc} - TP_{i}^{fc})k_{i}^{fc} \quad (3.5)$$

Where $QS_{i}^{fc}$ is the quantity of fed cattle supplied in each region $i$.

$h_{i}^{fc}$ multiplicative constant

$P_{i}^{fc}$ is the price fed cattle in region $i$

$TP_{i}^{fc}$ is threshold or shutdown price production of fed cattle, which is a function of, among other things, the price of the feedgrain used in that region.

$k_{i}^{fc}$ is an elasticity coefficient

The shutdown price for production ($TP_{i}^{fc}$) is estimated as the costs of production in each region.

$$TP_{i}^{fc} = NFC_{i}^{fc} + (P_{i}^{fc} \times FQ_{i}^{fc}) \quad (3.6)$$

Where $TP_{i}^{fc}$ is the shutdown price for fed cattle producers in region $i$.

$NFC_{i}^{fc}$ is the non feed component of the cost of production
\(P_{i}^{f} \) refers to the Price of feed in region \(i\)

\(FQ_{i}^{f} \) is the quantity of feed required to feed an animal to slaughter weight in region \(i\)

The result is a supply equation for fed cattle that is a function of not only the price and supply elasticity of fed cattle, but also the price of the major feed input required for production. A more detailed explanation of both the shutdown price and the supply elasticity coefficient follows in the Chapter 4.

It should be noted that potential use of dried distiller grains and other ethanol co-products as a substitute feed source for cattle is not included in the supply function. This is due to the relatively recent nature of the practice and the resulting lack of reliable information and research on the topic during the time of this research project. Early co-products were inconsistent in nutritional make up and quality, limiting their widespread use as a substitute feed source. In more recent years, as the quality and consistency have improved, so too has their regular incorporation as part of cattle feed rations increased. I will return to this issue in the discussion of my results later in this thesis.

The demand for fed cattle in each region of the model is written as a function of the price of fed cattle and the demand elasticity for fed cattle. Written as:

\[
QD_{i}^{f} = l_{i}^{f} P_{i}^{f} e_{i}^{f}
\]  

(3.7)

Where \(QD_{i}^{f} \) is the quantity of fed cattle demanded in each region \(i\)
$l$ is a multiplicative constant

$p_{i}^{fe}$ is the price fed cattle in region $i$

$m_{i}^{fe}$ is the demand elasticity coefficient for fed cattle in each region

The demand for fed cattle derives primarily from processors who require fed cattle in order to provide the market with processed beef. The markets in all three regions are characterized by a small group of processors as compared to a much larger population of cattle feeders.

3.2.5 Producers’ Surplus

Having linked the feed grains and feed cattle markets across Canada and the United, the model measures the producer surplus that is generated by each region of the fed cattle market. Producers’ surplus is measured as the area the lies above the supply curve and below equilibrium price line on a price quantity graph (Schmitz, Furtan, & Baylis, 2002). Given the non-linear nature of the supply curves found in the fed cattle markets, the producer surplus area must be found by taking the entire rectangular area that is beneath the equilibrium price line, up to the equilibrium quantity value, and then subtracting from that the area that is found beneath the supply function up the equilibrium quantity. Figure 3.4 gives a graphical representation of this area.

3.3 Summary

Chapter 3 detailed the conceptual model developed to answer the question of whether or not there are regional variations to the impacts that ethanol production has on
fed cattle producers in Canada and the United States. Chapter Four will outline the
decision to use 2002 as a base year, and describe the calibration of the model. As well, the
validation of the model will be addressed.
Figure 3.4 Producers’ Surplus Area with a non-linear Supply curve
Chapter 4

Model Calibration

4.1 Introduction

This chapter describes the calibration and validation of the conceptual model presented in Chapter 3. The model is calibrated to market conditions in 2002, to reflect equilibrium prior to most of the expansion of ethanol production in North America. The demand curve for feed grain is shifted backwards to simulate the removal of all ethanol production in the 2002 base year. The results from the ethanol free 2002 base year become the results with which all simulation results are compared. The interpretation of the model simulations, therefore, is that they isolate the effect of increased feedgrain use for ethanol production on feedgrain prices, fed cattle supplies and cattle feeder welfare.

The first section reviews the choice of 2002 as the base year for the model. The following sections cover the calibration of each section of the model to the 2002 base year. Following that, the model is validated to test reproduction of the chosen base year. The chapter concludes with a brief summary.

4.2.1 Calibration

The choice of an appropriate base year for the calibration of a simulation model is vital to the validity of the results of the model. The chosen year should be a time period that reflects an average year in terms of the data that is being used. Also, for this research, it should also be a year in which the effects of ethanol production on feedgrain prices were small. As well, the base year should be recent enough as to provide a realistic
comparison to the current environment. For the purpose of the calibration of this model the year 2002 has been chosen as the base year.

The year 2002 is chosen as a base year for calibration due to its qualities as a somewhat recent time period that appears regular in its market outcomes. While a more recent year may be preferable, there is also the danger that without the appropriate context it is difficult to assess whether a more recent year is truly representative. As well, within the context of North American agricultural markets, the 2003 Bovine Spongiform Encephalopathy (BSE) occurrence and the resulting trade distortions make the years beyond 2002 less suitable for a base year.

The following subsections present the historical price and quantity data employed for the calibration of the model. The oil, corn and feed grains, and fed cattle markets will be examined empirically. The tables of historical data will provide the context for the use of 2002 as the base year. As well, the pertinent elasticities required for calibration are provided and the calibrated functions of the model are shown. The presentation of the calibration will be broken down similarly to the presentation of the conceptual model. The oil and ethanol market will be followed by the corn and feed grains market, which will be followed by the regional fed cattle markets.

4.2.2 The Oil and Ethanol Market

The price for oil that is used in the model is the annual average per barrel cost for light crude in US dollars as posted in the Illinois Basin. Table 4.1 lists both nominal and inflation adjusted versions of this price beginning in 1975. The accompanying Figure 4.1 presents the data of the table graphically, including the magnitude of both the 1970’s oil
crisis and the more recent increases in oil prices. For the purpose of the base year calibration the 2002 oil price is used. The year 2002 falls near the end of a period where both nominal and real prices floated within a range of approximately 20 dollars between $20 US$ and $40 US$ per barrel. It is in the years just after 2002 that price of oil begins to greatly appreciate.

This 2002 value for the price of oil is used as the base to estimate the minimum bid that ethanol blenders can make for corn and feed grains. Section 3.2.2, and Appendix 2.0 describe the algebra used to estimate this minimum price. The calculations are made using the 2002 oil value as presented in the Table 4.1 and the calculations referenced in Section 3.2.2

4.2.3 The Corn and Feed Grains Markets

The minimum bid price for corn that is calculated in the previous section acts as a floor price for the corn and grains market in the scenarios that are tested by the model. In the baseline case, without the inclusion of the increased ethanol production, the model is calibrated in order to solve for the relevant 2002 price and quantity results. Table 4.2 lists the annual production and use data for corn in Canada and the United States between 1997 and 2008. Tables 4.11 – 4.13 are included at the end of the chapter and provide more detailed historical data for United States and Canadian corn supply and use.
Table 4.1 U.S. Annual Average Domestic Crude Oil Prices 1975 - 2008

U.S. Average in US$/barrel

<table>
<thead>
<tr>
<th>Year</th>
<th>Nominal</th>
<th>Inflation Adjusted$^{1}$</th>
<th>Year</th>
<th>Nominal</th>
<th>Inflation Adjusted$^{1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>12.21</td>
<td>48.91</td>
<td>1995</td>
<td>16.75</td>
<td>23.71</td>
</tr>
<tr>
<td>1977</td>
<td>14.40</td>
<td>51.22</td>
<td>1997</td>
<td>18.64</td>
<td>25.05</td>
</tr>
<tr>
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<td>1998</td>
<td>11.91</td>
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<td>1979</td>
<td>25.10</td>
<td>73.89</td>
<td>1999</td>
<td>16.56</td>
<td>21.39</td>
</tr>
<tr>
<td>1980</td>
<td>37.42</td>
<td>98.07</td>
<td>2000</td>
<td>27.39</td>
<td>34.29</td>
</tr>
<tr>
<td>1981</td>
<td>35.75</td>
<td>84.93</td>
<td>2001</td>
<td>23.00</td>
<td>28.03</td>
</tr>
<tr>
<td>1982</td>
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<td>71.20</td>
<td>2002</td>
<td>22.81</td>
<td>27.33</td>
</tr>
<tr>
<td>1983</td>
<td>29.08</td>
<td>63.00</td>
<td>2003</td>
<td>27.69</td>
<td>32.47</td>
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<tr>
<td>1984</td>
<td>28.75</td>
<td>59.71</td>
<td>2004</td>
<td>37.66</td>
<td>42.97</td>
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<tr>
<td>1985</td>
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<td>53.98</td>
<td>2005</td>
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<td>55.21</td>
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<td>28.41</td>
<td>2006</td>
<td>58.30</td>
<td>62.36</td>
</tr>
<tr>
<td>1987</td>
<td>17.75</td>
<td>33.69</td>
<td>2007</td>
<td>64.20</td>
<td>66.66</td>
</tr>
<tr>
<td>1988</td>
<td>14.87</td>
<td>27.16</td>
<td>2008</td>
<td>91.48</td>
<td>91.35</td>
</tr>
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<td>1989</td>
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<td>31.88</td>
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<tr>
<td>1990</td>
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<td>38.17</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1991</td>
<td>20.20</td>
<td>31.99</td>
<td></td>
<td></td>
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<td>22.78</td>
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<td></td>
<td></td>
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<tr>
<td>1995</td>
<td>16.75</td>
<td>23.71</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. This table shows the Annual Average Crude Oil Price from 1975 to the present. Prices are adjusted for Inflation to November 2008 prices using the Consumer Price Index (CPI-U) as presented by the Bureau of Labor Statistics.
Figure 4.1 Annual Average Domestic Crude Oil Prices 1975-2008

Notes

1. This table shows the Annual Average Crude Oil Price from 1946 to the present. Prices are adjusted for Inflation to November 2008 prices using the Consumer Price Index (CPI-U) as presented by the Bureau of Labor Statistics.
Both countries show gradual growth in both the supply of grain corn and the disappearance of grain corn over the course of these years. In both cases the United States features larger absolute growth, but the Canadian annual supply and disappearance grows faster on a percentage basis relative to 1997. The base year of 2002 falls near the centre of this time period, and is representative of supply and demand conditions in the market around this time. The uneven change in yearly values, small gains followed by small reductions, can be attributed to the restrictions imposed by the crop rotation strategies employed by most grain producers. Often fields that grow corn in any year are then used to grow another crop in the following year; this is due to the high nutrient requirements of producing corn. As a result a large increase in corn acreage in any year will most likely be followed by a small pull back in acreage the following year. As well the variability of weather and the resulting fluctuations in corn yields across both Canada and the United States will generate fluctuations in supply.

The price data used to calibrate the corn market is shown in Tables 4.3 and 4.4. Table 4.3 displays the Ontario nominal average price in Canadian dollars as well as the Canadian price in the American dollars. While the nominal value is of importance to the producers who receive that value and the processors who pay that value, it is the price in U.S. dollars that is important for comparisons in this model. The data show that, with the exception of 1995, when both Canadian and U.S. corn prices were far above the average, prices ranged from as low as $2.07 US$/bu in 2000 to as high as $2.87 US$/bu in 1990, 1997, and 2002. While the 2002 value of $2.87 US$/bu is above the average price of the time period, it is not a concern for this model.
Table 4.2 U.S. and Canadian Annual Supply and Disappearance of Grain Corn

(Millions of bushels)

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. (^1)</th>
<th>Supply Canada (^2)</th>
<th>Total (^3)</th>
<th>Disappearance U.S. (^1)</th>
<th>Canada (^4)</th>
<th>Total (^5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>10,098.80</td>
<td>282.66</td>
<td>10,381.46</td>
<td>8,791.00</td>
<td>585.31</td>
<td>9,376.31</td>
</tr>
<tr>
<td>1998</td>
<td>11,085.29</td>
<td>352.44</td>
<td>11,437.73</td>
<td>9,298.32</td>
<td>649.24</td>
<td>9,947.56</td>
</tr>
<tr>
<td>1999</td>
<td>11,232.33</td>
<td>360.66</td>
<td>11,592.99</td>
<td>9,514.78</td>
<td>692.22</td>
<td>10,207.00</td>
</tr>
<tr>
<td>2000</td>
<td>11,639.42</td>
<td>273.76</td>
<td>11,913.18</td>
<td>9,740.32</td>
<td>723.06</td>
<td>10,463.38</td>
</tr>
<tr>
<td>2001</td>
<td>11,411.83</td>
<td>330.27</td>
<td>11,742.10</td>
<td>9,815.40</td>
<td>802.53</td>
<td>10,617.93</td>
</tr>
<tr>
<td>2002</td>
<td>10,577.66</td>
<td>354.27</td>
<td>10,931.93</td>
<td>9,490.99</td>
<td>892.30</td>
<td>10,383.29</td>
</tr>
<tr>
<td>2003</td>
<td>11,188.04</td>
<td>377.44</td>
<td>11,565.48</td>
<td>10,229.95</td>
<td>958.23</td>
<td>11,188.18</td>
</tr>
<tr>
<td>2004</td>
<td>12,774.50</td>
<td>347.89</td>
<td>13,122.39</td>
<td>10,660.53</td>
<td>843.65</td>
<td>11,504.18</td>
</tr>
<tr>
<td>2005</td>
<td>13,234.97</td>
<td>367.39</td>
<td>13,602.36</td>
<td>11,267.80</td>
<td>783.11</td>
<td>12,050.91</td>
</tr>
<tr>
<td>2006</td>
<td>12,510.27</td>
<td>353.91</td>
<td>12,864.18</td>
<td>11,206.62</td>
<td>805.13</td>
<td>12,011.75</td>
</tr>
<tr>
<td>2007</td>
<td>14,361.54</td>
<td>458.59</td>
<td>14,820.13</td>
<td>12,737.39</td>
<td>883.94</td>
<td>13,621.33</td>
</tr>
<tr>
<td>2008</td>
<td>13,740.39</td>
<td>416.99</td>
<td>14,157.38</td>
<td>12,140.00</td>
<td>1,026.22</td>
<td>13,166.22</td>
</tr>
</tbody>
</table>

Sources

1. U.S. Supply and disappearance data come from Table 3.6
2. Canadian supply data come from Table 3.5
3. Total supply is the sum of U.S. and Canadian supply for each year.
4. Canadian disappearance data comes from Table 3.4
5. Total disappearance is the sum of U.S. and Canadian disappearance for each year.
Similarly, Table 4.3 includes the U.S. annual average price for grain corn, and the annual average difference between the two regional prices. While the 1995 price remains an outlying price, the variation in U.S. prices is similar to that of the Ontario data, and the 2002 price of $2.46 US$/bu is used for calibration.

The elasticities used in the corn and grains portion of the model are found in Table 4.5. These elasticities are taken from the literature sources explained in the notes of the Table, and constitute the most suitable and consistent elasticity estimates available during the time of research.

### 4.2.4 The Fed Cattle Market

The empirical supply and disappearance data for fed cattle the United States in the years between 1990 and 2004 is shown in Table 4.6. The regional supply and demand functions in the model for Fed Cattle are calibrated to 2002. As noted in the introduction to the calibration section, 2002 has been chosen as the appropriate base year for a number of reasons. It is recent enough that it is not an unrealistic comparison, yet also is void of the distortions caused by the 2003 Bovine Spongiform Encephalopathy (BSE) occurrence in both Canada and the United States. Table 4.8 displays similar data for the Canadian market between 1990 and 2004. Canadian data is restricted in its availability to national values. In order to estimate the regional supply and disposition values for Eastern and Western Canada the historical percentages of production in each region were used to divide the national production between the two regions.
### Table 4.3 Annual Grain Corn Prices and Basis

(No. 2 Yellow Grain Corn)

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. Annual Average Price (US$/bu)</th>
<th>Ontario Annual Average Price (US$/bu)</th>
<th>Annual Average Adjusted Basis</th>
<th>CDNS CPI 2002 = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2.41</td>
<td>2.67</td>
<td>0.26</td>
<td>78.5383</td>
</tr>
<tr>
<td>1991</td>
<td>2.52</td>
<td>2.27</td>
<td>-0.25</td>
<td>82.7667</td>
</tr>
<tr>
<td>1992</td>
<td>2.22</td>
<td>2.31</td>
<td>0.09</td>
<td>84.000</td>
</tr>
<tr>
<td>1993</td>
<td>2.68</td>
<td>2.15</td>
<td>-0.53</td>
<td>85.5667</td>
</tr>
<tr>
<td>1994</td>
<td>2.43</td>
<td>2.45</td>
<td>0.02</td>
<td>85.7083</td>
</tr>
<tr>
<td>1995</td>
<td>3.97</td>
<td>2.61</td>
<td>-1.36</td>
<td>87.550</td>
</tr>
<tr>
<td>1996</td>
<td>2.84</td>
<td>3.87</td>
<td>1.03</td>
<td>88.925</td>
</tr>
<tr>
<td>1997</td>
<td>2.56</td>
<td>2.78</td>
<td>0.22</td>
<td>90.3667</td>
</tr>
<tr>
<td>1998</td>
<td>2.06</td>
<td>2.27</td>
<td>0.21</td>
<td>91.2667</td>
</tr>
<tr>
<td>1999</td>
<td>1.97</td>
<td>1.99</td>
<td>0.02</td>
<td>92.850</td>
</tr>
<tr>
<td>2000</td>
<td>1.99</td>
<td>1.98</td>
<td>-0.01</td>
<td>95.375</td>
</tr>
<tr>
<td>2001</td>
<td>2.13</td>
<td>2.15</td>
<td>0.02</td>
<td>97.7833</td>
</tr>
<tr>
<td>2002</td>
<td>2.46</td>
<td>2.36</td>
<td>-0.10</td>
<td>99.9917</td>
</tr>
<tr>
<td>2003</td>
<td>2.66</td>
<td>2.68</td>
<td>0.02</td>
<td>102.750</td>
</tr>
<tr>
<td>2004</td>
<td>2.08</td>
<td>2.84</td>
<td>0.76</td>
<td>104.658</td>
</tr>
</tbody>
</table>

**Sources**

1. U.S. supply data were obtained from the USDA ERS Fields grains data set
2. Taken from Table 4.8
3. Canadian Consumer Price Index sourced from CANSIM Table 326 002

**Notes**

1. Data retrieved from the custom queries search page of the USDA ERS Fields Grains data set. The page allows the user to search the USDA data and build a data set that includes the variables and time period that are of interest. To retrieves the annual U.S. price data for No.2 yellow corn the search fields at custom queries page [http://www.ers.usda.gov/Data/feedgrains/FeedGrainsQueriable.aspx](http://www.ers.usda.gov/Data/feedgrains/FeedGrainsQueriable.aspx) were filled out as following: 1-price, 2-market price, 3-corn, 4-market year, 5- USA, 6-1990-2004.
2. Annual average adjusted basis measured as the difference between the U.S. and the Canadian prices for grain corn, both measured in U.S. dollars.
Table 4.4 Ontario Annual Average Grain Corn
(No. 2 Yellow A2 Grain Corn)

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Average Price (CDN$/bu)¹</th>
<th>Exchange Rate²</th>
<th>Annual Average Price (US$/bu)³</th>
<th>CDN$ CPI 2002 = 100⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>3.34</td>
<td>1.1668</td>
<td>2.87</td>
<td>78.3583</td>
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<tr>
<td>1991</td>
<td>2.82</td>
<td>1.1457</td>
<td>2.46</td>
<td>82.7667</td>
</tr>
<tr>
<td>1992</td>
<td>2.93</td>
<td>1.2087</td>
<td>2.43</td>
<td>84.0000</td>
</tr>
<tr>
<td>1993</td>
<td>3.00</td>
<td>1.2901</td>
<td>2.32</td>
<td>85.5667</td>
</tr>
<tr>
<td>1994</td>
<td>3.47</td>
<td>1.3656</td>
<td>2.54</td>
<td>85.7083</td>
</tr>
<tr>
<td>1995</td>
<td>3.80</td>
<td>1.3724</td>
<td>2.77</td>
<td>87.5500</td>
</tr>
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<td>1996</td>
<td>5.45</td>
<td>1.3635</td>
<td>4.00</td>
<td>88.9250</td>
</tr>
<tr>
<td>1997</td>
<td>3.97</td>
<td>1.3846</td>
<td>2.87</td>
<td>90.3667</td>
</tr>
<tr>
<td>1998</td>
<td>3.54</td>
<td>1.4835</td>
<td>2.39</td>
<td>91.2667</td>
</tr>
<tr>
<td>1999</td>
<td>3.14</td>
<td>1.4857</td>
<td>2.11</td>
<td>92.8500</td>
</tr>
<tr>
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<td>3.07</td>
<td>1.4851</td>
<td>2.07</td>
<td>95.3750</td>
</tr>
<tr>
<td>2001</td>
<td>3.33</td>
<td>1.5488</td>
<td>2.15</td>
<td>97.7833</td>
</tr>
<tr>
<td>2002</td>
<td>3.34</td>
<td>1.5693</td>
<td>2.87</td>
<td>99.9917</td>
</tr>
<tr>
<td>2003</td>
<td>2.82</td>
<td>1.4010</td>
<td>2.46</td>
<td>102.750</td>
</tr>
<tr>
<td>2004</td>
<td>2.93</td>
<td>1.3010</td>
<td>2.43</td>
<td>104.658</td>
</tr>
</tbody>
</table>

Sources

1. Price data sourced from CANSIM table v31212145
2. Annual Exchange U.S. Canadian exchange rate sourced from PACIFIC Exchange Rate Service, University of British Columbia
4. Canadian Consumer Price Index sourced from CANSIM table 326 0021

Notes

1. Ontario average grain corn prices reported monthly in Canadian dollars per metric ton. Monthly values were aggregated for the year and averaged to produce yearly values. Prices were converted from dollars per metric ton to dollars per bushel by multiplying the value by 0.00045359237 (the conversion factor from pounds metric tons) then multiplying by 56 (the standard bushels weight for grain corn).
3. Ontario annual average prices converted to U.S. dollars by dividing the Canadian dollar price by the annual average exchange rate.
Table 4.5 Base Model Calibration Elasticities

<table>
<thead>
<tr>
<th>Supply</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 2 yellow Corn</td>
<td>0.400$^1$</td>
</tr>
</tbody>
</table>

**Fed Cattle**

| Eastern Canada | 0.995$^3$ | -1.025$^4$ |
| Western Canada | 0.1.30$^5$| -1.025$^6$ |
| US            | 3.240$^7$  | -0.374$^8$  |

Sources

1. Taken from de Gorter and Just (2008)
2. Taken from de Gorter and Just (2008)
3. Taken from Kulshreshtha (1976)
4. Taken from Cranfield (2010)
5. Taken from Kulshreshtha (1976)
6. Taken from Cranfield (2010)
7. Taken from Marsh (1994)
8. Taken from Cranfield (2010)
Table 4.6 U.S. Annual Supply and Demand for Fed Cattle

(Millions of Pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Total Fed Cattle Production</th>
<th>Total Disappearance</th>
<th>Total Exports</th>
<th>Total Domestic Disappearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>22,743</td>
<td>24,030</td>
<td>1,006</td>
<td>23,024</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>22,917</td>
<td>24,115</td>
<td>1,189</td>
<td>22,926</td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>23,086</td>
<td>24,262</td>
<td>1,324</td>
<td>22,938</td>
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<td>23,049</td>
<td>24,006</td>
<td>1,275</td>
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<tr>
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<td>25,534</td>
<td>1,821</td>
<td>23,713</td>
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</tr>
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<td>25,861</td>
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</tr>
<tr>
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<td>25,490</td>
<td>25,611</td>
<td>2,136</td>
<td>23,475</td>
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</tr>
<tr>
<td>1998</td>
<td>25,760</td>
<td>26,305</td>
<td>2,171</td>
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<tr>
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<td>26,936</td>
<td>2,412</td>
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<tr>
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<td>27,338</td>
<td>2,468</td>
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<td>27,026</td>
<td>2,269</td>
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<td>27,877</td>
<td>2,448</td>
<td>25,429</td>
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<td>27,000</td>
<td>2,518</td>
<td>24,482</td>
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</tr>
<tr>
<td>2004</td>
<td>24,650</td>
<td>27,750</td>
<td>460</td>
<td>27,289</td>
<td></td>
</tr>
</tbody>
</table>

Sources

1. U.S. annual supply and disappearance of fed cattle sourced from USDA ERS Red Meat Yearbook (94006), table 94

Notes

1. Annual U.S. fed cattle statistics are reported quarterly, in millions on pounds. Quarterly values have been aggregated to yearly sums.
2. Total fed cattle production is reported separately for farms and commercial units in the U.S. Total annual production refers to the sum of these to annual values.
3. Total disappearance includes both domestic slaughter as well as exported quantities.
4. Total exports refer to the total quantity of fed cattle that is exported by the U.S. annually.
5. Total domestic disappearance is the annual difference between the total annual disappearance and the total annual exports. Values refer to fed cattle weight processed in the U.S.
Table 4.7 Canadian Annual Supply and Disappearance of Beef

(millions of pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Beef Supply¹</th>
<th>Total Beef Disappearance²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2335.0</td>
<td>1,891.05</td>
</tr>
<tr>
<td>1991</td>
<td>2321.7</td>
<td>1,813.82</td>
</tr>
<tr>
<td>1992</td>
<td>2402.0</td>
<td>1,888.65</td>
</tr>
<tr>
<td>1993</td>
<td>2431.1</td>
<td>1,813.12</td>
</tr>
<tr>
<td>1994</td>
<td>2570.3</td>
<td>1,900.07</td>
</tr>
<tr>
<td>1995</td>
<td>2579.9</td>
<td>1,957.51</td>
</tr>
<tr>
<td>1996</td>
<td>2722.6</td>
<td>2,151.63</td>
</tr>
<tr>
<td>1997</td>
<td>2907.8</td>
<td>2,309.01</td>
</tr>
<tr>
<td>1998</td>
<td>3084.9</td>
<td>2,514.38</td>
</tr>
<tr>
<td>1999</td>
<td>3319.7</td>
<td>2,694.93</td>
</tr>
<tr>
<td>2000</td>
<td>3354.1</td>
<td>2,695.11</td>
</tr>
<tr>
<td>2001</td>
<td>3427.0</td>
<td>2,685.63</td>
</tr>
<tr>
<td>2002</td>
<td>3525.9</td>
<td>2,758.48</td>
</tr>
<tr>
<td>2003</td>
<td>3192.6</td>
<td>2,514.10</td>
</tr>
<tr>
<td>2004</td>
<td>3551.9</td>
<td>3,198.54</td>
</tr>
</tbody>
</table>

Sources

1. Canadian Beef Supply data sourced from CANSIM Table 30037 Meat Production Supply and Disposition in Canada series v62246
2. Canadian Beef slaughter data sourced from CANSIM Table 30037 Meat Production Supply and Disposition in Canada series v62253
To reach an estimate of the demand from each region it is assumed that the per capita beef consumption is stable across Canada and the 2002 populations for the two regions are then used to divide to total demand across the two regions.

The prices that are used for the calibration of the fed cattle markets are found in Tables 4.8 and 4.9. Table 4.8 displays the U.S. annual average prices for fed cattle. The 2002 calibration value is $67.04 US$/cwt and is close to the mean of the data over the time period. Fed cattle prices do show considerable fluctuations. The Table 4.9 presents the fed cattle prices for eastern and western Canada as taken from Toronto, Ontario and Alberta respectively. The 2002 calibration values appear to be close to the highest prices experienced over the time period, though it is important to consider the impact the weak Canadian dollar on these values.

The elasticity’s used in the fed cattle models are found in Table 4.10. These elasticity’s are taken from the literature sources cited in the notes of the table, and constitute the most suitable and consistent elasticity estimates available during the time of research.

The following equations are the calibrated versions of the regional supply and demand functions for fed cattle in Canada and the United States were introduced in the first half of the chapter, as Equations 3.3 and 3.4. The complete set of calibration parameters for these six functions is included in Table 4.10.
The fed cattle supply and demand functions presented in chapter 3 are

$$QS_i^{fe} = h_i^{fe}(P_i^{fe} - TP_i^{fe})^{k_i^{fe}}$$

(3.5)

$$QD_i^{fe} = l_i^{fe}p_i^{m_i^{fe}}$$

(3.7)

The calibrated functions for Eastern Canada are:

$$QS_{ec}^{fe} = 854.788(P_{ec}^{fe} - 916.5070)^{0.083}$$

(4.1)

$$QD_{ec}^{fe} = 948.612.353P_{ec}^{fe^{1.025}}$$

(4.2)

The calibrated functions for Western Canada are:

$$QS_{wc}^{fe} = 1191.693(P_{wc}^{fe} - 838.631)^{0.219}$$

(4.3)

$$QD_{wc}^{fe} = 3,634,774.590P_{wc}^{fe^{-1.025}}$$

(4.4)

The calibrated functions for the United States are:

$$QS_{us}^{fe} = 1,375.925(P_{us}^{fe} - 854.864)^{0.619}$$

(4.5)

$$QD_{us}^{fe} = 557,149P_{us}^{fe^{-0.374}}$$

(4.5)
4.3 Validation of Base Model

The base model is validated against 2002 empirical data to demonstrate that the model reproduces the results of the 2002 calibration year. The comparison of the base model results and the empirical data from the base year is displayed in Table 4.7. While disparities between the base model results and the empirical data do exist, rounding errors are the most likely source of these differences. Such small variations are noted, but do not impact the general level of reliability of the model. Specifically, the price and quantity results of the fed cattle portion of the model have larger percentage variation as compared to the 2002 calibration data then the results of the grains portion of the model. These increases in variation are somewhat disappointing considering the accuracy of the grains portion of the model, but differences between the results and the empirical data are only greater than one percent on one occasion and are not cause for concern.

As well, the model has been validated in comparison to the expectations of general economic theory. Specifically, fluctuations to the price intercepts of both the supply and demand curves for the U.S. corn market and the Eastern and Western Canadian fed cattle markets have been imposed on the model. The resulting changes in the results are noted and compared with the expected outcome of such a shift as based on theory. For example, when the supply curve for Eastern Canadian fed cattle is shifted upwards, the resulting increase in equilibrium price, decrease in supply, and decrease in domestic demand are all consistent with what would be expected from such a shift. Similarly, when the U.S. demand curve for corn is shifted downwards, prices decrease, domestic supply decreases, and domestic demand decreases.
Table 5.7 Base Model Validation Results

<table>
<thead>
<tr>
<th>Model Results</th>
<th>2002 Data</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Price of Corn (Cdn$/bushel)</td>
<td>3.81</td>
<td>3.86</td>
</tr>
<tr>
<td>U.S. Supply of Corn (millions of bushels)</td>
<td>9,491</td>
<td>9,491</td>
</tr>
<tr>
<td>Ontario Price of Corn (Cdn$/bushel)</td>
<td>3.92</td>
<td>3.93</td>
</tr>
<tr>
<td>Alberta Price of Feed Barley (Cdn$/bushel)</td>
<td>3.03</td>
<td>3.05</td>
</tr>
<tr>
<td>Ontario Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1131.15</td>
<td>1,135</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Supplied</td>
<td>1,243</td>
<td>1,247</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Demanded</td>
<td>703</td>
<td>701</td>
</tr>
<tr>
<td>Alberta Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1084.15</td>
<td>1,088</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Supplied (thousands of head)</td>
<td>3,724</td>
<td>3,741</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Demanded (thousands of head)</td>
<td>2,815</td>
<td>2,805</td>
</tr>
<tr>
<td>U.S. Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1,154.15</td>
<td>1,158</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Supplied</td>
<td>38,426</td>
<td>38,846</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Demanded</td>
<td>39,874</td>
<td>39,824</td>
</tr>
</tbody>
</table>

Sources:
1. The base model results produced by the model
2. The 2002 calibration data and sources
3. The % Differences are calculated as \(((\text{Base Model} - \text{2002 Data}) / \text{2002 Data}) \times 100\)
Having validated the base model results with regards to both the empirical data of the calibration year, as well as the expected results of imposed shifts, the remaining sections of the chapter will focus on the scenarios tested by the model. The details and motivation of each scenario will be discussed, the results will be described, and comparisons will be drawn to the results of the base model.

4.4 Summary

This chapter has presented the calibrated version of the conceptual. The base model is validated against 2002 empirical data to demonstrate that the model reproduces the results of the 2002 calibration year. The following chapter will present and discuss the results of the scenarios tested by the model.
Table 4.8 U.S. Annual Average Fed Cattle Prices

<table>
<thead>
<tr>
<th>Year</th>
<th>Slaughter Steer Price, Choice 2-4</th>
<th>US CPI 1984 = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>78.56</td>
<td>130.7</td>
</tr>
<tr>
<td>1991</td>
<td>74.21</td>
<td>136.2</td>
</tr>
<tr>
<td>1992</td>
<td>75.35</td>
<td>140.3</td>
</tr>
<tr>
<td>1993</td>
<td>76.36</td>
<td>144.5</td>
</tr>
<tr>
<td>1994</td>
<td>68.84</td>
<td>148.2</td>
</tr>
<tr>
<td>1995</td>
<td>66.26</td>
<td>152.4</td>
</tr>
<tr>
<td>1996</td>
<td>65.05</td>
<td>156.9</td>
</tr>
<tr>
<td>1997</td>
<td>66.32</td>
<td>160.5</td>
</tr>
<tr>
<td>1998</td>
<td>61.47</td>
<td>163.0</td>
</tr>
<tr>
<td>1999</td>
<td>65.56</td>
<td>166.6</td>
</tr>
<tr>
<td>2000</td>
<td>69.65</td>
<td>172.2</td>
</tr>
<tr>
<td>2001</td>
<td>72.71</td>
<td>177.1</td>
</tr>
<tr>
<td>2002</td>
<td>67.04</td>
<td>179.9</td>
</tr>
<tr>
<td>2003</td>
<td>84.69</td>
<td>184.0</td>
</tr>
<tr>
<td>2004</td>
<td>84.75</td>
<td>188.9</td>
</tr>
</tbody>
</table>

Sources
1. Annual average fed cattle prices sourced from USDA ERS Red Meat Year book (94006) table 59

Notes
2. Annual Prices reported nominally for Choice 2-4 Slaughter Steers in Nebraska, reported in US dollars per hundred weight.
3. US CPI listed for all goods, 1984 price level = 100
Table 4.9 Canadian Annual Fed Cattle Prices

(CDNS/CWT for A1 and A2 Steers)

<table>
<thead>
<tr>
<th>Year</th>
<th>Eastern Canada (Toronto)</th>
<th>Western Canada (Alberta)</th>
<th>Exchange Rate</th>
<th>CDNS CPI 2002 = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>88.89</td>
<td>84.30</td>
<td>1.1668</td>
<td>78.3583</td>
</tr>
<tr>
<td>1991</td>
<td>84.56</td>
<td>78.31</td>
<td>1.1457</td>
<td>82.7667</td>
</tr>
<tr>
<td>1992</td>
<td>87.38</td>
<td>82.22</td>
<td>1.2087</td>
<td>84.000</td>
</tr>
<tr>
<td>1993</td>
<td>97.23</td>
<td>91.90</td>
<td>1.2901</td>
<td>85.5667</td>
</tr>
<tr>
<td>1994</td>
<td>92.58</td>
<td>86.17</td>
<td>1.3656</td>
<td>85.7083</td>
</tr>
<tr>
<td>1995</td>
<td>88.12</td>
<td>82.91</td>
<td>1.3724</td>
<td>87.5500</td>
</tr>
<tr>
<td>1996</td>
<td>82.89</td>
<td>78.42</td>
<td>1.3635</td>
<td>88.9250</td>
</tr>
<tr>
<td>1997</td>
<td>85.85</td>
<td>84.00</td>
<td>1.3846</td>
<td>90.3667</td>
</tr>
<tr>
<td>1998</td>
<td>88.26</td>
<td>83.56</td>
<td>1.4835</td>
<td>91.2667</td>
</tr>
<tr>
<td>1999</td>
<td>92.64</td>
<td>89.30</td>
<td>1.4857</td>
<td>92.8500</td>
</tr>
<tr>
<td>2000</td>
<td>102.86</td>
<td>95.00</td>
<td>1.4851</td>
<td>95.3750</td>
</tr>
<tr>
<td>2001</td>
<td>110.90</td>
<td>102.82</td>
<td>1.5488</td>
<td>97.7833</td>
</tr>
<tr>
<td>2002</td>
<td>103.21</td>
<td>98.88</td>
<td>1.5693</td>
<td>99.9917</td>
</tr>
<tr>
<td>2003</td>
<td>84.72</td>
<td>84.28</td>
<td>1.4010</td>
<td>102.7500</td>
</tr>
<tr>
<td>2004</td>
<td>77.00</td>
<td>78.40</td>
<td>1.3010</td>
<td>104.658</td>
</tr>
</tbody>
</table>

Sources

1. Annual average prices for A1 and A2 steers in Toronto Canada sourced from CANSIM table v41339198
2. Annual average prices for A1 and A2 steers in Alberta Canada sourced from CANSIM table v41339199
3. Annual Exchange U.S. Canadian exchange rate sourced from PACIFIC Exchange Rate Service, University of British Columbia
4. Canadian Consumer Price Index sourced from CANSIM table 326 0021

Notes

2. Annual Prices reported nominally for A1 and A2 Steers in N, reported in Canadian dollars per hundredweight.
Table 4.10 Calibration Parameters for the Regional Supply and Demand Curves for Fed Cattle

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>84.72&lt;sup&gt;1&lt;/sup&gt;</td>
<td>84.28&lt;sup&gt;1&lt;/sup&gt;</td>
<td>84.69&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;S&lt;/sub&gt;</td>
<td>580.00&lt;sup&gt;3&lt;/sup&gt;</td>
<td>2320&lt;sup&gt;3&lt;/sup&gt;</td>
<td>27000&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>h</td>
<td>574.842&lt;sup&gt;5&lt;/sup&gt;</td>
<td>2313.762&lt;sup&gt;5&lt;/sup&gt;</td>
<td>26755.197&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>k</td>
<td>82.310&lt;sup&gt;6&lt;/sup&gt;</td>
<td>80.444&lt;sup&gt;7&lt;/sup&gt;</td>
<td>82.750&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>l</td>
<td>0.010&lt;sup&gt;9&lt;/sup&gt;</td>
<td>0.002&lt;sup&gt;9&lt;/sup&gt;</td>
<td>0.014&lt;sup&gt;9&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Demand**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q&lt;sub&gt;D&lt;/sub&gt;</td>
<td>1759.8&lt;sup&gt;10&lt;/sup&gt;</td>
<td>754.2&lt;sup&gt;10&lt;/sup&gt;</td>
<td>24482&lt;sup&gt;11&lt;/sup&gt;</td>
</tr>
<tr>
<td>m</td>
<td>9103.402&lt;sup&gt;12&lt;/sup&gt;</td>
<td>3893.944&lt;sup&gt;12&lt;/sup&gt;</td>
<td>1897240.487&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>n</td>
<td>-0.370&lt;sup&gt;13&lt;/sup&gt;</td>
<td>-0.370&lt;sup&gt;13&lt;/sup&gt;</td>
<td>-0.98&lt;sup&gt;14&lt;/sup&gt;</td>
</tr>
<tr>
<td>r</td>
<td>0&lt;sup&gt;15&lt;/sup&gt;</td>
<td>0&lt;sup&gt;15&lt;/sup&gt;</td>
<td>0&lt;sup&gt;15&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Sources**

1. The calibration prices for Fed Cattle in both Canadian regions come from Table 3.13
2. The calibration price for U.S. Fed Cattle is found in Table 3.12
3. The calibration quantity supplied for both Canadian regions comes from Table 3.11
4. The calibration quantity supplied for the U.S. come from Table 3.10
5. The supply shift coefficient is solved for by the model.
8. The shutdown price for Fed Cattle is taken from Live Stock Enterprise Budget, Iowa State University (2009)
9. The elasticity coefficient is solved for separate from the model
10. The calibration quantity demanded for both Canadian regions comes from Table 3.11
11. The calibration quantity demanded for the U.S. come from Table 3.10
12. The demand shift coefficient is solved for by the model.
13. The Canadian demand elasticity for Fed Cattle sourced from Table 3.9
14. The U.S. demand elasticity for Fed Cattle comes from Table 3.9
15. The variable r is a income shift parameter that is set at 0 for the base year

**Notes**

5. Notes should start at 1 and be sequential in every Table or Figure. The supply shift coefficient is solved for by the model using the price, quantity and elasticity values from the base year. Subbing those three values into the supply functions for fed cattle (equations 3.3, 3.5, 3.7), the equations can be solved for h.
9. The supply elasticity coefficient is solved for by the same process as the supply elasticity coefficient in the supply curve for No.2 Yellow Corn (equation 4.1). See Math Appendix 1 for detailed explanation.
Table 4.11 Canadian Annual Disappearance of Grain Corn

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic Disappearance ²</th>
<th>Annual total (MT)³</th>
<th>Annual Total (millions of bu.)⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998-03</td>
<td>5,147,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-08</td>
<td>8,611,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-12</td>
<td>2,733,100</td>
<td>16,491,400</td>
<td>649.24</td>
</tr>
<tr>
<td>1999-03</td>
<td>5,662,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999-08</td>
<td>9,024,900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999-12</td>
<td>2,895,700</td>
<td>17,583,100</td>
<td>692.22</td>
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<tr>
<td>2000-03</td>
<td>5,709,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-08</td>
<td>9,331,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-12</td>
<td>3,326,400</td>
<td>18,366,600</td>
<td>723.06</td>
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<tr>
<td>2001-03</td>
<td>5,941,100</td>
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<td>2001-08</td>
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<tr>
<td>2001-12</td>
<td>4,060,800</td>
<td>20,385,300</td>
<td>802.53</td>
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<tr>
<td>2002-03</td>
<td>6,836,600</td>
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<td></td>
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<tr>
<td>2002-08</td>
<td>11,864,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002-12</td>
<td>3,964,700</td>
<td>22,665,500</td>
<td>892.30</td>
</tr>
<tr>
<td>2003-03</td>
<td>7,565,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003-08</td>
<td>12,755,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003-12</td>
<td>4,019,400</td>
<td>24,340,200</td>
<td>958.23</td>
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<td>2004-03</td>
<td>6,961,100</td>
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<td></td>
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<tr>
<td>2004-08</td>
<td>11,317,600</td>
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<td></td>
</tr>
<tr>
<td>2004-12</td>
<td>3,151,100</td>
<td>21,429,800</td>
<td>843.65</td>
</tr>
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<td>2005-03</td>
<td>6,148,500</td>
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</tr>
<tr>
<td>2005-08</td>
<td>10,367,800</td>
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<td></td>
</tr>
<tr>
<td>2005-12</td>
<td>3,375,700</td>
<td>19,892,000</td>
<td>783.11</td>
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<td>2006-03</td>
<td>6,301,100</td>
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<td>2006-08</td>
<td>10,792,400</td>
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<td>2006-12</td>
<td>3,357,800</td>
<td>20,451,300</td>
<td>805.13</td>
</tr>
<tr>
<td>2007-03</td>
<td>6,501,900</td>
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<tr>
<td>2007-08</td>
<td>11,454,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007-12</td>
<td>4,496,800</td>
<td>22,453,200</td>
<td>883.94</td>
</tr>
<tr>
<td>2008-03</td>
<td>8,677,300</td>
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<tr>
<td>2008-08</td>
<td>13,801,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008-12</td>
<td>3,588,500</td>
<td>26,067,100</td>
<td>1,026.22</td>
</tr>
</tbody>
</table>

Sources

1. Original data obtained from CANSIMM table 10042 V31185192. Reported three times yearly and measured in metric tons.
Table 4.11 con’t

Notes

1. Canadian corn disappearance is reported three times yearly, on the last day of the third eighth and twelfth month. The reported value is the total corn disappearance for that period and measured in metric tons.
   a. The data period for Table 4.4 does not match that of the other tables included in the chapter due to the limited availability of Canadian corn disappearance data.

2. Annual totals are calculated by summing the three observations for each year.

3. Annual total are converted from metric tons to pounds by dividing by a factor of 0.000453592.
   Annual totals are converted from pounds to bushels by dividing the observation by the standard bushel weight of corn, 56 pounds.
   Annual totals are converted from bushels to millions of bushels by dividing the observations by 1,000,000. This conforms the Canadian disappearance data to the U.S. unit convention of millions of bushels.
Table 4.12 Canadian Annual Supply of Grain Corn

(Millions on bushels)

<table>
<thead>
<tr>
<th>Year</th>
<th>Supply (bu.) 1</th>
<th>Supply (millions of bu.) 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>278200000</td>
<td>278.2</td>
</tr>
<tr>
<td>1991</td>
<td>291824000</td>
<td>291.8</td>
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<td>1992</td>
<td>194367000</td>
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<td>1993</td>
<td>265944000</td>
<td>265.9</td>
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<tr>
<td>1994</td>
<td>283057000</td>
<td>283.1</td>
</tr>
<tr>
<td>1995</td>
<td>286637000</td>
<td>286.6</td>
</tr>
<tr>
<td>1996</td>
<td>296905000</td>
<td>296.9</td>
</tr>
<tr>
<td>1997</td>
<td>282656000</td>
<td>282.7</td>
</tr>
<tr>
<td>1998</td>
<td>352440000</td>
<td>352.4</td>
</tr>
<tr>
<td>1999</td>
<td>360663000</td>
<td>360.7</td>
</tr>
<tr>
<td>2000</td>
<td>273757000</td>
<td>273.8</td>
</tr>
<tr>
<td>2001</td>
<td>330268000</td>
<td>330.3</td>
</tr>
<tr>
<td>2002</td>
<td>354266000</td>
<td>354.3</td>
</tr>
<tr>
<td>2003</td>
<td>377437000</td>
<td>377.4</td>
</tr>
<tr>
<td>2004</td>
<td>347891000</td>
<td>347.9</td>
</tr>
</tbody>
</table>

Sources

1. Canadian No. 2 yellow grain corn supply data sourced from CANSIMM table 10017 V46774. Originally reported in bushels, transformed to millions of bushels
Table 4.13 U.S. Annual Supply and Disappearance of Grain Corn

<table>
<thead>
<tr>
<th>Year</th>
<th>Supply</th>
<th>Disappearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>7,934.03</td>
<td>7,760.66</td>
</tr>
<tr>
<td>1991</td>
<td>7,474.77</td>
<td>7,915.34</td>
</tr>
<tr>
<td>1992</td>
<td>9,476.70</td>
<td>8,471.12</td>
</tr>
<tr>
<td>1993</td>
<td>6,337.73</td>
<td>7,621.38</td>
</tr>
<tr>
<td>1994</td>
<td>10,050.52</td>
<td>9,352.38</td>
</tr>
<tr>
<td>1995</td>
<td>7,400.05</td>
<td>8,548.44</td>
</tr>
<tr>
<td>1996</td>
<td>9,232.56</td>
<td>8,788.60</td>
</tr>
<tr>
<td>1997</td>
<td>9,206.83</td>
<td>8,791.00</td>
</tr>
<tr>
<td>1998</td>
<td>9,758.69</td>
<td>9,298.32</td>
</tr>
<tr>
<td>1999</td>
<td>9,430.61</td>
<td>9,514.78</td>
</tr>
<tr>
<td>2000</td>
<td>9,915.05</td>
<td>9,740.32</td>
</tr>
<tr>
<td>2001</td>
<td>9,502.58</td>
<td>9,815.40</td>
</tr>
<tr>
<td>2002</td>
<td>8,966.79</td>
<td>9,490.99</td>
</tr>
<tr>
<td>2003</td>
<td>10,087.29</td>
<td>10,229.95</td>
</tr>
<tr>
<td>2004</td>
<td>11,805.58</td>
<td>10,660.53</td>
</tr>
</tbody>
</table>

Sources
1. U.S. supply data were obtained from the USDA ERS Fields grains data set
2. U.S. disappearance data were obtained from the USDA ERS Fields grains data set

Notes
2. Again, start notes with 1. Data retrieved from the custom queries search page of the USDA ERS Fields grains data set. The page allows the user to search the USDA data and build a data set that includes the variables and time period that are of interest. To retrieves the annual U.S. supply data for No.2 yellow corn the search fields at custom queries page http://www.ers.usda.gov/Data/feedgrains/FeedGrainsQueriable.aspx were filled out as following: 1-supply and use, 2-supply total, 3-corn, 4-market year, 5- USA, 6-1990-2004.

Data retrieved from the custom queries search page of the USDA ERS Fields grains data set. The page allows the user to search the USDA data and build a data set that includes the variables and time period that are of interest. To retrieves the annual U.S. Disappearance data for No.2 yellow corn the search fields at custom queries page http://www.ers.usda.gov/Data/feedgrains/FeedGrainsQueriable.aspx were filled out as following: 1-supply and use, 2-Dissapearnce, total, 3-corn, 4-market year, 5- USA, 6-1990-2004.
Table 4.14 Base Model Calibration Parameters – U.S. Grain Market

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. corn supply elasticity</td>
<td>0.40&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>U.S. corn demand elasticity</td>
<td>-0.20&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>U.S. corn 2002 base model price (converted to 2002 Cdn$)</td>
<td>3.81&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>U.S. corn 2002 base model Quantity supplied (million bushels)</td>
<td>9,490.99&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>U.S. 2002 ethanol production (million U.S. gallons)</td>
<td>2,140&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>U.S. 2002 grain corn used for ethanol production (million bushels)</td>
<td>996&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Sources:
1. Taken from de Gorter and Just (2008)
2. Taken from de Gorter and Just (2008)
3. The base model U.S. corn price measured in Cdn$ is the average price for corn in the United States in 2002. See Table 4.3, for historical data, and source note 2 for detailed notes.
4. The base model U.S. corn quantity supplied is the total production of grain corn in the U.S. in 2002. See Table 4.2 for historical U.S. corn production
5. The base model U.S. ethanol production is the amount of ethanol produced in the United States in 2002. See Table 4.1 for historical U.S. ethanol production
6. The base model U.S grain corn used for ethanol is the amount of corn that was used to make ethanol in the United States in 2002. See Table 4.1 for historical U.S corn use in U.S. ethanol production
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Grain Producers’ Surplus (Million Cdn$/year)</td>
<td>23,436¹</td>
</tr>
<tr>
<td>U.S. Grain Consumers’ Surplus (Million Cdn$/year)</td>
<td>53,884²</td>
</tr>
<tr>
<td>U.S. Grain Social Surpluses (Million Cdn$/year)</td>
<td>77,321³</td>
</tr>
</tbody>
</table>

Sources:

1. U.S. grain producers’ surplus is measured as the area on the grain market supply-demand graph that falls below the equilibrium price, and above the supply function. In this model it is used as a measure of the relative well being of the grain producers.

2. The U.S. grain consumers’ surplus is measured as the area on the grain market supply-demand graph that falls above the equilibrium price, but below the demand function. Because the function of the demand curve is exponential, and prevents the demand curve from intersection the Y (price) axis, consumer surplus must be capped at some price level in order for it to be measurable. If a cap was not imposed consumers’ surplus would be immeasurable because the area above the equilibrium price and below the demand function would be unbounded. For use in this model the area is capped at a price level of $15 Cdn$/bu. See Chapter 4 and section 4.3 for a more complete description of this cap.

3. U.S. grain social surplus is calculated as the sum of the producers’ and consumers’ surplus.
Table 4.16 Base Model Calibration Parameters – Canadian Grain Market

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada - U.S. 2002 average currency exchange rate (Cdn$/US)</td>
<td>1.569¹</td>
</tr>
<tr>
<td>Ontario 2002 Average Adjusted corn basis (Cdn$/bushel)</td>
<td>+0.07²</td>
</tr>
<tr>
<td>Ontario 2002 Average corn price (Cdn$/bushel)</td>
<td>3.93³</td>
</tr>
<tr>
<td>Alberta 2002 Average Feed barley price (Cdn$/bushel)</td>
<td>3.05⁴</td>
</tr>
</tbody>
</table>

Sources:

1. The 2002 average currency exchange rate is the average quantity of Canadian dollars it would take to purchase one US dollar. See Table 4.3, note 2 for Exchange rate sources.

2. The 2002 Ontario adjusted corn basis is calculated as the difference between the annual average price for a bushel of corn in Ontario (measured in Cdn$) and the annual average price for bushel of corn in the United States (measured in $US). See Table 4.3 for historical data, sources and notes.

3. The 2002 Ontario corn price is the average price for a bushel of corn in Ontario in 2002. See Table 4.3 for historical data and source.

4. The Alberta barley price is solved for using the U.S. price of corn and the Alberta feed barley price factor. The calculation is

   \[
   \text{Alberta feed barley price (Cdn$/bu)} = 0.77 \times \text{US corn price ($US/bu)} + 0.09 \text{ CDN/bu}. 
   \]

   The Alberta feed barely price factor is described in more detail in Chapter 4, section 4.3.
Sources:
3. The base model calibration price for the fed cattle in Eastern Canada is the average annual price for A1 and A2 steers in Ontario Ontario Canada. For historical data and complete source notes see Table 4.9.
4. The base model calibration quantity supplied for Eastern Canada is the total number of steers produced in Ontario, Quebec and the Maritime provinces for 2002. For historical data, complete regional breakdowns and sources see tables 4.6 and 4.7.
5. The base model calibration quantity demanded for Eastern Canada is the total number of steers slaughtered in Ontario, Quebec and the Maritime provinces for 2002. For historical data, complete regional breakdowns and sources see tables 4.6 and 4.7.
6. The base model calibration net international export quantity for the three regions is the total number of steers exported to international counties by each of the three regions in 2002. See tables 4.5-4.7 for historical data, regional breakdowns and sources.

Table 4.17 Base Model Calibration Parameters -2002 Fed Cattle Markets

<table>
<thead>
<tr>
<th></th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Elasticity(^1)</td>
<td>0.995</td>
<td>1.30</td>
<td>3.24</td>
</tr>
<tr>
<td>Demand Elasticity(^2)</td>
<td>-1.025</td>
<td>-1.025</td>
<td>-0.374</td>
</tr>
<tr>
<td>Price (Cdn$/1100 lb steer)(^3)</td>
<td>1,131.15</td>
<td>1,084.15</td>
<td>1,154.15</td>
</tr>
<tr>
<td>Quantity Supplied (thousands of head)(^4)</td>
<td>1,243</td>
<td>3,724</td>
<td>38,426</td>
</tr>
<tr>
<td>Quantity Demanded (thousands of head)(^5)</td>
<td>703</td>
<td>2,815</td>
<td>39,874</td>
</tr>
<tr>
<td>Net International Export Quantity (thousands of head)</td>
<td>539</td>
<td>908</td>
<td>-1,448</td>
</tr>
</tbody>
</table>

Sources:
3. The base model calibration price for the fed cattle in Eastern Canada is the average annual price for A1 and A2 steers in Toronto Ontario Canada. For historical data and complete source notes see Table 4.9.
4. The base model calibration quantity supplied for Eastern Canada is the total number of steers produced in Ontario, Quebec and the Maritime provinces for 2002. For historical data, complete regional breakdowns and sources see tables 4.6 and 4.7.
5. The base model calibration quantity demanded for Eastern Canada is the total number of steers slaughtered in Ontario, Quebec and the Maritime provinces for 2002. For historical data, complete regional breakdowns and sources see tables 4.6 and 4.7.
6. The base model calibration net international export quantity for the three regions is the total number of steers exported to international counties by each of the three regions in 2002. See tables 4.5-4.7 for historical data, regional breakdowns and sources.
Fed cattle producers’ surplus in all three regions is measured as the area on the fed cattle supply-demand graph that falls below the equilibrium price, and above the supply function. In this model it is used as a measure of the relative well being of the fed cattle producers.

The fed cattle consumers’ surplus is measured as the area on the grain market supply-demand graph that falls above the equilibrium price, but below the demand function. Because the function of the demand curve is exponential, and prevents the demand curve from intersection the Y (price) axis, consumer surplus must be capped at some price level in order for it to be measurable. If a cap was not imposed consumers’ surplus would be immeasurable because the area above the equilibrium price and below the demand function would be unbounded. See Chapter 4 and section 4.5 for a more complete description of this cap.

Fed Cattle social surplus is calculated as the sum of the producers’ and consumers’ surplus.

### Table 4.18 Base Model Results -2002 Fed Cattle Markets

<table>
<thead>
<tr>
<th></th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
</table>
| Fed Cattle Producers’ Surplus (Million Cdn$)
1. | 13,340         | 38,613         | 441,646       |
| Fed Cattle Consumers’ Surplus (Million Cdn$)
2. | 6,745          | 27,106         | 1,177,042     |
| Fed Cattle Market Social Surpluses (Million Cdn$)
3. | 20,085         | 65,718         | 1,618,688     |

Sources:

1. Fed cattle producers’ surplus in all three regions is measured as the area on the fed cattle supply-demand graph that falls below the equilibrium price, and above the supply function. In this model it is used as a measure of the relative well being of the fed cattle producers.

2. The fed cattle consumers’ surplus is measured as the area on the grain market supply-demand graph that falls above the equilibrium price, but below the demand function. Because the function of the demand curve is exponential, and prevents the demand curve from intersection the Y (price) axis, consumer surplus must be capped at some price level in order for it to be measurable. If a cap was not imposed consumers’ surplus would be immeasurable because the area above the equilibrium price and below the demand function would be unbounded. See Chapter 4 and section 4.5 for a more complete description of this cap.

3. Fed Cattle social surplus is calculated as the sum of the producers’ and consumers’ surplus.
Chapter 5

Results and Discussion

5.1 Introduction

This chapter reports the base model results as well as the results of the two scenarios studied with the model. The base results and two test scenarios are presented and discussed in the following order: the base results are presented first, followed by Scenario One – 2008 Ethanol Production levels, Scenario Two – 2015 Ethanol Production Levels. Table 5.1 gives a summary of the base model and the two scenarios.

The base model is used to provide a standard against which the scenarios are compared. The base model is the 2002 model as it is calibrated in Chapter 4, with the 2002 ethanol production removed. The amount of grain corn used for ethanol production is removed from the quantity demanded for grain corn. The new price, quantity and surplus measures calculated for all three regions.

The results of the two scenarios also include equilibrium price and quantity values, as well as producers’ surplus values, for the feed grain and fed cattle markets in each of the regions. These results are compared to the price, quantity, and surplus results from the base model measure how the prices, quantities and surplus levels in the test scenarios vary from those solved for in the base model.
Table 5.1 Scenario Summary

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Details and Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Model</td>
<td>The base model removes the 2002 ethanol production, and associated demand for corn, from the grain corn market. The resulting corn market equilibrium prices and quantities are used to solve for base model results for the fed cattle market.</td>
</tr>
<tr>
<td>1</td>
<td>2008 Ethanol</td>
<td>This scenario imposes 2008 ethanol production quantities on the base year of 2002, and then compares the resulting price, quantity and surplus levels against the 2002 base model in order to assess what impact the 2008 ethanol production levels has on the 2002 markets.</td>
</tr>
<tr>
<td>2</td>
<td>2015 Ethanol</td>
<td>This scenario imposes 2015 ethanol production quantities on the base year of 2002, and then compares the resulting price, quantity and surplus level against the 2002 base model in order to assess what impact the 2008 ethanol production levels has on the 2002 markets. 2015 is chosen as a test year as this will be the year when first generation ethanol production will reach its peak allowable inclusion rate in U.S. transportation fuel.</td>
</tr>
</tbody>
</table>
5.2 Base Model Results

The calibration parameters for 2002 include the production of 2,140 million gallons of ethanol, requiring 994 million bushels of grain corn. Removing that ethanol production, and the associated demand for grain corn from the U.S. grain corn market by shifting the demand curve for corn results in new equilibrium price and quantities that estimate the outcome of 2002 without ethanol production. Using this ethanol free price for corn to solve for feed grain prices in Eastern and Western Canada, and using these new prices for feed grains in the regional fed cattle models provides equilibrium prices and quantities for fed cattle in all three regions in a zero ethanol production scenario. Calculating fed cattle producers’ surplus in each region for this zero ethanol base model provides base values to compare the fed cattle producers’ surplus found in each ethanol production scenario. The differences in the surplus values between the 2002 no ethanol base model and the two ethanol scenarios will provide a measure for the change in welfare of these producers across the scenarios.

The results of the base model are presented in Tables 5.2 to 5.4. Table 5.2 includes the results of the grain corn and feed grains portion of the model. Table 5.4 presents the results of the fed cattle markets of the model and Table 5.4 compares the base model results with the original calibration parameters for 2002. As, well Table 5.5 will present the cost of production or threshold prices for the fed cattle supply function for each region. Understanding how these cost of production estimates change as the price for feed grains in each region change is important in interpreting the results from each scenario.
Table 5.2 Base Model Feed Grain Results Model

**U.S. Grain Market**

*Scenario Calibration Parameters*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Corn Supply Elasticity</td>
<td>0.4</td>
</tr>
<tr>
<td>U.S. Corn Demand Elasticity</td>
<td>-0.2</td>
</tr>
<tr>
<td>U.S. Ethanol Production level (million US. gallons.)</td>
<td>0</td>
</tr>
<tr>
<td>Corn Used for U.S. Ethanol (millions of bushels)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>U.S. 2002 average currency exchange rate (Cdn$/US)</td>
<td>1.569</td>
</tr>
<tr>
<td></td>
<td>Ontario 2002 Average Adjusted corn basis (Cdn$/bushel)</td>
<td>+0.07</td>
</tr>
<tr>
<td></td>
<td>Alberta 2002 Average Adjusted feed barley basis (Cdn$/bushel)</td>
<td>+0.09</td>
</tr>
</tbody>
</table>

*Scenario Results*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Corn Price (Cdn$/bu)</td>
<td>3.23</td>
</tr>
<tr>
<td>U.S. Corn Quantity Supplied (mill. bu.)</td>
<td>8,816</td>
</tr>
<tr>
<td>Ontario corn price (Cdn$/bushel)</td>
<td>3.34</td>
</tr>
<tr>
<td>Alberta Feed barley price (Cdn$/bushel)</td>
<td>2.58</td>
</tr>
<tr>
<td>U.S. Corn Producers’ Surplus (Million Cdn$)</td>
<td>19,920</td>
</tr>
<tr>
<td>U.S. Corn Consumers’ Surplus (Million Cdn$)</td>
<td>55,483</td>
</tr>
<tr>
<td>U.S. Corn Social Surplus (Million Cdn$)</td>
<td>75,403</td>
</tr>
</tbody>
</table>
Table 5.3  Base Model Fed Cattle Market Results

<table>
<thead>
<tr>
<th>Fed Cattle Markets</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario Calibration Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Supply Elasticity</td>
<td>0.995</td>
<td>1.300</td>
<td>3.240</td>
</tr>
<tr>
<td>Fed Cattle Demand Elasticity</td>
<td>-1.025</td>
<td>-1.025</td>
<td>-0.374</td>
</tr>
<tr>
<td><strong>Scenario Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Price (CDN$/1,100 lb steer)</td>
<td>1,106.01</td>
<td>1,059.01</td>
<td>1,129.01</td>
</tr>
<tr>
<td>Fed Cattle Quantity Supplied (thousands of head)</td>
<td>1,261</td>
<td>3,704</td>
<td>38,841</td>
</tr>
<tr>
<td>Fed Cattle Quantity Demanded (thousands of head)</td>
<td>720</td>
<td>2,884</td>
<td>40,203</td>
</tr>
<tr>
<td>Fed Cattle Net International Export Quantity (thousands of head)</td>
<td>542</td>
<td>821</td>
<td>-1,362</td>
</tr>
<tr>
<td><strong>Welfare Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>13,093</td>
<td>37,495</td>
<td>436,645</td>
</tr>
<tr>
<td>Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>6,919</td>
<td>27,804</td>
<td>1,193,410</td>
</tr>
<tr>
<td>Fed Cattle Social Surpluses (Million Cdn$)</td>
<td>20,013</td>
<td>65,299</td>
<td>1,630,055</td>
</tr>
</tbody>
</table>
### Table 5.4 Comparison of 2002 Calibration Results and Zero Ethanol Base Model

<table>
<thead>
<tr>
<th></th>
<th>Calibrated Results</th>
<th>Base Model</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Price of Corn (Cdn$/bushel)</td>
<td>3.81</td>
<td>3.23</td>
<td>-15.2%</td>
</tr>
<tr>
<td>U.S. Supply of Corn (millions of bushels)</td>
<td>9,491</td>
<td>8,816</td>
<td>-7.1%</td>
</tr>
<tr>
<td>Ontario Price of Corn (Cdn$/bushel)</td>
<td>3.92</td>
<td>3.34</td>
<td>-14.8%</td>
</tr>
<tr>
<td>Alberta Price of Feed Barley (Cdn$/bushel)</td>
<td>3.03</td>
<td>2.58</td>
<td>-14.8%</td>
</tr>
<tr>
<td>U.S. Corn Producers' Surplus</td>
<td>23,436</td>
<td>19,920</td>
<td>-15.0%</td>
</tr>
<tr>
<td>U.S. Corn Consumers' Surplus</td>
<td>53,884</td>
<td>55,483</td>
<td>3.0%</td>
</tr>
<tr>
<td>Ontario Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1131.15</td>
<td>1106.01</td>
<td>-2.2%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Supplied</td>
<td>1,243</td>
<td>1,261</td>
<td>1.5%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Demanded</td>
<td>703</td>
<td>720</td>
<td>2.3%</td>
</tr>
<tr>
<td>Eastern Canada Net Fed Cattle Exports</td>
<td>539</td>
<td>542</td>
<td>0.4%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>13,340</td>
<td>13,093</td>
<td>-1.8%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>6,745</td>
<td>6,919</td>
<td>2.6%</td>
</tr>
<tr>
<td>Alberta Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1084.15</td>
<td>1059.01</td>
<td>-2.3%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Supplied</td>
<td>3,724</td>
<td>3,704</td>
<td>-0.5%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Demanded</td>
<td>2,815</td>
<td>2,884</td>
<td>2.4%</td>
</tr>
<tr>
<td>Western Canada Net Fed Cattle Exports</td>
<td>908</td>
<td>821</td>
<td>-9.7%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>38,613</td>
<td>37,495</td>
<td>-2.9%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>27,106</td>
<td>27,804</td>
<td>2.6%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1,154.15</td>
<td>1,129.01</td>
<td>-2.2%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Supplied</td>
<td>38,426</td>
<td>38,841</td>
<td>1.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Demanded</td>
<td>39,874</td>
<td>40,203</td>
<td>0.8%</td>
</tr>
<tr>
<td>U.S. Net Fed Cattle Exports</td>
<td>-1,448</td>
<td>-1,362</td>
<td>-5.9%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>441,646</td>
<td>436,645</td>
<td>-1.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>1,177,042</td>
<td>1,193,410</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

**Notes:**
1. Calibrated results produced by the model
2. All Base Model data produced by the model and taken from Tables 5.3 - 5.4
3. Change calculated as \(((\text{Base Model data} - \text{Calibrated Data})/\text{Calibrated Data})\times 100\)
Table 5.5  Base Model Fed Cattle Supply Curve Threshold Prices

<table>
<thead>
<tr>
<th>Fed Cattle Markets</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Grain Price (CDN$/bu)</td>
<td>3.34</td>
<td>2.58</td>
<td>3.23</td>
</tr>
<tr>
<td>Threshold Shutdown Price (CDN$/steer)</td>
<td>987.14</td>
<td>889.32</td>
<td>908.27</td>
</tr>
</tbody>
</table>
The base model results indicate that the greatest impact that the 2002 level U.S. grain based ethanol production has on the original calibrated model is on the price of grain corn and feed barley. Grain corn prices in both Eastern Canada and in the United States, as well as feed barley prices in Western Canada decrease by approximately 15 percent when the 2002 ethanol production is removed from the model. As well U.S. corn producers’ surplus also falls by 15 percent. As well, there are small decreases in the equilibrium prices for fed cattle in each region, and minor fluctuations in the resulting surplus calculations. Also of note is the near 10 percent decrease in fed cattle net exports in Western Canada as a result of modestly higher domestic demand. This increase in demand can be attributed to the reduced equilibrium price for fed cattle in the region.

Table 5.5 presents the cost of production threshold price that is included in each regional fed cattle supply curve. This value is dependent on the cost of feed in each region, and rises and falls as the price for feed increases or decreases.

5.3.1 Scenario One – 2008 Ethanol Production Levels

The first scenario tested by the model is impact of 2008 U.S. ethanol production levels on the market and welfare results for the 2002 base model. In 2008, the United States produced 9,237 million gallons of grain based ethanol, using an estimated 3,700 million bushels of grain corn. Given that the base model results are for a zero ethanol production level, this scenario tests the impact of the increase of 3,700 million bushels of corn used for ethanol in 2008 by shifting the demand curve for grain corn up by the 3,700 million bushels.
Table 5.6 includes the calibration parameters used for the U.S. grain corn market in Scenario One. The resulting U.S. corn producers’, consumers’ and social surplus results are also included in the table. As well, the Scenario 1 results for the prices of grain corn in Eastern Canada and the price of feed barley in Western Canada are included. Table 5.7 presents the calibration parameters for Scenario 1 for the three fed cattle regions in the model, the equilibrium, price and quantity results and the surplus calculations. Following that, Table 5.8 includes a comparison of the results of the Scenario One with the results of the base model. Table 5.9 presents the new cost of production threshold shutdown prices from the fed cattle supply functions for Scenario 1 with the original threshold shutdown prices from the base model.

5.3.2 Scenario One Results – Increase in the Price for grain corn

The first result presented in Table 5.8 is the increase in the price for grain corn in the United States to $6.46/bu Cdn$. This represents a near doubling of the price of grain corn from the 2002 baseline price of $3.25/bu. This increase is larger than many of the literature estimates presented in Chapter 2, but differs from those results in a number of ways. This increase is over a six year period, while many of the estimates in the literature cover a much shorter time frame. As well this change is based on the estimated 2002 price without ethanol production. If the new price of grain corn is compared to the original calibration price for grain corn in the United States in 2002, the percent increase is reduced to 68%.
Table 5.6 Scenario 1 Feed Grain Results Model

**U.S. Grain Market**

*Scenario Calibration Parameters*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Corn Supply Elasticity</td>
<td>0.4</td>
</tr>
<tr>
<td>U.S. Corn Demand Elasticity</td>
<td>-0.2</td>
</tr>
<tr>
<td>U.S. Ethanol Production level (million US. gallons)</td>
<td>9,237</td>
</tr>
<tr>
<td>Corn Used for U.S. Ethanol (millions of bushels)</td>
<td>3,700</td>
</tr>
<tr>
<td>Canada - U.S. 2002 average currency exchange rate (Cdn$/US)</td>
<td>1.569</td>
</tr>
<tr>
<td>Ontario 2002 Average Adjusted corn basis (Cdn$/bushel)</td>
<td>+0.07</td>
</tr>
<tr>
<td>Alberta 2002 Average Adjusted feed barley basis (Cdn$/bushel)</td>
<td>+0.09</td>
</tr>
</tbody>
</table>

*Scenario Results*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Corn Price (CDN$/bu)</td>
<td>6.46</td>
</tr>
<tr>
<td>U.S. Corn Quantity Supplied (mill. bu.)</td>
<td>11,248</td>
</tr>
<tr>
<td>Ontario corn price (Cdn$/bushel)</td>
<td>6.57</td>
</tr>
<tr>
<td>Alberta Feed barley price (Cdn$/bushel)</td>
<td>5.06</td>
</tr>
<tr>
<td>U.S. Corn Producers’ Surplus (Million Cdn$)</td>
<td>40,860</td>
</tr>
<tr>
<td>U.S. Corn Consumers’ Surplus (Million Cdn$)</td>
<td>16,825</td>
</tr>
<tr>
<td>U.S. Corn Social Surplus (Million Cdn$)</td>
<td>57,685</td>
</tr>
</tbody>
</table>

Sources:
1. U.S. ethanol production is the total ethanol produced in the United States in 2008. See Table 4.1 for historical U.S. Ethanol production levels and sources.
2. Corn used for U.S. ethanol is the total quantity of corn that was used to produce ethanol in the United States in 2002. See Table 4.1 for historical corn use in U.S. Ethanol production and sources.
Table 5.7  Scenario 1 Fed Cattle Market Results

<table>
<thead>
<tr>
<th>Fed Cattle Markets</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario Calibration Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Supply Elasticity</td>
<td>0.995</td>
<td>1.300</td>
<td>3.240</td>
</tr>
<tr>
<td>Fed Cattle Demand Elasticity</td>
<td>-1.025</td>
<td>-1.025</td>
<td>-0.374</td>
</tr>
<tr>
<td><strong>Scenario Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Price (CDN$/1,100 lb steer)</td>
<td>1,246.17</td>
<td>1,199.17</td>
<td>1,269.17</td>
</tr>
<tr>
<td>Fed Cattle Quantity Supplied (thousands of head)</td>
<td>1,036</td>
<td>3,764</td>
<td>36,858</td>
</tr>
<tr>
<td>Fed Cattle Quantity Demanded (thousands of head)</td>
<td>637</td>
<td>2,539</td>
<td>38,482</td>
</tr>
<tr>
<td>Fed Cattle Net International Export Quantity (thousands of head)</td>
<td>399</td>
<td>1,226</td>
<td>-1,624</td>
</tr>
<tr>
<td><strong>Welfare Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>12,825</td>
<td>43,274</td>
<td>466,065</td>
</tr>
<tr>
<td>Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>5,994</td>
<td>24,109</td>
<td>1,103,798</td>
</tr>
<tr>
<td>Fed Cattle Social Surpluses (Million Cdn$)</td>
<td>18,819</td>
<td>67,382</td>
<td>1,569,863</td>
</tr>
</tbody>
</table>
Table 5.8 Comparison of Base Model and Scenario 1 Results

<table>
<thead>
<tr>
<th></th>
<th>Base Model</th>
<th>Scenario 1</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Price of Corn (Cdn$/bushel)</td>
<td>3.23</td>
<td>6.46</td>
<td>99.8%</td>
</tr>
<tr>
<td>U.S. Supply of Corn (millions of bushels)</td>
<td>8,816</td>
<td>11,248</td>
<td>27.6%</td>
</tr>
<tr>
<td>Ontario Price of Corn (Cdn$/bushel)</td>
<td>3.34</td>
<td>6.57</td>
<td>96.5%</td>
</tr>
<tr>
<td>Alberta Price of Feed Barley (Cdn$/bushel)</td>
<td>2.58</td>
<td>5.06</td>
<td>96.3%</td>
</tr>
<tr>
<td>U.S. Corn Producers' Surplus</td>
<td>19,920</td>
<td>40,860</td>
<td>105.1%</td>
</tr>
<tr>
<td>U.S. Corn Consumers' Surplus</td>
<td>55,483</td>
<td>16,825</td>
<td>-69.7%</td>
</tr>
<tr>
<td>Ontario Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1106.01</td>
<td>1246.17</td>
<td>12.7%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Supplied</td>
<td>1,261</td>
<td>1,036</td>
<td>-17.9%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Demanded</td>
<td>720</td>
<td>637</td>
<td>-11.5%</td>
</tr>
<tr>
<td>Eastern Canada Net Fed Cattle Exports</td>
<td>542</td>
<td>399</td>
<td>-26.4%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>13,093</td>
<td>12,825</td>
<td>-2.1%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>6,919</td>
<td>5,994</td>
<td>-13.4%</td>
</tr>
<tr>
<td>Alberta Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1059.01</td>
<td>1199.17</td>
<td>13.2%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Supplied</td>
<td>3,704</td>
<td>3,764</td>
<td>1.6%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Demanded</td>
<td>2,884</td>
<td>2,539</td>
<td>-12.0%</td>
</tr>
<tr>
<td>Western Canada Net Fed Cattle Exports</td>
<td>821</td>
<td>1,226</td>
<td>49.3%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>37,495</td>
<td>43,274</td>
<td>15.4%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>27,804</td>
<td>24,109</td>
<td>-13.3%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1,129.01</td>
<td>1,269.17</td>
<td>12.4%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Supplied</td>
<td>38,841</td>
<td>36,858</td>
<td>-5.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Demanded</td>
<td>40,203</td>
<td>38,482</td>
<td>-4.3%</td>
</tr>
<tr>
<td>U.S. Net Fed Cattle Exports</td>
<td>-1,362</td>
<td>-1,624</td>
<td>19.2%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>436,645</td>
<td>466,065</td>
<td>6.7%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>1,193,410</td>
<td>1,103,798</td>
<td>-7.5%</td>
</tr>
</tbody>
</table>

Notes:
1. Base Model results produced by the model
2. All Scenario 1 data produced by the model and taken from Tables 5.6 - 5.7
3. Change calculated as \( ((\text{Scenario 1 data} – \text{Base Model Data}) / \text{Base Model Data}) \times 100 \)
Table 5.9 Scenario 1 Fed Cattle Supply Curve Threshold Prices

<table>
<thead>
<tr>
<th>Fed Cattle Markets</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Grain Price (CDN$/bu)</td>
<td>6.57</td>
<td>5.06</td>
<td>6.46</td>
</tr>
<tr>
<td>Threshold Shutdown Price (CDN$/steer)</td>
<td>1,216.47</td>
<td>1,023.24</td>
<td>1,066.54</td>
</tr>
</tbody>
</table>
In the Canadian context, the price for grain corn in Eastern Canada increases by 96.5%, while in Western Canada the price for feed barley jumps by 96.3%. While larger than the estimates in Chapter 2, these results also cover a longer time frame than many of the results from the literature, and would also decrease if compared to the calibration prices from 2002, as opposed to the estimated base model prices.

As well, there is a notable change in the distribution of social surpluses across the United States corn market. While total social surplus decreases from 75,403 to 57,685 (measured in millions of Canadian dollars), a decrease of 23.5 %, the distribution of this surplus changes dramatically. Originally corn producers captured only 26.4% of total surplus, but after the increase in ethanol production producers’ share increases 70.8% percent.

5.3.3 Scenario One Results – Fed Cattle

Concerning the fed cattle markets represented in the model, equilibrium prices for a fed cattle increase by 12.7%, 13.2%, and 12.4% in Eastern Canada, Western Canada and the U.S. respectively. These price increases are the result of the increased cost of production caused by increased feed grain prices. The increased feed grains prices increase the fed cattle cost of production, which shifts the regional supply curves for fed cattle upward. With no changes to the demand curves for fed cattle, this upward shift leads to a higher equilibrium prices, and lower equilibrium quantities.

The impacts of the increased ethanol production and the resulting price changes are apparent in all three regions of the model. In Eastern Canada the quantity of fed cattle
supplied decreases by 17.9%, while the quantity demanded only falls by 11.5%. This results in net exports falling by 26.4% to 399,000 head.

In Western Canada the production actually increases by 1.6%, while demand falls by 12%. This leads to a 49.3% increase in net exports from Western Canada. In the United States a 5.1% decrease in the supply of fed cattle outweighs the 4.3% decrease in quantity demanded. As a result, net exports fall to -1,624,000 head.

The end of results Western Canadian producers producing more fed cattle for a higher price is a 15.4% increase in producers’ surplus. This compares to the 26.4% decrease in producers’ surplus in Eastern Canada and the more modest 6.7% increase in the U.S. The increase in producers’ surplus in the U.S. may seem counterintuitive based on the U.S. actually having to import more cattle to meet domestic demand, but the 12.4% increase in prices more than balances out the 5.1% decrease in quantity supplied. In short; feed cattle producers in Western Canada are made much better off by the increase in ethanol producer and feed grain prices, while producers in the United States are only modestly better off and producers in Eastern Canada are considerably worse off.

5.4.1 Sensitivity Testing

Sensitivity testing is done to assess the sensitivity of the results of the model to the specifications used to calibrate it. The variations in the results of Scenario 1 that are presented in the preceding sections, and the results of Scenario 1 when tested with adjusted calibration parameters reflect the degree to which the Scenario 1 results are a function of the original calibrated parameters.
The sensitivity testing included in this research examines the result’s dependencies on two aspects of the calibration parameters; first that the supply function for fed cattle does not account for the inclusion of ethanol co-products as a ration component, and secondly the currency exchange rate between Canada and the United States. Table 5.10 summarizes the focuses of the sensitivity testing for this research.

5.4.3 DDG price transmission

As outlined in earlier chapters, the regional fed cattle supply function used in this research do not take into account the potential use of ethanol co-products in fed cattle rations. It was explained that this decision was due in part to the smaller scale regional use of such co-products early in the early timeframe of this research. Since then the use of DDGS and other co-products has become more widespread, and it is appropriate to make an attempt to include the potential impacts that feeding DDGS may have on the cost of producing fed cattle.

Work done in a companion study by Prosper (2011) that found that the inclusion of DDGS in the ration for fed cattle could reduce the price of feeding cattle to slaughter weight by between 0% and 7%, depending on feeding the feeding program being used. The potential savings for a fed cattle producer in Ontario Canada ranged from 3% to 7%, while fed cattle producers in Alberta Canada experienced no savings, due to the selection of a higher energy protein source.
Table 5.10 Sensitivity Tests

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Details and Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DDG Price effects</td>
<td>The use of feed grains to produce ethanol results in various co-products also being produced. Many of these co-products have been tested in animal rations in an attempt to find a low cost feed substitute. This sensitivity testing uses the inclusion of Dried Distiller’s Grains and Solubles (DDGS) in an effort to quantify the impacts that such inclusion may have on the results of Scenario 1.</td>
</tr>
<tr>
<td>2</td>
<td>Exchange Rate Parity</td>
<td>This scenario imposes equal value currency between Canada and the United States in order to measure the impact that the 2002 exchange rate had on the 2002 base model. This scenario is relevant given the dynamic nature of currency exchange rates between Canada and the United States</td>
</tr>
</tbody>
</table>
For the purposes of this sensitivity testing it is assumed that producers in Eastern Canada can offset the price of feed grains by 5% by including DDGS in their rations. Western Canadian fed cattle producers however, cannot offset any of their potential costs. As well, producers in the United States are also assumed to be able to save 5% on their feed costs, considering that at least portion of U.S. cattle producers operate under similar conditions to those in Eastern Canada.

The potential impacts of feeding DDGS will be modeled by reducing the transmission of feed grain prices to less than the 100% that is used in the original model. Recall that the supply function for fed cattle presented in Chapter 3 included a cost of production threshold shutdown price for cattle producers. This threshold price is a function of the non-feed costs of production as well as the price of feed and the quantity of feed required. The equation for this threshold price is:

\[ TP_i^{fc} = NFC_i^{fc} + (P_i^{c} \times FQ_i^{fc}) \]  

(3.6)

Where \( TP_i^{fc} \) is the shutdown price for fed cattle producers in region \( i \).

\( NFC_i^{fc} \) is the non feed component of the cost of production in region \( i \)

\( P_i^{c} \) is to the Price of feed in region \( i \)

\( FQ_i^{fc} \) is the quantity of feed required to feed an animal to slaughter weight in region \( i \)
The price for feed used in this equation is the price for grain corn or feed barley that is solved for in the model. By using the full price as it is solved for, it is assumed that there is no way to offset the higher prices in anyway.

In order to allow for the impact that ethanol co-products to be tested on the results for Scenario 1, a price transmission factor is included in the fed cattle supply function. The supply function for fed cattle now is:

\[ TP_{ic} = NFC_{ic} + ((1 - FPD_{ic}) \times P_{ic} \times FQ_{ic}) \] (5.1)

Where \( FPD_{ic} \) is the percent that DDGS have been shown to offset the price of feed grains. For Eastern Canada and the United States \( FPD_{ic} \) will equal 5%, or 0.05. For Western Canada \( FPD_{ic} \) will equal 0% or 0.00

Including the decreased price transmission as a way of accounting for the increased use of ethanol co-products in cattle rations does influence a number of the key results that are presented in section 5.3.3. Table 5.11 presents a comparison of the original results of Scenario 1 with the results that are produced with the inclusion of ethanol co-products.

In each of the three regions the equilibrium price for fed cattle decreases by little more than 1%. This uniform decrease is expected in a model that has open trade flows. For producers in Eastern Canada the 5% decreases in feed prices prompts a 6% increase in the quantity supplied as compared to the original results for Scenario 1. The quantity demand also increases in response to the decreased prices, though the increased supply outweighs the increased
Table 5.11 Comparison of Scenario 1 Results with DDGS Sensitivity Testing Results

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1</th>
<th>Sensitivity Results</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Price of Corn (Cdn$/bushel)</td>
<td>6.46</td>
<td>6.46</td>
<td>0.0%</td>
</tr>
<tr>
<td>U.S. Supply of Corn (millions of bushels)</td>
<td>11,248</td>
<td>11,248</td>
<td>0.0%</td>
</tr>
<tr>
<td>Ontario Price of Corn (Cdn$/bushel)</td>
<td>6.57</td>
<td>6.57</td>
<td>0.0%</td>
</tr>
<tr>
<td>Alberta Price of Feed Barley (Cdn$/bushel)</td>
<td>5.06</td>
<td>5.06</td>
<td>0.0%</td>
</tr>
<tr>
<td>U.S. Corn Producers' Surplus</td>
<td>40,860</td>
<td>40,860</td>
<td>0.0%</td>
</tr>
<tr>
<td>U.S. Corn Consumers' Surplus</td>
<td>16,825</td>
<td>16,825</td>
<td>0.0%</td>
</tr>
<tr>
<td>Ontario Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1246.17</td>
<td>1232.12</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Supplied</td>
<td>1,036</td>
<td>1,098</td>
<td>6.0%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Demanded</td>
<td>637</td>
<td>644</td>
<td>1.2%</td>
</tr>
<tr>
<td>Eastern Canada Net Fed Cattle Exports</td>
<td>399</td>
<td>453</td>
<td>13.7%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>12,825</td>
<td>13,363</td>
<td>4.2%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>5,994</td>
<td>6,082</td>
<td>1.5%</td>
</tr>
<tr>
<td>Alberta Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1199.17</td>
<td>1185.12</td>
<td>-1.2%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Supplied</td>
<td>3,764</td>
<td>3,702</td>
<td>-1.7%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Demanded</td>
<td>2,539</td>
<td>2,570</td>
<td>1.2%</td>
</tr>
<tr>
<td>Western Canada Net Fed Cattle Exports</td>
<td>1,226</td>
<td>1,132</td>
<td>-7.6%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>43,274</td>
<td>42,142</td>
<td>-2.6%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>24,109</td>
<td>24,459</td>
<td>1.5%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1,269.17</td>
<td>1,255.12</td>
<td>-1.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Supplied</td>
<td>36,858</td>
<td>37,057</td>
<td>0.5%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Demanded</td>
<td>38,482</td>
<td>38,642</td>
<td>0.4%</td>
</tr>
<tr>
<td>U.S. Net Fed Cattle Exports</td>
<td>-1,624</td>
<td>-1,585</td>
<td>-2.4%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>466,065</td>
<td>463,372</td>
<td>-0.6%</td>
</tr>
</tbody>
</table>

Notes:
1. Scenario 1 results produced by the model
2. All Sensitivity Test data produced by the model
3. Change calculated as \(((\text{Sensitivity test data} – \text{Scenario 1 data})/\text{Scenario 1 data})\)*100
demand, and net exports increase by 13.7% as compared to the original Scenario 1 outcome. Fed Cattle producer’s surplus in Eastern Canada increases by 4.2%.

The quantity demanded in Western Canada also increases due the lower equilibrium prices, but unlike in Eastern Canada where producers responded to lower feed costs with increased production, producers in Western Canada experience no such decrease in the cost of feed, and as a result produce fewer cattle. This results in a 7.6% decrease in net exports as compared to the original results, and a 2.6% decrease in fed cattle producers’ surplus.

In the United States the results of the 5% price decrease are less striking. U.S. producers supply 0.5% more cattle, while demand increases by 0.4%. This leads to 39,000 fewer head being imported into the U.S. The 0.5% increase in production does not balance out the 1.1% decrease in equilibrium price however, and the result is a 0.6% decrease in fed cattle producers’ surplus relative to the original Scenario 1 results.

Overall, the inclusion of DDGS in the rations for Eastern Canada mitigated the impacts that the original increase in ethanol production had on the trade flows and welfare levels for fed cattle producers in the region. Producers in the United States are marginally worse off due the inclusion of DDGS, but the decrease in welfare is a small 0.6%. As expected, producers in Western Canada are worse off when producers in competing regions experience a reduction in the cost of production.
Table 5.12 Comparison of Scenario 2 Results with Exchange Rate Sensitivity Testing Results

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1</th>
<th>Sensitivity Results</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Price of Corn (Cdn$/bushel)</td>
<td>6.46</td>
<td>4.12</td>
<td>-36.3%</td>
</tr>
<tr>
<td>U.S. Supply of Corn (millions of bushels)</td>
<td>11,248</td>
<td>11,248</td>
<td>0.0%</td>
</tr>
<tr>
<td>Ontario Price of Corn (Cdn$/bushel)</td>
<td>6.57</td>
<td>4.23</td>
<td>-35.7%</td>
</tr>
<tr>
<td>Alberta Price of Feed Barley (Cdn$/bushel)</td>
<td>5.06</td>
<td>3.26</td>
<td>-35.6%</td>
</tr>
<tr>
<td>U.S. Corn Producers' Surplus</td>
<td>40,860</td>
<td>24,266</td>
<td>-40.6%</td>
</tr>
<tr>
<td>U.S. Corn Consumers' Surplus</td>
<td>16,825</td>
<td>62,874</td>
<td>273.7%</td>
</tr>
<tr>
<td>Ontario Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1246.17</td>
<td>1143.78</td>
<td>-8.2%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Supplied</td>
<td>1,036</td>
<td>1,231</td>
<td>18.9%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Demanded</td>
<td>637</td>
<td>695</td>
<td>9.2%</td>
</tr>
<tr>
<td>Eastern Canada Net Fed Cattle Exports</td>
<td>399</td>
<td>536</td>
<td>34.4%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>12,825</td>
<td>13,441</td>
<td>4.8%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>5,994</td>
<td>6,659</td>
<td>11.1%</td>
</tr>
<tr>
<td>Alberta Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1199.17</td>
<td>1096.78</td>
<td>-8.5%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Supplied</td>
<td>3,764</td>
<td>3,719</td>
<td>-1.2%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Demanded</td>
<td>2,539</td>
<td>2,782</td>
<td>9.6%</td>
</tr>
<tr>
<td>Western Canada Net Fed Cattle Exports</td>
<td>1,226</td>
<td>937</td>
<td>-23.6%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>43,274</td>
<td>39,018</td>
<td>-9.8%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>24,109</td>
<td>26,761</td>
<td>11.0%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1,269.17</td>
<td>1,166.78</td>
<td>-8.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Supplied</td>
<td>36,858</td>
<td>38,240</td>
<td>3.7%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Demanded</td>
<td>38,482</td>
<td>39,712</td>
<td>3.2%</td>
</tr>
<tr>
<td>U.S. Net Fed Cattle Exports</td>
<td>-1,624</td>
<td>-1,472</td>
<td>-9.4%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>466,065</td>
<td>444,343</td>
<td>-4.7%</td>
</tr>
</tbody>
</table>

Notes:
1. Scenario 1 results produced by the model
2. All Sensitivity Test data produced by the model
3. Change calculated as \(((\text{Sensitivity test data}) - \text{Scenario 1})/\text{Scenario 1})\times100
5.4.5 *Equal Exchange Rates*

Another aspect of the calibration parameters that is worth examining is the exchange rate that is applied as part of the original 2002 calibration parameters. In the base model and in Scenario One, the exchange rate is set at 1.5693 CDN$/US$. This is the average exchange rate between Canada and the United States for the calibration year of 2002. Applying an equal valued currency to the model for Scenario 1 tests the impact that the 2002 currency landscape has on the results for Scenario 1 as they are presented in Section 5.3.2 and 5.3.3.

The results presented in Table 5.12 present a comparison of the equal currency test results and the original results for Scenario 1. There are a number of notable changes in the results; starting with the 36.3% decrease in the price for grain corn in the U.S. Prices for grain corn in Eastern Canada and feed barley in Western Canada are a similar 35.7% and 35.6% lower as compared to the original Scenario 1 results. The quantity of grain corn does not change with the adjusted currency due to the fact that the model for grain corn includes only the United States, and the price for corn in the United States expressed in U.S. dollars has not changed.

Grain corn producers’ surplus does fall by 40.6%, as Canadian dollars are equal to American dollars and as such, measures in Canadian dollars are deflated by roughly 40%, the value the Canadian dollar appreciated by when the currencies are set equal.

Fed cattle prices in all three regions fall by slightly more than 8%. In Eastern Canada currency parity drives down the price of feed and prompts a 18.9% increase in cattle supplied. The quantity demanded for fed cattle in Eastern Canada increases by 9.2%, results in an 34.4% increase in net exports from Eastern Canada as compared to Scenario 1 results. The increase in
fed cattle supplied counters the decrease in prices and results in a 4.8% increase in fed cattle producer’s surplus in Eastern Canada.

In Western Canada the 8.5% decrease in fed cattle prices prompts producers to produce 1.2% fewer cattle as compared to the original Scenario 1 results. Paired with a 9.6% increase in the quantity demanded for fed cattle, the result is a 23.6% decrease in net exports relative to the original results. For Western Canadian fed cattle producers the results of a lower price and fewer cattle produced is a 9.8% decrease in producers’ surplus as compared to the original Scenario 1 results.

For fed cattle producers in the United States a 3.7% increase in cattle supplied outpaces the 3.2% increase in cattle demanded, and the United States imports 152,000 fewer cattle with an equal currency than it did with the unequal currency in the original Scenario 1.

Overall, it appears that the original currency exchange rate of 1.5693 Cdn$/US$ favoured both producers in Western Canada and the United States. In this test scenario, with the currencies set equal, only the fed cattle producers in Eastern Canada experience improved welfare results as compared to the original results.

5.4.6 Summary of Sensitivity Testing Results

Both variations to the calibration parameters tested on the Scenario 1 results resulted in an improvement in the outcome of fed cattle producers in Eastern Canada at the expense of fed cattle producers in the Western Canada and the United States. This is not surprising considering that both variations involved a decrease in the price for feed grains. Producers in Eastern Canada proved in Scenario 1 to be the most price sensitive in regards to the cost of production,
decreasing the number of cattle supplied by 17.9%, as opposed to a 1.6% increase by Western Canadian producers, and a 5.1% decrease by Producers in the U.S. It stands to reason then, that a decrease in the price for feed prompts the largest reaction in the opposite direction.

5.5.1 Scenario 2 2015 Ethanol level

The second scenario tested by the model is an increase in U.S. grain ethanol production to the expected 2015 level of 15 billion gallons annually. This year and volume are significant because this value represents the maximum mandated grain ethanol that the United States will enforce under the Renewable Fuels Standard. In the years after 2015 mandated cellulosic ethanol levels will increase, but first generation grain ethanol will remain constant at 15 billion gallons. Applying the 20 year average yield for corn ethanol production of 2.5 gallons of ethanol per bushel of corn, 15 billion gallons will require approximately six billion bushels of grain corn. This represents greater than six times the amount used in the calibration year of 2002, and more than twice the quantity of grain used in 2008 for ethanol production.

Scenario Two will be tested holding all other parameters of the base model constant at the 2002 values. This includes the supply and demand elasticitites for both U.S. corn and the three fed cattle regions. The results and the discussion are presented similar to those of Scenario One; with two tables used to detail the results and a third table to compare the Scenario 2 outcomes with the base model results. Table 5.13 includes the results of the corn and grain portions of the model. Table 5.14 details the results of the fed cattle portion of the model and Table 5.15 compares the Scenario Two results with the base model results.
Table 5.13 Scenario 2 Feed Grain Results Model

<table>
<thead>
<tr>
<th>U.S. Grain Market</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario Calibration Parameters</strong></td>
</tr>
<tr>
<td>U.S. Corn Supply Elasticity</td>
</tr>
<tr>
<td>U.S. Corn Demand Elasticity</td>
</tr>
<tr>
<td>U.S. Ethanol Production level (million US. gallons.) $^1$</td>
</tr>
<tr>
<td>Corn Used for U.S. Ethanol (millions of bushels) $^2$</td>
</tr>
<tr>
<td>Canada - U.S. 2002 average currency exchange rate (Cdn$/US)</td>
</tr>
<tr>
<td>Ontario 2002 Average Adjusted corn basis (Cdn$/bushel)</td>
</tr>
<tr>
<td>Alberta 2002 Average Adjusted feed barley basis (Cdn$/bushel)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Scenario Results</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Corn Price (CDN$/bu)</td>
</tr>
<tr>
<td>U.S. Corn Quantity Supplied (mill. bu.)</td>
</tr>
<tr>
<td>Ontario corn price (Cdn$/bushel)</td>
</tr>
<tr>
<td>Alberta Feed barley price (Cdn$/bushel)</td>
</tr>
<tr>
<td>U.S. Corn Producers’ Surplus (Million Cdn$)</td>
</tr>
</tbody>
</table>

Sources:
1. 15 billion gallons of Ethanol is the maximum volume of grain based ethanol to be counted against the U.S. fuel blend mandate in 2015.
2. Using the historical average ethanol yield from corn in the United States of 2.5 gallons/bu, it is estimated that 15 billion gallons of ethanol will require 6 billion bushels of corn. See table 4.1 for additional ethanol production and yield details.
### Table 5.14  Scenario 2 Fed Cattle Market Results

<table>
<thead>
<tr>
<th>Fed Cattle Markets</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario Calibration Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Supply Elasticity</td>
<td>0.995</td>
<td>1.300</td>
<td>3.240</td>
</tr>
<tr>
<td>Fed Cattle Demand Elasticity</td>
<td>-1.025</td>
<td>-1.025</td>
<td>-0.374</td>
</tr>
<tr>
<td><strong>Scenario Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Price (CDN$/1,100 lb steer)</td>
<td>1,547.42</td>
<td>1,500.42</td>
<td>1,570.42</td>
</tr>
<tr>
<td>Fed Cattle Quantity Supplied (thousands of head)</td>
<td>0</td>
<td>0</td>
<td>38,063</td>
</tr>
<tr>
<td>Fed Cattle Quantity Demanded (thousands of head)</td>
<td>510</td>
<td>2,018</td>
<td>35,535</td>
</tr>
<tr>
<td>Fed Cattle Net International Export Quantity (thousands of head)</td>
<td>-510</td>
<td>-2,018</td>
<td>2,528</td>
</tr>
<tr>
<td><strong>Welfare Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>0</td>
<td>0</td>
<td>595,218</td>
</tr>
<tr>
<td>Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>4,323</td>
<td>17,475</td>
<td>922,872</td>
</tr>
<tr>
<td>Fed Cattle Social Surpluses (Million Cdn$)</td>
<td>4,323</td>
<td>17,475</td>
<td>1,518,089</td>
</tr>
</tbody>
</table>
Table 5.15 Comparison of Base Model and Scenario 1 Results

<table>
<thead>
<tr>
<th></th>
<th>Base Model</th>
<th>Scenario 2</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Price of Corn (Cdn$/bushel)</td>
<td>3.23</td>
<td>10.65</td>
<td>229.5%</td>
</tr>
<tr>
<td>U.S. Supply of Corn (millions of bushels)</td>
<td>8,816</td>
<td>12,734</td>
<td>44.4%</td>
</tr>
<tr>
<td>Ontario Price of Corn (Cdn$/bushel)</td>
<td>3.34</td>
<td>10.76</td>
<td>221.9%</td>
</tr>
<tr>
<td>Alberta Price of Feed Barley (Cdn$/bushel)</td>
<td>2.58</td>
<td>8.29</td>
<td>221.5%</td>
</tr>
<tr>
<td>U.S. Corn Producers' Surplus</td>
<td>19,920</td>
<td>73,697</td>
<td>270.0%</td>
</tr>
<tr>
<td>U.S. Corn Consumers' Surplus</td>
<td>55,483</td>
<td>-81,474</td>
<td>-246.8%</td>
</tr>
<tr>
<td>Ontario Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1106.01</td>
<td>1547.42</td>
<td>39.9%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Supplied</td>
<td>1,261</td>
<td>0</td>
<td>-100.0%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Quantity Demanded</td>
<td>720</td>
<td>510</td>
<td>-29.1%</td>
</tr>
<tr>
<td>Eastern Canada Net Fed Cattle Exports</td>
<td>542</td>
<td>-510</td>
<td>-194.2%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>13,093</td>
<td>0</td>
<td>-100.0%</td>
</tr>
<tr>
<td>Eastern Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>6,919</td>
<td>4,323</td>
<td>-37.5%</td>
</tr>
<tr>
<td>Alberta Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1059.01</td>
<td>1500.42</td>
<td>41.7%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Supplied</td>
<td>3,704</td>
<td>0</td>
<td>-100.0%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Quantity Demanded</td>
<td>2,884</td>
<td>2,018</td>
<td>-30.0%</td>
</tr>
<tr>
<td>Western Canada Net Fed Cattle Exports</td>
<td>821</td>
<td>-2,018</td>
<td>-345.9%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>37,495</td>
<td>0</td>
<td>-100.0%</td>
</tr>
<tr>
<td>Western Canada Fed Cattle Consumers' Surplus (Million Cdn$)</td>
<td>27,804</td>
<td>17,475</td>
<td>-37.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Price (Cdn$/1,100 lb steer)</td>
<td>1,129.01</td>
<td>1,570.42</td>
<td>39.1%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Supplied</td>
<td>38,841</td>
<td>38,063</td>
<td>-2.0%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Quantity Demanded</td>
<td>40,203</td>
<td>35,535</td>
<td>-11.6%</td>
</tr>
<tr>
<td>U.S. Net Fed Cattle Exports</td>
<td>-1,362</td>
<td>2,528</td>
<td>-285.6%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Producers’ Surplus (Million Cdn$)</td>
<td>436,645</td>
<td>595,218</td>
<td>36.3%</td>
</tr>
<tr>
<td>U.S. Fed Cattle Consumers’ Surplus (Million Cdn$)</td>
<td>1,193,410</td>
<td>922,872</td>
<td>-22.7%</td>
</tr>
</tbody>
</table>

Notes:
1. Base Model results produced by the model
2. All Scenario 1 data produced by the model and taken from Tables 5.6 - 5.7
3. Change calculated as
   \[
   \text{((Scenario 1 data - Base Model Data)/Base Model Data) \times 100}
   \]
Table 5.16 Scenario 2 Fed Cattle Supply Curve Threshold Prices

<table>
<thead>
<tr>
<th>Fed Cattle Markets</th>
<th>Eastern Canada</th>
<th>Western Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Grain Price (CDN$/bu)</td>
<td>10.76</td>
<td>8.29</td>
<td>10.65</td>
</tr>
<tr>
<td>Threshold Shutdown Price (CDN$/steer)</td>
<td>1,513.96</td>
<td>1,197.66</td>
<td>1,271.85</td>
</tr>
</tbody>
</table>
The impact of an additional 6 billion bushels of corn used for ethanol in the United States is apparent across the results of the model. Grain prices more than triple in comparison to the base model results. The equilibrium quantity of corn produced increases in response to the increase in ethanol demand and the higher prices, though the increase in grain corn use is less than the increases in demand by ethanol. This implies that other demands for corn are decreasing in response to the increased price.

The fed cattle industry is impacted severely by the increased grain prices and the associated higher costs of production. The increased price of feed grains drives up the cost of cattle to such a point where both Eastern and Western Canada cease to produce fed cattle at all, relying completely on imports to supply the domestic processors. The United States experiences a 2.0% decrease in supply and a 11.6% percent decrease in demand, and shifts to a net export trade balance. The United States becomes the sole producer of fed cattle amongst the regions, exporting approximately nine percent of its annual production.

Welfare measures across both fed cattle markets in Canada also decrease in Scenario Two. There is no longer any surplus to be captured by producers in either region as neither region produces any fed cattle. Consumers’ surplus decreases by approximately 37% in each region, due to both decreases in the equilibrium quantity demanded by each region, and the increases in price for the fed cattle that are demanded. Fed Cattle producers’ welfare in the United States increases by 36.3% in Scenario Two, with a 11.6% decrease in supply being counteracted by the 39.1% percent increase in price. Consumers’ surplus falls by 22.7% due to both decreases in demand and increases in price.
Scenario Two provides insight into the dramatic impacts that the 2015 ethanol production levels would have on the 2002 grain and fed cattle markets. The complete disappearance of the fed cattle production in Canada, as well as the significant decrease in the processing of fed cattle in Canada are not trivial consequences.

5.6 Comparison of Results with the Literature

The second half of chapter Two summarized the results of 11 studies that examined the impacts of the ethanol production, and stated that the results of this study would be compared to those of the literature. This section put the results of this study into the context of the literature.

Scenario One tested the impact of 2008 level ethanol production on the 2002 corn market. Results showed 99.8% increase in the price for Corn in the United States, as well as a 96.5% increase for the price of corn in Ontario, and a 96.3% increase in the price of feed barley in Alberta. The result for the increase in the U.S. price for grain corn falls beyond the range found in the review of the literature, however the longer time frame for the changes, as well as the fact that the change is based on the theoretical price for corn in 2002 without ethanol production lends some explanation to the differences.

The Ontario result is far greater than the results summarized by Daynard and Daynard(2011), though those increases where only basis effects, where as the results of this study are the total price effect. The price increase for feed grain in Alberta is also beyond the increases found in the review literature.

Scenario Two tests the impact of the 2015 maximum first generation ethanol production on the 2002 market. The price increases for corn and feed grains for all three
regions is between 220 and 230%. This clearly far exceeds the levels found by the reviewed literature. The main source of such a disparity is the fact that all the reviewed research examined actual ethanol production levels between 2002 and 2011, which were a great deal smaller than the 2015 maximum level that was applied in Scenario Two.

Overall, the results of this study exceed those found in the literature. The longer time frame, the theoretical 2002 price, and the lack of ethanol co-product as part of the supply curves for fed cattle all would seem to influence the larger results of this study. Certainly there are discrepancies, and that is not surprising considering the scale of this project relative to those referenced in Chapter 2.

5.6 Summary

Chapter 5 has described and discussed the results of the base model, calibrated to 2002 with the removal of 2002 ethanol production, as well the results of the two scenarios that have been tested by the model. Scenario 1 tested the impacts that 2008 U.S. grain ethanol production levels would have on the market and welfare outcomes of the 2002 base model. Scenario Two examined the potential affects that the anticipated 2015 U.S. grain based ethanol production would have on the basemodel grains and fed cattle markets.
Chapter 6

Summary and Conclusions

This chapter reviews and summarizes the conceptual and empirical models, the main findings of the scenarios that were tested, and the key conclusions that were drawn. As well, recommendations drawn from the research are made, and considerations for future research are suggested.

6.1 Summary

The purpose of this research is to assess the impact that increasing ethanol production in Canada and the United States will have on the costs and competitiveness of the Canadian Beef industry, and to measure any regional discrepancies within these impacts. To that end, a multi-level simulation model is developed that links the North American corn market with the regional fed cattle markets in Eastern and Western Canada, and the United States. This model is calibrated to reproduce the 2002 equilibrium prices and quantities for both the corn and fed cattle markets in all three regions of the model.

Having constructed the baseline model, the producer and consumer surpluses for both corn and cattle producers are measured. These serve as benchmarks by which the results of the four scenarios are compared.

Scenario One tests the imposition of 2008 ethanol production levels on the 2002 market. The notable results include the decreases in fed cattle producers’ surplus in Eastern Canada, while fed cattle producers in Western Canada experience a gain in producers’ surplus. The 26.4% decrease in fed cattle producer surplus in Eastern Canada suggests...
that the larger, feedlot style producer practices of Western Canada are less sensitive to increases in the price of corn in North America.

Scenario Two applies the projected 2015 U.S. ethanol production level of 15,000 million gallons on the 2002 market. The result is a 229.5% increase in equilibrium price of corn, and a complete end to the production of fed cattle in both Eastern and Western Canada. This results in a zero producer surplus in eastern and western Canada, while U.S. fed cattle producer surplus increases by 36.3%.

6.2 Main Findings

The main findings of this research project are that increases in the level of grain based ethanol production in North America increases the price of corn in North America. This leads to increases in the equilibrium price and quantity values for fed cattle in all three regions. Secondly, that variations in the cost structure of cattle production between eastern and western Canada, and the United States lead to changes in the flow of cattle trade as the price of corn increases.

More specifically, the calculation of the base model by removing the 2002 ethanol production from the original calibrated parameters decreased the prices of grain corn in the United States by 15.2%. The results of Scenarios 1, when ethanol production is increased to 9,237 million gallons, show feed grain prices in all three regions increasing by between 96% and 100%. In Scenario 2, when the projected level of ethanol production for 2015 is applied to the model, feed grain prices increase in all three regions by between 220% and 230%.
The changes to the equilibrium price of corn in the base model and both scenarios support the conclusion that all else being held equal, increases in the amount of ethanol produced has a positive relationship with the price of corn and feed barley.

Changes to the price of corn result in regionally varying changes to the fed cattle equilibrium quantities supplied and demand. Scenarios 1 results for the Eastern and Western Canadian fed cattle portions of the model show that a 96% increase in the price of corn leads to a 17.9% reduction in the quantity of fed cattle supplied in Eastern Canada, and a 1.6% increase in western Canada. Results for the United States show a 5.1% decrease.

Similarly, results from Scenario Two show that a 221% increase in the price of feed grains would lead to a complete end of cattle production in both Eastern and Western Canada, but only a 2% decrease in the equilibrium quantity supplied by the United States.

The second major finding of the research is that the differing cost structures for the production of fed cattle amongst the three regions of the model that result in varying changes the equilibrium quantities for fed cattle also lead to changes in the magnitude and direction of the movement of fed cattle between the three regions. In the base model of 2002, both Eastern and Western Canada are net exporters of fed cattle, while the United States is a net importer of fed cattle.

In Scenario One, the increased price of corn leads to increases in the price of fed cattle in each region and changes the flow of cattle trade. Eastern Canada remains a net exporter of cattle, though exports decrease by 26.4%. In Western Canada, net cattle exports increase by 49.3, as western fed cattle producers increase their production modestly while the demand in the region decreases.
Changes to the flow of exports become even more pronounced in the Scenario Two, when an increase in ethanol production to 15,000 million gallons leads to a 229.5% increase in the price of corn. At such high corn prices, not only do both Eastern and Western Canada become net importers of fed cattle, but also completely abandon the production of fed cattle at all, leaving the United States to supply the fed cattle for all three regions.

6.3 Recommendations

The findings of this study show that increased ethanol production increased the price of feed grains and that 2008 levels of grain based ethanol production has a negative impact on cattle producers in Eastern Canada. As well, that the projected ethanol production in 2015 will have a devastating impact on cattle production in both Eastern and Western Canada. Given these impacts, it is the recommendation of the author that fed cattle producers in Eastern and Western Canada carefully consider whether government policy has made an appreciable impact on the viability of the ethanol industry.

If it is found that the ethanol industry in Canada and the United States would show similar production levels in the absence of government support, then cattle producers may have no choice but to compete with the ethanol industry for feed grains as it does with other users. If however, it is found that government support policies have positively influenced the production of grain based ethanol, than it can be argues that these government policies have driven up the price of feed grains and negatively impacted the welfare of fed cattle producers in Eastern Canada. In such a case, it is the recommendation of this author cattle producers carefully consider some action to retrieve
the welfare benefits that they have lost to ethanol production and the increasing price of feed grains.

6.4 Suggestions for further Research

Further work in this area should include an examination of whether other the cost of feeding meat animals; mainly pork production in Canada but also poultry production in the United States, has been as sensitive the impacts of ethanol production in North America. It may also be of interest and value to examine whether disparities in the rate of growth between Canadian and U.S. ethanol production are widening the competitive gap between Canadian and U.S. cattle producers.

References


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Appendix 1.0

1. The calculations to solve for the supply elasticity coefficients used in the both the Corn and Fed Cattle supply curves are shown below. The example is for the North American Supply curve for No. 2 Yellow Corn, the calculations are the same for all the supply curves used in the model.

   a. The supply curve is shown
      \[ QS_{NAC} = a(P - b)^c \]
   
   b. The function is rearranged to solve for \( a \)
      \[ a = \frac{Qs_{NAC}}{(P - b)^c} \]

   c. The elasticity of supply can be written as:
      \[ \eta_s = \frac{dQs}{P} \times \frac{P}{Q} \]
   
   d. The partial derivative of the supply curve with respect to price is written as:
      \[ \frac{dps}{dP} = a(P - b)^{c-1} \times c \]

   e. Subbing that partial into the elasticity equation
      \[ \eta_s = \frac{a(P - b)^{c-1} \times c \times P}{1 \times \frac{Q}{Q}} \]
   
   f. Rearrange this equation to solve for \( c \), the elasticity coefficient;
      \[ c = \eta_s \times \frac{P - b}{P} \]

   g. Sub in the calibration price, quantity and elasticity to solve to \( c \)
Appendix 2.0

Ethanol Producers Maximum Bid Calculations

Parameters Used

Prices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil (US$/barrel)</td>
<td>$30.00</td>
</tr>
<tr>
<td>Co products (US$/lb)</td>
<td>$0.05</td>
</tr>
</tbody>
</table>

Yields

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol (gal/bu)</td>
<td>2.8</td>
</tr>
<tr>
<td>Co products (lb/bu)</td>
<td>17.75</td>
</tr>
</tbody>
</table>

Ethanol Costs & Subsidies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non corn variable costs</td>
<td>$1.50</td>
</tr>
<tr>
<td>Blend credit ($/gal)</td>
<td>$0.51</td>
</tr>
</tbody>
</table>

1. Price of crude converted to the retail price of gasoline

\[
\text{30$/Barrel / 28.9} = 1.03806
\]

2. Retail price of gasoline converted to an energy equivalent value

\[
1.03806 \text{ $/gal} * 0.66 = 0.69
\]

3. Energy value per bushel

\[
\text{Energy value} * \text{ethanol yield per bu} \\
\text{0.69*2.8} = 1.932 \text{ $/bu}
\]

4. Additional a value of co-product

\[
\text{Co product yield} * \text{price of co-product} \\
17.57\text{lb/bu} * 0.05 \text{ $/lb} = 0.885 \text{ $/bu}
\]

\[
\text{Ethanol value} + \text{plus co-product value} \\
1.932 \text{ $/bu} + 0.885 \text{ $/bu} = 2.817 \text{ $/bu}
\]

Total Revenue per bushel = $2.782

5. Less the variable non-corn cost of production

\[
\text{Total revenue} – \text{VCOP} \\
2.782 – 1.50 = 1.782 \text{ $/bu}
\]
6. Added value of support programs

Remaining value + support value
1.782 $/bu + 0.51
Maximum Bid price = 2.292 $/bu
Appendix 3.0 General Algebraic Modeling System (GAMS) Codes

****Model of North American corn market*

option limcol=0, limrow=0, nlp=minos ;

Parameters

************************************************************************************
**exchange rate**
exch CND USA EXR /1.5693/
**ontario corn basis estimate**
cbas ontario corn basis estimate /0.11/

************************************************************************************

*Supply parameters*
cses supply elasticity /0.4/
csdp shutdown price /1.30/

*Demand Parameters*
cdes demand elasticity /-.2/
cemq ethanol mandate quantity /5006/
ccscap arbitrary cs cap /15/

*Observed price and quantity from 2003 - base year*
cbyp 2002 price of corn /2.43/
cbyq 2002 quantity of corn /0/

*Supply coefficients*
a supply shift parameter
b avc
c supply elasticity factor

*demand coefficient*
d demand coefficient
f demand elas
g emandate shift
z arbitrary con cap

*exchange rate*
xr canadian exchange rate
acbyp us price of corn in canadian dollars
acsdp us shutdown price for corn in canadian dollars

*corn basis*
ecb eastern canada corn basis
wwb western canada wheat basis

*calibrate exchange rate*
xr = exch ;
acbyp = cbyp*exch ;
acsdp = csdp*exch ;

*calibrate corn basis*
ecb = cbas ;
wwb = wbas ;

*calibrate the supply curve*
c = cses*((acbyp-acsdp)/acbyp) ;
a = cbyp/(acbyp - acsdp)**c ;
b = acsdp ;

*Calibrate demand curve*
\[ d = \frac{cbyq}{acbyp^{cdes}}; \]
\[ f = cdes; \]
\[ g = cemq; \]
\[ z = ccscap; \]
\[ \text{display } a, b, c, d, f, g, z; \]

*declare the choice variables*

variables

price equilibrium price
QS equilibrium quant supplied
QD equilibrium quant demanded
faux objective function;

positive variable

price, QD, QS;

Equations

objfn objective function
supply corn supply function
demand corn demand function
equilib equilibrium condition;

objfn .. faux =e= 0;
supply .. QS =e= a*(price - b)**c;
demand .. QD =e= g + d*price**f;
equilib .. QS =e= QD;

model Cmarket / objfn, supply, demand, equilib /;
price.l = b +.1;
price.lo =1;
solve Cmarket maximizing faux using nlp;

********************************************************************
********************************************************************

parameter cbase (*,*) parameter to base results;
cbase ('usa', 'price') = price.l;
cbase ('usa', 'quantity') = QD.l;

parameter cwelfare (*,*) parameter to store corn producers welfare;
cwelfare ('usa', 'ps') = (price.l*QD.l) - ((a/(c+1))*(price.l - b));
cwelfare ('usa', 'cs') = ((g*z+(d/(f+1))*z**(f+1)) - (g*price.l+(d/(f+1))*price.l**(f+1))) - (price.l*QD.l);
cwelfare ('usa', 'ss') = cwelfare('usa','ps') + cwelfare ('usa','cs');

parameter CPRICE(*,*) parameter to store prices for the beef model;
CPRICE ('ecnd','price') = (price.l) + ecb;
CPRICE ('wcnd', 'price') = (price.l)*.77 + 0.09;
CPRICE ('usa','price') = price.l;

display cbase, cwelfare, CPRICE;

********
*Sontext
********
option limcol=0, limrow=0, nlp=minos;

SET i Index of regions / ecnd, wcnd, usa / ;
alias (i,j) ;

Parameters
*Supply parameters*
  bses(i) supply elasticity / ecnd 0.995, wcnd 1.30, usa 3.24 /
  bavc(i) shutdown price / ecnd 750, wcnd 750, usa 750 /
  bscr(i) amount of feed grain in ration / ecnd 74, wcnd 51, usa 49 /

*Demand Parameters*
  bdes(i) demand elasticity / ecnd -1.025, wcnd -1.025, usa -.374 /
  bscap(i) arbitrary cs cap / ecnd 7500, wcnd 7500, usa 7500 /
  bincome(i) demand curve shifts / ecnd 0, wcnd 000, usa 000 /

*Observed price and quantity from 2002 - base year*
  byp(i) 2002 price of beef / ecnd 1135, wcnd 1088, usa 1158/
  bSQbl(i) baseline quantity supplied / ecnd 1247, wcnd 3741, usa 38846 /
  bDQbl(i) baseline quantity demanded / ecnd 701, wcnd 2805, usa 39824 /
  tc1 transportation costs between ecnd and usa
  tc2 transportation costs between ecnd and wcnd

  xx(i) saved calibration for ba from the basemodel / ecnd 854.788, wcnd 1191.693, usa 1375.925 /
  zz(i) saved calibration for bc from basemodel / ecnd 0.083, wcnd 0.219, usa 0.619 /

*Supply coefficients*
  ba(i) supply shift parameter
  bb(i) tavc
  bc(i) supply elasticity factor

*demand coefficient*
  bd(i) demand coefficient
  bf(i) demand elastic
  bw(i) demand shift coef
  bz(i) arbitrary con cap

;  
*calibrate the supply curve*
  bb('usa') = bavc('usa') + (bscr('usa')*CPRICE ('usa','price')) ;
  bb('ecnd') = bavc('ecnd') + (bscr('ecnd')*CPRICE ('ecnd','price')) ;
  bb('wcnd') = bavc('wcnd') + (bscr('wcnd')*CPRICE ('wcnd','price')) ;

  *bc(i) = bses(i*)((byp(i)-bb(i))/byp(i)) ;
  *ba(i) = bSQbl(i)/((byp(i) - bb(i)**bc(i)));

  bc(i) = zz(i);
  ba(i) = xx(i);
*Calibrate demand curve*
bd(i) = bDQbl(i)/byp(i)**bdes(i) ;
*bf(i) = bdes(i) ;
bw(i) = bincome(i) ;
bz(i) = bscap(i) ;
tc1 = byp('ecnd') - byp('usa');
tc2 = byp('ecnd') - byp('wcnnd');
display ba, bb, bc, bd, bf, bw, bz, tc1, tc2 ;

*Context

*declare the choice variables*
variables
beefprice(i) equilibrium price
BQS(i) equilibrium quant supplied
BQD(i) equilibrium quant demanded
BQT(i) equilibrium quantity traded
faux objective function ;

positive variables
beefprice(i), BQD(i) ;

Equations
bobjfn objective function
bsupply(i) beef supply function
bdemand(i) beef demand function
btrade(i) beef trade equation
bequilib equilibrium condition
lop1
lop2
;

bobjfn .. faux =e= 1 ;
bsupply(i) .. BQS(i) =e= ba(i)*((beefprice(i) - bb(i))** bc(i)) ;
bdemand(i) .. BQD(i) =e= bw(i) + bd(i)* beefprice(i)** bf(i) ;
btrade(i) .. BQS(i) =e= BQD(i) + BQT(i) ;
bequilib .. sum (i, BQT(i)) =e= 0 ;
lop1 .. beefprice('ecnnd') =e= beefprice('usa') + tc1;
lop2 .. beefprice('ecnnd') =e= beefprice('wcnnd') + tc2;

model market /bobjfn, bsupply, bdemand, btrade, bequilib, lop1, lop2 / ;
beefprice.lo(i) = bb(i)+1 ;
solve market maximizing faux using nlp ;

*Context

*************************************************************
parameter inputs (*,*) parameter to store inputs ;
inputs('ecn','Ses') = bses('ecn') ;
inputs('ecn','Des') = bdes('ecn') ;
inputs('usa','Ses') = bses('usa') ;
inputs('usa','Des') = bdes('usa') ;
inputs('ecn','CoP') = CPRICE('ecn','price') ;
inputs('ecn','QoC') = bscr('ecn') ;
inputs('ecn','SDP') = bb('ecn') ;

parameter Base (*,*) para to store baseline results ;
base('ecn','P') = beefprice.l('ecn') ;
base('ecn','QS') = BQS.l('ecn') ;
base('ecn','QD') = BQD.l('ecn') ;

parameter welfare (*,*) parameter to store welfare results;

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welfare('usa', 'cs') = ((bw('usa')*bz('usa')+(bd('usa')/(bf('usa')+1))*bz('usa')**(bf('usa')+1)) -
(bw('usa')*base('usa','P')+(bd('usa')/(bf('usa')+1))*base('usa','P')**(bf('usa')+1))) -
(base('usa','P')*base('usa','QD'));

welfare('ecnd', 'ss') = welfare('ecnd', 'ps') + welfare('ecnd', 'cs');
welfare('wcnd', 'ss') = welfare('wcnd', 'ps') + welfare('wcnd', 'cs');
welfare('usa', 'ss') = welfare('usa', 'ps') + welfare('usa', 'cs');

parameter welfare2 (*,*) parameter to store welfare results;

welfare2('ecnd', 'ps') = ((base('ecnd','P')*base('ecnd','QS'))-
(ba('ecnd')/(bc('ecnd')+1))*(base('ecnd','P')-
bb('ecnd')))/100;
welfare2('wcnd', 'ps') = ((base('wcnd','P')*base('wcnd','QS'))-
(ba('wcnd')/(bc('wcnd')+1))*(base('wcnd','P')-
bb('wcnd')))/100;
welfare2('usa', 'ps') = ((base('usa','P')*base('usa','QS'))-
(base('usa')/(bc('usa')+1))*(base('usa','P')-
bb('usa')))/100;

welfare2('ecnd', 'cs') = (((bw('ecnd')*bz('ecnd')+(bd('ecnd')/(bf('ecnd')+1))*bz('ecnd')**(bf('ecnd')+1)) -
(bw('ecnd')*base('ecnd','P')+(bd('ecnd')/(bf('ecnd')+1))*base('ecnd','P')**(bf('ecnd')+1))) -
(base('ecnd','P')*base('ecnd','QD')))/100;
welfare2('wcnd', 'cs') = (((bw('wcnd')*bz('wcnd')+(bd('wcnd')/(bf('wcnd')+1))*bz('wcnd')**(bf('wcnd')+1)) -
(bw('wcnd')*base('wcnd','P')+(bd('wcnd')/(bf('wcnd')+1))*base('wcnd','P')**(bf('wcnd')+1))) -
(base('wcnd','P')*base('wcnd','QD')))/100;
welfare2('usa', 'cs') = (((bw('usa')*bz('usa')+(bd('usa')/(bf('usa')+1))*bz('usa')**(bf('usa')+1)) -
(bw('usa')*base('usa','P')+(bd('usa')/(bf('usa')+1))*base('usa','P')**(bf('usa')+1))) -
(base('usa','P')*base('usa','QD')))/100;

welfare2('ecnd', 'ss') = welfare2('ecnd', 'ps') + welfare2('ecnd', 'cs');
welfare2('wcnd', 'ss') = welfare2('wcnd', 'ps') + welfare2('wcnd', 'cs');
welfare2('usa', 'ss') = welfare2('usa', 'ps') + welfare2('usa', 'cs');

display cwelfare, inputs, base, welfare2;

*offtext