The Effects of Biofuels Policy on Global Commodity Markets

by

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A Thesis submitted to the Faculty of Graduate Studies of
The University of Manitoba
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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

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The undersigned certify that they have read the Master's Thesis/Practicum entitled:

The Effects of Biofuels Policy
on Global Commodity Markets

submitted by

Brooke E. Fridfinnson

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ABSTRACT
The Effects of Biofuels Policy of Global Commodity Markets

Significant expansion of biofuels production capacity in the last decade, particularly in the United States, has raised questions as to the impacts of this political involvement on agricultural commodity markets.

The objective of this analysis is to quantify the price effects of biofuels policies in Canada, the United States and the European Union on the major agricultural commodities serving as inputs in the production process: corn, vegetable oil and wheat. Using a recursive dynamic, multi-region, partial equilibrium agricultural trade model, the price impacts on these commodities will be determined for 2005 - 2015. The effects of increased domestic feedstock use will be analyzed in terms of trade flows, as well as with respect to the implications of increased feed grain prices on the livestock sector.

The results of this research show the averaged increases in the representative world prices of corn, vegetable oil and wheat to be 45 percent, 17 percent and 9 percent higher than baseline projections, respectively. Over the projection period, the average Canadian livestock producer faces a 28 percent increase in the feed costs associated with coarse grains, wheat and oilseed meal. As such, declines are noted in Canadian cattle herd size, as well as in the quantity of pork produced, slaughtered and exported.

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CHAPTER ONE
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1.1 Introduction

Within the past decade, biofuel has become a buzz-word with the potential to mitigate a range of the world's problems, spanning the gamut from reducing environmentally damaging transportation emissions to boosting economic development, be it in jatropha-growing countries in south-east Asia or the corn belt in the United States. Biofuels have undoubtedly become a policy tool, surrounded by political rhetoric and clouded in a haze of conflicting social objectives and scientific discord about their purported benefits. Yet, despite the uncertainty surrounding the industry in terms of environmental effects, profitability and sustainability in the absence of government support, and undoubtedly, the long-term effects on crop production practices and food security, biofuels policies continue to encourage expansion across the globe and increasingly, in developing countries where issues such as food security are prevalent and environmental standards are little to none.

Domestic biofuels production and consumption continue to be encouraged in countries for a variety of a reasons; however, regardless of the motivations behind this political intervention, large quantities of agricultural feedstocks are being removed from both domestic and international markets and are being used as source material for biofuel production. This thesis examines the biofuel consumption goals in several countries and the corresponding amounts of the feedstock inputs to determine the impacts of biofuels production on agricultural markets.

1.2 Problem Statement

The rapid rise of biofuels production capacity encouraged by political forces has left academics with the task of both identifying and quantifying the impacts of global biofuels expansion in relation to a number of areas involving transportation, the environment, the global food supply, energy markets, and particularly, agriculture. This is by no means a slim task, as the nature and the scope of biofuels have the potential for economy-wide impacts. The wide range of potential biofuels impacts illustrates the need to understand specific sectoral effects before trying to make a broad-sweeping statement about the impact of biofuels on the global economy.

As such, agriculture seems a logical place to begin, as primary agriculture provides the feedstocks that serve as inputs for current large-scale biofuels production. The purpose of this thesis is to quantify the direct impacts of additional biofuels-induced demand on the feedstocks that serve as inputs, particularly with respect to price effects. It is hypothesized that biofuels mandates will significantly increase the prices of these grains and oilseeds inputs. More specifically, it is anticipated that increased ethanol production will increase the corn grain price and result in a reallocation of resources to its production. It is also expected that increased biodiesel production will lead to an increase in the price of vegetable oil. The increased demand for biofuel-specific feedstocks is also expected to affect the markets for other crops, both those in competition for land with biofuel feedstocks and those that may be close end-use substitutes for them.

While increased grain prices have the potential to directly benefit grain farmers, livestock farmers are faced with the increased costs of sourcing grain for animal feed rations. Although the distillers' grains resulting from ethanol production are able to be incorporated into livestock rations, the extent to which this is possible varies by species. It is hypothesized that despite the incorporation of distillers' grains into the livestock feed market, biofuels mandates will have negative effects on the livestock sector and cause temporary declines in production.

1.3 Thesis Objectives and Methodology

This thesis has multiple objectives, all relating to the hypotheses above and ultimately, to the broader goal of quantifying the impacts of biofuels production on agricultural markets. Given the level of political intervention in the biofuels market, a qualitative section is provided to give a snapshot of the current policy environment in which biofuels are being produced.

Despite the potential for economy-wide impacts of biofuels, this research focuses on the effects of these renewable fuels on agricultural markets. As such, the theory behind partial equilibrium models is presented in the context of those commonly used for institutional agricultural trade modeling. In addition to the theoretical background, a review of recent biofuel analyses provides insight into two methods of quantifying biofuels impacts: building an endogenous biofuels component into a larger pre-existing trade model or applying exogenous shocks to specific variables within pre-existing commodity components.

Utilizing the tools outlined in both economic theory and the relevant literature, AGLINK, a partial equilibrium model is used to provide quantitative estimates for the price impacts of biofuels on the corn, wheat and vegetable oil markets resulting from consumption goals in Canada, the US and the EU. Ambitious consumption mandates will likely increase the need for imported biofuels or biofuel feedstocks in situations where domestic production is insufficient to source domestic consumption. As such, significant trade impacts on the major commodities are examined, as are the effects on the various livestock markets in terms of production and feed costs.

Higher grain prices also have implications for the biofuel plants themselves. Rapid expansion of ethanol production capacity causes upward pressure on corn prices; however, price increases for corn also lead to lower profit margins for ethanol plants. The projected price increases are briefly examined with respect to the profitability of a standard ethanol production facility.

1.4 Thesis Organization

Following the introductory chapter, a background to biofuels and a discussion of the policy environment is presented in Chapter Two. The third chapter contains the theoretical background related to partial equilibrium models with specific ties to agricultural trade. Eight criteria by which to categorize multi-region, multi-commodity models are outlined, as classified by van Tongeren, van Meijl and Surry (2001). This theoretical background leads into the fourth chapter, in which four impact analyses of biofuels are reviewed to provide an overview of both endogenous biofuels components and exogenous shocks. The results of these studies are presented to provide a frame of reference for the results of this analysis. The fifth chapter gives an overview of AGLINK and discusses the exogenous shocks in detail. Chapter Six contains the results of this analysis, specifically the price impacts of biofuels demand on world corn, wheat and vegetable oil markets. The implications for the livestock sector, ethanol productivity and trade flows are discussed. A sensitivity analysis is performed by the varying the assumptions related to the by-product incorporation into the feed market. The impacts of higher corn prices are briefly discussed with respect to the profitability of ethanol production facilities. The seventh and final chapter provides a broad overview of the study and draws both conclusions and implications from its findings.

CHAPTER TWO
Industry Background

2.1 Introduction

This chapter will provide a brief background on biofuels and the current state of the major policy instruments being used by biofuel-producing countries to encourage both domestic production and consumption. Being a relatively new industry in a large-scale sense, government policies and programs are continually being updated; however, with that being said, many of the issues that these policies are being designed to address remain fairly consistent across biofuels-producing countries. This chapter will also look at the issues being addressed by current biofuels policies and assess their efficacy in meeting their purported objectives. Rather than provide an all-encompassing overview of the policies, this chapter is an attempt to provide a snapshot of the most recurrent issues arising in the policy environment at the time of writing.

2.2 Background

Biofuels are defined as "liquid, gaseous or solid hydro-carbon fuels derived from bio-mass" (IFATPC 2006). More plainly, biofuels are transportation fuels made from biological sources, primarily agricultural commodities. These grains and oilseeds-based biofuels are currently known as first-generation biofuels, in order to distinguish them from future biofuels, which are already regarded as second-generation or next-generation biofuels and are anticipated to be sourced from woody, cellulosic material. The two biofuels currently in large-scale production are biodiesel and bioethanol[1], both of which

[1] Ethanol can also be derived from non-biological sources, such as natural gas or coal (WRI 2008). Hereon in, the term *ethanol* will refer to bioethanol; that is, ethanol derived from biological sources.

are commonly used in low-level blends, but with varying degrees of engine modifications, can be used as a pure fuel[2].

2.2.1 *Ethanol*

Ethanol is produced from high-starch and subsequently, high sugar crops. Currently, inputs for ethanol are based highly on the availability of regional feedstocks, rather than on the most efficient input-output process. Large-scale production occurs through either the dry milling or the wet milling process. Both produce the same ethanol, but yield different by-products from the process. Dry mills produce distillers' grains (which can be used as is or can be dried for transport), solubles and carbon dioxide, while wet mills produce corn gluten meal, corn gluten feed, corn oil and carbon dioxide. These distillers' grains, as well as the corn gluten meal and feed, have value in the livestock sector, as they can partially replace the energy and the protein components in most animal rations.

Brazil and the US are the biggest producers of ethanol. The most recent production comparison can be drawn from 2006, with the US producing roughly 18.4 billion litres of primarily corn-based ethanol, and Brazil producing approximately 17 billion litres sourced from domestically-sourced sugar cane. Current US production capacity numbers (including 55 plants under expansion) put that number at over 50 billion litres per year (RFA 2008a). Production numbers out of other countries are significant as well, with Canadian wheat and corn-based production estimated at one billion litres for 2008, following the completion of several expansion and construction

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[2] When describing biofuels blended with regular petroleum or diesel fuel, abbreviations are used. E85, for example, refers to a blend of 85 percent ethanol and 15 percent gasoline; B10, in similar fashion, refers to a blend of 10 percent biodiesel and 90 percent diesel.

projects (CRFA 2008). The most recent numbers from Europe rank Germany, Spain and France as the top three producers in 2006, with total ethanol capacity at roughly 1.6 billion litres with feedstocks ranging from wheat to sugar beets to wine (eBio 2007).

2.2.2 *Biodiesel*

Biodiesel is produced from oil-based crops such as canola[3], soybeans, palm, mustard or corn oil, as well as from animal fats or previously used cooking oils and greases. Biodiesel is produced through a process called transesterification, where the oil content from the input material is removed and separated from the glycerine and methyl esters (NBB 2007a). Under certain conditions, consumers can use pure biodiesel (B100) as a substitute in existing engines; however, with blends containing more than 20 percent biodiesel, caution is recommended by the US National Biodiesel Board.

Biodiesel is more prominent in the EU than in North America, and is sourced largely from rapeseed in Northern Europe, and from sunflower and waste oils in Southern Europe (Agra CAES 2006). European statistics from 2006 peg biodiesel production at nearly 5 million metric tons; however roughly 63 percent of production is concentrated in Germany, Italy and France (EBB 2007). American biodiesel numbers are smaller, with production in 2006 estimated at 950 million litres per year, mainly utilizing soybean oil as a feedstock (NBB 2007b). Canadian numbers are smaller still, with current large-scale production estimated at roughly 100 million litres per year. Expansion and construction projects are expected to boost capacity to roughly 325 million litres in the foreseeable

[3] For the purposes of this analysis, the terms *canola* and *rapeseed* will be used interchangeably, despite differences in erucic acid levels and therefore, oil profiles and potential end-uses.

future (CRFA 2008). Inputs for Canadian biodiesel production are mainly canola oil and animal fats.

2.3 Current Policy Environment

The biofuels industry is heavily supported and protected by multiple levels and types of government policy action.[4] Commonly, biofuels policies are in place to stimulate both domestic production and consumption. In terms of consumption, governments worldwide are mandating the substitution of biofuel-blended transportation fuel for a specific share of regular transportation fuel and in some cases, heating oil. The EU for example, aimed to displace two percent of conventional transportation fuel with renewable fuels in 2005, a share expected to increase to 5.75 percent in 2010. An interim report released by the Commission however, stated that 2010 goals are unlikely to be met (CEC 2007). These consumption mandates effectively create a minimum supply guarantee for biofuel producers and encourage aggressive production capacity expansion in the early stages of market development.

Consumption and production are also promoted through the use of tax incentives directed at transportation fuel suppliers, aimed at promoting the use of ethanol or biodiesel-blended fuels. Most commonly at the national level, these tax breaks come in the form of exemptions for biofuel-blended transportation fuel from the fuel excise taxes imposed on regular petroleum and diesel fuels. In Canada, these federal taxes amount to 10 cents per litre on regular gasoline and 4 cents per litre on diesel fuel. In addition, several Canadian provinces have also provided tax incentives to boost their local

[4] For a more detailed overview of biofuels policies in Canada, the US and the EU, see Fridfinnson and Rude (2008).

industries. Manitoba for example, has moved away from excise tax exemptions and towards a declining production grant. For 2008-2009, ethanol producers are eligible to receive 20 cents per litre of ethanol sold to fuel suppliers, with this amount dropping gradually until 2015. The production grant then caps out at 10 cents per litre of pure ethanol (STEM 2008). Both types of tax incentives are used to bolster production to levels in line with consumption mandates.

Domestic production sufficient to fulfill consumption mandates requires large-scale production facilities. Many governments provide programs that offer either direct capital investment or repayable long-term loans to encourage capacity construction or expansion. Through Natural Resources Canada (NRC), the federal government has funded two rounds of the Ethanol Expansion Program, an initiative that provides capital loans to biofuels producers. It is also likely that with the encouragement of government programs, advancements in second-generation biofuels will come about sooner than market conditions would encourage. Significant federal funding in the area of $500 million was recently announced for the development and construction of a cellulosic or "second-generation" biofuel plant north of Saskatoon, as part of the NextGen Biofuels Fund (SDTC 2008). Programs such as these are often part of a government's strategy to promote domestic or local production.

Given incentives to promote production, sufficient domestic production capacity and government action to promote consumption and integration into domestic fuel supply, the market is protected from imports through the use of trade measures. Arguably the most cited example of trade barriers is the 54 cents per gallon import tariff on ethanol imposed by the US. This is in addition to a 2.5 percent ad valorem tariff, which is related to the value of the imports entering the country.[5] Higher prices for ethanol lead to higher tariff revenues collected on imports and higher protection for domestic producers.

2.4 Policy Issues related to Biofuels Production

Governments encourage biofuels production for different reasons; however, many countries are using biofuels to treat a series of policy issues. This is counter-intuitive to the Tinbergen rule in policy analysis – that one policy instrument is needed for each policy objective. While not all of the following objectives are pursued by every country, many countries are able to incorporate biofuels into several policy areas.

2.4.1 *Energy Security*

With crude oil prices reaching 100 USD per barrel in early 2008, countries such as the US are actively searching for ways to decrease their dependence on energy derived from imported fossil fuels. In 2006, the US imported roughly 3.7 billion barrels of crude oil, as well as nearly 1.3 billion barrels of finished petroleum products and other liquid fuels including ethanol (EIA 2008). Coupled with the fact that much of the developed world relies on imported fossil fuel is the age-old realization that large amounts of crude oil supply are sourced from regions of political uncertainty, most notably Saudi Arabia and Russia. In 2006, roughly 40 percent of US crude oil and crude oil product imports were sourced from countries in which Foreign Affairs and International Trade Canada

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[5] Signals out of the US suggest that the status of these import tariffs may be in question. High crude oil prices, as well as increasing feedstock prices have put pressure on both ethanol production margins and food prices. The removal of import tariffs would likely decrease the domestic prices of renewable fuels, as well as relieve corn prices. Lobby groups such as the National Corn Growers' Association, the American Corn Growers' Association and the Renewable Fuels Association are in opposition to the tariff removal (Delta Farm Press 2006).

have recommended that citizens avoid non-essential travel due to specific security concerns or “extreme risk to personal safety” (FAITC 2008; EIA 2008).

One only needs to look back to the Arab Oil Embargo of 1973 to see the economic effects of shutting off fuel supply to energy-dependent importers. Pró-Álcool, Brazil’s national ethanol program, was formed as a result of the embargo (Bourne 2007). It could be argued that decreased power associated with the Organization of Petroleum Exporting Countries (OPEC) cartel, as well as relatively high crude oil prices, have encouraged both the emergence of new players in the oil market and the exploration for oil in areas such as the Alberta tar sands.

Looking to the future, transportation fuel consumption is not expected to decrease. The International Energy Agency uses a 42 percent increase over 2004 transportation fuel numbers in its reference scenario for the energy outlook to 2030 (EIA 2007). With countries such as the US and Japan increasing consumption, in addition to the staggering increases seen from emerging economic powerhouses such as China and India, energy demand can only be expended to remain strong. While biofuels could theoretically help to stretch the supply of petroleum-based fuels, Westcott (2007) points out the disproportional relationship between the volume of biofuel production and US transportation fuel consumption. In 2006, roughly 16 percent of the domestic corn crop in the US went to ethanol production, replacing only 3 percent of transportation fuel (Forge 2007). Brazil on the other hand, directed roughly 51 percent of its sugarcane crop into ethanol production in 2007 (Brandao 2007), with reports from the same year suggesting that the displacement ratio of ethanol to gasoline is nearly 40 percent (Bourne 2007).

While energy security may be a valid concern, one has to question both the ability of minimal blending requirements to mitigate energy security concerns, as well as the impact of converting massive quantities of agricultural feedstocks into fuel additives. This argument may or may not apply to second generation biofuels when they become more relevant in a large-scale sense.

2.4.2 *Expansion of Agricultural Markets*

Until recently, agricultural commodities have been on a downward price trend in real terms. The movement of commodities such as corn, rapeseed, and sugarcane into the transportation fuel industry provides agricultural producers with an expanded market for their products. Although the three commodities mentioned above are currently the most significant for the biofuels market, their sustained high prices encourage agricultural producers to increase their production to capitalize on the higher prices. This leads to acres being diverted away from other crops such as soybeans, and to generally higher prices being observed for most grain and oilseeds (Klein and LeRoy 2007).

With governments striving to meet legislated production and blending mandates, sometimes in accordance with sourcing criteria, this alternative market for agricultural commodities is fixed in the medium-term or at least until either large-scale second-generation biofuels become commonplace or biofuel trade becomes more feasible and free of barriers.

2.4.3 *Fix for Farm Income*

In theory, high prices for agricultural commodities translate into high incomes for agricultural producers, assuming that input costs do not change. While high prices may generate high revenues, fuel and energy costs are a large part of the grain production process. MAFRI (2006) estimates that fuel and fertilizer bills comprise about 33 percent of operating costs of corn production in Manitoba. Extension economists from Iowa State University (ISU) currently estimate that in a corn-corn rotation roughly 38 percent of variable costs are related to fertilizers alone, and do not include the fuel necessary for seeding, cultivating, harvesting, spraying, and transporting the grain (Duffy and Smith 2008). With that being said, between 2004 and 2005 the price of nitrogen fertilizer increased 20 percent, with the cost of diesel rising by approximately 50 percent (Duffy and Smith 2005).

The positive side of this argument is also more relevant to grain and oilseed producers. Livestock operators who use grain such as corn in animal feed rations are facing higher costs to obtain feedstock. The most recent Economic Research Service (ERS) estimates show feed grain costs nearing 28 percent of the operating expenses for a cow-calf operation and fully 30 percent for a farrow-finish operation (ERS 2006). Higher grain prices mean higher input costs for livestock producers.

One of the major assumptions made in many of the analyses of the biofuels market is that a certain proportion of distillers' grains can and will be utilized by livestock producers in feed rations to replace the traditionally-used feed grains (Westcott 2007; Tokgoz et al. 2006). The ability of livestock producers to capitalize on this relatively cheaper feedstock would also depend on their proximity to the biofuel production facility, the consistency of the supply and nutrient composition of the DDGs, as well as the type of livestock being raised. While ruminants such as beef cattle are able to absorb more DDGs into their diet, monogastric animals including hogs and poultry, can only handle smaller amounts of these by-products in their daily rations (Westcott 2007).

Klein and Leroy (2007) argue that while high grain prices will lead to an increase in gross revenue, the overall increase in net income is questionable. As well as the increases in input costs previously mentioned, the appreciation in value of both marginal and productive agricultural land is seen in times of high prices. Research out of the US points shows national crop land values increasing by about 14 percent from 2006 to 2007 (NASS 2007), while cropland in the corn belt increased roughly 22 percent over the same period of time. Since 1997, grain land in the corn belt has risen by about 113 percent (Duffy and Smith 2007). This phenomenon also extends to the livestock sector, where national pasture land prices have increased by about 16 percent (NASS 2007).

In Canada, these numbers are not quite as dramatic. An annual farmland values survey by Farm Credit Canada (FCC) shows an average increase in the value of farmland by 3.6 percent during the first half of 2007, with no provinces showing declines (FCC 2007).

This supports the argument that much of the gain captured from higher commodity prices will quickly be counteracted by higher input and land costs. However, if and when the argument of "higher commodity prices equals higher farm income" holds, those advocating for decreases in government support for agricultural producers should be applauding. With changes in government programs going from price support to decoupled income support, higher overall producer incomes means fewer tax dollars allocated to stabilizing income. The Renewable Fuels Association (RFA) cites an estimated $6 billion savings in reduced farm program payments directly related to the increased value of corn (RFA 2008b).

2.4.4 *Rural Economic Benefits*

Higher farm net income increases the potential for economic activity in rural areas. Whether increases in disposable income are reinvested in agricultural machinery, land, non-agricultural investments or household spending, more money flowing throughout different rural businesses may help to keep people in these areas. This coupled with both the management and production-type jobs found in ethanol plants could lead to boosts in local economies. The RFA claims that more than 160,000 jobs in all sectors of the US economy were created as a result of the current ethanol boom (RFA 2008b).

On the other side of situation, Canadian as well as Australian and European hog producers, are facing tighter margins due to the ethanol boom, as well as the relative weakness of the American dollar. The Post-Crow era of Western Canadian agriculture has seen an increased concentration of livestock production near grain-producing areas. High grain prices have been one of the factors hedging in on the profits of large-scale livestock operations and have contributed to minor slaughter capacity reductions and processing plant closures (Grier 2007).

Looking at the bigger picture, global expansion in biofuels production has the potential to boost the economies of countries capable of producing biofuels from low-cost biomass with cheap and plentiful labour. Countries such as Thailand and Malaysia are currently investing in biofuel production facilities and have the potential to enjoy a comparative advantage to countries producing relatively high-cost biofuels, such as corn-based ethanol in the US. For this to happen however, large-scale production would need to be reliable and trade barriers would need to be decreased or removed.

2.4.5 *Environmental Goals*

The environmental aspect of biofuels is arguably the most controversial, with issues ranging from the destruction of the Brazilian rainforest to reduced crop rotations by American corn farmers. Many countries see biofuels as a way to reduce carbon dioxide emissions and meet either domestic or international environmental goals. While the energy-balance debate seems to have subsided, there are still questions as to the relationship between biofuels from various feedstocks and their ability to mitigate greenhouse gas emissions. The EU is particularly vocal about environmental issues and sees biofuels as a way to meet its Kyoto commitments. As well, the EU is supporting research in areas such as nitrous oxide emissions and the effects of large-scale production on localized water use (CEC 2007).

In the US, water issues have directly led to an increase in demand for ethanol as a fuel additive. When small quantities of methyl tertiary-butyl ether (MTBE), an oil industry-advocated fuel additive and a suspected carcinogen, were detected in the aquifers sourcing drinking water, states began banning the use of the oxygenate, subsequently creating a floor demand for ethanol.

In terms of production, the vast majority of American ethanol is produced from corn, a highly fertilized and intensive crop. The huge increases in production, both relative and absolute, are expected to contribute to increased soil erosion and increased concentrations of pesticides and fertilizers in the waterways, with the latter factoring into hyper-nutrient, low-oxygen "dead zones". These factors not only negatively affect the quality of water, some of which is destined for human consumption, but the increased irrigation requirements have the potential to deplete regional aquifers (NAS 2007).

The high price of corn has diverted more land to corn production and reduced an already thin corn-soy rotation in part of the US. There are reports of farmers seeding the entirety of their land to corn (Bourne 2007). This raises agronomic issues associated with reduced diversity, such as the potential for increased disease and pest infestation.

These production practices are not only of concern in the US, but also extend to countries whose biofuels industries are in the developing stages, many of which have lax environmental standards. The EU in particular, may be reluctant to import cheap tropical oils or biofuels from countries that are not able to guarantee their exports have been produced in an environmentally friendly manner (Mason and Schomberg 2007).

2.5 Conclusion

In its current state, the biofuels industry is both highly driven and protected by political intervention in the market. Government action to encourage domestic consumption and production takes many forms including blending mandates, which essentially create a minimum demand for biofuels; exemptions from fuel excise taxes on regular petroleum and diesel fuels; declining production grants to encourage production while gradually reducing government support; and research grants, capital injections and long-term repayable loans, all to encourage construction and expansion. Currently, these measures to promote the domestic industry are accompanied by border measures to limit imports from entering the market. Import tariffs are common, most notably the 54 cents per gallon import tariff in addition to a 2.5 percent ad valorem tariff applied by the US.

Governments encourage biofuels production for reasons that span across many policy issues. Strong agricultural lobbies, particularly in the American grain sector, are appeased by policies that stimulate high grains and oilseeds prices, as well as introduce new markets for their commodities and promote the rural economy. For many countries, the prospect of reducing reliance on imported oil-based products, often from regions of geopolitical instability, is appealing. Environmental issues, both negative and positive, are seen as an important factor in developing biofuels policies and encouraging domestic production, particularly in the EU. Regardless of motivation, these policies are continuing to encourage expansion in production capacity and consumption worldwide.

CHAPTER THREE
Theoretical Overview

3.1 Introduction

This chapter explores the background and motivations behind agricultural policy modeling, with a focus on multi-region, multi-commodity partial equilibrium models. The theory behind partial equilibrium models is presented and put in the context of basic demand theory. A review of van Tongeren, van Meijl and Surry (2001) outlines eight features by which partial equilibrium models can be classified. The classification of these attributes allows an analyst to evaluate the merits of using one model over another, depending on the purposes of the analysis. Based on these criteria, AGLINK, the partial equilibrium model used by the Organization for Economic Cooperation and Development (OECD), was determined to be an appropriate model for this analysis. A more detailed description of AGLINK and its characteristics will be given in Chapter Five as justification for its use.

3.2 Agricultural Trade Models

The degree of globalization of agricultural markets and markets in general, has increased significantly over the past few decades. To maintain their relevance and efficacy as tools for meaningful analysis, most institutional agricultural trade models have been adjusted to account for changes in the policy environment.

The reasons for maintaining and/or creating these models vary by institution and analyst; however, Thompson (1981) identifies three motivations behind an institution or an individual economist channeling resources into agricultural trade modeling. Firstly, to build on the policy work of past analysts and to create a framework for understanding the observed movements in the commodity markets around us. Similarly, Roningen (1997), attributes the progression of the Uruguay Round of WTO negotiations for spurring a new movement in studies utilizing partial equilibrium trade models for assessing the impacts of agricultural policy reform and ultimately, for providing the knowledge that led to the beginnings of global agricultural market reform.

Secondly, trade modeling allows analysts to provide empirical support to trade theory; conversely, evidence can also be provided to suggest that the theory is inadequate. Perdikis and Kerr (1998) provide an overview of the Heckscher-Ohlin factor proportions theory of trade, the subsequent work of many economists to empirically validate it, and the alternative theories that have arisen either as modifications to the original theory or as a result of abandoning it entirely.

Thirdly, the results of trade modeling serve as a quantitative foundation for policy makers. Using models, analysts are able to provide short or medium-term forecasts based on current trends, or even quantify the market effects of enacting a specific policy. For example, the OECD and the FAO collaborate annually to provide the OECD-FAO Agricultural Outlook. This document provides a snapshot of the major factors affecting commodity markets in the current period and contains ten-year projections based on current policies and market trends.[6]

While the objectives of trade policy modeling are clear, there is less certainty involved in choosing the appropriate model for undertaking analyses. Factors affecting the choice of model for an analyst include the particulars of scenario under investigation

[6] For a more detailed description of both past and current OECD-FAO Agricultural Outlook projections, see www.agri-outlook.org .

and the availability of a reliable and appropriate dataset. More administratively pragmatic factors include the cost of acquiring the appropriate model and the timeframe in which the analyst is facing (Roningen 1997). Regardless of model choice, it is widely acknowledged that no model is considered “the best” model for all purposes (Roningen 1997; Rude and Meilke 2004; Thompson 1981; van Tongeren, van Meijl, Surry 2001).

However with that being said, Rude and Meilke (2004) state that the first decision to be made when establishing a new model is whether to build a partial or a general equilibrium model. Given this statement, it is logical to assume that if faced with a policy question in which a model is needed for analysis and if existing models were available, the first decision would be whether to use a partial or general equilibrium model, based on their relative characteristics and the question at hand.[7]

3.3 Partial Equilibrium Models

Partial equilibrium models allow an analyst to examine a specific market at the exclusion of other markets (particularly factor markets) and of macroeconomic factors influencing the economy. Segregating a market from external influences creates the potential for more detail to be included in policy representation, relative to general equilibrium models (Rude and Meilke 2004). Francois and Hall (1997) comment, “...it may be difficult to justify devoting otherwise scarce resources to more complex and less transparent models, when they may yield only marginal extensions of the basic insights drawn from simpler approaches.”

[7] General equilibrium analysis examines the interactions of supply and demand over several markets, in order to determine market prices for many goods. Simplifying assumptions involve perfect competition and a small, arbitrary number of goods and consumers. Market trade can be incorporated, or for simpler cases, analysis using the assumptions related to the pure exchange of fixed endowments can be performed (Varian 2003). The theory behind CGE models will largely be ignored in this section.

Partial equilibrium models can used for the analysis of a single commodity or for multiple commodities. Thompson (1981) provides a survey of early studies for both instances and van Tongeren, van Meijl and Surry (2001) provide an overview of the more recent multi-commodity, multi-region agricultural trade models used for institutional analysis.

Van Tongeren, van Meijl and Surry (2001) identify eight criteria by which partial and general equilibrium models used for agricultural trade analysis can be classified: the regional scope, the regional unit of analysis, the dynamics, the modeling of trade, characterization of global markets, the representation of policies, the theoretical consistency and the model closures. Knowledge of these characteristics is essential for the understanding and interpretation of results generated by the model of choice.

3.3.1 *Regional Scope*

Large institutional models vary in the degree of country inclusion and the aggregation of countries into regions. Depending on the motivations and the scope of analysis conducted by the institution updating the model, the policies of specific countries may be represented with more or less detail than those of other countries.

Trade models that are global in nature involve closed systems that encompass specific country components for the commodities covered by the model, thereby accounting for global trade flows (van Tongeren, van Meijl and Surry 2001). In some cases, a rest of world (ROW) component is present to aggregate countries where policy-level details are either unavailable or deemed unnecessary for the policy objectives of the institution.

Currently, most multi-region trade models are used for primary commodities that are assumed to be homogenous, which ignores existing issues regarding quality differentiation within commodities and increasing levels of trade in value-added goods (Rude and Meilke 2004).

3.3.2 *Regional Unit of Analysis*

Van Tongeren et al. (2001) identify two methods for modeling a country component within the structure of a multi-region partial equilibrium model. The difference involves the level of detail given to an individual country. A model-builder may choose a fundamental structure to represent all economies in the model, essentially creating a skeleton model capable of representing any given country. Differences between countries are not only accounted for in the data, but also in the parameter differences between endogenous equations. The transparency in this approach improves the ease with which the country components can be updated, specifically in terms of data collection and parameter recalibration. Interpretation of results is also simplified; however, the universal nature of the underlying economic structure requires the modeler to capture the intricacies of the policy environment within parameters of the country component. Depending on the scope of the model, the type of economic and political structure within the country and the type of policies relevant for model inclusion, the implicit inclusion of policies may not be sufficient depending on the objectives of the analysis.

This downfall is addressed by the second method, in which individual countries are represented in unique components which reflect the institutional particulars affecting its policy environment. The detailed country components are linked globally through trade flows, capital flows and in some cases, factor mobility (van Tongeren, van Meijl and Surry 2001). Although this approach may be more capable of providing the basis for a detailed analysis, model results must be interpreted on the basis of the theoretical background for each country component. Given differences between developed and developing countries and the theoretical attention given to the economic particulars of each, results must be examined bearing exogenous factors which may be included in other country components.

3.3.3 *Dynamics*

The comparative static approach looks at the instantaneous effects of policy changes without regard for the path of equilibria between points. Where comparative statics are used in partial equilibrium models to project a baseline, it is important to note that these mid-way points are not representative of equilibria positions. Rather, these points are based on assumptions and growth rates and subsequently have little econometric value (van Tongeren, van Meijl and Surry 2001).

Incorporating dynamics into an analysis refers to the inclusion of a lagged adjustment process into the model over the projection period. Dynamics are necessary to capture the effects of factors such as imperfect knowledge, uncertainty, expectations and more generally, the time involved in decision-making. These factors are all incorporated to acknowledge that quantity adjustments do not occur instantaneously (Tomek and Robinson 1990). Incorporating dynamics into an agricultural trade models is significant, in that it also allows for commodity stocks to accumulate over time (van Tongeren, van Meijl and Surry 2001).

Commonly, dynamics are incorporated using the recursive dynamics framework, in which a path of temporary equilibria is created to represent both the exogenous changes of the policies under analysis, as well as changes in the endogenous variables that contain the lagged policy effects from the previous period.

3.3.4 *Modeling of Trade*

The large multi-commodity, multi-region trade models used in agricultural trade policy analysis generally treat commodities as homogenous; that is, differentiation based on the origin of production, either country or firm, is not possible. Given homogenous commodities and the further assumption of perfect competition, each actor is either a buyer or a seller. The inability to influence price, as well as the inability to produce at non-negative profit levels forces inefficient producers from the market in a competitive situation (van Tongeren, van Meijl and Surry 2001). The assumptions of homogenous goods and perfect competition also imply that all producers will receive the same price for their product in the absence of costs related transportation, storage and policy interventions.

Assuming that agricultural commodities are homogeneous not only ignores market power, but also product differentiation based on issues ranging from food safety and genetic modification to environmental standards and non-conventional commodity uses such as biofuels and nutraceuticals (Rude and Meilke 2004). Increasing trade among heterogeneous products, as well as the presence of market power in the food production and processing chain raises the need to question the ability of current models to accurately address policy issues[8].

3.3.5 *Characterization of Global Markets*

On an aggregated level, countries can either be net exporters or net importers of a given commodity. Furthermore, under the assumption of homogenous goods, imports are considered perfect substitutes for domestic production (Francois and Hall 1997). These assumptions simplify trade modeling significantly, since it becomes unnecessary to track bilateral trade flows when countries are either net exporters or net importers of a homogenous good (van Tongeren and van Meijl 1999). This pooled approach is known as non-spatial modeling.

As with most aspects of trade model specification, there exists a tradeoff between simplicity and detail. While a homogenous, pooled world market determined by the supply and demand of net exporters and importers creates ease in modeling, it ignores potentially significant bilateral trade flows. Bilateral specification is an element in spatial modeling, where prices are linked solely between trading partners. Thompson (1981) identifies the distinguishing features between non-spatial and spatial equilibrium (partial or general) as the endogenous trade flows and market shares of the latter, as well as differences in solution techniques.[9]

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[8] In the interest of brevity, the incorporation of product differentiation into trade modeling will not be discussed in detail; however, it is important to note that there are ways in which to address it. By assuming that the demand for domestic production of a commodity does differ than that of imports, Armington introduced exogenous differentiation based on country of origin. Alternatively, firm-level product differentiation can be introduced, creating endogenous supply-side reactions (van Tongeren, van Meijl and Surry 2001).

[9] A non-spatial partial equilibrium model is essentially a system of simultaneous equations which is solved by matrix inversion if linear, or by an iterative procedure if non-linear. Spatial partial equilibrium models are solved through different programming techniques involving algorithms.

3.3.6 *Representation of Policies*

Careful sectoral policy representation is essential for accurately reflecting the global market in which producers act and ultimately, contribute to the national supply of a commodity. Domestic policies have the potential to influence the type and the quantity of commodities produced domestically. This in turn affects the quantity of domestic surplus and the magnitude of exports to international consumers. Trade policies can affect the quantity of imports into a country, the quantity of exports leaving a country, as well as the relative price difference between commodities available domestically and those imported from other regions.

Including policies into a multi-region model can be done by directly incorporating the structural mechanisms of the policies or by indirectly accounting for the policy effects through the use of price transmission equations that link domestic and international prices, commonly through tariff equivalents or price wedges (van Tongeren, van Meijl and Surry 2001).

3.3.7 *Theoretical Consistency*

Partial equilibrium models take into account the basic economic theory behind supply and demand. In a multi-region, multi-commodity partial equilibrium model, the demand for any given commodity in a specific country can be thought of as the national aggregated consumer demand. Given these underpinnings, it is necessary to understand the literature behind consumer theory, as the theory related to the preferences of individual consumers has strong and direct implications for the properties of demand functions[10]. Similarly, the national supply of a commodity can be thought of as the aggregated supply of individual producers.

Building on the foundations of consumer theory, van Tongeren, van Meijl and Surry (2001) briefly note the four main components of demand theory that can be used to restrict the parameters within the model. Firstly, given prices of available goods and fixed incomes, the sum of expenditures will be equal to total expenditure, and therefore, demand:

$$[3.1] \quad y = \sum_{i=1}^{N} p_i x_i = p_1 x_1 + p_2 x_2 + \ldots + p_n x_n$$

p_i :	price of good i
x_i :	quantity of good i
y :	income

This "adding up" characteristic serves as the basis for Engel aggregation, such that the weighted sum of income elasticities for all items in a consumer's budget is equal to one (Tomek and Robinson 1990):

$$[3.2] \quad \sum w_i \varepsilon_{iy} = 1 \qquad where: w_i = \frac{p_i x_i}{y} \quad and \quad \varepsilon_{iy} = \frac{\partial x_i}{\partial y} * \frac{y}{x_i}$$

$w_i \varepsilon_{iy}$:	expenditure on good i as a proportion of income, y
ε_{iy} :	income elasticity

Secondly, the homogeneity criterion has shown that the Marshallian demand is homogeneous of degree zero in prices and income; that is, when the prices and income in

[10] Choosing a combination (bundle) of goods so as to maximize his utility under a budget constraint, an individual reveals preferences consistent with the axioms of consumer theory. An individual is able to rank these bundles of goods such that in a two-bundle example, A is preferred to B, B is preferred to A, or the individual is indifferent between the two. Similarly, if the individual prefers A to B, but prefers B to C, then the consumer would also prefer A to C. If B is considered better than A (A < B), the individual will rationally choose B, as more is preferred to less. These preferences reflect the axioms of completeness, transitivity and non-satiation, respectively (Varian 2003).

a Marshallian demand function are multiplied by an equivalent factor, there is no change in demand. Equation 3.3 shows the Lagrangian method of optimization for a reduced-form utility function under a budget constraint. Equation 3.4 shows the optimization for the same utility function, but with prices and incomes multiplied by an augmenting factor, t.

$$[3.3] \quad \ell = U(x_1 x_2) + \lambda(y - p_1 x_1 - p_2 x_2)$$

$$[3.4] \quad \ell = U(x_1 x_2) + \lambda(t * y - t * p_1 x_1 - t * p_2 x_2)$$

ℓ :	Lagrangian expression
$U(x_1 x_2)$:	reduced form utility function
λ :	Lagrangian multiplier
y :	income
p_i :	price of good i (i = 1,2)
x_i :	quantity consumed of good i (i = 1,2)

For both equations 3.3 and 3.4, taking first-order conditions by calculating the partial derivative of the utility function with respect to good 1 and good 2 results in the same price ratio[11]:

$$[3.5] \quad \frac{\frac{\partial U}{\partial x_1}}{\frac{\partial U}{\partial x_2}} = \frac{p_1}{p_2}$$

However, it should be noted that the compensated or Hicksian demand for Equation 3.3 is homogenous of degree one in prices alone. In order to maintain the same utility level under a uniform increase in all prices, an individual must see a proportional increase in income; therefore a doubling of all prices, holding utility constant would require a doubling in a consumer's income (Nicholson 2005).

[11] Varian (1992) suggests the right-hand side of Equation 3.5 be called the economic rate of substitution. Reaching a maximized, optimal solution ensures that this economic rate of substitution is equal to the marginal rate of substitution between good i and good j.

Thirdly, the cross-price elasticities should reflect a symmetric relationship when represented in matrix form; that is, the effects of a price change for good A on the quantity consumed of good B should be equivalent to the effects of a price change for good B on the quantity consumed of good A (Tomek and Robinson 1990). This is reflected in the following equation, which is a mathematical extension of the Slutsky condition:

$$[3.6] \quad \varepsilon_{ij} = \varepsilon_{ji}\omega_j + \omega_j * (\varepsilon_{jy} - \varepsilon_{iy})$$

ε_{ij}:	cross price elasticity of good i with respect to good j
ε_{ji}:	cross price elasticity of good j with respect to good i
ω_j:	expenditure on good j as a proportion of total expenditure
ω_i:	expenditure on good i as a proportion of total expenditure
ε_{jy}:	income elasticity of good j
ε_{iy}:	income elasticity of good i

Fourthly, the criterion of negativity ensures that the matrix of own and cross-price derivatives in the demand functions are negative semi-definite. A negative semi-definite Hessian matrix relates to the downward shape of the demand function and the properties of the own and cross elasticities. The nature of this matrix allows for Cournot aggregation to be defined as:

$$[3.7] \quad \sum_{i=1}^{N} \omega_i \varepsilon_{ij} = -\omega_j$$

ω_i:	expenditure on good i as a proportion of total expenditure
ε_{ij}:	cross-price elasticity for good i with respect to good j
ω_j:	expenditure on good j as a proportion of total expenditure

This condition is also present to assert that the own-price effects of Good j are not completely off-set by the cross-price effects between it and the other goods under analysis (van Tongeren, van Meijl and Surry 2001).

In addition to these four majors areas of demand theory[12], it is assumed that there is one bundle of goods capable of maximizing a consumer's utility (Varian 1992). A function capable of more than one optimal equilibrium solution concurrently would violate the axioms of consumer theory.

Because partial models focus on one specific part of the economy, they lack the full economy-wide accounting framework of a CGE model; this can make incorporating these theoretical components into a large partial equilibrium model challenging. Van Tongeren, van Meijl and Surry (2001) identify two methods by which modelers deal with the theoretical restrictions: ensuring that elasticities are consistent with dominant and properly-signed own-price effects, and/or by ensuring that smaller components of the global model satisfy the full set of regularity conditions.

3.3.8 *Model Closure*

Proper model closure requires that the number of equations equal the number of endogenous variables determined by the model. Closing the model requires the analyst to make decisions regarding the scope of the model with respect to the variables that are

[12] Similar supply-side theory is applicable as well: homogeneity of degree zero in prices for the supply function and symmetric cross-price effects. The upward sloping supply curve has a positive semi-definite Hessian matrix. Varian (1992) notes one significant supply-side difference relating to a unique solution, in that "if the production set exhibits constant returns to scale, then if some net output vector y yields maximal profits of zero, then so does t*y for any $t \geq 0$. Hence there is an infinity of bundles that are optimal net supplies".

determined within the model endogenously and those which will be calculated outside of the model exogenously and inputted into the model.

Depending on the size and the coverage of the model, the number of endogenous regions and/or commodities can be reduced by making specific model components exogenous. For partial equilibrium models dealing with agricultural trade, closure is less complicated as macroeconomic factors linking investment and savings are ignored (van Tongeren, van Meijl and Surry 2001).

3.4 Summary

The theoretical considerations behind partial equilibrium trade models used in agriculture extend back to the basics of economic theory. The axioms of consumer theory build towards the main components of demand theory: homogeneity, "adding-up", symmetry and negativity. Van Tongeren, van Meijl and Surry (2001) identify eight criteria by which to classify a partial equilibrium model, including the regional scope of the model, the structure design for individual regions and the characterization of global markets through pooling or bilateral specification. Models can also utilize the dynamic or comparative static approach to quantify the effects of a specific policy. Classifying goods as homogeneous or heterogeneous impacts the complexity of the model, as does the chosen method for representing national policies. In addition to theoretical consistency, general rules were given for closing a partial equilibrium model. The recognition and understanding of these attributes is important for an analyst to make an informed decision about either choosing the correct model for a specific analysis or attempting to build a new model to address a study's objectives.

CHAPTER FOUR
Literature Review

4.1 Introduction

Having examined the motivations that encourage governments to promote the domestic production and consumption of biofuels in Chapter Two, as well as the theory behind partial equilibrium models in Chapter Three, it is necessary to examine the institutional partial equilibrium models that are currently being used for agricultural analysis and become familiar with how they are being used in terms of assessing the impacts of biofuels. While there are several institutional partial equilibrium models that would be interesting for general analysis, only those which have been used for an analysis of the price impacts of biofuels on agricultural markets will be discussed. Four analyses of biofuels and therefore, four models will be examined. For each model, a brief organizational introduction will give a background as to the objectives of institutional analysis and to the audience at which analyses will be directed. In some cases, these models have already been adapted to include endogenous biofuels components; where applicable, these model modifications will be discussed. Where endogenous biofuels models are not present, the exogenous shocks will examined in order to understand the requirements of working with AGLINK, the partial equilibrium model chosen for this analysis. The results of all the studies will be presented as a framework of reference for the price impacts of biofuels determined in this analysis and presented in Chapter Six.

4.2 Center for Agricultural and Rural Development

CARD is a research group based out of Iowa State University and focused on interdisciplinary policy research involving agriculture, trade, environment, food, risk management, science, technology and bio-resources. CARD also maintains a close relationship with the Food and Agricultural Policy Research Institute (FAPRI) in terms of economic model development and maintenance (FAPRI 2008). Audiences for the group's research publications and quarterly bulletins involve federal and state-level policy-makers, academics, special interest groups and international organizations (CARD 2008).

Tokgoz et al. (2007) utilize FAPRI's system of international temperate-crop supply and demand models. The biofuels model interacts with international oilseeds and sugar models, and also with the US crops model, which feeds directly into the international grains model. In general terms, all of these models are non-spatial, multi-country and use behavioral equations for production, consumption, ending stocks and net trade. A representative world price is determined for each commodity, which is then linked back to domestic commodity prices through price transmission equations (Elobeid 2007).

4.2.1 *Biofuels Component*

As shown in Figure 4.1, an endogenous biofuels component is created and integrated into the international agricultural market. This component is non-spatial and is made up of behavioral equations for production, consumption, ending stocks and net trade for the US, Canada, Brazil, EU-27, China and India. The ethanol components for each of these countries is linked back to the appropriate feedstock used in production.[13] Net trade equations are incorporated for Japan, South Korea, and a ROW aggregate (Tokgoz 2008).

[13] Ethanol production in China is linked back to the Chinese grain model to account for corn ethanol production, while the Indian ethanol component is linked to its domestic sugar model to account for ethanol production from molasses. Brazilian production is linked back to its sugar model (Tokgoz 2008).

The model solves for the world prices of relevant crops, as well as the Brazilian anhydrous ethanol price (chosen as the representative world price) by equating the pooled excess supply and demand from individual countries to determine an equilibrium point.[14] Domestic ethanol prices are linked through price transmission equations to the world price, incorporating exchange rates and price policy wedges (Elobeid and Tokgoz 2006).

Assuming constant returns to scale $\widetilde{C}$, the refiners' conditional input demand for ethanol is derived from the cost function using Shephard's Lemma:

$$[4.1] \quad E_{F*}^{US} = \frac{\partial C}{\partial P_E^{US}} = f\left(P_E^{US} - TR^{US}, P_O^{US}, Mandate, RFS\right) * g\left(P_G^{US}, P_E^{US} - TR^{US}, GDP^{US}, Pop^{US}\right)$$

E_{F*}^{US} :	fuel ethanol demand
C :	refiners cost function
P_E^{US} :	price of ethanol in the US
TR^{US} :	refiners' tax rebate for blends of E10
P_O^{US} :	price of oil in the US
$Mandate$:	state-level mandates in percentage terms
RFS :	Renewable Fuels Standard
P_G^{US} :	price of gasoline in the US
GDP^{US} :	gross domestic product
Pop^{US} :	population in the US

Domestic transportation use is given as a function of the price of gasoline, the adjusted price of ethanol, the domestic GDP and population numbers. Given that regular unleaded gasoline is combined with ethanol to form a composite fuel, a decrease in the fuel's ethanol component will decrease the overall composite fuel price, encouraging

[14] It should be noted that the nature of the Brazilian market is unique, both on the consumer demand side due to the abundance of flex-fuel vehicles, and on the supply side due to the ability of processors to arbitrage between ethanol and sugar markets. As Brazil is not part of this analysis, its country model will not be addressed; however, Elobeid and Tokgoz (2006) and Tokgoz (2008) provide details on the modeling procedure.

consumer purchases. This complementary relationship is assumed to be dominant (Elobeid and Tokgoz 2006).[15]

Given the demand for ethanol, production is introduced through a fixed proportions profit function and a production capacity equation as shown in Equation 4.2:

$$[4.2] \quad Y^{US} = h\left(\pi^{NET}, PC\right)$$

Y^{US}:	ethanol supply
π^{NET}:	net return (per bushel of corn)
PC:	production capacity

Profits (net returns) for ethanol plants are differentiated between the wet milling and dry milling processes. The relative shares between the production methods are each multiplied by the marginal revenues from their byproducts[16] in order to determine gross revenue. Corn and natural gas costs are then incorporated to determine net returns.

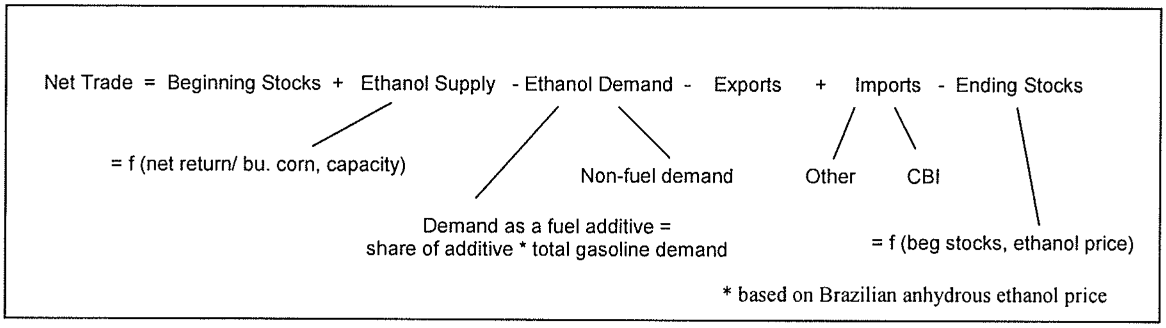
Production capacity is modeled to incorporate industry profitability. If profits are above a fixed trigger cost of building a new ethanol plant in the previous period (assumed to be 35 cents per bushel of corn), capacity will expand to reflect investors' expectations. Capacity expansion will not occur if it is not profitable to do so. Based on the supply of grain-based ethanol, a fixed proportion of distillers' grains are produced. The domestic production of these by-products are linked into the distillers' grains model (which also encompasses consumption and trade) in order to account for their feed value (Tokgoz 2008).

Given domestic ethanol production and consumption, stocks and trade are endogenized. US exports are held constant, with US imports being modeled as the sum of

[15] This complementary relationship between ethanol and gasoline is assumed to be dominant over the ability of ethanol to substitute for gasoline simply due to the relatively small numbers of flex-fuel vehicles on US roadways.
[16] The by-products of the corn wet milling process are gluten feed, gluten meal and oil. The dry mill process produces distillers' grains.

imports from the Caribbean Basin Initiative (CBI) and other countries.[17] This biofuels component is depicted in Figure 4.1:

Figure 4.1 CARD/FAPRI U.S. Biofuels Model



4.2.2 *Scenarios and Results*

Tokgoz et al. (2007) present the long-run equilibrium[18] results of three scenarios relative to a baseline. One of the major baseline assumptions is the uninhibited transportation of ethanol, distillers' grains, fertilizer and corn, assuming that all logistical issues that may hinder the long-distance movement of ethanol and distiller grains and that may be associated with large-scale regionalized corn production, are resolved. Despite the potential for unending corn-corn crop rotations, yields are assumed to be unaffected. Incorporating distillers' grains into livestock rations is assumed to have no effect on meat quality, and the effects of ethanol production on food prices are limited to the direct effects from increased feed costs. The feedstock used in ethanol production is limited to corn, switchgrass and corn stover. The final assumption is that the price increases for corn due to ethanol expansion are permanent in nature, allowing for long-term adjustment by the livestock industry.

[17] CBI imports are modeled as a TRQ, while imports from other countries are subject to the out-of-quota tariff rate.
[18] In this study, long-run equilibrium is defined as a market situation in which no group of producers or consumers has incentives to change its behaviour.

The first scenario looks at the impacts of crude oil permanently remaining 10 USD per barrel above the baseline comparisons. The second looks at the effects of pulling roughly seven million acres of land out of the Conservation Reserve Program. The third scenario shows the impact of a drought in 2012, given a 14.7 billion gallon ethanol mandate. Table 4.1 presents selected results from this analysis.

Table 4.1: Selected Results from Tokgoz et al. (2007)

	% Δ in World Price				
	Corn	**Soybeans**	**Soybean Meal**	**Soybean Oil**	**Wheat**
Scenario 1	40.3	19.7	17	11.5	17.5
Scenario 2	-2.5	-2.3	-3.1	~ 0	~ 0
Scenario 3*	~ 0	~ 0	~ 0	~ 0	~ 0

It should be noted that the short-run crop failure simulated in the third scenario had effects similar to baseline and ultimately, did not effect long-run equilibrium results. Trade impacts were significant in the first scenario, in that high crude oil prices led to major trade declines in agricultural commodities across the board (with the exception of soybean meal). Corn exports fell by about 62 percent relative to the baseline, with wheat and soybeans showing similar declines, at 31 percent and 29 percent respectively. Soybean oil exports also showed a dramatic 76 percent decrease over baseline numbers.

4.3 Economic Research Service, USDA

The ERS is the economic research group within the USDA, focusing its research on issues related to food, farming, natural resources and rural development. Research work within the ERS is aimed at a variety of audiences including other employees of the USDA, public policy groups within the government, as well as the academic community. Through research and outlook reports, briefs, publically available magazines and a detailed website, the findings of ERS work are also utilized by the media, trade groups, other national governments and the general public (ERS 2008).

Stillman et al. (2007) use the comparative static version of the ERS model PEATSim, a multi-commodity, multi-region partial equilibrium model, to analyze scenarios with varying degrees of world-wide increases in biofuel production. PEATSim is a reduced-form model.

For each commodity i in region r, supply and demand are balanced using the net trade equation shown in Equation 4.3. Each country is assumed to be either a net importer or a net exporter of commodity i. The smaller of imports and exports for a country is structured with a trade equation consistent with the base period trade, while the larger of the two adjusts as required to clear the international market (Stout and Abler 2004). The constraint placed on global markets restricts the sum of net trade over all of the regions in the model to zero, in order to close the country component.

$$[4.3] \quad NT_{ir} = QP_{ir} - QD_{ir}^{FO} - QD_{ir}^{FE} - QD_{ir}^{CR} - QD_{ir}^{PRO} - QD_{ir}^{X} - STK_{ir}$$

NT_{ir}:	net trade (exports minus imports)
QP_{ir}:	regional production (area * yield)
QD_{ir}^{FO}:	food demand
QD_{ir}^{FE}:	feed demand
QD_{ir}^{CR}:	crush demand (only applicable to oilseeds)
QD_{ir}^{PRO}:	processing demand (only applicable to raw milk)
QD_{ir}^{X}:	other demand
STK_{ir}:	net increase in stocks

Both area and yield are endogenous and specified as constant elasticities for grain production. The area harvested of commodity i is specified as a function of its own price and cross-prices, while yield is modeled as a function of the crop price and the historical yield. For oilseeds, both vegetable oil and meal are a function of crusher demand and extraction rates. Crush demand is modeled based on the previous year's crush demand, as well as the crushing margin (yield multiplied by the dividend of the value of the crush and the value of the seed). Livestock production is a function of production in the previous year, current prices and an indexed feed cost.

Based on the market clearing equilibrium from adjusting net trade, the representative world prices are determined for each traded commodity. World prices are linked back to individual countries through price transmission equations, which take into account transportation costs for imported goods, tariffs, tariff-rate quotas and any commodity-specific duties in order to calculate domestic prices.

4.3.1 *Biofuels Methodology, Assumptions and Scenarios*

No endogenous biofuels component is added to PEATSim, and exogenous shocks are performed by changing the QD_{ir}^{X} variable (other demand) in the US corn equation, the EU rapeseed equation, the Brazilian sugar equation and the Chinese corn equation where applicable. Comparative static predictions are performed in all scenarios for 2010.

It is assumed that the EU is only capable of meeting two thirds of its biofuels mandate due to capacity limitations in domestic rapeseed production and reluctance to import less-environmentally friendly tropical oils. It is also assumed that one pound of corn produces one third of a pound of DDGS, which substitute equivalently with feed corn in beef rations. Lower substitution rates are used for other livestock.

The first scenario involves a 10 percent underestimation of American corn-ethanol production in 2010, given constant European, Brazilian and Chinese production.

The second scenario holds Chinese and Brazilian production constant, American ethanol production at its projected 2010 levels, and assumes that European biodiesel production levels are understated by 10 percent. The third run is structured to project the effects of a 10 percent overshoot of biofuels production in all four countries.

4.3.2 *Results*

The effects of the scenarios were generated for six commodities: rice, wheat, corn, soybeans, cotton and sugar. The percentage changes in domestic production and consumption, as well as in exports and imports, were determined for the US, the EU, Brazil, China and Argentina. Selected results are presented in Table 4.2:

Table 4.2: Selected Results from Stillman et al. (2007)

	% Δ in World Price			Significant Effects	
	Corn	Rapeseed	Beef	US	EU
Scenario 1	3.65	N/A	1.09 (1.42 US)	slight ↓ wheat, soybean prod'n ↓ corn exports (12%)	↓ corn imports (9%) slight ↑ wheat, corn, soybean prod'n
Scenario 2	0.33	9	0.11	N/A	↑ world rape oil price (19%) ↑ rape oil production (5%) minimal livestock impact
Scenario 3	4.28	9.93	1.31	↓ corn exports (12%) ↓ livestock prod'n (1%)	↑ world rape oil price (20%) ↓ corn imports (10%)

4.4 Organization for Economic Cooperation and Development

The Organization for Economic Cooperation and Development (OECD) is a 30-member group, consisting of countries dedicated to the principles of democracy and of a market economy. The OECD is a global leader in comparative economic and social data, and not only provides economic forecasts and analyses, but also conducts research in areas related to agriculture, trade and the environment, among others (OECD 2008).

AGLINK is the partial equilibrium agricultural trade model used by the OECD. A more detailed description of AGLINK is given in the following chapter; however, the endogenous biofuels component outlined in OECD (2006) will be described and the results of three scenarios will be presented.

4.4.1 *Biofuel Modifications*

A 14-equation endogenous biofuels component is added to AGLINK which is not only capable of incorporating biodiesel and ethanol, but also other biofuels that are sourced from alternative feedstocks and that may increase in importance over time. Shares are used to differentiate between the different feedstocks for specific biofuels; the following would hold across all input commodities for all biofuels:

$$[4.4] \quad BF_{ij} = \alpha_{ij} * QP_j * BFS_{ij}$$

BF_{ij} :	quantity of feedstock i used in production of biofuel j
α_{ij} :	quantity of feedstock i required for one tonne of biofuel j
QP_j :	quantity produced of biofuel j
BFS_{ij} :	share of biofuel j produced from feedstock i

Depending on the feedstock and the milling process used, the by-products can be used in varying proportions as substitutes for the energy and protein components of livestock rations. Given QP_j, the amount of energy-rich or protein-rich feed per tonne of j is determined and summed across all biofuels. These aggregated protein and energy components are then linked back to the feed market.

For a given year, QP_j is calculated as a result of utilizing some proportion of biofuel-specific production capacity in a certain country. This production capacity is modeled as a log-log function of the utilization capacity in the previous year, an annual growth rate, the elasticity of production capacity for that biofuel with respect to its cost ratio, a three year moving average of cost ratios and an exogenous adjustment factor for production capacity.

The capacity utilization is modeled as a logistical function, occurring within an upper production limit and a lower production limit, which is assumed to be 50 percent of current capacity. The cost ratio is defined such that:

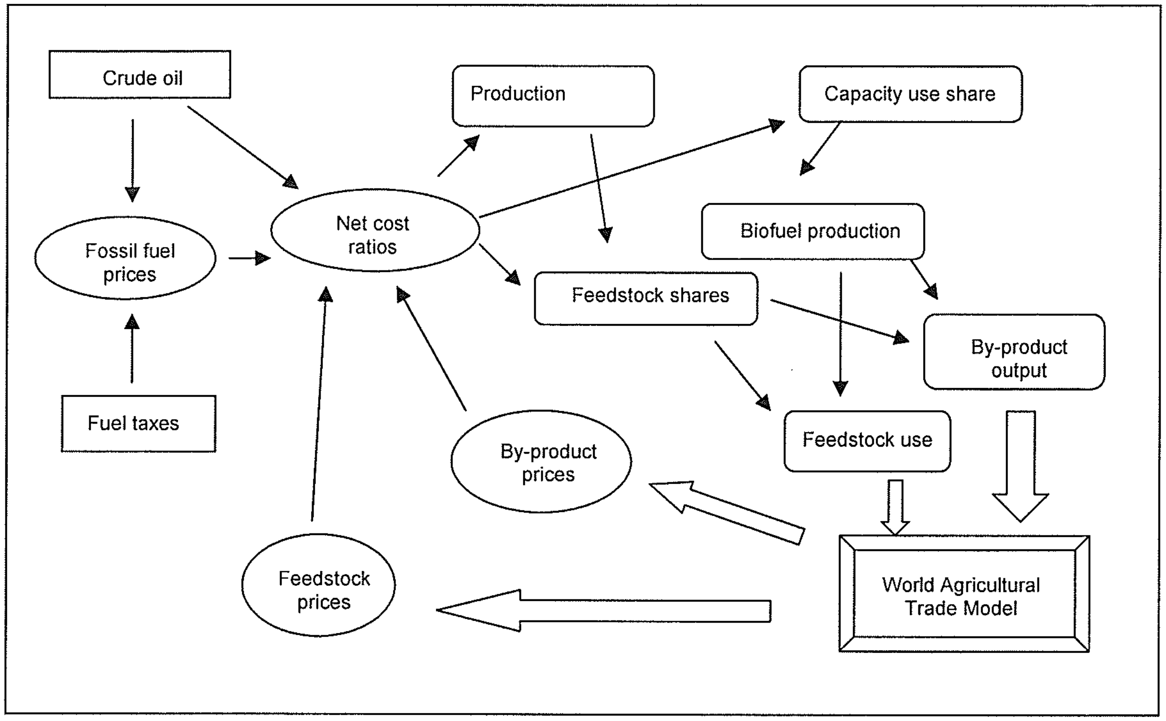
$$[4.5] \quad CRT_j = \frac{\frac{NC_j}{\lambda_{jk}}}{CP_k}$$

CRT_j:	cost ratio of biofuel j
NC_j:	net production costs of j
λ_{jk}:	energy content of j, relative to petroleum fuel, k
CP_k:	retail price of fuel, k

Net production costs include the aggregate of feedstock, energy and unspecified exogenous expenses incurred, which are then offset to compensate for the feed value of the byproducts, as well as any cost-reducing industry subsidies. Total net production costs are summed across feedstocks to account for cost differences between production processes. The retail price of fossil fuel is modeled as a function of the price of crude oil adjusted to account for exchange rates and taxes imposed by individual countries.

Figure 4.2 shows the relationship between the main agricultural model and biofuel component outlined in Section 4.4.1:

Figure 4.2: OECD (2006) Biofuel Module (von Lampe 2007)



4.4.2 Scenarios and Results

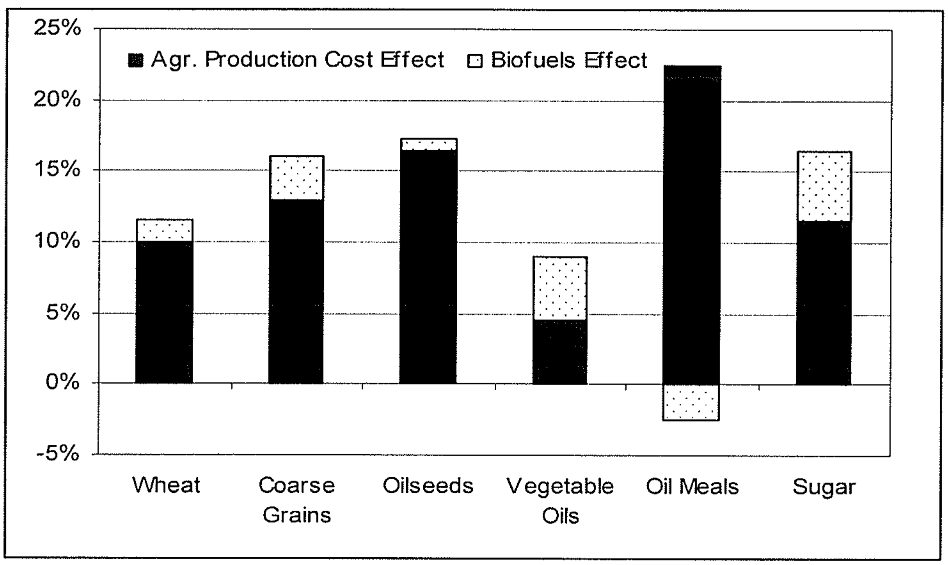
Three scenarios are simulated in the analysis, and the results for Brazil, Canada, the EU and the US are presented relative to a baseline (only US and Brazilian biofuels growth is projected). The first scenario assumes constant biofuel production in all countries at 2004 levels. Scenario two takes into account government-set consumption goals and policy initiatives, assuming that countries would meet their stated targets. The third scenario examines the effects of high oil prices (60 USD per barrel in each year of the projection period). Selected results are presented in Table 4.3 below:

Table 4.3: Selected Results from OECD (2006)

	% Δ in World Prices over the baseline			
	Coarse Grains	Wheat	Vegetable Oil	Sugar
Scenario 1	-2.5	-1	-1.5	-37
Scenario 2	7	4	15	60
Scenario 3*	13 + <3	10 + <3	17 + 4	12 + 4

It should be noted that the final scenario in OECD (2006) acts to capture the complementary nature of the relationship between petroleum fuel and agricultural commodities, as well as the substitution effects between petroleum fuel and biofuels. Figure 4.3 gives a graphical representation of the results from the third scenario:

Figure 4.3: Results of OECD (2006): High-Oil Price Scenario (von Lampe 2007)



The dark sections of the bars in Figure 4.3 indicate the effects of higher petroleum fuel prices on the costs of agricultural production, which in turn increase the costs of the feedstocks used in biofuel production. The dotted sections of the bars indicate the price impacts related to consumer choices in which the higher prices of crude oil and therefore transportation fuel, increase the demand for alternatives (von Lampe 2007). This augments the price impacts on agricultural commodities above those associated with higher fuel input costs. Figure 4.3 shows that the price impacts of higher fuel costs have more of an effect on the price of agricultural commodities than the demand for alternative transportation fuels due to high crude oil and gasoline costs.

4.5 Strategic Policy Branch, AAFC

The Strategic Policy Branch (SPB) within AAFC is responsible for agricultural policy analysis, with specific units working quantitatively on economic issues. In this analysis, the SPB also uses AGLINK[19] to analyze the effects of increased biofuel demand in OECD-member countries. Based on GDP projections, national fuel consumption levels for the OECD countries were determined and extrapolated from 1999 to 2006.

4.5.1 *Scenarios and Assumptions*

The scenario dictates an annual increase of one percent in the share of biofuels in national fuel consumption, ending where all OECD countries have an eight percent biofuel share in the transportation fuel sector.[20] The first year of the scenario was 1999 in which all of the OECD countries had an effective biofuel share of zero, with the exception of the US, Canada, and the EU. In the first year of the scenario, it was assumed that biofuel production would be expanded just enough to bring all countries to one percent. In each of the following years, an additional one percent was added to the biofuel share in total transportation fuel consumption.

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[19] Refer to Section 5.2 for a description of AGLINK.

[20] It is noted that as a one percent increase is added in every year of the projection period, the results in the final year are not to be interpreted as long-run equilibrium predictions.

A two-part exogenous increase was used to model these effects. By positively shocking the demand for wheat, corn and vegetable oil, the direct demand effects on the commodity markets are accounted for. The second shock expands the supply of coarse grains and soybean meal in the feed market by instituting a shock equal to the by-products from biofuels production.

Due to the dominance of gasoline over diesel in the Canadian transportation sector, it was assumed that all of the expansion in the Canadian and American biofuels sectors would be completely ethanol-based. While the American ethanol supply is produced primarily from corn, the Canadian industry is assumed to be split by about 80 percent corn and 20 percent wheat. The European biofuels sector is dominated by biodiesel; however, ethanol production does exist, with 70 percent being produced with sugar beets and the remainder produced from wheat. It is assumed that these shares remain constant across countries throughout the projection period.

For countries using corn as an input, it is assumed that the by-products would have a feed value equivalent to a ration of 56 percent soybean meal and 44 percent corn. For wheat, the feed value is 53 percent soybean meal and 47 percent wheat. The by-products of the wet milling process in the US are assumed equal to 61 percent soybean meal and 39 percent corn. Throughout this analysis, it is also assumed that by-products stay at comparative prices relative to the main feed ingredients.

4.5.2 *Results*

The price impacts resulting from the shocks described above are presented in Table 4.4, and represent the average of the projected prices from the final three years of the analysis.

Table 4.4: Selected Results from AAFC (2002)

	% Δ Prices		% Δ Exports
Commodity	**World**	**Western Canada**	**Canada**
Wheat	22	31	-6
Corn	45	38	-73*
Canola	N/A	44	7
Soybeans	12	13	N/A
Vegetable Oils	66	N/A	N/A
Protein Meal	-33	N/A	N/A

* total coarse grains

The results above have implications for both agricultural producers and processors. High grain prices increase the appeal of seeding grains over other crops, including oilseeds. Lower soybean supply, resulting from these crop rotation decisions as well as the direct influences from biofuel production, puts upward pressure on the price of soybeans. This upward price movement is counteracted by meal prices.

Livestock producers face mixed effects, as feed grain prices are increase and protein meal prices are decrease. US producers faced a 12 percent increase in feed costs, while Canadian producers saw an increase of 21 percent.

4.6 Other Models

The models and analyses reviewed thus far have been exclusively multi-region, multi-commodity partial equilibrium models, simply due to the nature of the model chosen for this analysis. Studies using Computable General Equilibrium (CGE) models to examine the impacts of biofuels on commodity markets are also present in the literature.

Banse et al. (2007) use LEITAP, a land-substitutability extension of the GTAP model, to analyze the impacts of the EU Biofuels Directive in a variety of areas, including agricultural land use, commodity prices and GDP. Grain prices in the EU increased by roughly 12 percent, while oilseed prices rose nearly 5 percent. Wiggins et al. (2008) utilize a modified GTAP database with a customized version of the GLOBE CGE model to examine the effects of 5 percent, 7 percent and 10 percent biofuel shares in transportation fuel for the North American region and the EU. The average increase for grain export prices in North America was 22 percent, while oilseed export prices rose 53 percent in the EU.

4.7 Summary

The increasing attention to the effects of biofuels on agricultural markets is apparent in the mass of literature emerging from research groups and academic institutions. It should be noted that none of the institutional reports overviewed in this section are peer-reviewed with respect to academic journals; however, this is more likely caused by the lags associated with publishing rather than with major flaws in methodology or credibility. It is also important to note that these institutional models are continually being updated, particularly with respect to endogenous biofuels components.

Table 4.5 provides a brief summary of surveyed articles with respect to the impacts on the world prices of corn, wheat and vegetable oil, the commodities that will be under focus in this analysis.

Table 4.5: Survey of Price Impacts on Wheat, Corn and Vegetable Oil

	% Δ in World Price		
	Corn	**Wheat**	**Vegetable Oil**
Tokgoz et al. 2007	40	17.5	11.5
Stillman et al. 2007	4	N/A	20
OECD 2006	7	4	15
AAFC 2002	45	22	66

The wide range in the results presented above shows the importance of clearly identifying assumptions and defining scenarios. Similarities among the studies relate to the incorporation of the distillers' grains into livestock rations and the importance of adjusting the feed market relative to energy and protein values of these ethanol by-products. The identification of scenarios based around government mandates (Stillman et al. 2007; OECD 2006) and their price impacts also highlights the political intervention occurring in the biofuels industry, particularly with respect to the consumption mandates in developed countries. The studies which assumed aggressive expansion in the biofuel share of transportation fuel (AAFC 2002) had larger impacts than the studies with more conservative increases in biofuel demand.

The price effects seen in scenarios featuring high crude oil prices (Tokgoz et al. 2007; OECD 2006) also point to the interrelationship between biofuels and their respective petroleum counterparts. These studies suggest that higher crude oil prices increase the magnitude of price effects on the commodities used as inputs. In particular, the study by the OECD (2006) quantifies the price impacts of high crude oil prices on agricultural production costs relative to the price effects from consumers demanding alternatives to high-cost petroleum fuel.

Whether using exogenous shocks to multi-region, multi-commodity partial equilibrium models (Stillman et al. 2007; AAFC 2002) or building endogenous biofuels components (Tokgoz et al. 2007; OECD 2006), the complex nature of the relationship between biofuels, agricultural markets and energy markets is apparent.

CHAPTER FIVE
Model Description and Scenario Development

5.1 Introduction

Based on the literature review presented in Chapter Four, quantifying the effects of biofuels policies on agricultural markets can be done with a partial equilibrium model by either introducing an endogenous biofuels component or by applying exogenous shocks to specific variables already contained in the model. AGLINK, the model chosen for this study due to its characteristics, its previous use in a biofuels analysis and its availability, does not contain a biofuels component available for use in this analysis. Although building an endogenous biofuels component would allow for an application of the theory discussed in Chapter Three, it is a hefty task, one that is currently being done thoroughly by the OECD. As such, it was determined that exogenous shocks would be sufficient to provide the answers for this analysis.

This chapter provides the methodology behind the results that will be presented in Chapter Six. It begins by providing a detailed description of AGLINK with respect to the global scope of the country models, the commodities covered and the variables used to create domestic markets and link them to world markets. The exogenous shocks will be described, outlining the data sources used to determine the magnitude of the adjustments. The assumptions and the conversion factors used to adjust the variables for biofuel-induced demand are explicitly defined.

5.2 AGLINK

AGLINK is a multi-country, recursive-dynamic partial equilibrium model employed by the OECD and its member countries to aid in evaluating national and international agricultural policy decisions. Supply and demand for various agricultural commodities in both OECD member and selected non-member countries are linked together to provide policy-makers with a mechanism to analyze the medium-term effects of agricultural policy decisions.

5.2.1 Model Description

The following description is based on OECD (2007). The complete modeling system is composed of over 10,800 equations, covering 39 individual countries and 19 regions. Coverage includes Australia, Canada, the EU-25, Japan, Korea, Mexico, New Zealand and the US as well as a number of developing countries such as Argentina, Brazil, China and Russia. Commodity coverage includes wheat, coarse grains (corn, barley, oats, sorghum, rye and other cereals), rice, oilseeds (rapeseed, soybeans, sunflower), oilseed meals (soybean, rapeseed, sunflower), vegetable oils (soybean, sunflower, rapeseed, palm oil), milk and dairy products (cheese, whole-milk-powder, skim milk powder, fresh dairy product, butter, whey powder, casein, other dairy products,) beef and veal, pork, poultry meat, sheep meat and eggs.

With respect to crops, production is modeled as the product of the yield per hectare and the amount area harvested. Both areas and yields (represented individually) are determined by relative crop prices and government policies. Cross-price effects (more precisely, cross gross revenues), are included in the equations for the amount of area harvested, in order to reflect the competition for land between alternative crops. Yields are modeled as a function of prices and/or a time trend to proxy technological change.

With the exception of wheat and rice, significant aggregation occurs with respect to the complete supply and utilization of crops. Although the yield and the production of individual coarse grain and oilseed crops are each represented, the demand side of the supply/disposition identity is accounted for as an aggregate.

The national demand for a crop is disaggregated into domestic food use, domestic feed use, domestic crush (in the case of oilseeds), other domestic use (an exogenous variable for wheat and coarse grains only), net trade and ending stocks. Food demand depends on prices, income and population. Feed demand depends on relative feed prices and an index of ruminant and non-ruminant livestock production[21].

The production of vegetable oils and oilseed meal is also represented endogenously in AGLINK. Oilseed processing in each country is assumed to occur at an aggregate level through equations that link the quantity of oilseeds crushed to the input price of the oilseeds and the output prices for vegetable oil and oilseed meal. The amount of vegetable oil and oilseed meal produced from the crush are each expressed relative to an extraction rate.

The model also includes livestock components for beef, dairy, pork and poultry. The dairy module covers production and consumption of milk, as well as the main dairy products. As the EU and Canada determine national levels of milk production using a quota system, production is assumed to be fixed. Dairy and beef production are linked through culled animals. Breeding inventories for beef cattle are a function

[21] Feed quantities are used to calculate total feed expenditure, feed share and consequently a feed cost index. This index is then used in the determination of livestock production.

expected producer prices, as well as feed costs and other factors. Production of beef and milk are linked to lagged breeding inventories and also depend on producer prices and production costs. Pork production also incorporates lagged breeding inventories and expected producer returns. Poultry and egg industries are assumed to have prices that are completely determined by production costs. Quantities produced are determined by demand.

Products are homogenous across countries. Markets are assumed to be competitive and imports into a country are treated in the same manner as domestic production. The functional forms are mostly linear in logarithms. World and domestic producer and consumer prices are linked through linear price transmission equations. Domestic prices are a function of world market prices adjusted to account for local currency, transportation costs, border measures and occasionally, differences in quality. AGLINK is a non-spatial model and is therefore limited to describing the imports and exports of a specific commodity in terms of the net trade for that country. As such, countries are either a net exporter or a net importer for each commodity in their country module.

Countries are responsible to update data annually for each variable in their country component. For example, AAFC is responsible for maintaining and updating the Canadian components of the model. These updates are collected from all countries by the OECD and standardized to create a reliable dataset. From there, the updated model is sent back to member countries to be used for policy analyses. It is these numbers within AGLINK that will be adjusted to account for the excess demand due to biofuels production.

5.2.2 AGLINK Relative to Partial Equilibrium Theory

Given the description of AGLINK in the previous section, it is important to explicitly examine the characteristics of the model with respect to the eight criteria outlined by van Tongeren, van Meijl and Surry (2001) and reviewed in Chapter Three.

The regional scope of AGLINK is considered to be global, given the wide range of developed and developing countries and the incorporation of the FAO Cosimo model with the original AGLINK model. To be theoretically considered as a global model, the system must try to account for all trade flows of individual commodities (van Tongeren, van Meijl and Surry 2001). This is deemed to be the case with AGLINK, considering the inclusion of 19 regions and 39 individual country units.

Rather than deal with detailed economy representations for the many countries and regions included in the model, the basic structure of a national economy remains relatively constant, with differences between countries being represented through the data and subsequent parameter calibration.

AGLINK is classified as a recursive dynamic model, in that forward-looking projections account for the lagged effects from previous periods and are considered to be temporary equilbria reflecting an adjustment path over time. Commodity stock variables are capable of being adjusted to reflect the endogenous adjustments in the previous period, a feature that is outside the capacity of a comparative static model.

In terms of modeling trade, individual commodities are assumed to homogeneous, both with respect to quality and country of origin. This not only implies that imports of a commodity into a country are considered to be perfect substitutes for domestic production, but also that no differentiation is made with respect to quality grades in either grains or livestock.

The characterization of global markets in AGLINK is non-spatial, as countries are either net exporters or net importers for each commodity in their national component. Countries with excess supply of a commodity are theoretically considered to export national surplus into a global "pool" from which countries unable to meet demand domestically are assumed to import. To be considered a spatial model, the trade flows between specific countries would be specifically accounted for in the system, and this is not the case with AGLINK.

Policies placing quantitative restrictions are modeled explicitly in AGLINK (van Tongeren, van Meijl and Surry 2001). Price transmission equations are also in place to account for the policy-induced distortions between the international price of a commodity and its domestic prices in different countries.

Van Tongeren, van Meijl and Surry (2001) describe the task of imposing all of the theoretical conditions described in Section 3.3.7 as "insurmountable" and identify two methods of dealing with the need for theoretical consistency, both of which are used in AGLINK. The specification of supply and demand are such that the own-price effects are dominant over the cross-price effects, addressing the negativity condition. The feed demand relationships contained in the model are also theoretically consistent (van Tongeren, van Meijl and Surry 2001).

Model closure occurs in AGLINK by treating the factor markets and the rest of the economy as exogenous. The number of equations must equal the number of endogenous variables for the model to close properly and the agriculture sector represented in AGLINK is closed by meeting this condition.

5.2.3 Exogenous Analysis of Biofuels

The version of AGLINK used in this analysis is calibrated based on 2004 data and does not contain an endogenous biofuels component. Therefore, to quantify the effects of biofuels policies, it is necessary to identify the feedstocks that directly serve as inputs for biofuels production. AGLINK contains projections for every variable in the model; for this version of the model, the projection period is 2005 to 2015. It is assumed that in 2004, individual country analysts are aware of the burgeoning biofuels industry, and have incorporated its effects into the projections given to the OECD. As such, a "reverse shock" was performed by quantifying the amount of the feedstock annually required to produce mandated levels of biofuels and removing it from the system. Given the value of the by-products to the feed market, it was assumed 75 percent were absorbed, and their subsequent feed value was also removed from the market. Essentially, a new baseline is created to reflect a scenario in which biofuel production has not expanded relative to 2004 numbers. The data required and the specific adjustments made to the variables are detailed in the following section.

5.3 Data Sources, Assumptions and Conversion Factors

In order to determine the necessary magnitude of the shocks to the relevant variables, it is necessary to project biofuels production in order to quantify feedstock requirements and the corresponding amount of by-product production. For the US, it was assumed that all of the current ethanol production capacity relies on corn as the sole feedstock. The ERS Feed Grains Yearbook provides historic evidence for the amount of corn used for fuel alcohol production. Projected future corn utilization is determined by applying a growth rate to these historic numbers that will roughly satisfy the mandated requirements for 2015 under the Renewable Fuels Standard. The conversion factors used in this study are common to the literature: one bushel of corn is capable of producing 2.8 gallons (roughly 10.5 litres) of ethanol regardless of production process (Elobeid and Tokgoz 2006; Davis 2001).

The same conversion factor was used for corn-ethanol production in Canada. It was assumed that the relative distribution between corn and wheat-based ethanol in Canada would remain the same over the projection period, with 70 percent of Canadian ethanol derived from corn and 30 percent from wheat. For wheat-based production, it assumed that one bushel of wheat produced 10 litres of ethanol and 9.5 kg of distillers' grains (Bonnardeaux 2007; NRC 2003). Feedstock requirements are based on current ethanol production capacity numbers from the Canadian Renewable Fuels Association (CRFA 2008) with projections based on capacity estimates obtained from AAFC.

Canadian projections of biodiesel production were based on historical and current capacity numbers from the CRFA (2008). It was assumed that capacity expansion projects listed with the current capacity would come into production in 2009, and that capacity would continue to expand at an annual rate until 2 percent of Canadian diesel fuel consumption was replaced with biodiesel. This is the consumption goal for 2012 set by the federal government in their renewable fuels strategy; however, it was assumed that it would take until 2015 to reach this goal. Based on reports from the FAS (2003), it was assumed that one ton of biodiesel required an input of 2.672 tons of canola; similarly, the Canola Council of Canada (2008) reports that one metric ton of canola produces about 390 litres of biodiesel from 350 kg of canola oil. Doing the conversions, this translates to 7.4 lbs of canola oil for every gallon of biodiesel.

Given that the largest producers of biodiesel in the EU use canola or sunflowers as the primary feedstock, it was assumed that production was based entirely on domestic vegetable oil. It was also assumed that the conversion factors for canola-based production in Canada would be equivalent to rapeseed-based production in the EU. Biodiesel projections for the EU are based on estimates from the European Biodiesel Board and the FAS of the USDA.

These conversions differ between soybeans and canola. For US biodiesel, it was assumed that 7.5 lbs of soybean oil was required for one gallon of biodiesel (Urbanchuk 2006). Based on these assumptions, it is calculated that one bushel of soybeans yields 1.49 gallons of biodiesel. Projected production was based on a report prepared by John Urbanchuk (2006) for the National Biodiesel Board.

5.4 Scenario Development

For this analysis, ethanol production is assumed to occur in Canada and the US, while biodiesel production is modeled for Canada, the US and the EU. All increases in biofuel production are modeled as exogenous shocks to the model over the projection period 2005 to 2015. By-products from the biofuels production were calculated exogenously from AGLINK and were added back into the model as additional sources of animal feed.

The main grain affected by the increase in global ethanol production is corn, which in the model, is aggregated into the larger category of coarse grains. The increased demand for coarse grains occurs primarily because of US ethanol demand and to a much lesser extent because of ethanol production in Eastern Canada. Additional demand for wheat for ethanol production occurs in Western Canada.

Oilseeds are used in large-scale biodiesel production. In the US, soybeans are primarily used for biodiesel production, while in Europe and Canada, biodiesel is sourced from canola. AGLINK aggregates all vegetable oils together. The price effects of direct biofuel-induced demand are simulated over the ten year period and are compared with the AGLINK baseline for a reference period.

5.4.1 *Ethanol Adjustments and By-Product Treatment*

The following two-part exogenous shock was applied in a similar manner for both American and Canadian ethanol production. In AGLINK, coarse grain use is broken down into feed, food and other use. The use of feedstock in biofuel production in each region is captured in the other/alternative use variable. The identity for total coarse grains use is presented below in Equation 5.1:

$$[5.1] \quad QC_i^{CG} = CG_i^{FE} + CG_i^{FO} + CG_i^{OU}$$

QC_i^{CG} :	total quantity of coarse grains consumed
CG_i^{FE} :	quantity of coarse grains used for livestock feed
CG_i^{FO} :	quantity of coarse grains used for human consumption
CG_i^{OU} :	quantity of coarse grains used for other purposes
i :	regions US and Canada

Coarse grains for feed and food have their own endogenous equations. The feed equation is based on own prices and oilmeal prices, as well as both ruminant and non-ruminant production. The food equation is based on the population, the national economic activity of a country and the price of coarse grains. The third variable, CG_i^{OU} is exogenous and is used to capture the extra demand for coarse grains due to biofuels. Based on projected ethanol requirements (total production in the US and 70 percent of Canadian production), the annual corn requirements are calculated. Based on the conversion factors in Section 5.3, CG_i^{OU} is adjusted to reflect these annual increases.

The shock of biofuel-induced corn demand affects the total quantity of coarse grains consumed in both Canada and the US, and also affects the world coarse grains market through net trade flows. The world price of coarse grains adjusts through a market clearing condition that equates global aggregate demand and supply of coarse grains.

However, this shift in the demand for corn due to biofuels must also be adjusted to reflect the increased availability of the by-products for feed rations for various types of livestock. Information from Westcott (2007) is used to account for the distillers' grains (DDGs) from corn ethanol production that are put back into the feed system as partial substitutes for the corn and soymeal components in animal feeding rations. A formula is applied based on different feeding requirements for each type of livestock:

$$[5.2] \quad CORN: 0.75*[(0.8_{BF}*1)+(0.1_{DY}*0.45)+(0.05_{PK}*0.85)+(0.05_{PLT}*0.55)]$$
$$[5.3] \quad SOYMEAL: 0.75*[(0.1_{DY}*0.55)+(0.05_{PK}*0.15)+(0.05_{PLT}*0.45)]$$

BF:	beef
DY:	dairy
PK:	pork
PLT:	poultry

Westcott assumes that 75 percent of the DDGs produced would be fed back into the livestock sector rather than be used for export or other domestic industrial purposes.

This is a crucial assumption that will later be varied to perform a sensitivity analysis around the price effects.

It is assumed that for beef, dairy, pork and poultry, there are differences in the relative amounts of the energy and protein components in the rations and therefore, between the amount of corn or soy that can be replaced with distillers' grains. Beef cattle, for example, are assumed to consume 80 percent of the DDGs allocated to total livestock rations. These DDGs are assumed to be a perfect substitute for corn. It is assumed that dairy cattle will consume 10 percent of DDGs allocated to livestock, 45 percent of which will replace corn and 55 of which will replace soy meal. Pork and poultry are minor users of these by-products, both of which are expected to consume five percent of total livestock distillers' grains. In pork rations, corn and soy substitution are expected to occur at 85 percent and 15 percent respectively, while poultry is assumed to absorb 55 percent in lieu of corn and 45 percent for soy.

The DDGs from Canadian ethanol production were dealt with slightly differently, according to conversion factors from an NRC paper (2003) and the assumption that 30 percent of Canadian ethanol is produced from wheat. DDGs from wheat-based ethanol production can be used in the same markets as DDGs from corn ethanol at a displacement ratio of 1:1 for corn and 1:1.04 for soy meal. This relationship is modeled based on the lower energy content and the higher protein levels of wheat by-products over corn by-products. Similar to the assumption for the US, 75 percent of distillers' grains from Canadian ethanol production were put back into the livestock sector at the same beef-dairy-pork-poultry ratios as the American sector, keeping in mind the relative split between corn and wheat-based production.

Rather than simply reduce the exogenous shock to CG_i^{OU} by the corresponding amount of DDGs being fed back into the feed system, it was deemed necessary to account for these by-products as direct inputs into the livestock sector so as to allow feeding regimes to adjust to the increased supply of corn and protein substitutes. An exogenous shock is therefore applied to the feed demand equation shown below:

$$[5.4]\quad \ln\left(CG_i^{FE}\right) = \alpha + \beta_1 * \ln\left(\frac{PRICE_i^{CG}}{PRICE_i^{WT}}\right) + \beta_2 * \ln\left(\frac{PRICE_i^{OM}}{PRICE_i^{WT}}\right) +$$

$$\beta_3 * \ln\left(QP_i^{NR}\right) + \left(1-\beta_3\right) * \left(QP_i^{RU}\right) + \beta_4 * \ln\left(TRND\right) + \ln\left(R.CG_i^{FE}\right)$$

CG_i^{FE} :	total coarse grains used for feed
$PRICE_i^{CG}$:	producer price of coarse grains
$PRICE_i^{WT}$:	producer price of wheat
$PRICE_i^{OM}$:	producer price of oilmeal
QP_i^{NR} :	total monogastric livestock production
QP_i^{RU} :	total ruminant livestock production
$TRND$:	trend incorporated into AGLINK
$R.CG_i^{FE}$:	intercept-shifter for feed grain equation
i :	regions US and Canada

Although it was assumed that 75 percent of the DDGs were absorbed by the feed market, the coarse grains feed equation above effectively only absorbs 69 percent. The remaining six percent substitute for soybean meal and as such, the oilmeal market was similarly adjusted to reflect the extra biofuel-induced oilmeal.

By calculating the amount of by-products from annual ethanol production and applying the methodology of Westcott (2007), the intercept-shifter in Equation 5.4 is exogenously shocked to compensate the increase in biofuel-induced coarse grain demand with the feed value of the by-products.

5.4.2 *Biodiesel Adjustments and By-Product Treatment*

The following adjustments to the oilseed crush demand were applied in a similar manner to reflect the impacts of Canadian, American and European biodiesel production. The demand for oilseeds (the sum of the demands for canola, sunflowers and soybeans) is split into an endogenous crush demand and an exogenous feed demand. Because the biofuel-induced demand for oilseeds would increase due to the value of its oil content for biodiesel, the demand for the oilseed crush was shocked over the simulation period. This demand is represented in the following equation:

$$[5.5]\quad \ln\left(OS_i^{CR}\right)=\alpha+\beta_1*\ln\left(\frac{PRICE_i^{OM}*YLD_i^{OM}+PRICE_i^{OL}*YLD_i^{OL}}{GDP_i}\right)$$

$$-0.9*\beta_2*\ln\left(\frac{PRICE_i^{OS}}{GDP_i}\right)+\beta_3*\ln\left(OS_i^{CR(-1)}\right)+\ln\left(R.OS_i^{CR}\right)$$

OS_i^{CR}:	quantity of oilseeds crushed
$PRICE_i^{OM}$:	producer price of oilmeal
YLD_i^{OM}:	oilmeal extraction rate from oilseed crush
$PRICE_i^{OL}$:	producer price of oil
YLD_i^{OL}:	oil extraction rate from oilseed crush
GDP_i:	gross domestic product
$PRICE_i^{OS}$:	implicit price deflator for GDP with base year 2000
$OS_i^{CR(-1)}$:	quantity of oilseeds crushed in the previous year
$R.OS_i^{CR}$:	intercept shifter for oilseed crush equation
i:	regions US, Canada and EU

While the oilseed crush demand is a function of the prices and extraction rates of both the oil and the oilmeal, the price of the seed and the historical crush, the last variable in the equation $R.OS_i^{CR}$, allows the demand to be adjusted by an exogenous amount equivalent to the new biofuel-induced crush. The oilseeds and the oilmeal are each connected back to their respective world markets. The quantity of oil produced feeds into the vegetable oil market, which subsequently clears.

Given that oilseed crush is endogenous, the oilmeal and oil markets will adjust to reflect the exogenous shock in demand. Additional oilmeal resulting from the increased crush will become available for animal feed; therefore, it is not necessary to make an additional exogenous adjustment to account for this by-product.

5.5 Summary

Given the theoretical attributes and the considerations for agricultural trade modeling and partial equilibrium models presented in Chapter Three, as well as the overview of biofuels analyses in Chapter Four, AGLINK was selected as an appropriate tool with which to analyze the impacts of additional demand for wheat, corn and vegetable oil due to biofuels demand in Canada, the US and the EU. As an endogenous biofuels component was not present in the available version of AGLINK, it was determined based on the literature that exogenous shocks would be sufficient for the purposes of this analysis.

The demands for coarse grains in the US and Canada were exogenously shocked in each year from 2005 to 2015 to reflect the annual increase in demand for corn due to ethanol production. Canadian wheat was adjusted to reflect 30 percent of domestic ethanol production. These adjustments required a two-part exogenous shock: first to account for the direct effects of biofuel-induced demand on the feedstocks and second, in order to reflect the feed value of the distillers' grains for the livestock sector.

The national oilseed crushes were each shocked to represent the increased demand for canola oil due to biodiesel in the EU and Canada and for soybean oil due to increases in American biodiesel production. In contrast with the shocks required for ethanol production, the biodiesel shock required one step, as the crush equation endogenously generated increased levels of by-products.

In addition to providing details about the shocks to individual variables, this chapter also outlines the assumptions made in developing the scenario, the conversion factors used to quantify the exogenous shocks and the data sources from which projected biofuels capacities were determined. The methodology in this chapter provides the background and context through which the results presented in Chapter Six may be interpreted.

CHAPTER SIX
Results

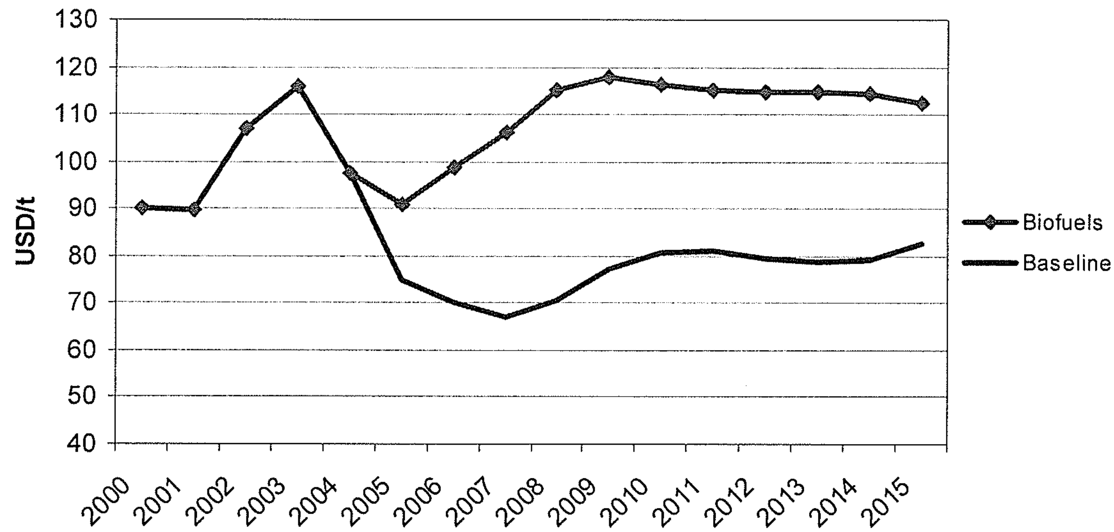
6.1 Introduction

This chapter will present the quantified impacts of additional biofuel-induced demand for corn, wheat and vegetable oil in Canada, the US and the EU on the world prices of these commodities. These price impacts (resulting from the exogenous shocks to AGLINK that were described in the previous chapter) will preface the indirect impacts on other agriculture markets that are related to domestically consuming large amounts of feedstock for biofuels. Specifically, the impacts on the net trade of these commodities will be examined, particularly in Canada and the US. The implications of higher feedstocks for livestock production will also be discussed relative to the assumptions surrounding by-product incorporation into the feed market. The results will then be presented relative to a sensitivity analysis, in which the incorporation of distillers' grains into the feed market will be varied from zero to 100 percent. The intent of this sensitivity analysis is to show how dependent the price impacts of the major commodities are on the feed value of the biofuels by-products. The effects of higher feedstock prices will also be put in the context of biofuel plant profitability and a quick calculation will be performed to show the dependency of profit on low commodity prices.

6.2 Results: Price Impacts

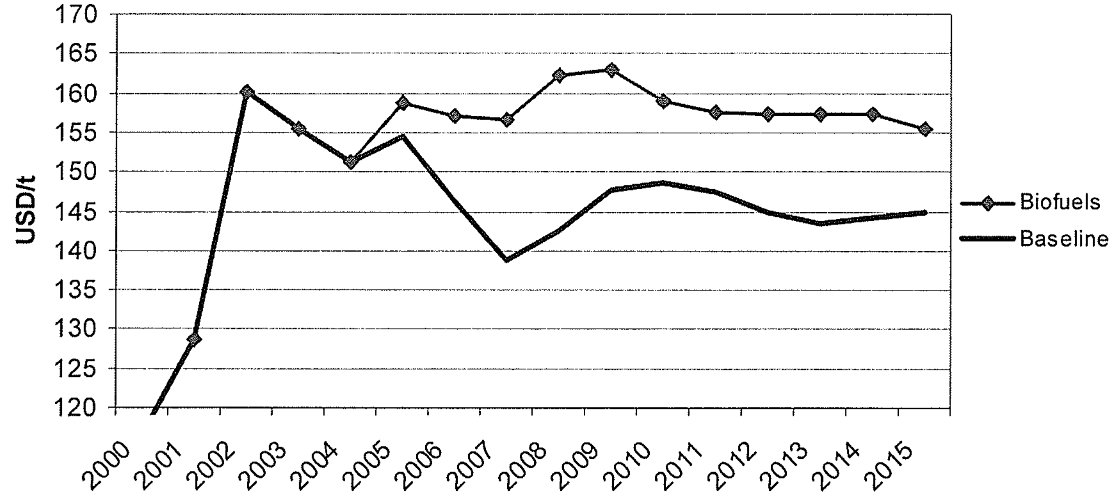
The representative world price for corn is given as the FOB USA price for yellow No.2 corn. The results of the biofuel-induced demand for corn are presented in Figure 6.1. The upward price trend due to biofuels expansion continues until 2009, with the largest difference between the baseline and the biofuels scenario occurring in the previous year at roughly 64 percent. Although not to be considered a long-run equilibrium, the end of the projection period shows a 36 percent increase over baseline projections.

Figure 6.1: Impacts on the World Price of Corn



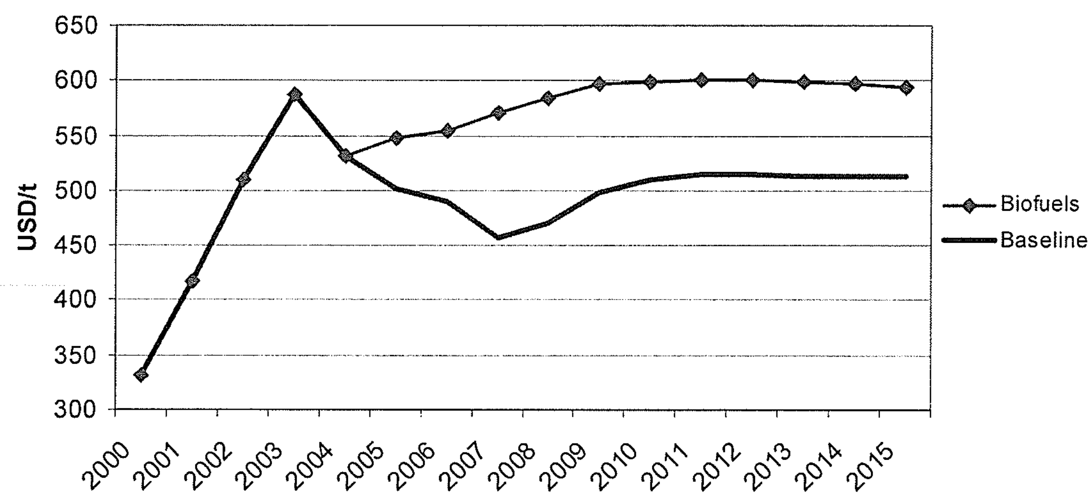
The representative world price for wheat is that of USA No.2 Hard Red Spring ordinary protein FOB at gulf ports; Figure 6.2 shows the price impacts on the world wheat market. Similarly, prices moved higher in the wheat market until 2009, with the largest spread between baseline numbers and those in the biofuels scenario occurring in 2008 at 14 percent. The end of the projection period brought an increase of seven percent over the baseline.

Figure 6.2: Impacts on the World Price of Wheat



The vegetable oil world price is given as the weighted average of the aggregated oilseed oils and palm oil at European ports. The price impacts are shown in Figure 6.3. Again, the same upward price trend as in the corn and wheat markets is also present in the vegetable oil market and continues until 2012. The largest differences between the baseline and the biofuels scenario occur in 2007 and 2008, both at 24 percent. Differences at the end of the projection period were roughly 16 percent.

Figure 6.3: Impacts on the World Price of Vegetable Oil



These impacts are in line with current literature, as Table 6.1 shows (Table 4.5 is presented again to include the results of this study). In terms of corn impacts, the price effects determined in this analysis are slightly lower but still similar to those in Tokgoz et al. (2007). Although an endogenous market for distillers' grains is created and incorporated with the livestock market to account for the feed value of the by-products, it is not clear if it is assumed that all distillers' grains are absorbed into the feed market. If this is the assumption, it would make sense intuitively that the price impacts would be lower than those in this study, which assumes 75 percent inclusion. Corn impacts were the same as the AAFC (2002) study, although the shocks to the model in that study are ambitious over the projection period, resulting in 8 percent of transportation fuel in Canada, the US and the EU being replaced by biofuels. This would explain the large differences between the estimated impacts on the vegetable oil and wheat markets in this study and those in AAFC (2002), particularly with respect to the assumptions made to the EU biodiesel market penetration. The US ethanol industry has also changed significantly since 2002, particularly with respect to the ratio of dry milling to wet milling facilities (assumed to be 25:75 in 2002; now roughly 80:20), as well as to the ethanol extraction rate from the dry milling process.

The numbers in Stillman et al. (2007) represent the additional shock to agriculture markets over 2010 USDA projections, which already incorporate the effects of biofuels mandates and which are not presented in the analysis. The results from OECD (2006) are similar for vegetable oil and wheat; however, are significantly difference for corn. This may be related to the timing of the analysis, in that information relating to the full extent of US ethanol mandates may not have been available to OECD analysts at the time of writing, but which was able to incorporated into this study, written in a later stage of industry development.

Table 6.1: Price Impacts Relative to Literature

	% Δ in World Price		
	Corn	**Wheat**	**Vegetable Oil**
Fridfinnson 2008*	45	9	17
Tokgoz et al. 2007	40	17.5	11.5
Stillman et al. 2007	4	N/A	20
OECD 2006	7	4	15
AAFC 2002	45	22	66

* averages over the ten-year projection period

6.3 Implications

The price impacts for corn, wheat and vegetable oil projected in Section 6.1 have implications for other sectors within agriculture. Livestock producers generally face higher feed costs due to biofuel-induced demand, while processors and consumers of other agricultural crops also face increased prices as a result of producers, particularly in the US corn belt, switching land from other crops to corn and similar grains.[22] As the consumption of domestically-produced biofuels increases as a result of government mandates, the excess supply of crops available for export also declines[23], while the increasing prices of feedstocks have effects on the profitability of the ethanol plants themselves.

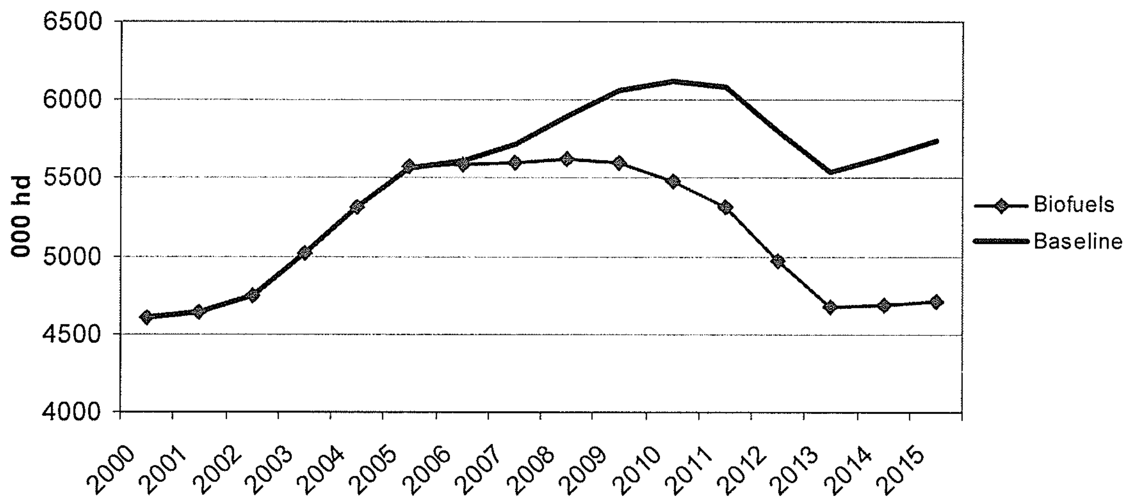
[22] Although higher corn prices increase the incentive for producers to increase corn-corn rotations, particularly in the US corn belt, the agronomic effects and potential for soil degradation will not be explicitly considered as biofuel-induced effects.
[23] Trade effects will be measured in terms of net trade (ie: exports minus imports).

6.3.1 Livestock

In general, feed grain costs comprise a significant portion of the operating expenses for an average livestock producer. As the price of these grains increases, profit margins shrink in the absence of an increase in the price for the animals. Results from the analysis show that a typical livestock producer in the US faces an average 26 percent increase in feed expenditures on coarse grains, wheat and oilseed meal over the projection period, reaching as high as 36 percent over the baseline. Livestock producers in Canada face similar increases, on average 28 percent. Based on the assumptions related to the incorporation of distillers' grains into the rations of various livestock, beef producers should theoretically be affected the least by these increases, unless these by-products are unavailable locally or their cost including transportation exceeds that of the feedstock itself. However, Tokgoz et al. (2007) found that the inclusion of a distillers' grains market into the modified FAPRI/CARD model resulted in distillers' grain prices that actually tracked corn values. This was an unanticipated result, and was attributed to the feed value of the distillers' grains, in that the large national and international ruminant feed grain demand had a greater effect on the distillers' grains price than the large increases in supply due to ethanol production.

Despite these rising feed costs, the market price for a Grade A steer only increases for a Canadian cattle producer by an average of 6 percent. Canadian cow inventory numbers, representative of the national herd, concurrently fall by an average of nine percent, although as shown in Figure 6.4, the rate of change for the declines in cow inventory increases continually through the projection period. In conjunction with these impacts on cattle inventory, Canadian beef and veal slaughter production increases an average of five percent over the period, despite consumption remaining relatively constant. Given increased slaughter production and stagnant domestic consumption, net trade increases dramatically at the beginning of the projection period, reaching highs of 25 percent. This path eventually converges at the baseline, resulting in an average increase of ten percent over the projection period.

Figure 6.4: Impacts of Biofuels Scenario on Canadian Cattle Inventory



Pork producers also face the same increased feed costs as livestock producers, yet are less able to incorporate the same quantities of by-products into their rations. In Canada, domestic pork production drops an average of three percent over the baseline, with the largest declines coming in the end of the period. Domestic consumption remains unchanged over the projection period; however, pork exports fall by an average of five percent in response to continually decreasing slaughter capacity, which was roughly six percent lower at the end of the period. The combination of these factors contributed to an average increase in pork prices of about 12 percent.

Other livestock industries were also affected. The market price of poultry showed strong increases throughout the period, averaging 13 percent over the baseline. The price of milk also increased by roughly two percent over the same period.

Relative to the literature, these changes in the livestock industry are to scale. In AAFC (2002), Canadian production of beef, pork and poultry combined falls by 1.3 percent on average. Considering the high price impacts seen for corn and wheat, this is fairly low, despite an average increase in feed costs for livestock producers of roughly 12 percent. OECD (2006) focuses on biofuel-induced crop impacts, only to say that in the scenario involving mandated consumption targets, most international meat prices are slightly higher than without growth in the biofuels sector. Pork is more affected by increased biofuel production than beef. In the high oil price scenario, Tokgoz et al. (2007) estimate that beef and veal, broiler and pork prices in Canada increase 9 percent, 4 percent and 16 percent respectively, with similar price changes occurring in the US for beef and pork.

Looking internationally, results from this analysis show significant effects with respect to European and American livestock sectors. Beef production in the US drops roughly two percent relative the baseline and is accompanied by similar declines in cattle inventory. Although US beef exports decline on average 12 percent, the difference between baseline numbers and the biofuels projections continues to widen towards the end of the period. Price impacts within the US are estimated at an average increase of five percent over the baseline. European net trade in beef falls by 25 percent at the end of the projection period, although these numbers do not take into account trade with other

EU members. Domestic beef production in the EU remains fairly constant over the period.

6.3.2 Crops

The crops sector faces increased demand all three countries in the analysis, particularly with respect to the commodities predominantly used domestically in each as biofuels feedstocks. In Canada, despite small amounts of wheat going towards ethanol production, the amount of wheat both planted and harvested fell roughly four percent in each year of the projection period. Net trade in wheat fell an average of 17 percent, with the margin between the baseline and the biofuels scenario increasing each year. Increases in corn area, a consistent five percent throughout the period, are not only producer responses to a higher world price, but also to a 38 percent higher domestic price. In addition to increases in corn area, barley hectarage increased on average 17 percent, ending the projection period roughly 20 percent higher than the baseline.

The impact of biofuels places both upwards and downwards pressure on Canadian oilseeds, depending on the product in question. The producer price of Canadian oilseeds increased by roughly ten percent. The price of vegetable oil averaged a 17 percent increase over baseline numbers, while oil meal prices fell by approximately two percent. Oilseed net trade fell by an average of seven percent with period-end differences from the baseline of roughly ten percent. These losses in trade were incurred through a decline in exports averaging six percent, as well as a 2 percent decrease in canola hectarage.

Beyond Canadian borders, domestic producer prices for coarse grains in the US increased by an average of 40 percent. American exports of coarse grains decreased roughly 62 percent over the course of the projection period. Coarse grain production in Europe remained relatively unchanged; however, exports fell by roughly eight percent. Despite higher increases in the world price for vegetable oil, the producer price for soybeans in the US rose on average, six percent, while European rapeseed prices peaked at roughly eight percent over baseline numbers. The vegetable oil market in the US responded to changes in the European world price by increasing exports by an average of 17 percent.

6.3.3 *Ethanol Profitability*

While higher grain prices provide grain and oilseeds producers with higher gross revenues, the implications for the ethanol plants are not as positive. Rising corn prices mean a declining profit margin for ethanol plants. According to economic theory, as margins become tighter, plants should be squeezed out of the market. Reports out of the US confirm that some plants are closing their doors and that other planned construction projects are being put on hold (Neeley 2008).

The body of literature surrounding the economics of ethanol production is growing, particularly with respect to the break-even costs of production[24]. While these detailed spreadsheets are available, a rough calculation is sufficient to get an idea of the cost structure faced by a typical ethanol production facility. Similar to Eidman (2007), a 100 million gallon dry milling plant will be chosen as a typical large facility. For this

[24] Researchers at Iowa State University have developed a detailed economic model of an ethanol production facility in spreadsheet form (ISU 2008), while Eidman (2007) builds on Tiffany and Eidman (2003) to calculate break-even costs for a dry mill ethanol production facility.

plant to produce at full capacity for one year, 35.7 million bushels of corn would be required, producing roughly 0.3 million tons of distillers' grains.[25]

Using July 2008 corn futures prices valued at 6.83 USD per bushel and July 10, 2008 closing prices for ethanol at 2.74 USD per gallon (Ethanol Statistics 2008), it can be determined that the costs for corn feedstock alone comprise 72 percent of the total revenue of the ethanol plant, factoring the value of the distillers' grains into the feed market[26]. This number excludes various costs related to labour and management, heat, chemicals and enzymes used for the production process, taxes and insurance, among others (Eidman 2007).

The relative corn price increase produced from this analysis also has interesting implications for ethanol plant profitability. Using the price impacts (percentage change) determined from this analysis to create a "without ethanol" scenario relative to current corn prices yields a new corn price of 4.71 USD per bushel and a distillers' grain price of 98.79 USD per US ton. Based on the plant described above (needing 35.7 million bushels of corn feedstock to run at full capacity for one year) corn requirements are roughly 52 percent of total revenue. Given a constant price of ethanol, a 45 percent increase in the price of corn led to a decline in net profit (defined roughly as total revenue less corn costs) of 36 percent.

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[25] Calculated at the standard industry conversion factor of 2.8 gallons of ethanol and 0.0087 tons of distillers' grains per bushel of corn.

[26] Eidman (2007) assumes, and it is assumed for this calculation, that the price of distillers' grains responds to increases in the corn price by a factor of 0.9. It is also assumed that the prices of corn and distillers' grains are equal when corn is two dollars per bushel (71.43 USD per ton). A bushel of corn at 6.83 USD then gives a value of 219.54 USD per ton of distillers' grains. Therefore, at 100 million gallons * 2.74 USD per gallon plus the value of the distillers' grains (219.54 USD per ton * 0.311 million tons = 68.18 million USD), total revenue would equal roughly 340 million USD per year. Corn requirements sourced at 6.83 USD per bushel would cost 244 million USD.

6.4 Sensitivity Analysis

The results of this analysis are sensitive to several assumptions both within the scenario and the model itself. To put these results into context with one of the assumptions, a price sensitivity analysis will be performed for the three commodities in Section 6.1, by varying the amount of distillers' grains absorbed by the feed market. The original scenario included a 75 percent absorption of distillers' grains by livestock; effectively, 69 percent replacing corn and the remainder replacing the soy meal ration component.

Simulations were run for two extreme situations as well as for scenarios based on more moderate assumptions. In order to define the limits to the sensitivity analysis, it was assumed that the feed market was unable to absorb any by-products from biofuel production. A second scenario was run under the assumption that 100 percent of the by-products could be incorporated into livestock rations. These first two scenarios effectively created the upper and lower bounds of the sensitivity analysis. Another scenario was also run at a 50 percent incorporation rate in order to put the 75 percent assumption of the original scenario into context.

Given the range of price impacts in Table 6.2 below, it is evident that by-product treatment is capable of influencing the magnitude of the price effects, particularly in the corn and wheat markets. While the price impacts on corn in this study were equivalent to those in AAFC (2002), the sensitivity analysis brings estimates similar to Tokgoz et al. (2007), assuming that all distillers' grains are capable of being absorbed by the feed market. The price variability in the wheat market due to distillers' grains assumptions brings wheat impacts closer to Tokgoz et al. (2007) as fewer distillers' grains are incorporated. The vegetable oil market seems relatively insulated from the impacts of the distillers' grains assumptions, keeping projected price increases similar to OECD (2006).

Table 6.2: Sensitivity of Price Impacts to By-Product Assumptions

	% Average Price Δ Relative to Baseline			
	0%	**50%**	**75%**	**100%**
Corn	57.17	54.56	44.85	40.89
Wheat	11.03	10.68	8.68	7.94
Vegetable Oil	17.88	17.78	17.39	17.22

One of the key assumptions in the original profit approximations in Section 6.3.3 is the relationship between the prices of distillers' grains and corn. It is assumed that distillers' grains prices track corn prices and are equal to roughly 90 percent the value of corn. It is unlikely that this relationship would remain in a fixed proportion at lower levels of distillers' grains absorption.

CHAPTER SEVEN
Summary and Conclusions

7.1 Introduction

The biofuels industry has exploded within the past decade, particularly in regard to corn-based ethanol in the United States. This rapid expansion in domestic production and consumption has been encouraged through political intervention in both energy and agricultural markets and has the potential for wide-ranging impacts spanning important global issues such as food security and environmental quality. Despite the wide scope of potential impacts, the purpose of this study was to narrow the effects to the agriculture industry by quantifying the direct impacts of biofuels-induced demand on world corn, vegetable oil and wheat prices as well as the more indirect impacts on other crops and the livestock sector.

Given the agriculture-specific objectives, AGLINK, the partial equilibrium model used by the Organization for Economic Cooperation and Development (OECD) was chosen for this analysis, based on its commodity and country coverage, its theoretical consistency and its availability. The results from this analysis show that biofuels-induced demand has large and significant impacts on agricultural markets, particularly on those commodities serving as inputs for the renewable fuels: corn, vegetable oil and wheat. The livestock sector is negatively impacted through higher feed costs, despite the incorporation of the distillers' grains by-products into the feed market.

7.2 Summary and Implications

The objective of this research was to quantify the impacts of biofuels-induced demand on agricultural markets, particularly on the commodities that serve as inputs in the production process. The price effects on the three main commodities in this analysis represent the impacts of biofuels policies in Canada, the US and the EU on world corn, wheat and vegetable oil markets. While the impacts on these three commodities are presented as the main results of this study, their price increases are not isolated from other agricultural commodities. In addition to having significant price impacts on global markets, large quantities of feedstock being used domestically for biofuels purposes have impacts on levels of global trade flows. More feedstock being used domestically leads to smaller amounts available for export purposes. This has repercussions for countries that rely on imported agricultural commodities for human consumption, livestock feed or their own biofuels processing, as feedstock available for import becomes increasingly scarce and more expensive.

One of the objectives of this analysis was to determine the indirect effects of biofuel-induced demand on other competing crops. These effects are evident from this analysis. Relative crop prices impact producer decisions regarding current crop mixes and sustained levels of high prices can also impact long-term crop rotations. This is currently being seen in the US corn belt, where producers are not only seeding entire farms to corn, but also increasing corn-corn rotations over the long-term. These types of intensive agricultural practices increase the agronomic risks associated with disease and pests and also contribute to the deterioration of long-term soil health. Significant amounts of land switched into corn area leads to lower supplies of other crops and subsequently, upward pressure on crop prices in general. Higher crop prices also increase incentives for producers to use higher levels of inputs such as fertilizers and pesticides. Increased demand for inputs also creates upward pressure on input prices, as is currently being observed in Canadian fertilizer markets.

It was hypothesized that the effects of biofuels mandates would be extended to the livestock sector. The results from this analysis show that in general, livestock producers are negatively impacted by the increase in feedstock going towards biofuel production. Higher grain prices lead to lower profit margins unless the end-value of the animal also increases. As profit margins decline, smaller and/or more inefficient producers are forced to exit the market, lowering domestically-produced supply. Lower supplies of livestock lead to lower domestic supplies of meat at the retail level and ultimately, to higher consumer prices for meat. One of the assumptions of this analysis is the incorporation of by-products into the feed market; however, the utilization of these by-products depends on the ability of livestock producers to actually buy the distillers' grains. It seems logical that those producers closest to the ethanol production facilities would have an easier time purchasing distillers' grains, and therefore might also be more insulated from higher feedstock prices.

High grain prices have mixed effects on the biofuels plants that are ultimately driving the upward price pressure in the grain market. Looking specifically at corn-based ethanol production in the US, the higher that corn prices go, the more the profit margins of the ethanol plants shrink, given relatively constant ethanol prices. In the short- to medium-run, shrinking profit margins place pressure on the market and force inefficient and/or smaller plants to exit the market or be bought by competitors. Looking more long-term, those plants that are able to stay in production likely become more efficient ethanol producers and emerge in the arguably stronger position of being players in a more concentrated biofuel industry. In terms of rural development goals, this scenario may not be favorable. Many of the firms forced to exit the market are likely to be smaller plants funded by local producers as an investment in the "value-added" sector. Bankrupt plants affect local investors, the local workforce and the general morale of the surrounding community. It could be argued that in a case where a plant is bought out by a competitor, investors are compensated and employees may continue to work at the facility; however, the amount of direct and in-kind subsidies provided by the local and/or state-level governments also need to be factored into any kind of net welfare calculation.

All of the issues discussed above relate to the effects of policies designed to promote the domestic production and consumption of biofuels. This study quantified the impacts of this biofuel-induced commodity demand on agricultural markets, particularly with respect to the feedstocks being used as inputs in the production process.

7.3 Research Contributions

This study contributes to a growing volume of institutional analyses which look at a wide range of issues associated with large-scale biofuel production and with the relationships between agricultural commodity markets, energy markets and the political intervention in them.

For academic researchers, this study adds to a number of analyses that examine the impacts of biofuel-induced demand on agricultural commodity markets. In addition to the value of the empirical results and their implications, the insight of varying the assumption of distillers' grains incorporation into the coarse grains feed market provides estimates of the sensitivity of corn prices to the feed value of ethanol by-products. The range of results from the sensitivity analysis also show the value of the distillers' grains in providing downward pressure on world corn prices. Moving from zero percent incorporation of distillers' grains into the coarse grains feed market to 100 percent incorporation results in significant differences in world corn prices. This effect is two-fold for livestock producers, as distillers' grains not only serve as a partial corn substitute in animal feed rations, but also act to keep corn prices lower in the event that distillers' grains are locally unavailable.

For renewable energy and agriculture policy-makers, the results of this analysis point to the effects of implementing policies and programs with the purpose of influencing the allocation of agricultural commodities and of resources in general. While it is a challenging task to create and implement "successful" policies, the scope and magnitude of the impacts revealed in this analysis provide a valuable ex-post commentary on the effects of creating market incentives to stimulate rapid production and capacity development in order to domestically meet annual mandated consumption targets. It also illustrates the need to include as many agricultural sectors in pre-implementation policy analysis to estimate the impacts across the industry.

For the general public, this study provides an overview of the government intervention that is encouraging biofuels production and frames the types of incentives as a function of the political pressures related to energy security, the environment, the agricultural lobby and rural development goals. The quantitative results provide a basis for understanding the direct impacts of biofuels production and consumption on agricultural commodity markets, given current commodity prices.

In general, studies such as this thesis are especially relevant, given recent food riots and surging commodity prices. Although this study in particular is not designed nor intended to quantify the effects of biofuels relative to other factors influencing current commodity and food prices, it does serve to give a quantitative perspective to a very controversial and timely issue by illustrating the direct impacts of biofuel-induced demand on agricultural commodities.

7.4 Future Research

There are several caveats that should be mentioned with regard to this analysis. The first, particularly with respect to the adjustments made to reflect the increased ethanol production in the US, is the simplistic assumption that all of the ethanol production in the US is done using the dry milling process. This in fact, is not the case[27]; however, this assumption mainly affects the treatment of by-products. Wet milling for corn-based ethanol produces gluten meal, gluten feed and corn oil as co-products with ethanol, in comparison with the dry milling process, which produces distillers' grains. Both processes produce roughly 2.8 gallons of ethanol. It is not expected that the exclusion of the wet-milling process would have significant impacts on the results of this study, as distillers' grains have slightly higher energy value for livestock rations than gluten meal, particularly when dried for transport purposes.

[27] The U.S. Department of Energy estimates that over 80 percent of ethanol production facilities use the dry milling process (USDOE 2008). The dry milling share has increased dramatically over the past decade; estimates from 1999 suggest dry milling - wet milling market share to be 46 percent and 54 percent, respectively (Brown et al. 2007).

The projections also assume that no major advances in cellulosic or second-generation biofuel technology will be made. A major technological breakthrough, either in the efficiency of existing first generation technology or in utilizing other feedstocks for second generation technology, would likely serve to mitigate the magnitude of these impacts. The study does recognize and account for the fact that beginning in 2009, under the RFS in the US, the rate of mandated conventional biofuel quantities slow in the face of increasing amounts of advanced and cellulosic biofuels.[28]

The absence of Brazil and the effects of sugarcane-based ethanol are noticeable in this analysis. The incorporation of the World Sugar model with AGLINK as in OECD (2006) would provide insights into the price effects between sugar and other commodities. It would also provide perspective into the trends occurring between sugarcane and soybean hectarage, given the current size of the Brazilian ethanol industry and the fast-paced development of domestic biodiesel. It is likely that the addition of Brazilian biofuels to the analysis would contribute a greater impact on the price of vegetable oils due to increasing domestic biodiesel production, as well as to changing producer cropping decisions between sugarcane and soybeans.

The incorporation of Brazilian ethanol would be particularly relevant given the presence of an endogenous biofuels component in AGLINK. As Brazilian exports of ethanol increase to countries around the world, so does the need for an endogenous ethanol component capable of accounting for differences in feedstocks and by-products across countries and incorporating these dissimilarities into net trade flow calculations. A

[28] Under the RFS, conventional biofuel refers to ethanol derived from corn starch. Advanced biofuels refers to any renewable biofuel other than corn-based ethanol with specific GHG properties. Cellulosic biofuel refers to any renewable biofuel produced from cellulose, hemi-cellulose or lignin and also has specific greenhouse gas properties (RFA 2008c).

similar biodiesel component would be also be useful to provide insight into biodiesel markets as global production continues to grow. As shown in OECD (2006), the task of incorporating biofuels into AGLINK is currently being undertaken by researchers at the OECD.

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APPENDIX A
List of Acronyms

The following is list of acronyms used throughout this thesis document:

AAFC	Agriculture and Agri-Food Canada
CARD	Center for Agricultural and Rural Development
CBI	Caribbean Basin Initiative
CGE	Computable General Equilibrium
DDGs	dried distillers' grains
ERS	Economic Research Service (of the USDA)
FAO	Food and Agriculture Organization (of the United Nations)
FAPRI	Food and Agricultural Policy Research Initiative
FOB	free on board
GTAP	Global Trade Analysis Project
NRC	Natural Resources Canada
OECD	Organization for Economic Cooperation and Development
PEATSim	Partial Equilibrium Agricultural Trade Simulator
RFS	Renewable Fuels Standard
ROW	rest of world
SPB	Strategic Policy Branch (of AAFC)
TRQ	tariff-rate quota
USDA	United States Department of Agriculture
WTO	World Trade Organization