Effects of Disease Outbreak on the Ontario Pork Industry

By

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Abstract

EFFECTS OF DISEASE OUTBREAK ON THE ONTARIO PORK INDUSTRY

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The purpose of this thesis is to estimate the economic consequences of a disease outbreak on the Ontario pork industry. The thesis uses a partial equilibrium model to simulate disease outbreak scenarios and observe its effects on the industry in the short run. The study uses the hog value chain as its basis for constructing the model. The hog value chain encompasses the entire pork industry starting from the decision of the breeding herd size to pork consumption. The constructed model is comprised of 8 regression equations containing a total of 29 estimated parameters (16 in the live pigs market and 13 in processed pork market) and 6 identities of which 2 are market clearing identities. This thesis considers two disease outbreak scenarios with varying level of trade restriction. Regression results and simulations conducted reveal closing the US borders would result in the hog slaughter going up slightly within Ontario along with significantly higher interprovincial trade of live pigs. Pork production would go up slightly because of the slight increase in the hog slaughter. Ontario being a net importer of pork, trade restrictions from the US would result in lower provincial imports for Ontario. The main takeaway from this study is, as long as CFIA recognized provincial zoning is acknowledged, meaning Ontario can trade with the other provinces and these provinces can trade with the US there won’t be major consequences to the Ontario pork industry.
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1 Introduction

With roughly $3 billion in annual exports, Canada is the third largest pork exporter in the world (Canadian Pork Council, 2015). Compared to Canada’s other agri-food sectors, pork ranks third in terms of amount of production exported (Agriculture and Agri-Food Canada, 2016). Pork exports account for around 50% of Ontario’s total production. Ontario is among the three major pork producing provinces of Canada along with Quebec and Manitoba (Young, Dewey, and Friendship, 2010). Both Ontario and Canada not only have high pork exports but also have high live pig exports. Canada constituted 99% of US’s live pig imports (Haley, 2004). Ontario faces a processing capacity constraint since Maple Leaf Foods Inc. cut their processing capacity from 7 million pigs to 4-5 million pigs (Li, 2011) and Quality Meat Packers shut down their processing plant in 2014. Not surprisingly, the result of both is a higher volume of live pigs exported from Ontario. In 2015, approximately 1.1 million pigs went to Quebec, 60,000 went to Manitoba and 640,000 went to the US. Although Canada’s live pig imports come from various destinations, they are reportedly small in numbers. Ontario’s live pig imports were less than 3,000 head in 2015 (CANSIM Table 003-0102).

While live pig trade for Ontario is restricted to nearby areas, pork trade has other destinations like Japan, Mexico, China and Russia (trade with Russia is now closed for political reasons). US still holds the majority share, accounting for 71% of Ontario’s pork exports. Although the US is Ontario’s most significant market, Mexico has been growing rapidly as an export destination over the past 5 years. Japan has on average (2010-2015) been the highest value market for Ontario pork. US dominance is even more prominent in pork imports. In 2015 by weight, 96.4% pork imports came from the US and between 2010-2015 an average of 97.9% of imports came from the US (calculated from data).

As Ontario is the largest province in terms of population, it has a high domestic demand for pork. Though Ontario is the second largest pig supplier in Canada, its supply is slowing over time. The total pig supply of Ontario rose to 8 million in 2004 from 6.8 million in 2000
but fell to 7 million in 2015. Constraints with processing capacity has resulted in greater pig exports from Ontario. The prevailing high demand for pork is met by imports of pork from the international market as well as from other provinces. Due to lack of data on provincial pork trade, an identity (explained in a later chapter) is used to calculate it.

The discussion thus far highlighted the importance of international and interprovincial trade of both live pigs and pork to Ontario; trade can create both opportunities and risks. A sudden fluctuation of the Canada-US exchange rate might result in significantly greater or less exports of live pigs and pork. Consider for example the trade ban by Russia. Canada initiated a ban on Russia’s current president Vladimir Putin about the Ukraine crisis, in response to which Russia imposed ban on trade with Canada. Where Ontario exported $70 million worth of pork to Russia in 2012, the amount dropped to zero in 2015. Such unforeseeable situations can and always arise.

Another constant threat in the live animal industry is disease outbreak. An outbreak can lead to huge direct and indirect financial losses for the affected herds and regions (Elbers et al., 1999). Economic consequence of disease outbreaks can be devastating for the entire industry. Many other countries have faced the consequences of disease outbreaks in their live animal industry. The recent PEDv outbreak of 2013-2014 in the US has resulted in losses borne mainly by growers of the infected pigs and consumers. (Paarlberg, 2014) estimated that net welfare loss ranged from $900 million to $1.8 billion for the outbreak that spread across 13 states. It is important to note the responses of US trading partners during this PEDv outbreak. Mexico restricted their imports of live pigs from the US on case by case basis while France and Japan banned all live pig imports from the US. Pseudorabies is another swine disease which is caused by the herpes virus and causes productive failures and high mortality in preweaned pigs. Its infections are sometimes catastrophic. Studies (Ebel, Hornbaker, and Bane, 1991) conducted in the US show roughly 50% of the infected firms do not experience outbreaks in the acute stages of infections. In the event of an outbreak however, cost is estimated to be $20 to $30 per sow in affected herds with an industry total
cost ranging from $21 million to $72 million (Elbers et al., 1999). The Dutch pig industry has been susceptible to classical swine fever (CSF) disease for a long time. The direct costs of the control program for the CSF epidemic amounted to $93 million in the period 1983 - 1985 (Elbers et al., 1999). It is presumed that CSF virus spread to Spain, Italy and later Belgium through the shipment of infected piglets before transportation was restricted (Elbers et al., 1999). Clearly, unforeseeable disease outbreaks could lead to catastrophic outcomes. Given the threat of disease outbreak it is important for policy makers to be able to analyze their economic impacts. This is particularly important for the Canadian hog industry which accounts for $3 billion in exports alone. Understanding potential damage can help understand the extent of any sudden shock as well as identify policy responses.

A partial equilibrium model, which is a model of a market, is a tool commonly used by economists to estimate the economic consequences of a specific shock. The ability to conduct ex-ante analysis is an important benefit of using these models. In comparison to general equilibrium model, partial equilibrium models allow for detailed analysis of supply and demand for a specific market with less data (Cairns et al., 2017). Partial equilibrium models are not free from limitations either. The inability of these models to conduct economy wide analysis is a drawback. Study of price determination of a commodity in a partial model is simplified by maintaining ceteris paribus on prices of other commodities. Partial equilibrium models have been used extensively to study the impact of disease outbreak, trade restrictions, trade embargo etc. (Moschini and Meilke, 1992) used a semi-partial equilibrium framework to study the justification of a US countervailing import duty that aimed to offset the subsidies provided to the hog farmers by the Canadian government. (Cairns et al., 2017) used a partial equilibrium model to analyze the economic impact of a foot and mouth disease outbreak on the Ontario beef industry. (Klein and Roy, 2010) estimated the welfare effects of the BSE outbreak in Alberta for Canadian beef industry. (Li, 2011) used a partial framework to assess the potential reduction of the Ontario slaughter capacity on the economic welfare of the Ontario hog growers. Several other studies that have used similar methods and/or
techniques include ((Chi et al. 2002); (Mangen, Burrell, and Mourits 2004); (Paarlberg 2014)).

1.1 Economic Problem

Disease outbreak in the North American hog market is a prominent threat for the hog industry. Since May 2013, 8,400 cases of Porcine Epidemic Diarrhea (PED) infected herds have been reported in the US (SECD Testing Summary Report). This disease increases piglet mortality (almost 100%) which reduced swine numbers in the US by 3% resulting in a welfare loss of approximately $1 billion in total to producers and consumers (Paarlberg 2014). The situation has been better in Ontario with only 84 herds reporting infections since January 2014 (Weng et al. 2016). Number of infected herds has risen to 100 in February 2017. Despite low amounts of live pig imports, risk of outbreak remains high in Ontario because majority of the imports come from the US. The Canadian livestock sector has experienced strong negative economic consequences from disease outbreaks in the past. The Bovine spongiform encephalopathy (BSE) outbreak in 2003 was damaging for the Canadian beef industry although the outbreak was notably restricted to Alberta. (Klein and Roy 2010) estimated the losses to be $4 billion and interestingly 96.5% of the losses were resulted from temporary closure of live cattle export markets. Trade orientation of Canada’s agricultural commodity has risen since 2003 and a similar border closure would result in even bigger losses now. The risk of such disease outbreaks highlights the importance of studying their potential economic effects.

1.2 Economic Research Problem

With the largest population base and access to the US market through New York and Michigan, Ontario is an important component of the Canadian pork industry. Any unforeseen external shock to Ontario’s pork industry might be economically crippling for both Ontario and Canada. Studying the effects of an external shock to this industry and estimating the
of economic consequences is essential.

The main purpose of this thesis is to study the economic effects of a disease outbreak on the Ontario pork industry. Given that there has not been a disease outbreak in this industry in the recent past, a partial equilibrium model is used to estimate the economic effects of a potential disease outbreak. The constructed partial equilibrium model encompasses both the live pig market and pork retail market. The model is be used to simulate two counterfactual scenarios and analyze their results.

Quarantining the infected region is an obvious response for any disease outbreak as found by (Paarlberg, 2014). Given the US and Ontario share borders and have highly integrated live pig markets, a trade embargo would be a likely response from the US. In order to better assess the effects of trade embargo of different levels, two hypothetical scenarios are created. In the first scenario it is assumed there is a small scale disease outbreak in a few specific regions of Ontario. The US response is to restrict trade to 50% on both live pigs and pork. The second scenario assumes a disease outbreak on large scale in Ontario. The US response is to impose a full trade embargo on both live pigs and pork.

1.3 Objectives

The main objective of this thesis is to construct a partial equilibrium model that mathematically represents the pork industry of Ontario. The aim is to simulate the outcomes of a disease outbreak on the industry using the model. The model can be used to estimate the effects of a potential trade embargo from the US because of a disease outbreak on the industry. An important objective is to construct the model so that effects of the disease outbreak on the live pig market and pork market can be estimated separately. Another goal is to capture the live pigs and pork movements across national and provincial borders.
1.4 Thesis Outline

The outline of the thesis follows a sequential order where Chapter 2 discusses relevant literature to the study with a focus on disease outbreak and partial equilibrium model construction. Chapter 3 discusses the Ontario Pork industry followed by discussion on the model specification in Chapter 4. Chapter 5 contains description on data used for the study. Chapter 6 is dedicated to discuss regression and simulation results. Finally, Chapter 7 concludes the thesis.
2 Literature Review

Several studies have looked into the effects of a disease outbreak in North American meat industries of which only a few have been mentioned in the previous chapter. Many studies used the partial equilibrium model framework to carry out simulation based analysis whereas others have used different methods to estimate the welfare effects of disease outbreaks. Recent literature that discuss various aspects of the Ontario pork industry are reviewed in this chapter followed by a review of studies that highlight consequences of disease outbreaks. Discussion on studies that use partial equilibrium models are included as well. Literature related to effects of disease outbreak using varying methods are emphasized here.

Not many studies have looked into the effects of a disease outbreak on the Ontario pork industry. (Weng et al. 2016) studied the economic consequences of PED outbreak on individual farrow-to-finish herds. The purpose of the study is to estimate the net benefits of PED control and elimination strategies. The study looks into the net benefit from different PED prevention strategies and simulates profit under normal operating condition to compare profit with an outbreak of PED. One of the strategies considered for the study is the closure of the breeding herd, under which the estimated annual costs of a PED outbreak is approximately $300,000 for a 700-sow farrow-to-finishing herd. The net returns on a farm are affected shown by a fall in price from $255 to $174 per sow. Other 16 interventions evaluated in the study result in significantly reduced cost. Studying several strategies showed front-loading gilts in combination with herd closure is more cost-effective than back-loading whereas vaccination proved to be the least cost effective strategy. (Li 2011) studied the effects of a potential reduction in Ontario’s hog slaughter capacity on the economic welfare of Ontario hog growers using a simulation model. The simulation results revealed that a reduction would decrease the price of market hogs of Ontario and increase its exports to the rest of North America. Ontario hog growers would face welfare losses because of the price reduction but given the opportunity of market hog exports prevails, the losses would be relatively moderate. Hog packers in rest of North America would gain from this capacity
reduction. Sensitivity analysis in the study considered three separate scenarios. In the first scenario, high own price elasticity of supply and demand is assumed and it was found that hog growers and packers suffer lower welfare losses when supply and demand elasticity is higher than the base scenario. In the second scenario shutdown price for hog growers was assumed higher to test whether the hog price and welfare effects are sensitive to shutdown price and it was found higher shutdown price lead to higher welfare loss. Finally the third scenario considered higher transportation cost, to check sensitivity of welfare to it and results show welfare losses are not sensitive to high transportation cost.

(Ma, 2010) looked into effects of discounts on the demand for pork products in Canada using a linear approximation of Almost Ideal Demand System (LA/AIDS). The study used a two-step sample selection procedure where the first step focuses on the consumer characteristics affecting the probability of purchasing pork products whereas the second step looks into the effects of discount and price variables that dictates purchase. Coupons, membership discounts, price cuts and quantity discounts are the types of discounts that have been used in the study. The findings showed discount coupons or price cuts positively affect the demand for selected pork products. (Moschini and Meilke, 1992) studied the justification of countervailing import duty imposed on live hogs and pork products by the US as a counter measure for the subsidy provided to the hog growers by the Canadian government. The subsidies were provided under the Quebec Farm Income Stabilization Insurance Program (QFISIP) and Agricultural Stabilization Act (ASA) which later became National Tripartite Stabilization (NTS) for hogs. In the presence of a dual force by GATT and Canada-United States Trade Agreement (CUSTA) countervailing duty was removed in June 1991. This study found that the countervailing duty more than offsets the production subsidy and concludes that duty on both hog and pork imports are required to restore the pre-subsidy equilibrium but the duty should be less than what prevailed.

Studies regarding disease outbreak explore wide ranges of diseases in many parts of the world. While studying the PEDv outbreak of 2013-2014 in the US, (Paarlberg, 2014) found
that the US faces a net welfare loss ranging from $900 million to $1.8 billion. The loss of pigs due to the disease outbreak raise both the hog and pork prices leading to a reduction of consumers’ surplus and increased producers’ surplus. The gain of the uninfected growers outweighs the losses of the infected growers but the welfare losses incurring from returns to hog slaughter, retail value added and consumers’ surplus outweighs the net gain at the grower stage. One of the major highlights of the study was the response from different trading partners of the US to the disease outbreak. Japan and France banned swine imports altogether while China imposed ban on imports pending a testing protocol. Mexico responded to the outbreak by restricting the import of US hogs on a case by case basis. (Ebel, Hornbaker, and Carl, 1992) conducted a welfare analysis to evaluate market and distributional effect of a completed pseudorabies\(^1\) eradication effort in the US. The study solved for price and yield change for disaggregated agents in a single market using first order and market equilibrium condition. Welfare analysis showed large farm owners will enjoy a net gain from the eradication so will consumers whereas individual hog operations would lose growers’ surplus. Altogether, the national pseudorabies eradication program was shown to be economically efficient. (Elbers et al., 1999) studied a severe Classical Swine Fever (CSF) epidemic or otherwise known as hog cholera in the Netherlands and found a total of 429 outbreaks were observed and approximately 0.7 millions pigs were slaughtered during the epidemic. The epidemic was presumed to spread to neighbouring countries via trade of live pigs. The two main reasons for the wider spread of the disease was a gap between the introduction of the virus and detection of the first outbreak and the second reason being the initial measures taken to counter the situation proved inadequate.

(Rezitis and Stavropolous, 2009) analyzed the supply response of pork market in Greece. The study estimated pork supply response equation for Greece using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. They found feed price to be an important cost factor of the supply response function and high uncertainty of it is important.

\(^1\)Pseudorabies is a herpes virus caused swine disease
found own price has a negative effect on pork demand whereas the cross prices, price of beef and chicken that were used along with income had a positive effect on the pork demand. The study considers a semi partial framework for modeling the hog and pork market making the assumption that these two markets are separated from the rest of the world. They ignore the rest of the world claiming that both Canada and the US trade live hogs mainly among themselves. This argument works for Canada but the US has other trading partners in terms of live hogs as outlined in other studies (Paarlberg, 2014). The model considered hogs and pork to be two vertically connected sectors where three participating agents are primary producers (farmers), processors and retailers. Separate equations are used to estimate the demand and supply of the hog and pork market. (Paarlberg, 2014) used a simultaneous system of dynamic differential equations. The model described logarithmic changes in variables which are endogenous to the model from its benchmark level given shock to the exogenous variables. The model was used to estimate the national economic impact of the disease. It studied differing welfare outcome under alternative assumptions about the disease behaviour.

To study the economic costs of a disease outbreak in live animal industry, a popular method is a partial budgeting spreadsheet model (Weng et al., 2016). The basic framework of it is described by (McInerney, Howe, and Schepers, 1992). A partial budget is a financial tool to evaluate changes made on a farm. It analyzes net financial return from small changes or refinements made to farm operation. (Bennett, Christiansen, and Clifton-Hadley, 1999) estimated the direct costs of 30 separate livestock diseases in Great Britain by developing a static partial budgeting model. (Meuwissen et al., 1999) used a partial budgeting analysis framework to construct EpiLoss, a disease simulation model that can determine the direct costs and consequent losses attributed to a Classical Swine Fever outbreak. (Alarcon et al., 2013), constructed an epidemiological stochastic simulation model that can determine the net costs of producing a pig infected with post-weaning multi systemic wasting syndrome (PMWS) or porcinecircovirus type 2 subclinical infections (PCV2SI). (Alarcon, Rushton, and
another study used the said cost estimates to study the cost effectiveness of alternative control strategies.

To calculate the cost of a PED disease (Weng et al., 2016) uses a similar technique. They used a production simulation model to estimate the pig population by cohorts on a weekly basis. This involved tracking the number of sows gestated in a given period and with a given birth and death rate, estimating the number of piglets added to the herd each week. The model could track the number of market hogs produced each week as the duration of each pig life stage since birth is known. Revenue was then estimated with the estimated number of market hogs available to sell and their market price. The estimated profit was calculated by utilizing the estimated revenue and information available on hog farming cost. To simulate the effects of a PED outbreak they estimated the number of pigs that would be lost due to the disease. To measure the loss, estimated profits of two periods were compared. The study also investigated effects of different intervention strategies on preventing or mitigating the disease outbreak losses and compared across different strategies.

While this model is easy to construct and used for the evaluation of specific farming related projects the partial equilibrium model constructed for this thesis is more elaborated and captures the whole industry. Moreover, (Weng et al., 2016) is more focused on studying the cost of a disease outbreak at the farm level whereas this thesis varies in rigor and context and is more focused at studying the impact on the various participants of the pork industry of Ontario on a provincial level. Another study already mentioned in the first chapter, (Cairns et al., 2017) studied the effects of a foot-and-mouth disease on the Ontario beef industry using a partial equilibrium model. The model used in this thesis uses similar methods as the model constructed by (Cairns et al., 2017). The beef industry is broken down to six separated markets of cow-calf market, backgrounding market, finishing market, non-fed market, processed beef market and retail market. Each market segment has equations representing the demand and supply. Market identities are used for certain calculations like calculating the number of heifers and steers in the calves market with an identity used for
market clearing. A price transmission mechanism is used connecting the prices in all the separated markets. The model captured international trade in different segments of the market as choice variables whereas provincial trade was treated as identities. The model constructed for this thesis uses similar logical basis with lesser market segments.

The reviewed literature focuses on recent studies conducted on the Ontario pork industry and a global overview of effects of disease outbreaks on pork industry. The review also covers literature on understanding the trade relations with the US. The recent studies on the Ontario pork industry highlight the current status of and challenges facing the industry. Having the knowledge of these challenges are necessary for meaningfully interpreting the results of this thesis. The studies related to disease outbreak shed light on the effects, consequences and possible mitigation of such outbreaks. Review of these literature helps to create the hypothetical disease scenarios and compare the outcomes of this thesis with the previous literature. As the study looks into the effects of trade restrictions from the US, having a good understanding of the existing trade relations between Ontario and the US is significantly important.
3 Ontario Pork

The objective of the study is to simulate the effects of a potential disease outbreak on the Ontario pork industry. In order to accomplish the objective, a partial equilibrium model of the industry is constructed. The model is a mathematical representation of the pork industry that will explain the determination of prices, directions and destinations of trade, demand and supply of pork etc. details of which will be discussed in Chapter 4. Before constructing the model, having a clear understanding of the institutions that govern the pork industry is a crucial first step. This chapter is dedicated to discussing the core components of the industry in broad details beginning with a brief description of the hog value chain.

3.1 About the Industry

In hog farming, the first thing farmers have to do is decide the size of their breeding stock. The sows and gilts in the breeding herd give birth to piglets with roughly two pig crops per year. Piglets are kept with the mother sow for 14-28 days for feeding and when they are weaned-off they enter the weaner pig stage. The weaner pig stage is the first of the three stages of a pig’s life where piglets require special care. The three stages of a pig’s life is categorized by weight. Upon gaining the required weight, pigs reach the second stage termed feeder pig stage where extra attention is attributed towards feeding the pigs to gain weight rapidly. The following stage is called the market pig stage where they are kept in bigger barns for their enlarged size and fed further to gain more weight. Across all these life stages of pigs trade is an important aspect. Live pigs are traded across provinces and international borders with exports dominating the imports by a large margin. Market pig is the last stage of live pigs. Pigs are sent to processing plants for slaughter upon reaching farmers’ desired weight levels. After being slaughtered and processed, the pork is consumed domestically or exported internationally. Due to having shared borders, Ontario has a high volume of exports going to the US.
Figure 1: Hog Value Chain
The discussion below briefly outlines the hog value chain. Figure 1 depicts flow chart of the hog value chain with arrows indicating the flow of pigs and pork. The value chain starts with the breeding stock. The first step in pig farming is to determine the size of the breeding stock. This is a crucial decision for farmers because this dictates how many hogs will be available to sell to processing plants in seven to eight months time. This number of market hogs that is likely to be available, can be predicted fairly accurately. OMAFRA prepares Swine Budgets which reports estimates of various statistics like piglets born alive per litter, death rate of weaner, feeder and market pigs, number of pig crops per year etc. It takes roughly 5 months for a sow to farrow and piglets weaned which allows roughly 2.35 pig crops per year (Smith, 2016). Estimates on birth rate says given an average pre-weaning death rate of 12%, 12.5 piglets are born alive per litter (Smith, 2016). These estimates help yield approximate number on pigs that will enter the live pig stages for a given size of the breeding stock. In Figure 1 this flow is indicated by the purple line. Across all life stages, trade is an important component, directions for which is indicated by the orange arrows in Figure 1. Starting from early weaned to market pigs, all categories of pigs are exported and/or imported both internationally and interprovincially. Details of live pig trade will be provided later in the chapter.

After birth, piglets are kept with the mother sow for feeding. Prevailing practice to wean-off piglets is when they reach 7 kg. Although this is the dominant practice, there are cases when piglets are weaned off before reaching the aforementioned weight and they are called early weaned piglets. The duration of different life stages of pigs vary significantly across different farming techniques. For example, duration for weaning-off piglets depending on farming techniques can vary from 14 - 28 days. After weaning, piglets enter the weaner pig stage as indicated by the flow of purple arrow in Figure 1. The weaner pig stage, otherwise known as Nursery is basically a barn where pigs are kept in a warm environment for an average duration of 4-7 weeks before moving to the feeder pig stage. Pigs enter this stage weighing 7 kg and are moved to the next stage upon reaching weight of 23 kg. One of the
primary reasons for keeping pigs at this stage is to take better health care because of their tender age. Moreover, at this stage farmers seek out the immunologically weaker and sick pigs to separate from the better herd to prevent disease transmission \citep{MacDonald2016}. Pigs become less vulnerable and are less prone to death at this stage compared to piglets at birth. Average death rate at the weaner pig stage is 4\% \citep{Smith2016}.

When the pigs exceed the weight of 23 kg they are moved to bigger barns and enter the feeder pig stage and kept their until reaching 53 kg. This movement is indicated in figure 1. Special care is attributed to food intake of pigs at this stage for their rapid growth. As the feeder pigs grow big, space management becomes an issue. On average, for a feeder pig weighing around 23 kg, a minimum of 3-4 square feet per head is required. Duration of this stage varies but is expected to last between 11-16 weeks. The feeder pig stage has an estimated death rate of 6\% indicating 94\% of the feeder pigs move into the market pigs stage \citep{OMAFRA_Swine_Budget}. The market pig stage is the final stage of live pigs where pigs are fed to gain more weight before being sold off to the processing plants. Pigs are sold in the market upon reaching a desired weight and index decided by the farmer. There are several factors including price of the market hogs, cost of feed, available space in the barn etc. that influence farmers’ decision of selling market hogs. Movements of pigs across different life stages is indicated with purple arrows in the central box in Figure 1.

Given that information on provincial trade across different weight categories is not available, three life stages of pigs are collapsed and used as live pigs instead. This allows to simulate and observe any effect on farmers’ and does not compromise the main goals of the thesis. This is given in figure 2.

### 3.2 Trade of Live Pigs

Trade is an important component across all life stages of pigs and the orange lines in figure 1 indicate inflows and outflows of live pigs. Ontario’s exports of live pigs are significantly higher than its imports. High volume of production, access to large US market and slaughter
Figure 2: Hog Value Chain
Canadian Live Pigs Imports 2011 2012 2013 2014 2015

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Hog Imports - US Only</td>
<td>2,843</td>
<td>2,428</td>
<td>1,371</td>
<td>2,977</td>
<td>6,330</td>
</tr>
<tr>
<td>US Share in Total Imports</td>
<td>83.3</td>
<td>100</td>
<td>100</td>
<td>99.2</td>
<td>98.7</td>
</tr>
<tr>
<td>Total live pigs imported by - Ontario</td>
<td>800</td>
<td>1000</td>
<td>500</td>
<td>2400</td>
<td>2900</td>
</tr>
</tbody>
</table>

Table 1: Imports of Live Pigs - Canada (Number of Heads)

Source: Statistics Canada, Prepared by AAFC/MISB/AID/Redmeat Section

capacity constraints are few of the reasons for the export-import discrepancy.

Ontario imports very small number of live pigs from the international market consisting of only a few hundred heads. As live pig imports data for Ontario with import sources is not available, the study uses the same data for Canada which includes Ontario. Observing the data for Canadian imports provides a reflection on Ontario’s live pigs imports market. Table 1 portrays the US dominance on Canadian live pig imports. Table 1 shows since the year 2012 the US has been responsible for more than 98% of the import market share of live pigs across Canada. Given the ease of transportation, similar dominance over Ontario can also be anticipated. The last row in table 1 shows the number of pigs that are imported by Ontario in the last few years of study. Imports of live pigs has been somewhat higher of late.

International exports of live pigs is higher than its interprovincial counterpart. Ontario exports all categories of live pigs internationally. US is the main market for international exports as well and since 2008 they have on average been responsible for more than 98% of Canada’s total international live pig exports. Data for live pig exports for different weight categories are available for the US which enables a detailed analysis. Table 2 indicates live pig exports are dominated by trade in early weaned piglets weighing less than 7 kg. Despite high risk of death at younger age, exports of early wean piglets are quite high. Farmers use specialized trucks with necessary arrangement to keep piglets warm and safe to export at
<table>
<thead>
<tr>
<th>Year</th>
<th>Early-wean</th>
<th>Weaner Pig</th>
<th>Feeder Pig</th>
<th>Market Pig</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>41.98</td>
<td>12.42</td>
<td>7.69</td>
<td>37.92</td>
<td>100</td>
</tr>
<tr>
<td>2013</td>
<td>40.21</td>
<td>23.11</td>
<td>9.92</td>
<td>26.75</td>
<td>100</td>
</tr>
<tr>
<td>2014</td>
<td>40.38</td>
<td>23.71</td>
<td>10.18</td>
<td>25.74</td>
<td>100</td>
</tr>
<tr>
<td>2015</td>
<td>32.07</td>
<td>18.79</td>
<td>23.82</td>
<td>25.32</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2: Live Pig Exports to the US by Stage of Pig Growth in %

*Source:* Statistics Canada, Prepared by AAFC/MISB/AID/Redmeat Section

this age. The early wean exports has almost tripled from 2010 to 2015 going from 247,000 to 610,000 annually. One reason for such high trade of piglets is, Canada has efficient farrowing system and the US has relatively lower cost farming systems. As a result farmers are making the best use of the efficient farrowing and then utilizing the benefits of low cost farming. Market pigs are the second largest category in live hog exports followed by weaner pig and then feeder pig but the ordering switch between weaner pig and feeder pig is for the year 2015 only. US is an important destination for exporting live market hogs such that the number of market hogs exported to the US is almost equal to total live pig exports across provinces.

As weight category disaggregated data on interprovincial trade of live pigs is not available, the study focuses on total interprovincial imports and exports. For Ontario’s provincial trade, a good approximation is majority of the imports are feeder pigs and exports are market pigs. Ontario’s trade destinations within Canada are mainly Quebec and Manitoba where Quebec is the larger trading partner. For provincial trade of live pigs, Ontario exports a lot more than it imports. High processing capacity of the said two provinces is a driving factor of this large export. Table 3 shows the total interprovincial pig trade of Ontario summed across all the provinces.

As the birth and death rate of pigs are known and volume and direction of trade in live pigs are recorded, tracing the number of pigs that flow through the system becomes feasible.
<table>
<thead>
<tr>
<th>Description</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interprovincial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exports of hogs</td>
<td>601.3</td>
<td>559.7</td>
<td>470.7</td>
<td>519.8</td>
<td>475.2</td>
</tr>
<tr>
<td>Interprovincial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>imports of hogs</td>
<td>105.2</td>
<td>100.6</td>
<td>117.9</td>
<td>84.6</td>
<td>73.3</td>
</tr>
</tbody>
</table>

Table 3: Interprovincial Trade of Ontario

Source: CANSIM Table 0030102

3.3 Processing of Hogs and Pork Trade

Pigs’ journey of reaching market hog stage since birth has been discussed thus far (refer figure [1]). Hogs that are not traded and kept on the farm until reaching market weight are sold to processors or packaging plants for slaughter and further processing. This movement is indicated in figure [1] by the purple arrow flow. The term processing includes everything from slaughter of hogs, curing, baking and other reformations.

The main processing plants in Ontario are Sofina Foods (formerly Fearman’s pork process), Maple Leaf Foods (reduced their capacity), Conestoga Meat Packers’ Cooperative and Quality Meat Packers (shutdown in 2014). Both federally and provincially inspected plants operate in Ontario but on an average more than 90% of the hogs are slaughtered in federally inspected plants (Calculated from data). Once hogs reach market weight they are carried in a trailer to processing plants where they undergo an initial inspection by the Canadian Food Inspection Agency (CFIA). Hogs are moved from trailers to holding pen and then to the kill floor for slaughter. Hogs moving to the kill floor need to be in good physical condition. If any hogs are found to be stressed, they are either quickly moved to the kill floor or are euthanized in the trailer (MacDonald, 2016). Slaughtered pigs are processed and made ready for market. Some meat packers go to retailers directly for marketing processed pork and some use contractors. Modeling these individual packers’ decision is beyond the purpose of the thesis hence it only focuses on pork production, consumption and provincial and international trade. However, data for total production, consumption and provincial
Table 4: International Pork Exports from Ontario (in Thousand Canadian Dollars)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>268098.70</td>
<td>319305.93</td>
<td>415866.92</td>
<td>381741.66</td>
<td>364800.73</td>
</tr>
<tr>
<td>China</td>
<td>13320.23</td>
<td>14202.31</td>
<td>9513.14</td>
<td>2324.41</td>
<td>36705.76</td>
</tr>
<tr>
<td>Japan</td>
<td>33410.85</td>
<td>36015.82</td>
<td>18514.51</td>
<td>14526.48</td>
<td>23497.86</td>
</tr>
<tr>
<td>Mexico</td>
<td>4798.53</td>
<td>13409.49</td>
<td>24178.79</td>
<td>17128.61</td>
<td>17336.47</td>
</tr>
<tr>
<td>Taiwan</td>
<td>6342.07</td>
<td>7825.55</td>
<td>8986.91</td>
<td>7716.29</td>
<td>4134.3</td>
</tr>
</tbody>
</table>

Source: Agriculture and Agrifood Canada

The US domination in both trade categories are visible but imports are more dominated than exports. In the last five years on an average more than 94% of the imports and more than 75% of the exports were from the US. Although Japan appears third in the list, they have been the second largest market for Ontario for a long time until 2016. The high value pork market in Japan is one of the most important destination for Ontario pork. China in the recent past has been a significant export destination for Ontario followed by Mexico. Pork imports from countries other than the US are negligible. The pork trade scenario further emphasizes that Canada and the US markets are very integration.

3.4 Understanding Ontario’s Pork Trade

The chapter so far has discussed various aspects of the pork industry. This subsection of the chapter is focused on providing a economic justification for the pattern of Ontario’s
trade with the US and highlights the possible effects of a trade embargo. Understanding the pattern of Ontario’s pork trade is more complicated than its live pigs trade. High demand due to a large population base, existence of large retail chains, access to a large US market, easier trade opportunities with the US due to shared borders, free movement of products from other provinces etc. are the main factors that complicate the Ontario pork trade.

Ontario is home for almost 39% of Canada’s total population that makes it the largest market in Canada. This large population base attracts large retailers like Sobey’s, Metro and Loblaws which makes Ontario a lucrative market for other provinces. Along with high provincial trade, easy access to the US market boosts potential for trade significantly. Ontario exports 50% of its produced pork to the international market and over 60% of that is exported to the US\(^2\). In order to meet high local demand, Ontario imports relatively large quantity of pork despite having high exports of pork to the global market. 95% of total international imports to Ontario come from the US\(^3\). Ontario trades five different cuts of pork products and their trade shares provide some insight to understanding Ontario’s trading patterns. It can be observed from figure 3 in terms of amount traded, Ontario’s international pork exports are dominated by fresh cuts followed by frozen cut, pig fat, processed and offal whereas imports are dominated by fresh cuts and processed meat followed by offal and frozen cuts and almost no pig fat.

The breakdown of trade in different cuts in figure 3 shows in 2015 fresh cuts dominate both exports and imports but for processed, only imports are high. Similarly, where pig fat is the third largest of the 5 categories in exports, imports for this item is zero in 2015. This suggests differentiation in products exists for trade to occur. But obviously this is just one of the many reasons that explains only a certain portion of trade. There is an aspect of differing value as well. Ontario exports lower value products and imports higher value products (Group, 2016). These two are important reasons for Ontario to have high exports and imports.

---
\(^2\)Calculated from the data  
\(^3\)Calculated from the data
Figure 3: Trade of Different Cuts of Pork
Given that pork supply cannot be adjusted in the short run (market hogs are slaughtered upon reaching certain weight), in the event Ontario based middlemen with contractual obligation face shortage of supply in the Ontario market, most likely response for them would be to meet the shortage by importing from the US market. This is a case of contractual rigidity causing trade of a commodity that might normally be available in the Ontario market.

*Sudden demand shocks* might also induce trade. Pork retailers in general manage their supply taking into account seasonal and other rotational demand fluctuations. In the event there is an unaccounted for shock (i.e. natural disaster, price reduction of a complementary good etc.) that increases/decreases market demand creating shortage of/excess supply in the short run, then that shortage of/excess supply must be met by exports/imports.

![Figure 4: Short Run Demand Shock](image)

If we assume for a specific pork product (fresh cuts or processed) market in Ontario is in equilibrium at price P as depicted in figure 4. The figure resembles a small open price taking economy with its prices equaling the world market price. Panel A portrays a situation where sudden shock increases the demand whereas panel B portrays a situation where demand is decreased due to a sudden shock. In both the cases demand shifts from D to D'. In the first
case the demand shift creates a shortage of supply of QQ’ which can be met by importing from the US. On the other hand panel B shows the case of excess supply of Q’Q amount where the excess supply can be exported to the US market. This one of the reasons of having high level of exports and imports at the same time.

A different type of shock that might lead to similar result is a supplier induced demand shock. For example, a supplier or a big retailer (i.e. Costco) decides to have a promotion on pork and provides a 50% discount on pork. The discount will bring the price down which would correspond to a higher quantity demanded and in the very short run when supply cannot be increased that sudden increase in demand has to be met by imports.

The discussion put forward is important to understand the trade dynamics of Ontario and the US. It should be evident from the discussion that a conventional trade diagram representation cannot explain the possible effects of a trade embargo by the US. Trade embargo would have both short run and long run effects on the pork industry. Ontario is a small open economy in the global pork market and a price taker with US being the price setter. A valid hypothesis for Ontario is that in the short run the trade embargo would mainly affect its trade (both pork and live pigs) with the US and other provinces. It is very likely that the short run and long run effects would be different. Inevitably a trade embargo would reduce Ontario’s trade with the US. As the herd size and gestation of sows is planned in advance, sudden trade embargo will not allow for any changes in the supply of live pigs at the farm level in the short run. With supply of live pigs remaining unchanged and less live pigs moving to the US, Ontario would strive to enhance its slaughtering capacity and process more hogs locally (by doing extra shifts and operating plants in the weekends). With prevailing processing capacity constraint in Ontario, it would not be enough to take care of the excess supply of live pigs created by the embargo. In the process the live hogs that are not traded with the US would be sent to Quebec and Manitoba. Effects on pork trade is likely to be slightly different. It is not surprising that pork trade with the US would fall by the amount of embargo imposed. Ontario being the net importer of pork in provincial
trade, the likely effect is Ontario importing less pork from other provinces. If no embargo is imposed from the other international markets, exports to those destinations might go up as well.

Effect of trade embargo on prices too are hypothesized to be different in short and long run. It is fair to assume that prices in the short will remain relatively sticky. Justification for this assumption can be provided with a hypothetical scenario. Say Ontario gets a 100% trade embargo from the US both on live pigs and pork in the middle of a time period (data is available at 6 months interval), Ontario would continue to trade with Quebec and Manitoba at the previously determined price because it would take time for domestic factors (i.e. supply of hogs, supply of pork, constrained slaughtering capacity etc.) to start effecting in deciding the price domestically. If the US imposes the trade embargo say in period 1 then it is likely that domestic factor would effect price determination in period 2 meaning prices would remain sticky in the short run. Moreover, the Ontario prices would remain bounded from the above by the US price because Ontario can still import from the US.

One of the main reasons for the differing effects of short and long run of a trade embargo is farmers inability to respond to the situation. This is similar for most of the livestock industry. This thesis focuses on the short run effects of a US trade embargo.
4 Model Specification

Discussion thus far lays the background for the partial equilibrium model to be constructed. The goal of the model is to analyze the effects of trade restriction due to a disease outbreak in the Ontario pork industry. The details of the hog value chain has been discussed in chapter 3. This section is dedicated to discuss the regression equations and market identities that describes the Ontario pork industry.

The Ontario pork industry is divided into two broad segments: live hog market and the processed pork market. While the first market focuses on supply-demand, prices and trade of live pigs, the second market focuses on the supply-demand and prices along with provincial and international trade of pork. Equations and identities have been used to represent both the markets. The first step in the live pigs market is deciding the size of breeding stock and the last step of this market is decision of hogs slaughter whereas the pork market starts with the calculation of amount of pork produced in Ontario. The pork production establishes the connection between the two markets as it’s calculated using average carcass weight and the number of hogs slaughtered which is the last step of the live pigs market. Emphasis is put on international and interprovincial trade in both market segments as they constitute a big portion of the entire industry. The regression equations identify the choice variables and the market identities direct the flow of market products.

4.1 Live Pig Market

As chapter 3 outlines, the first decision farmers need to take is deciding the size of the breeding stock on which depends, approximately how many market hogs would be available to sell in the next 5-8 months. Market hog price, which is the end product price of a pig farmer, is an important factor in farmers’ decision of the breeding herd size. The market
hog price is a function of factors that is represented by equation (1) in the model.

\[
MH Price_t = \beta_0 + \beta_1 US MH Price_t + \beta_2 Can US ExRate_t + \beta_3 MH Price_{t-1} + \epsilon_t \tag{1}
\]

The market hog price \( (MH Price_t) \) in Ontario is a function of the US market hog price \((US MH Price_t)\), Canada-US exchange rate \((Can US ExRate_t)\) expressed in CAD and the lag of the market hog price \((MH Price_{t-1})\). Ontario is a small open economy, a price taker in the global market where US is the price setter. Ontario price is formula price off of the US marketplace adjusted to Ontario conditions. [Haley, 2004] emphasized that Canada is the price taker where the US sets the price and the exchange rate between these two markets has been an important driver of the market hog price in Ontario. This pricing method works well for Ontario because of the high volume of trade taking place between Ontario and the US. To understand the relationship better, Ontario and US market hog prices are plotted in figure 5.

The US and Ontario market hog prices have a positive association as shown in 5 where both the prices over the time period of the study are plotted. A Dicky-Fuller test revealed that the series are cointegrated. It is apparent that the prices have similar patterns of movement. Exchange rate, as it is expressed in CAD, is also expected to have a positive effect on the Ontario price, because when exchange rate goes up, Ontario price relative to US price should also go up.

Once farmers know the market hog price, farmers can make an informed decision on the size of the breeding stock. The factors affecting breeding stock decision by farmers are given by equation 2

\[
BS_t = \beta_0 + \beta_1 MH Price_t + \beta_2 ON Corn Price_t + \beta_3 BS_{t-1} + \beta_4 Can US Ex Rate_t + \epsilon_t \tag{2}
\]
Cost of farming is one of the important factors. Feed cost accounts for more than 64% of total cost of hog farming (Smith, 2016). Given that the main ingredient for hog feed is corn, the Ontario corn price is included in the model to incorporate farming costs. One period lag of the dependent variable is added as a separate regressor. Exchange rate is included in the model because Ontario and the US markets are very integrated that Canadian currency affects aspects of hog farming other than the market hog price and hence might have an effect on the farmers decision of breeding stock size.

Breeding sows are inseminated using boars and artificial insemination. The breeding stock gives birth to the new supply of pig crops. This is best represented with the identity in equation 3:

\[ SPC_t = (BS_t \times \lambda)(Identity)(\lambda = \text{piglets born alive per litter}) \]  

(3)
The average number of piglets born alive per litter is given by OMAFRA Swine Budget, which helps to figure out the supply of pig crops for a given period using this identity. The number of pigs born alive per litter represented by $\lambda$ is after taking into account the death rate of piglets at birth.

As per the hog value chain, trade of live pigs is the next decision farmers need to make. The decision of international trade of live pigs considers various factors. Among different trade variables, international import of live pigs is too small in number to model and obtain meaningful results hence this thesis refrains from modeling this decision. To include the international import of live pigs in the model, it is added to total hog supply identity. The international export of live pigs is an important decision for farmers and is added as a separate equation (explained later in the chapter). The interprovincial export of live pigs on the other hand is added to the model as market clearing identity (explained later in the chapter). For the interprovincial export identity to work the interprovincial import of live pigs is added to the total hog supply identity.

Total hog supply is an important information for farmers which is added to the model as an identity and is given by equation 4.

$$\text{Tothogsupply}_t = \text{BegInv}_t + \text{SPC}_t + \text{MProv}_t + \text{MInt}_t \quad (\text{Indentity}) \quad \text{(4)}$$

The first item in the total hog supply identity is the beginning inventory. Farmers generally have pigs in the barn at the end of a time period which are called the ending inventory. The ending inventory of a time period is called the beginning inventory of the next time period. That means farmers generally have an inventory at the beginning of a time period. This beginning inventory is added as the first element in the total hog supply identity. The new pig crop supplied during a time period is added to the existing pig inventory in that period. There are provincial and international imports of live pigs that are also added to obtain the total number of pigs available to a farmer at a time period. For this model this identity is generated for Ontario and not for a specific farmer.
Deciding the number of pigs to be traded internationally is an important one farmers. Given the model is at provincial level, the collective decision of all Ontario based farmers will be modelled for this variable. This regression is given by equation 5.

\[ X_{\text{Int}_t} = \beta_0 + \beta_1 M\text{HPrice}_t + \beta_2 U\text{SMHPrice}_t + \beta_3 U\text{SCornPrice}_t + \beta_4 O\text{NCornPrice}_t + \beta_5 T\text{ot hog supply}_t + \epsilon_t \]  

The decision to export pigs internationally is a function of price of market hogs both Ontario and the US. It also depends on cost of raising and maintaining pigs both in Ontario and the US as represented by both regions corn prices. High market hog price in Ontario is likely to lower international export and the converse applies for the US price. On the other hand the effects are expected to be reversed for both regions corn prices. Total hog supply is added as a separate regressor and the anticipated outcome is higher hog supply would lead to larger exports and vice-versa.

As the market hogs reach the desired weight, they are moved to processing plants to slaughter. In the plants hogs are taken to the holding pens from the trailer temporarily before being taken to the kill floor. The determinant of number of hogs to be slaughtered is a combination of factors. There is individual slaughter plant capacity constraint, processing plants willingness to buy hogs at a given market price, market hogs available to sell, farmers cost of feeding the hogs if not sold etc. The slaughter decision reflects both farmers and plants choices. The hog slaughter decision is represented by equation 6.

\[ \text{Hogslaughter}_t = \beta_0 + \beta_1 M\text{HPrice}_t + \beta_2 O\text{NCornPrice}_t + \beta_3 X_{\text{Int}_t} + \beta_4 B\text{S}_{t-1} + \epsilon_t \] 

Number of hogs slaughtered by processing plants is a function of current market hog price, corn price of Ontario, international live hog exports and lagged breeding stock. Market hog price is reflective of plants’ willingness (or lack of willingness) to purchase hogs for slaughter.
The anticipated coefficient for this variable is negative as plants are more likely to buy less when price is high or vice-versa. Corn prices represent cost of holding hogs where high corn prices make it more expensive for farmers not to sell them. Corn prices should have a positive relationship with the number of hogs slaughtered. International exports and breeding stock size are added to control for the movement and size of the herds respectively. As it takes over six months (one time period in this model) from farrowing to a hog reaching market weight, breeding stock is lagged by one period.

Most of the data on live pigs have been collected from CANSIM table 003-0102. Understanding the method of data recording in this table is crucial for understanding the use of the next identity. A snapshot of most recent years of the CANSIM table is given in table 6.

Table 6: CANSIM Table 003-0102

<table>
<thead>
<tr>
<th>Category</th>
<th>2016 01</th>
<th>2016 02</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning inventory of hogs</td>
<td>3335.7</td>
<td>3351.2</td>
<td>6686.9</td>
</tr>
<tr>
<td>Pig crop</td>
<td>3707.5</td>
<td>3686.3</td>
<td>7393.8</td>
</tr>
<tr>
<td>Interprovincial imports of hogs</td>
<td>37.9</td>
<td>35.4</td>
<td>73.3</td>
</tr>
<tr>
<td>International imports of hogs</td>
<td>0.8</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Total Hog Supply</td>
<td>7081.9</td>
<td>7073.5</td>
<td>14155.4</td>
</tr>
<tr>
<td>Interprovincial exports of hogs</td>
<td>241.4</td>
<td>233.8</td>
<td>475.2</td>
</tr>
<tr>
<td>International exports of hogs</td>
<td>704.1</td>
<td>620.5</td>
<td>1324.6</td>
</tr>
<tr>
<td>Deaths and condemnations of hogs</td>
<td>171.1</td>
<td>169.9</td>
<td>341</td>
</tr>
<tr>
<td>Other disposition of hogs</td>
<td>2614.1</td>
<td>2668.4</td>
<td>5282.5</td>
</tr>
<tr>
<td>Total disposition of hogs</td>
<td>3730.7</td>
<td>3692.6</td>
<td>7423.3</td>
</tr>
<tr>
<td>Ending Inventory</td>
<td>3351.2</td>
<td>3380.9</td>
<td>6732.1</td>
</tr>
</tbody>
</table>

Source: CANSIM Table 003-0102 (Reorganized)
able other disposition constitutes the major portion of total disposition. This variable represent dispositions across all weight categories instead of just market hogs. Other disposition means any disposition other than international and interprovincial trade, deaths and other condemnations. This may include hogs sold to processing plants, hogs sold as breeding hogs to other farmers, hogs kept to be used for breeding stock in the next period, hogs sold as barbecue hogs to customers directly by farmers, pigs sold locally for any other reasons by farmers before reaching market weight etc. Given the CANSIM table under discussion is recorded maintaining the flow of live pigs data, it is important to use the variables as they are recorded. However, for the purpose of the study it is important to model the number of hogs slaughtered by processing plants separately. The number of hogs slaughtered is a part of the other disposition variable, hence the other disposition variable could not be used the way it is recorded in the data table. It is an important aspect that over the time frame of the study number of hog slaughtered by processing plants on average constitutes 87% of the other disposition variable. This means by using the variable for hog slaughter leaves 13% of the other disposition of hogs unaccounted for. To take care of this 13% of hogs the next identity is added. This identity is given by equation 7.

\[ \text{OtherDisp}_t = \text{OtherDisposition}_t - \text{HogSlaughter}_t \]  

(7)

The variable Other Disp is created to account for the difference in the number of hogs slaughtered and the number of hogs that were sold elsewhere from farms. This variable is obtained by subtracting number of hogs slaughtered from other disposition. Since this identity is added as a buffer to maintain the flow among of the equations, this identity is kept constant in the simulations. This will help reflect the real effect of trade embargo on the interprovincial exports of Ontario.

Next identity used in the model is the provincial hog exports which is the last component.
of the live pigs market. The identity is given by the equation

\[ X_{Prov_t} = \text{tot hog supply}_t - (X_{Int_t} + \text{Death}_t + \text{Other Disp}_t + \text{Hog Slaughter}_t + \text{Ending Inventory}_t)(Identity) \]  

This is the market clearing identity of the live pigs market. The provincial exports can be obtained by subtracting international pig exports, Other Disp, hog slaughtered and the ending inventory from the total hog supply. Basically pigs that are not traded internationally or not sold to processing plants and/or somewhere else or not kept in the barns are the ones that are traded provincially. All the equations discussed, represent the live pigs market segment of the hog value chain. The pork produced in the processing plants from slaughtered hogs are discussed in the following discussion.

4.2 Processed Pork Market

This segment includes discussion on production of pork, demand at the retail level and the trade with international markets and other provinces. The processing plants process the slaughtered hogs for pork which is the first identity of the processed pork market. This identity establishes the link between the live pigs market processed pork market. The production is represented by an identity given by the equation

\[ \text{Production of Pork ON}_t = \text{Hog Slaughter}_t \times \text{Average Dressed Weight}(Identity) \]  

The carcass weight of slaughtered hogs is measured by the processing plants. A close approximation for amount of pork produced can be obtained by multiplying the number of hogs slaughtered with the average reported dressed weight. In order to obtain approximate total amount of pork produced in Ontario the number of hogs slaughtered in Ontario is multiplied by the average dressed weight.
The next component of the model is the retail price of pork. As Ontario is a small open economy it is a price taker in the global pork market. The US is the large open economy that sets the price. The retail price of pork in Ontario is given by the equation\(10\)

\[
RetailPrice_t = \beta_0 + \beta_1 US\ Pork\ chop\ landed_t + \beta_2 Production\ of\ Pork\ ON_t + \epsilon_t
\]

\(RetailPrice_t\) is the landed US price. Given the high level of integration with the US market and Ontario being a price taker, it is highly likely that US price would be an important factor. Retail price, for a given level of demand is determined by the total supply of pork hence pork supply of Ontario is added as a separate regressor.

With its large population base Ontario is an important market for pork because of its high demand. Demand for pork in Ontario is presented with equation\(11\)

\[
PorkDemand_t = \beta_0 + \beta_1 RetailPrice_t + \beta_2 Beef\ Price_t + \beta_3 Chicken\ Price_t + \beta_4 Per\ Capita\ Income\ ON_t + \epsilon_t
\]

The demand equation is comprised of basic demand determinant i.e. Own price, cross price and income. The retail price of Ontario which is given by equation\(10\) is used as the own price in the demand equation whereas beef and chicken retail prices are used as cross prices. Per capita GDP of Ontario has been used to represent per capita income. The issue in estimating the demand equation was lack of available data. First issue was absence of recent data on per capita income which led to the use of per capita GDP of Ontario. The next issue was lack of variation in the data. Data for both per capita GDP of Ontario and pork demand were available on a yearly basis and was converted to semiannual data by splitting the yearly data by half and using the same number for two time periods of one year. This conversion resulted in compromised variation of the data. The circumstance led to obtaining estimates of the demand equation from another study (Moschini and Meilke, 1992) which
looks into the demand for pork in Canada using the same regressors as was planned for this study. A report [Pomboza and Mbaga, 2007] by Agriculture and Agri-Food Canada, used AIDS model to obtain estimates on demand for several consumable goods including pork which revealed similar estimates.

International trade of pork is a core component for modeling the pork industry of Ontario. The US is Ontario’s main trading partner accounting for over 70% and 95% of Ontario’s pork exports and imports respectively. Shared borders, trade agreements (NAFTA), low transportation cost, similarity in socio-economic norms are few of the reasons for the high volume of pork trade. Given the circumstances, Ontario’s pork trade is modeled using two separate equations: One representing trade with the US and the other representing trade with the Rest of the World (ROW). Determinants of Ontario-US trade will be different from Ontario-ROW trade which justifies the use of separate equations. For the purpose of this thesis it is important to understand the trade flows and the impact of a disease outbreak on that, hence net export (exports - imports) of pork are used as the dependent variables on the trade equations. Net exports of pork with the US is given by equation 12

\[ NetXPorkUS_t = \beta_0 + \beta_1 US\ Pork\ chop\ landed_t + \beta_2 RetailPrice_t \]
\[ + \beta_3 NetXPorkUS_{t-1} + \epsilon_t \]  

(12)

Price is one of the major factor in deciding directions of trade. The landed retail price of the US has been used along with the retail price of pork in Ontario. Lagged of the dependent variable is added to the regression as well. When the price in Ontario goes up, the net exports with the US is likely to fall, however net exports would rise if the US price goes up.
The net exports of pork to ROW is given by the equation 13

\[
Net \ XPork \ ROW_t = \beta_0 + \beta_1 Japanese \ Pork \ price_t + \beta_2 Can \ Japan \ Ex \ Rate_t \\
+ \beta_3 RetailPrice_t + \beta_4 Net \ XPork \ ROW_{t-1} + \epsilon_t
\]  

Similar variables have been used for net pork exports to ROW equation. Japan has been Ontario’s second largest pork destination for the majority of the time period being studied. Thus Japan’s retail pork price is used as a regressor. As the Japanese retail pork price is given in index, Japan’s exchange rate used as a separate variable. The Ontario retail price and the lagged dependent variable are the other two variables in the equation.

Regressions of both the net exports equations were conducted differently. These two equations were estimated using monthly data. The data for trade were available on a monthly basis from AAFC. As the whole model is constructed using a six months time period, to maintain consistency six months of trade data needed to be summed up for regressing. However, time sensitivity is immensely crucial for trade hence to properly capture the dynamics of trade monthly trade data were used for the net exports regressions.

There is no official data available for provincial trade of pork. This had to be calculated from the model by adding provincial trade as the market clearing identity for this segment of the market. The identity is given by equation 14

\[
Net \ Provincial \ Trade \ of \ Pork_t = Production \ of \ Pork_t - (Pork \ Demand_t + Net \ XPork \ US_t \\
+ Net \ XPork \ ROW_t)(Identity)
\]  

Given this identity is used to calculate the provincial trade of pork, this equation is very important for this model. The identity takes the provincial pork production of Ontario and subtracts provincial demand (consumption), net US exports and net ROW exports to obtain
how much pork is imported (exported) from the other provinces. The last identity is also important in understanding the direction of trade if any provincial trade restrictions are imposed.
Chapter 5 discusses the specifications of the model constructed to represent the Ontario pork industry. The choice variables of the model, in both the live pigs market and processed pork market are represented with regression equations. Multiple factors affect the choice variables as represented by the equations and there are identities that interlinks components of the industry and enforces the market clearing conditions in both market segments. This chapter discusses the data that has been used to conduct the analysis for the study.

This thesis uses secondary data and the sources that are frequently used for data collection are Statistics Canada and Agriculture and Agri-Food Canada, USDA, US Bureau of Labor Statistics (BLS) and Ontario Pork. Statistics Bureau of Japan was used for collecting Japanese pork price data. Table 7 and 8 contains brief description of the variables used along with their units and sources.

The red meat price report published by AAFC contains market hog prices for all the provinces in Canada, feeder pig prices for Ontario and Quebec and also it contains the US market hog prices for few regions along with the national closing average. In order to maintain comparability, both the US and Ontario market hog price data were collected from the same source and these prices are for 100 index hog per 100 kilogram. Data for market hogs price of Quebec and Manitoba were also collected from the same source but were not used for regression purpose. Hog prices in Ontario are formula priced off the US marketplace. USDA publishes a report titled National Daily Direct Hog Prior Day Report Slaughtered Swine which is also known as the “201 report”. Ontario Pork uses the Chicago Mercantile Exchange (CME) constructed price based on the USDA’s “lm_hg 201” report as the reference price for the formula price. The prices reported here are adjusted to Ontario’s conditions to derive an Ontario based price. The 201 report has approximately 90 - 94 million hogs slaughter information. The prices are adjusted to account for the differences in exchange rate, dressing percentage, index and metric conversions. One of the major drawbacks of using this formula based price is, it is not reflective of the Ontario demand and supply conditions.
Data on different statistics of live pigs (i.e. breeding stock, pig crop, ending inventory etc.) are available on a semiannual (twice a year) basis. This restricts the study to use semiannual data for other variables because live pigs data are used abundantly for the construction of the model. All the variables related to live pigs were collected from two CANSIM tables as mentioned in table [7]. The data on live pigs are reported as stock and flow data in the two aforementioned tables. Most of the variables collected for this study are flow variables. For example beginning inventory, supply of pig crop and imports both international and provincial add up to total hog supply. Similarly the ending inventory is obtained by subtracting total disposition from the total hog supply. Details of this calculation for one time period is given in table [6] which shows the flow of the variables. The breeding stock on the other hand is a stock variable.

Data on Ontario corn price and Canada-US exchange rates were collected from different CANSIM tables which are also mentioned in table [7]. Data for both these variables were collected as monthly data and were converted to semiannual data by taking the average of the first and the last six months. As mentioned already, the data frequency of live pigs are restricted to semiannual level hence all the remaining data needed to be collected on same or a higher frequency (i.e. quarterly or monthly) and then converted to semiannual frequency. Most of the prices data were collected on a monthly basis and averaged across first and last six months for the conversion. One exception was the US corn price because it was collected on a quarterly basis and then averaged across first two and last two quarters. The hog slaughter in Ontario on the other hand was collected from the AAFC Red Meat and Livestock Slaughter report on a weekly basis and then summed up for the conversion to semiannual data.

The first component in the processed pork market is the pork production in Ontario which was calculated by multiplying the total number of hogs slaughtered in Ontario with Average Dressed Weight (ADW). Average Dressed Weight data is collected from the AAFC, a part of the AIMIS report, reposted by Canadian Food Inspection Agency and compiled
by AAFC. Monthly data for ADW was collected and averaged to convert it to semiannual data. This method of calculating pork production doesn’t give the actual amount of pork produced in Ontario but this is a very close approximate of the actual production. The next component of the processed pork market is the pork demand in Ontario which is also a calculated variable. Data on total pork demand for Ontario is not available hence it had to be calculated. Canadian average per capita pork disappearance is used for the calculation. The amount pork consumed in Ontario was obtained by multiplying per capita pork disappearance with the Ontario population.

Retail prices of pork, beef and chicken were collected from the same CANSIM table as indicated in data table 8. Instead of using retail price of a specific product like ham or bacon for pork, aggregated price indices have been used for all the three variables because index prices are more representative and devoid of product specific bias. The Japanese pork retail price is collected from the government’s official database, Statistics Bureau of Japan and the collected data is also an index of Japanese retail pork price. The US pork chops price was collected from the Bureau of Labor Statistics (BLS) which contains data on prices, price indices, CPI etc. Similar to the live pigs market, all the prices data were collected monthly and averaged across first and last six months to convert to semiannual data. Data on per capita income was not available for the years required hence per capita GDP of Ontario is used. Even though the study requires semiannual data, only yearly data is available for GDP of Ontario. The per capita GDP data was obtained by dividing the Ontario’s GDP by its population. The yearly data was split equally to convert it to semiannual data.

The pork trade data were collected by contacting AAFC via email. The main source of the data is Statistics Canada, but a report is prepared by AAFC - Redmeat Section which contains the data required for the study. Trade data in terms of dollar value were available on the web site but since the trade of pork in terms weight (kilogram) is used for this study and it had to be collected through communication. It has been mentioned in model specification chapter that pork trade of Ontario is separated into two parts: trade with the US and trade
with the ROW and data was collected maintaining this distinction.

Unit and brief description of each variable are given in tables 7 and 8. All the prices used for the study were deflated using Consumer Price Index. For Canadian prices Consumer Price Index (includes all items except 8 most volatile components as defined by Bank of Canada) (2002 = 100) is used. Similar deflators from the local data sources were used to deflate US and Japanese prices as well. Sixteen years span demands that prices were properly deflated to obtain meaningful and accurate results.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Name</th>
<th>Unit or Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Hog Price</td>
<td>MH Price</td>
<td>Index 100 hogs $ per 100 kg</td>
<td>Agriculture and Agri-Food Canada Red Meat Price Reports</td>
</tr>
<tr>
<td>US Market Hog Price</td>
<td>US MH Price</td>
<td>Index 100 hogs US$ per CWT (National)</td>
<td>Agriculture and Agri-Food Canada Red Meat Price Reports (Hogs) USDA Prices</td>
</tr>
<tr>
<td>Canada-US Exchange Rate</td>
<td>Can US Ex Rate</td>
<td>In Canadian Dollars</td>
<td>Table 176-0064 Foreign Exchange Rates in Canadian Dollars, Bank of Canada</td>
</tr>
<tr>
<td>Ontario Corn Price</td>
<td>ON Corn Price</td>
<td>Dollars per metric ton Price of Grain Corn</td>
<td>Table 002-0043 Farm product prices, crops and livestock, monthly</td>
</tr>
<tr>
<td>Breeding Stock</td>
<td>BS</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030100</td>
</tr>
<tr>
<td>Supply of Pig Crop</td>
<td>SPC</td>
<td>Number of pigs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>Total Hog Supply</td>
<td>Tot Hog Supply</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>Beginning Inventory</td>
<td>Beg Inv</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>Interprovincial Imports of Live Hogs</td>
<td>MProv</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>International Imports of Live Hogs</td>
<td>Mint</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>International Exports of Live Hogs</td>
<td>XInt</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>US Corn Price</td>
<td>US Corn Price</td>
<td>Dollars per bushel (Prices received by farmers)</td>
<td>USDA Feed Grains Database</td>
</tr>
<tr>
<td>Hog Slaughter</td>
<td>Hog Slaughter</td>
<td>Number of hogs in 1000</td>
<td>AAFC Red Meat and Livestock slaughter report</td>
</tr>
<tr>
<td>Other Disposition</td>
<td>Other Dispo-</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>Other Disp</td>
<td>Other Disp</td>
<td>Number of hogs in 1000</td>
<td>This is a calculated number</td>
</tr>
<tr>
<td>Interprovincial Export</td>
<td>XProv</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>Death</td>
<td>Death</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
<tr>
<td>Ending Inventory</td>
<td>Ending Invent-</td>
<td>Number of hogs in 1000</td>
<td>CANSIM 0030102</td>
</tr>
</tbody>
</table>

Table 7: Variable Details - Live Hog Market
<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Name</th>
<th>Unit &amp; Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pork Production in Ontario</td>
<td>Production of Pork ON</td>
<td>In Thousand kg</td>
<td>Average Dressed Weight x Hog Slaughtered</td>
</tr>
<tr>
<td>Average Dressed Weight</td>
<td>Average Dressed Weight</td>
<td>Kg</td>
<td>Ontario Pork (Compiled by Jaydee Smith OMAFRA)</td>
</tr>
<tr>
<td>Retail Price of Pork in Canada</td>
<td>Retail Price</td>
<td>Fresh or Frozen pork price index</td>
<td>Table 326-0020 Consumer Price Index</td>
</tr>
<tr>
<td>Pork Demand Ontario</td>
<td>Pork Demand</td>
<td>In Thousand kg/Pork Disappearance x Ontario Population</td>
<td>CANSIM Table 002-011</td>
</tr>
<tr>
<td>Retail Price of Beef</td>
<td>Beef Price</td>
<td>Fresh or Frozen Beef Price Index</td>
<td>Table 326-0020 Consumer Price Index</td>
</tr>
<tr>
<td>Retail Price of Chicken</td>
<td>Chicken Price</td>
<td>Fresh or Frozen Beef Price Index</td>
<td>Table 326-0020 Consumer Price Index</td>
</tr>
<tr>
<td>Per Capita GDP of Ontario</td>
<td>Per Capita GDP ON</td>
<td>GDP by Industry &amp; Chained (2007) Dollars</td>
<td>CANSIM Table 379-0030</td>
</tr>
<tr>
<td>Net Export of Pork to Rest of World (ROW)</td>
<td>Net XPork ROW</td>
<td>Pork Meat Trade in Thousand kg &amp; (Pork Export ROW Pork Import ROW)</td>
<td>Agriculture and Agri-Food Canada</td>
</tr>
<tr>
<td>Japanese Exchange Rate</td>
<td>Japanese Ex Rate</td>
<td>In Canadian Dollars</td>
<td>CANSIM Table 176-0064</td>
</tr>
</tbody>
</table>

Table 8: Variable Details - Processed Pork Market
6 Regression and Calibration

The purpose of the thesis is to construct the model to simulate effects of an assumed disease outbreak. Regression equations were estimated and identities were used to ensure market clearing conditions are met. Ordinary Least Squares - OLS method in level form has been used to run the regressions. The data frame is 16 years with each time period consisting of 6 months. After the coefficients were collected, second half of 2015 was selected as baseline year for calibration. Having obtained the calibration results simulations were carried out. Details of simulations are described later in the chapter. This chapter is dedicated to compare the simulation results with the calibrated results in order to understand the impacts of a potential disease outbreak. It is important to look into the regression and calibration results before focusing on the simulations.

6.1 Regression Results

It has been discussed in chapter 3 that the pig value chain is mainly categorized into two large market segments. The regression results in this section are reported the same way. The results for the live pig market is given in table 9 and the results for the processed pork market is given by table 10. In both the tables dependent variables are at the top and the regressors are in the left column, written vertically. Results are reported in the standard way where the estimate is followed by * sign which is used to indicate the statistical significance of the estimate followed by the value of standard error in the parenthesis below the estimate. One important point that needs to be discussed is the data frequency is semi annual, hence any effect that is discussed in the results is for a six months period. For example, when a change in price is discussed it means the price change is on average for the whole six months period. Similarly a change in, say number of hog slaughtered will be a change in total in a six months period. The reason for emphasizing on this point is effects of different variables are likely to be large because of the longer span.
Regression results will be discussed in the sequence they were introduced in chapter five. Looking at table 9, we can see market hog price in Ontario has a positive significant relationship with all the independent variables. If US market hog price goes up by a dollar that will increase the Canadian market hog price by almost 4 CAD. On the other hand if CAD were to depreciate against the USD, a change in the Canada-US exchange rate even by one unit would lead to an increase in the market hog price of about 59 CAD. The effect of exchange rate might seem quite high but there are good reasons here too. First of all the longer time span issue mentioned just now is a reason. Moreover, it is important to understand the exchange rate variable is expressed in terms of the value of CAD for 1 USD. The average exchange rate in 2016 was 1.33. Hence an increase by one unit would mean Canadian currency depreciating down to half of it’s current value. That’s why this variable has a large effect. Compared to the two variables discussed, the effect of own lag is quite small.

The fact that breeding stock is an important step in pig farming has been stressed during the discussion of it in chapter five. As we can see from table 9, except for corn price, other independent variables have a positive and significant relationship with breeding stock. It shows if market hog prices were to go up by a dollar then the size of the breeding stock would go up by 150 heads. This makes sense because if farmers can sell hogs at a higher price they would want to sell more hogs. Again we can see that the coefficient is high for the exchange rate variable, reason for this is just explained. When Canadian currency depreciates it would make the US market import more hogs which means Canadian farmers would have to have more hogs at their disposal. The own lag is also showing to have positive impact on the current size of breeding stock.

Following the equation sequence in chapter five, two equations following the breeding stock are supply of pig crop and total hog supply which are identities. The next item in discussion is the international pig export decision represented by international live hogs exports equation. It can be observed from table 9 all the variables have statistically significant effect.
on international export of live hogs variable although the statistical significance is not same for all the independent variables. Market hog prices in Ontario has a negative association reflecting the obvious price demand relationship: when hog prices are higher US demands less from Canadian market. On the contrary, when US market hog prices are higher, US demands more and exports of live hogs goes up. Since the US takes pigs of different weight levels and not only market hogs, this outcome makes sense. Corn prices in both regions have opposite signs which is quite logical. Higher corn prices in Ontario means farmers have incentive to sell more hogs so that their cost are lowered and profits higher. Similarly higher corn prices in the US would make sense that they would demand less pigs as costs of maintaining them are high. Finally a positive relationship with the total hog supply indicates that when more hogs are available, exports to the US goes up and the magnitude is large as well. An increase by 1000 hogs increases international exports by 400 heads.

The next equation is the number of hogs slaughtered at processing plants. It has been mentioned in chapter five that this equation reflects decisions of both farmers and plant owners. Both market hog price and corn price has statistically significant effect on hog slaughter but the effects go in opposite direction. The market price of hogs has two opposing effects on this variable because on the one hand farmers would be willing to sell less when the price is low but on the other hand farmers would want to buy more on a low price and vice-versa. Negative association of the market hog price variable suggests processing plants dominates the farmers on the price battle. That means with everything else held fixed, a rise in the market hog price will lead to a reduction in the number of hog slaughtered. A dollar increase in price would lead to a reduction of hog slaughter by 4.56 thousand heads. The positive effect of corn price reflects farmers’ cost of holding hogs in the barns which is why higher corn price forces farmers to sell their hogs to processing plants leading to higher slaughter number. Increase of corn price by 1 dollar leads to increase in hog slaughter by 2.068 thousand heads in a six months period. Among the other two variables international hog exports has the desired sign but not the statistical significance however lag of breeding
stock is statistically significant coupled with the desired sign. According to the results shown in table 9, an increase of breeding stock a period prior by 1 thousand heads leads to an increase of hog slaughter by 1.725 thousand heads.

The following two equations in the first segment of the market are identities where the provincial live hogs trade equation is the market clearing identity. Justification for using and keeping it constant for the simulation of the Other Disp variable is explained in chapter five. The Other Disp identity is used as a buffer and held constant in the simulations to have the correct effects of trade restrictions on provincial live pigs trade. The provincial live pigs trade identity shows the number of pigs that have been exported to other provinces primarily Manitoba and Quebec. The provincial exports of live pigs is given in the CANSIM data set and the fact that the identity generates the same result as the data shows that the model is working properly. Discussion thus far summarizes the regression results and the identity description of the live pigs market.

The equation that starts the processed pork market is the identity that connects both the markets together. Data used for it and how it is calculated is elaborately explained in chapter six. The next item on hand is the retail price of pork. The same small open economy argument put forward in chapter four will be used here. Using the same assumption it can be argued being a small open economy Canadian pork price is decided based on the large US pork market. The price of pork should be effected by its total supply. This is why pork retail price is regressed not only against US price but also against local pork meat supply. Although table 10 shows meat supply doesn’t have statistically significant effect but the effect of US prices is significant. Exchange rate is not added as variable here because the landed price for US retail price has been used which takes care of the exchange rate. The pork retail price results suggest one CAD increase in the US landed pork price will increase the Canadian index pork price by 7.04 units.

It has already been discussed in chapter six that due to lack of variability in available data meaningful result could not have been obtained for the demand for pork equation.
This has lead to using the coefficient of the demand equation from a different study which is elaborately discussed in the methods section of chapter six. Table 10 shows that the variables have the signs expected from conventional demand theory with own price having a negative effect on demand and cross prices and income having a positive effect.

The method section in chapter six also highlights that the trade equations i.e. net exports to the US and ROW are conducted using monthly data. Since the objective of the paper is to see the effects of a disease outbreak among other things on trade flows, net trade flows has been used for both trade equations. Net exports to the US has a positive significant influence from the US price and previous net trade with the US. If landed US price of pork changes by a dollar that induces trade of pork by 615.79 kilograms. On the other hand retail price of pork in Ontario has a negative significant effect on net trade with ROW whereas the Japanese pork price and lagged of net trade has a positive significant effect net trade with ROW. Effect of Japanese exchange rate is not statistically significant. The final equation in the model is the market clearing identity that represents the provincial trade of pork. With lack of official data on pork trade across provinces in Canada, this identity give the direction of pork trade of Ontario with other provinces. The negative result of this identity suggests that Ontario is a net importer of pork. Having the largest population base and good trading relationship with the US it is likely that Ontario import from other provinces.

6.2 Calibration

Calibration results of the constructed model are reported in table 11 and 12. The results are presented as following: first column has the variable names and their unit of measurement. The second column contains the values of baseline year of the variables followed by their calibrated value in the third column along with (in parenthesis) how much the calibrated values differ from their baseline counterpart expressed in percentage. The next four columns present the outcomes of the simulations which will be discussed later in the chapter. Closer observation of the calibrated results reveals that the Other disp varialbe is 31.21% off of the
baseline value but all the other calibrated values showed in table[11] are within ± 0% to 13% of their actual values. Table [12] shows except for the net pork export variables, calibrated values of the remaining variables are within ± 0% to 8% of their actual value. The calibrated values of the net exports to the US and ROW however are respectively -16.05% and -29.40% different from the baseline value. Overall for all the 14 variables calibration results were fairly consistent and closer to its actual baseline value.

6.3 Simulation

It has been mentioned in chapter one that two hypothetical scenarios would be created to observe the effects of a trade embargo imposed to counter a Ontario wide disease outbreak. A trade embargo is likely to adversely affect the Ontario pork industry. However given the nature of the pork industry in chapter three it is more likely that long run consequences would be more challenging than the short run. Depending on the nature of the disease outbreak, trade embargo can be imposed on various magnitude. If the severity is minimal then partial embargo could be imposed by the US only whereas a massive outbreak could result in an embargo from other provinces within Canada as well. To get an idea how trade embargo would affect the Ontario pork industry, the thesis considers two scenarios which differ in their magnitude of trade embargo. For this thesis only embargo from the US is considered but the constructed model is capable of studying embargo on a larger scale. One implicit assumption for both the scenarios is Canadian Food Inspection Agency’s (CFIA) provincial zoning efforts are recognized by international jurisdictions. This zoning by CFIA means that CFIA identifies the infected zones and controls the movement of live pigs from those zones. This control helps mitigate the spread of disease outside of the infected area. With the zoning in place other provinces feel comfortable in importing live pigs and pork from Ontario.

Studying the effects through hypothetical scenario is beneficial. A simulation scenario provides insight on the possibilities of what might happen. The main benefit of it is, it
provides opportunity to take precautions in the event of an actual outbreak. Precautions help mitigate the actual damage of an outbreak to the industry. This portion of the chapter is going to discuss the trade embargo and the effects of the embargo as per the simulation results.

6.3.1 Scenario 1

The first hypothetical scenario assumes there is a small scale disease outbreak in few specific regions of Ontario. The disease is contagious and can spread to other pigs through the infected ones. Moreover, unlike PED, the disease is not such that consumption of pork will not have any effect. The outbreak of it is contained in few specific regions hence the US can still import from other regions of Ontario safely. This leads the US to restrict trade from the specific infected regions. For this study it is assumed that the US ended up restricting 50% import of both live pigs and pork from Ontario. The outbreak of the disease is at a level where the provincial trade is not restricted. This means, although Ontario’s trade with the US is restricted, Ontario is still trading with other provinces as before. In a crisis situation of international trade restriction, provincial trade of Ontario would play critical role in mitigating the damage caused by the US trade restriction. The baseline scenario results of the study are with no trade restrictions. The restriction of 50% is chosen as a simulation scenario for the study because it is equidistant from no trade restriction and full trade embargo. Benefit of this scenario is, it will provide insight of an intermediate trade restriction. It can be anticipated that this restriction from the US would push Ontario to trade its live pigs to Manitoba and Quebec more. The reduction in pork exports to the US due to restriction can be compensated by less imports from other provinces.

Large number of live pigs and great amounts of pork are exported to the US from Ontario, hence a 50% restriction is likely to have an immense impact on the industry. Middle two columns in table 11 and 12 reports the effects of a 50% trade cut down. The study only focuses on the short run effects meaning it only observes the effects on the same time period.
It is implicitly assumed that the trade restriction wouldn’t affect any of the variables that are decided prior to the international live pigs trade. The reason for this assumption is, data for most of the variables used in the model is available on a six months basis hence any change to the variables decided prior to the trade restriction cannot be accounted for in the same time period. Referring back to figure 2, market hog price, size of the breeding stock, pig crop supply and total hog supply in the model are decided before the decision on international live pig exports. These four variables won’t be affected in the short run because of the trade restriction. In the event the study is extended to incorporate the effects on the next period, then all the prior variables, including the market hog price would reflect major changes. A graphical representation will make it easy to visualize the changes occurring from the trade restrictions.

The null effect on the first four variables is visible in the graph. As the reduction of trade in live pigs by 50% is the created situation that is not depicted in the graph. This reduction causes the hog slaughter to go up but by a very small amount 0.76%. This increase can be brought upon by increasing working shifts (overtime, weekend shifts) in the processing plants. The reason for the that increase isn’t big is mainly due to existing capacity constraint of processing plants in Ontario and the fact that hog slaughter cannot be increased sharply on a short notice. The Other Disp variable would remain unchanged for reasons described in chapter four. The main effect of trade embargo in live pigs is borne by the Interprovincial exports of live pigs. Quebec and Manitoba has excess capacity to process hogs and that pushes the pigs that can’t be exported internationally to be exported to those provinces and be processed. In the short run, the quickest response for the farmers is to sell the pigs to the other provinces and utilize their excess capacity. It is however assumed for simplicity that farmers are utilizing their barns full capacity hence holding the hogs in the barns is not a viable option.

The bottom portion of the figure depicts the changes of the processed pork market. The production of pork is 0.76% higher in this counter-factual scenario because the number
of hogs slaughtered went up. This equation links both the markets together and the effects of changes in the live pigs market is translated into the processed pork market through this equation. As the increase in hog slaughter was trifle considering the size of the pork industry, this excessive supply doesn’t really create a pressure on the market prices for pork. The increased supply reduces the retail pork price by 0.05% which is very negligible. Such a small price reduction doesn’t have any effect on the Ontario pork demand. This scenario considers a reduction of pork exports by 50% as well from the US. The 50% reduction in
exports to the US brings a greater change in the net exports to the US which is shown in table 11 but as this is created situation, it is not shown in the 6. The restriction on pork exports to the US doesn’t affect the net exports to the ROW a great deal as international trade to the ROW is not contingent upon trade with the US but the slight reduction in price increases net exports to ROW by 0.01%. The effect of pork exports restriction is reflected in the net provincial imports which reduces by almost 23%.

6.3.2 Scenario 2

The second hypothetical scenario assumes there is a disease outbreak on a larger scale in Ontario. The disease is similarly contagious as the first scenario renders consumption of pork is also dangerous. The outbreak in this scenario of is spread sporadically in Ontario and not contained in few regions. This makes importing from Ontario for US risky and unsafe. This forces the US to restrict trade from Ontario altogether and impose a trade embargo of 100%. For this scenario as well the outbreak of the disease is at a level where the provincial trade is not unsafe because of CFIA zoning and hence not restricted. This means although Ontario’s trade with the US is fully restricted, Ontario can still trade with other provinces as before. In a crisis situation of international trade restriction, provincial trade of Ontario would play critical role in mitigating the damage caused by the US trade restriction. This scenario would help understand what would happen to the industry if our largest trading partner stops trading.

As mentioned in this scenario the scale of the outbreak was large enough that the US response is to impose a full trade embargo on both live pigs and pork. Two columns on the right of in table 11 and 12 contains the outcomes of a full trade embargo from the US. For the convenience of visualization, the outcome of the second scenario is also depicted graphically in figure 7. This scenario studies the short run effects as well meaning it is only looking into the effects on the same time period hence the trade restriction wouldn’t affect variables decided prior to international live pigs trade.
The null effect on the first four variables sustains in this scenario and is visible in figure 7. Under scenario 2, hog slaughter increases by 1.52%, larger than the change in scenario 1 because there is a larger number of hogs not traded and need to be slaughtered. The effect of the full live pig exports restriction would be on the provincial live pig imports as before. As the two neighbouring provinces Quebec and Manitoba have the processing capacity, the non-traded live pigs would be traded interprovincially resulting in an increase of interprovincial exports by 348.38%.
As more hogs were slaughtered under this counter-factual scenario the increase in pork supply is also higher for this scenario. Pork supply increases by 1.52% in this case and the larger increase in pork supply would have a downward pressure on the pork retail price, pushing price down by 0.09%. The reduction in price is still not large enough to bring about a major change in pork demand. Pork demand increases by 0.1% which is very negligible. Net exports to ROW under this scenario increases by 0.02% because of a reduction in price by 0.09%. Under the full restriction, the trade embargo will result in lesser import from other provinces and the reduction as show in figure[4] would be 46.48%. It is evident from the discussion that the net trade with ROW is not a function of net trade with the US hence trade embargo with the US in the short run will not have a major effect on the net trade with the ROW. With the US enforcing the trade embargo the pork that couldn’t go out would have to be consumed in Ontario leading to a reduction of provincial imports as shown by the simulations results.

6.3.3 Simulation Summary

The main takeaway from both the simulated scenarios is that as long as Ontario can trade live pigs with the other provinces and those provinces don’t face trade embargo from the US or any other international community, the effects of the trade embargo on the Ontario pork industry wouldn’t have a devastating effect. As long as Ontario can continue trading live pigs to the other provinces the damage to the industry from the disease outbreak would remain low. It needs to be emphasized that the reason other provinces continued trading with Ontario was because of the assumption that CFIA imposed provincial zoning. If this zoning was not recognized and other provinces stopped trading with Ontario or the US stopped trading with the other provinces then the Ontario pork industry would have faced damages from drastic price reduction and animal depopulation.
<table>
<thead>
<tr>
<th>Description</th>
<th>MH Price (in CAD)</th>
<th>Breeding Stock (in 1000 hogs)</th>
<th>International Exports (in 1000 hogs)</th>
<th>Hog Slaughter (in 1000 hogs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH Price</td>
<td>0.150*</td>
<td>-5.457*</td>
<td>-4.009***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(2.266)</td>
<td>(0.719)</td>
<td></td>
</tr>
<tr>
<td>Corn Price (in CAD)</td>
<td>0.083</td>
<td>6.381**</td>
<td>2.286**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
<td>(2.032)</td>
<td>(0.705)</td>
<td></td>
</tr>
<tr>
<td>US MH Price (in USD)</td>
<td>3.964 ***</td>
<td></td>
<td>28.280 *</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.376)</td>
<td></td>
<td>(11.700)</td>
<td></td>
</tr>
<tr>
<td>Exchange Rate (in CAD)</td>
<td>58.945 ***</td>
<td>37.712 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(10.128)</td>
<td>(8.277)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MH Price Lagged</td>
<td>0.272 **</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breeding Stock Lagged</td>
<td>0.992 ***</td>
<td></td>
<td>2.102*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td></td>
<td>(0.816)</td>
<td></td>
</tr>
<tr>
<td>US Corn Price (in USD)</td>
<td></td>
<td>-363.700 **</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(121.800)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Hog Supply (in 1000 hogs)</td>
<td></td>
<td>0.403 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.039)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>International Export</td>
<td></td>
<td></td>
<td>-0.041</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.115)</td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.9004</td>
<td>0.9809</td>
<td>0.907</td>
<td>0.6563</td>
</tr>
<tr>
<td>F Statistic</td>
<td>94.47</td>
<td>410.8 on 4</td>
<td>61.44</td>
<td>16.28</td>
</tr>
</tbody>
</table>

Note:  \( P < 0.001 = ***; P < 0.01 = **; P < 0.05 = *; P < 0.1 = . \)
Standard Errors are in Parenthesis

Table 9: Regression Results - Live Pig Market
<table>
<thead>
<tr>
<th>Description</th>
<th>Retail Price</th>
<th>Pork Demand (1000 kg)</th>
<th>Net Export US (1000 kg)</th>
<th>Net Export ROW (1000 kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail Price</td>
<td>-0.795***</td>
<td>-22.5716</td>
<td>-58.510***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.232)</td>
<td>(16.189)</td>
<td>(15.870)</td>
<td></td>
</tr>
<tr>
<td>US Retail Price (USD)</td>
<td>7.043**</td>
<td></td>
<td>615.797*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.229)</td>
<td></td>
<td>(252.376)</td>
<td></td>
</tr>
<tr>
<td>Meat Supply (1000 kg)</td>
<td>-0.026</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.078)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef Price (index)</td>
<td></td>
<td>0.724 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.133)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken Price (index)</td>
<td></td>
<td>0.109 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.277)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per Capita GDP (CAD)</td>
<td></td>
<td>0.008 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.007)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Export US Lagged</td>
<td></td>
<td>0.786 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.044)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japanese Retail Price (index)</td>
<td></td>
<td></td>
<td>69.630 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(22.880)</td>
<td></td>
</tr>
<tr>
<td>Japanese Exchange Rate (CAD)</td>
<td></td>
<td></td>
<td>18500</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(66380)</td>
<td></td>
</tr>
<tr>
<td>Net Export ROW Lagged</td>
<td></td>
<td>0.562 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.058)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.3393</td>
<td>0.74</td>
<td>0.7007</td>
<td>0.4866</td>
</tr>
<tr>
<td>F Statistic</td>
<td>9.215</td>
<td>158.6 on 3</td>
<td>48.86</td>
<td></td>
</tr>
</tbody>
</table>

Note: $P < 0.001 = ***; P < 0.01 = **; P < 0.05 = *; P < 0.1 = .$

Table 10: Regression Results - Processed Pork Market
<table>
<thead>
<tr>
<th>Variables</th>
<th>Baseline</th>
<th>Calibrated</th>
<th>Simulated Result 50%</th>
<th>% Change</th>
<th>Simulated Result 100%</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH Price</td>
<td>152.88</td>
<td>133.32 (-12.79%)</td>
<td>133.32 0%</td>
<td>133.32 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breeding Stock</td>
<td>313.1</td>
<td>316.16 (0.97%)</td>
<td>316.16 0%</td>
<td>316.16 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply of Pig Crop</td>
<td>3758.8</td>
<td>3795.63 (0.97%)</td>
<td>3795.63 0%</td>
<td>3795.63 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Hog Supply</td>
<td>6901.1</td>
<td>6937.93 (0.53%)</td>
<td>6937.93 0%</td>
<td>6937.93 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>International Export</td>
<td>769.80</td>
<td>814.42 (5.79%)</td>
<td>407.20 -50.0%</td>
<td>0 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hog Slaughter</td>
<td>2036.75</td>
<td>2188.43 (8.78%)</td>
<td>2205.08 0.76%</td>
<td>2221.73 1.52%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Disp</td>
<td>572.74</td>
<td>421.07 (-31.21%)</td>
<td>421.07 0%</td>
<td>421.07 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interprovincial Export</td>
<td>232</td>
<td>224.22 (-3.35%)</td>
<td>614.78 174.19%</td>
<td>1005.34 348.38%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The value in parenthesis is the percentage difference between baseline and calibrated data

Table 11: Calibration and Simulation Results - Live Pig Market
<table>
<thead>
<tr>
<th>Variables</th>
<th>Baseline</th>
<th>Calibrated</th>
<th>Simulated Result 50%</th>
<th>% Change</th>
<th>Simulated Result 100%</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pork Meat Production</td>
<td>207.89</td>
<td>223.37 (7.45%)</td>
<td>225.07</td>
<td>0.76%</td>
<td>226.76</td>
<td>1.52%</td>
</tr>
<tr>
<td>Retail Pork Price</td>
<td>103.42</td>
<td>97.51 (-5.90%)</td>
<td>97.47</td>
<td>-0.05%</td>
<td>97.42</td>
<td>-0.09%</td>
</tr>
<tr>
<td>Pork Consumption</td>
<td>118654.53</td>
<td>119254.70 (0.51%)</td>
<td>119254.70</td>
<td>0%</td>
<td>119254.80</td>
<td>0.1%</td>
</tr>
<tr>
<td>Net Export to US</td>
<td>4602.08</td>
<td>3863.36 (-16.05%)</td>
<td>-30004.24</td>
<td>-676.64%</td>
<td>-64610.56</td>
<td>-1572.39%</td>
</tr>
<tr>
<td>Net Export to ROW</td>
<td>34642.07</td>
<td>24435.45 (-29.46%)</td>
<td>24438.08</td>
<td>0.01%</td>
<td>24440.71</td>
<td>0.02%</td>
</tr>
<tr>
<td>Net Provincial Trade</td>
<td>-157690.8</td>
<td>-147330.10 (-6.57%)</td>
<td>-113463.50</td>
<td>22.99%</td>
<td>-78858.15</td>
<td>46.48%</td>
</tr>
</tbody>
</table>

Note: The value in parenthesis is the percentage difference between baseline and calibrated data.

Table 12: Calibration and Simulation Results - Processed Pork Market
7 Summary

The purpose of this thesis was to estimate the economic consequences of a disease outbreak on the Ontario pork industry. The thesis uses a partial equilibrium model to simulate a disease outbreak and observe its effects on the industry. The effects of BSE outbreak on the cattle industry in 2003 amplifies the necessity of ex ante analysis of this sort. The study focuses on the short run effects on different stages of the hog value chain of a hypothetical disease outbreak. The results obtained are important to observe as they reveal necessary information on potential outcome of an actual disease outbreak. Major benefit of this exercise is that understanding the direction of potential effects and taking necessary steps in tackling them can reduce the severity of such outbreaks. Especially for an industry that is heavily depended on trade, future trade with partners can be hampered if disease outbreaks are not efficiently dealt with. Having a concentrated trade market with the US is critical for Canada because in the event of any disease outbreak, trade embargo from the US poses a major risk. As we found from the analysis, trade embargo from the US has major implications for provincial trade both in the live pigs and the pork market. Given the provincial borders remained functioning during the embargo, it resulted in less effect on price and demand of pork in the short run but the effects would likely magnify if the provincial borders are also shut down.

The study uses the hog value chain as the basis for constructing the model. The hog value chain outlines the different stages of pigs life starting from deciding the size of the breeding stock to the number of hogs that are slaughtered along with the trade taking place at different stages. Deciding the size of the breeding stock is the most important first step for the farmers as a lot of the farming decisions depends on this crucial first step. Roughly two pig crops per year are born with an average of 12-13 piglets born alive per litter. The piglets are kept with the mother sow for a brief period of time and then weaned off to go through the subsequent life stages namely weaner pig stage, feeder pig stage and market pig stage. Each stage has its own significance in terms of feeding and taking special care. Pigs
are traded across all the life stages and it’s mostly exported to the US and other provinces. The high volume of life pigs trade with the US emphasizes the necessity of the study. An important finding of the study was provincial trade of live pigs, in the short run will envelope the pigs that are not traded internationally because of the trade restrictions. This plays an important role in preventing major losses to the industry. The non-traded pigs that grow to market weight are sold to the processing plants were they are processed to produce pork. As per the findings of the study, both the simulated trade restrictions result in increased number of hog slaughter and higher production of pork. Important thing is, Ontario is faced with a processing capacity constraint which restricts the increase in hog slaughter and pork production. For this, in the short run the price of pork does not get affected a great deal. Ontario’s pork trade with the US and other provinces is somewhat complicated because Ontario has a large population base and shares borders with the US. Data showed Ontario exports and imports pork to and from the US and results of the thesis found Ontario to be a net importer of pork on provincial trade. The simulations suggested when facing the trade restrictions, Ontario would import less from the provinces in the short run. The effects from the trade restrictions simulated here are likely to be very different in the long run. This is very intuitive to comprehend as in the long run factors effecting the price and demand of pork and live pigs are likely to vary under the restricted trade scenarios. As the value chain incorporates all the stages of a pig’s life, this is great tool for using as the basis of constructing the partial equilibrium model.

Partial equilibrium model is an effective tool for conducting simulation on industries like the Ontario pork. Given its size and its contribution to the Ontario economy, a general equilibrium model would have required more data and more restriction on estimated parameters. In comparison to that, partial equilibrium models impose lesser restriction on its parameters and requires less data. Another important distinction is partial models allow for more detailed analysis of a particular industry. As the purpose of the thesis is to understand the consequences of a disease outbreak on the Ontario pork industry, use of the
partial equilibrium model provided better insight of the effects on industry for the hypothetical counterfactual scenario. The partial equilibrium model is constructed taking into consideration the specification of the Ontario pork industry. The model mathematically represents various market participants of the pig value chain and their relationship to the industry. The live pigs market and the processed pork market are represented as separate market segments in the model. The model is constituted of 8 equations containing a total of 29 estimated parameters (16 in the live pigs market and 13 in processed pork market) and 6 identities of which 2 are market clearing identities for both the markets. The model contains the price determination of market hogs as the first equations as this is an important determinants for all the other variables. The market hog price along with other variables, affects the selection of breeding stock size represented by the second equation. Next six equations and identities reveal how many piglets enter the system, how many get exported internationally at different stages of life and upon reaching certain weight level how and many are marketed for slaughtering while the remainder are traded interprovincially. This allows for studying the effects of the trade restrictions on different market participants. The processed pork market has separate equations for detailed analysis as well. It incorporates pork price determination, its demand and trades with various parties.

The regression conducted reveal interesting results. Market price of hogs and pork has statistically significant effect on several of the variables in the model and the market prices has significant relationship with exchange rates meaning fluctuations in the exchange would have important implications for the model. Effects of feed cost represented by corn price are important factors in driving the international exports. Positive effect of feed cost on hog slaughter suggest farmers prefer to sell their hogs to processing plants than keeping them and incur high feed cost. Main takeaway from the simulation models are closing the international borders would result in higher interprovincial trade for live pigs but lower provincial imports of pork for Ontario. Trade restrictions from the US doesn’t really effect the other trading partners but this may have a different long run outcome.
The constructed model has several future research potentials as well. The model can simulate effects of: disease outbreak, exchange rate volatility, market hog and pork price volatility, variation in birth and death rate, increased and/or decreased provincial and international trade, various economic shocks on both demand and supply side, increased/decreased slaughter capacity, Shock on the US price etc. The finding of this thesis is very helpful in understanding the US trade restrictions effects in the short run on the Ontario pork industry.
References


8 Appendix

8.1 Codes for Regressions and Identities

```
setwd("c:/D - Stuff")
data1 <- read.csv(file.choose(), header = TRUE, sep = ",")
data <- as.data.frame(data1)
attach(data)
result1 <- lm(MH_Price.CPI.Adj US.MH.Price.CPI.Adj + Can.US.Ex RATE +
               MH_Price.CPI.Adj.Lagged1)
summary(result1)
result2 <- lm(Breeding.Stock MH_Price.CPI.Adj + Corn_Price.CPI.Adj +
               Breeding.Stock.Lagged1 + Can.US.Ex RATE)
summary(result2)
spc <- Breeding.Stock * Pigs.born.alive.per.litter
tot_hog_supply <- Beginnig.Inventory + spc + Interprovincial.imports.of.hogs +
                   International.imports.of.hogs
result5 <- lm(International.exports.of.hogs..8. MH_Price.CPI.Adj +
               US.MH.Price.CPI.Adj + US.Corn.Price.CPI.Adj +
               Corn_Price.CPI.Adj + tot_hog_supply)
summary(result5)
result6 <- lm(Hog.Slaughter MH_Price.CPI.Adj + Corn_Price.CPI.Adj +
summary(result6)
other_disp <- OtherDisposition - Hog.Slaughter
Interprov.exports.of.hogs <- tot_hog_supply -
(International.exports.of.hogs..8. + Deaths + other_disp + Hog.Slaughter +
Ending.Inventory)
meat_prod.1000.kg <- (Hog.Slaughter * Average.Warm.Carcass.Weight)/1000
```
result7 <- lm(Fresh.or.frozen.pork.Index.CPI.Adj
US.All.Pork.Chops.Price.per.pound.Landed.CPI.Adj + meat.prod.1000.kg)
summary(result7)

# Estimates for demand equation: Calculating the intercept
beta1 <- -0.795
beta2 <- 0.724
beta3 <- 0.109
beta4 <- 0.008

# Intercept for 2015 2
alpha <- pork.cons.in.1000.kg[32] -
(beta1*Fresh.or.frozen.pork.Index.CPI.Adj[32]) +
(beta2*Fresh.or.frozen.beef.Index.CPI.Adj[32]) +
(beta3*Fresh.or.frozen.chicken.Index.CPI.Adj[32]) +
(beta4*Per.Capita.GDP.ON[32])

# Monthly Data Start setwd(“c:/D - Stuff”)
data2 <- read.csv(file.choose(), header = TRUE, sep = “,”)
data1 <- as.data.frame(data2) attach(data1)
US.Pork.Price.CPI.Adj.m.landed <- US.Pork.Price.CPI.Adj.m *
Can.US.Exchange.Rate.m
japan.pork.price.CPI.Adj.landed.m <- Pork.A.CPI.Adj.m *
Japanese.Exchange.Rate.m

result9 <- lm(Net.Export.US.m US.Pork.Price.CPI.Adj.m.landed +
Fresh.or.frozen.pork.CPI.Adj.m + Net.Export.US.lagged1.m)
summary(result9)

result10 <- lm(Net.Export.ROW.m Pork.A.CPI.Adj.m +
Japanese.Exchange.Rate.m + Fresh.or.frozen.pork.CPI.Adj.m +
Net.Export.ROW.lagged1.m)
summary(result10)

# Monthly Data End

net.prov.pork.trade<- meat_prod.1000.kg - (pork.cons.in.1000.kg +
Net.Exorts.to.US + Net.Exports.to.ROW)

8.2 Codes for Calibration

cal.MH.price<- result1$coefficients[1] + (result1$coefficients[2] *
US.MH.Price.CPI.Adj[32]) + (result1$coefficients[3] *
Can.US.Ex.Rate[32]) + (result1$coefficients[4] *
MH_Price_CPI_Adj_Lagged1[32])

cal.bs <- result2$coefficients[1] + (result2$coefficients[2] *

cal.spc<- cal.bs * Pigs.born.alive.per.litter[32]

cal.tot_hog_supply<- Beginnig.Inventory[32] + cal.spc +

cal.Int.exp.hog<- result5$coefficients[1] +
US.MH.Price.CPI.Adj[32]) + (result5$coefficients[4] *
US.Corn.Price.CPI.Adj[32]) + (result5$coefficients[5] *

cal.hog.slaughter <- result6$coefficients[1] +
Corn.Price.CPI.Adj[32]) + (result6$coefficients[4] *

cal.other.disp <- Other.Disposition[32] - cal.hog.slaughter
cal.Interprov.exports.of.hogs <- cal.tot_hog_supply -
(cal.Int.exp.hog + Deaths[32] + cal.other.disp + cal.hog.slaughter +
Ending.Inventory[32])

cal.meat_prod.1000.kg <- (cal.hog.slaughter *
Average.Warm.Carcass.Weight[32])/1000

cal.Fresh.or.frozen.pork.Index.CPI.Adj <- result7$coefficients[1] +
(result7$coefficients[3] * cal.meat_prod.1000.kg)

cal.pork.cons.in.1000.kg <- alpha + (beta1 * cal.Fresh.or.frozen.pork.Index.CPI.Adj) +
(beta2 * Fresh.or.frozen.beef.Index.CPI.Adj[32]) +
(beta3 * Fresh.or.frozen.chicken.Index.CPI.Adj[32]) +
(beta4 * Per.Capita.GDP.ON[32])

(result9$coefficients[3] * cal.Fresh.or.frozen.pork.Index.CPI.Adj) +

(result10$coefficients[2] * japanese.pork.price) +
(result10$coefficients[4] * cal.Fresh.or.frozen.pork.Index.CPI.Adj) +

Cal.net.prov.trade <- cal.meat_prod.1000.kg -

8.3 Codes for First Simulation

sim1.MH.Price <- result1$coefficients[1] + (result1$coefficients[2]
* US.MH.Price.CPI.Adj[32]) + (result1$coefficients[3] *
Can.US.Ex.Rate[32]) + (result1$coefficients[4] *
MH_Price_CPI_Adj_Lagged1[32])

    sim1.bs <- result2$coefficients[1] + (result2$coefficients[2] * 
    sim1.MH.Price + (result2$coefficients[3] * Corn_Price.CPI.Adj [32]) + 
    (result2$coefficients[5] * Can.US.Ex.Rate[32])

    sim1.spc <- sim1.bs * Pigs.born.alive.per.litter[32]

    sim1.tot.hog.supply <- Beginnig.Inventory[32] + sim1.spc + 

    sim1.int.exp.hog <- (cal.Int.exp.hog * 0.50)

    sim1.hog.slaughter <- result6$coefficients[1] + 
    * Corn_Price.CPI.Adj[32]) + (result6$coefficients[4] * 

    sim1.other.disp <- OtherDisposition[32] - cal.hog.slaughter

    sim1.Interprov.exports.of.hogs <- sim1.tot.hog.supply - 
    (sim1.int.exp.hog + Deaths[32] + sim1.other.disp + sim1.hog.slaughter + 
    Ending.Inventory[32])

    sim1.meat.prod.1000.kg <- (sim1.hog.slaughter * Average.Warm.Carcass.Weight[32])/1000

    sim1.Fresh.or.frozen.pork.Index.CPI.Adj <- result7$coefficients[1] + 
    (result7$coefficients[2] * 
    US.All.Pork.Chops.Price.per.pound_Landed.CPI.Adj[32]) + 
    (result7$coefficients[3] * sim1.meat.prod.1000.kg)

    sim1.pork.cons.in.1000.kg <- alpha + 
    (beta1 * sim1.Fresh.or.frozen.pork.Index.CPI.Adj) + 
    (beta2 * Fresh.or.frozen.beef.Index.CPI.Adj[32]) + 
    (beta3 * Fresh.or.frozen.chicken.Index.CPI.Adj[32]) + 
    (beta4 * Per.Capita.GDP.ON[32])
\[
\text{sim1.Net.Export.US} \leftarrow (\text{Export.to.US.1000.kilograms}[32] \times 0.50) - \\
\text{Import.from.US.1000.kilograms}[32]
\]
\[
\text{sim1.Net.Export.ROW} \leftarrow \text{result10}\$coefficients[1] + \\
(\text{result10}\$coefficients[2] \times \text{japanese.pork.price}) + \\
(\text{result10}\$coefficients[3] \times \text{Japanese.Exchange.Rate}) + \\
(\text{result10}\$coefficients[4] \times \text{sim1.Fresh.or.frozen.pork.Index.CPI.Adj}) + \\
(\text{result10}\$coefficients[5] \times \text{Net.Exports.to.ROW.lagged}[32])
\]
\[
\text{sim1.net.prov.trade} \leftarrow \text{sim1.meat prod.1000.kg} - \\
(\text{sim1.pork.cons.in.1000.kg} + \text{sim1.Net.Export.US} + \text{sim1.Net.Export.ROW})
\]

### 8.4 Codes for Second Simulation

\[
\text{sim2.MH.Price} \leftarrow \text{result1}\$coefficients[1] + (\text{result1}\$coefficients[2] \times \text{US.MH.Price.CPI.Adj}[32]) + (\text{result1}\$coefficients[3] \times \text{Can.US.Ex.Rate[32]}) + \\
(\text{result1}\$coefficients[4] \times \text{MH_Price_CPI_Adj_Lagged1}[32])
\]
\[
\text{sim2.bs} \leftarrow \text{result2}\$coefficients[1] + (\text{result2}\$coefficients[2] \times \text{sim2.MH.Price}) + (\text{result2}\$coefficients[3] \times \text{Corn_Price.CPI.Adj}[32]) + \\
(\text{result2}\$coefficients[4] \times \text{Breeding.Stock.Lagged1}[32]) + \\
(\text{result2}\$coefficients[5] \times \text{Can.US.Ex.Rate[32]})
\]
\[
\text{sim2.spc} \leftarrow \text{sim2.bs} \times \text{Pigs.born.alive.per.litter[32]}
\]
\[
\text{sim2.tot.hog.supply} \leftarrow \text{Beginnig.Inventory[32]} + \text{sim2.spc} + \\
\text{Interprovincial.imports.of.hogs}[32] + \text{International.imports.of.hogs}[32]
\]
\[
\text{sim2.int.exp.hog} \leftarrow 0
\]
\[
\text{sim2.hog.slaughter} \leftarrow \text{result6}\$coefficients[1] + (\text{result6}\$coefficients[2] \times \text{sim2.MH.Price}) + \\
(\text{result6}\$coefficients[3] \times \text{Corn.Price.CPI.Adj}[32]) + \\
(\text{result6}\$coefficients[4] \times \text{sim2.int.exp.hog}) + (\text{result6}\$coefficients[5] \times \text{Breeding.Stock.Lagged1}[32])
\]
\[
\text{sim2.other.disp} \leftarrow \text{Other.Disposition[32]} - \text{cal.hog.slaughter}
\]
\[
\text{sim2.other.disp} \leftarrow \text{Other.Disposition[32]} - \text{cal.hog.slaughter}
\]

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sim2.Interprov.exports.of.hogs <- sim2.tot.hog.supply - (sim2.int.exp.hog + Deaths[32]
+ sim2.other_disp + sim2.hog.slaughter + Ending.Inventory[32])

sim2.meat.prod.1000.kg <- (sim2.hog.slaughter * Average.Warm.Carcass.Weight[32])/1000

sim2.Fresh.or.frozen.pork.Index.CPI.Adj <- result7$coefficients[1] +
(result7$coefficients[3] * sim2.meat.prod.1000.kg)

sim2.pork.cons.in.1000.kg <- alpha + (beta1 *
sim2.Fresh.or.frozen.pork.Index.CPI.Adj) + (beta2 *
Fresh.or.frozen.beef.Index.CPI.Adj[32]) + (beta3 *
Fresh.or.frozen.chicken.Index.CPI.Adj[32]) + (beta4 *
Per.Capita.GDP.ON[32])


(result10$coefficients[2] * japanese.pork.price) +
(result10$coefficients[4] * sim2.Fresh.or.frozen.pork.Index.CPI.Adj) +

sim2.net.prov.trade <- sim2.meat.prod.1000.kg -