University of Alberta

Canada’s Beef Cattle Industry: Shocks, Cycles and Loan Guarantees

by

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Dedication

For my Parents

Abstract

This dissertation examines three issues crucial to the competiveness of Canada's beef cattle industry. The first study undertakes an *ex post* analysis of the impact of the U.S. country of origin labeling (COOL) law on U.S. imports of Canadian beef and cattle. The study employs a test of structural change that is able to endogenize break points and one that is able to detect end-of-sample structural breaks. Results suggest that COOL has led to significant reductions in U.S. imports of Canadian beef and cattle.

The second study examines the impacts of the appreciation of the Canadian dollar relative to the U.S. dollar and feed price escalation on Canadian cattle cycles. It estimates Canadian beef cattle cycles using total cattle inventories, beef cow inventories, beef supply, and beef prices. Spectral decomposition of the variables reveals ten-year cycles in total cattle inventories, beef cow inventories and beef supply, and an eight-year cycle in prices. Modeling exchange rate appreciation and feed price escalation as pure jumps, the study finds significant impacts of both shocks on total inventories, but beef supply appears to have been impacted only by exchange rates. A spectral comparison of the pre- and post-shock periodogram of beef supply reveals a 58% reduction in the peak amplitude of the beef supply cycle.

The third study deals with Alberta's Feeder Association Loan Guarantee Program. The purpose is to determine the extent of the risk exposure faced by commercial banks participating in the program, the value of the loan guarantee provided to cattle feeders through the program, and the subsidy embodied within

the program. Enterprise budgeting is combined with Monte Carlo simulation to capture production and price risk. A consolidated measure of risk is obtained and fed into option pricing models to estimate the value of the loan guarantee. Results suggest that feeding cattle is, indeed, a risky undertaking, and the resulting risk exposure to lenders is significant, especially with respect to backgrounding. Also, the study finds the price of the loan guarantee to be 4% to 5% of the loan amount, which is sufficient to offset the subsidy inherent in the program.

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CHAPTER ONE: INTRODUCTION

1.1 Background

The Canadian beef cattle industry is important to the Canadian economy. Comprised of cow-calf operations, backgrounding, feedlot finishing, beef processing (packing) and retailing, the industry contributes more than $20 billion to the country's economy annually from nearly 90,000 cattle producers (Beef Information Centre, 2009). The industry is the fourth largest cattle and beef exporter in the world, with a market share of 11% of global exports (Agriculture and Agri-Food Canada, 2010). But from 2004 to 2011, overall profitability in the industry declined (Canfax Research Services, 2011). This may be associated with the various shocks that have been experienced by the industry in the last ten years. The overall objective of this study therefore is to investigate the effects of these shocks on the industry, and to assess the cost to the government of a cattle loan guarantee program.

The Canadian beef cattle industry is highly dependent on export markets, exporting around 50% of beef and live cattle production (Canfax Research Services, 2011). Before the outbreak of Bovine Spongiform Encephalopathy (BSE) in May 2003, beef was exported to over 100 markets (Haney, 2010), compared to about 70 that are currently fully or partially open to Canadian beef (Canadian Cattlemen's Association, 2012). The U.S. historically has been the largest market for Canadian beef and cattle. Prior to the BSE crisis, over 70% of beef, and almost all cattle exports went to the U.S. (Grier, 2005). According to Miljkovic (2006), high dependence on trade means that domestic prices are much more vulnerable to exogenous shocks that may reduce trade flows. A shock in one output market will be transmitted across the border to the other output market via adjustments in demand and supply if there is price cointegration (Young and Marsh, 1998). In analyzing Canada-U.S. livestock market integration, Miljkovic finds that if there is a sudden fall in Canada's trade dependence in cattle and beef (measured by the ratio of cattle exports plus imports to marketed cattle), there will be a concomitant decline in Canadian cattle prices.

The vulnerability of the industry to exogenous shocks became apparent after the 2003 BSE crisis when all international markets were closed to live cattle and beef products from Canada, leading to considerable losses to the industry. More recently, the industry has been buffeted by several other shocks, namely, the 2008 introduction of mandatory country of origin labeling (COOL) by the U.S., a hike in feed prices due in part to the emergence of a bio-fuels market, exchange rate appreciation relative to the U.S., and a decline in real income due to the 2007/08 global economic crisis. Studies undertaken so far indicate that these shocks have had a negative impact on the competitiveness of Canada's hog and pork industry (Rude, Gervais and Felt, 2010; Rude, Wang and Unterschultz, 2010). According to the Beef Industry Alliance (2009), the industry is downsizing and declining as evidenced by a reduction in exports and producer prices, an increase in the slaughter of cows, and an increase in the proportion of heifers in cattle slaughter. Recent estimates by the U.S. Department of Agriculture (2010a) indicate that between January 2009 and January 2010, the Canadian cattle herd dropped to 11 million head, down 1.4 percent and the lowest in 15 years. Further, cattle exports in 2009 declined by 33 percent from the 1.6 million head exported in 2008, and beef exports fell by 3 percent in 2009 because of a reduction in exports to the U.S. U.S. total cattle inventories have also declined; they stand at 92.58 million head, the lowest since 1958 (Canfax and Canfax Research Services, 2011). But because prices are determined in the U.S. market, it is likely that these shocks have had a larger impact on the Canadian industry.

1.2 Problem Statement

The beef cattle industry in Canada and elsewhere exhibits strong cyclicality, and therefore any analysis of the industry's dynamics as well as interventions aimed at addressing its challenges and/or increasing its competitiveness should be undertaken through the lens of its cyclical character. For instance, the cattle cycle may have implications for the timing of investments in the industry; on one hand, counter-cyclical investment appears to be reasonable during a downturn because of the relatively low opportunity cost of capital, but on the other hand, substantially huge profits may accrue from pro-cyclical investment during an upturn (Tan and Mathews, 2010). But in the Canadian livestock sector where scale effects have been found to be more important than technical change in the growth of total factor productivity (Stewart *et al*., 2009), it would be helpful to understand the implications of the cattle cycle for the timing of policies that promote structural change, and conversely, the effect that structural change in the industry would have on the cycle.

A typical Canadian cattle cycle – measured as the time period from the lowest cattle inventory to the next lowest inventory – lasts about ten to twelve years, and has four distinct phases, namely, consolidation, expansion, peak, and liquidation. This cyclicality can be attributed to exogenous shocks in demand and supply coupled with time lags in production (Rosen *et al*., 1994; Aadland, 2004). An exogenous shock will initiate a cycle or alter an existing one, and the subsequent peaks and troughs will be driven by the mismatch between demand and supply caused by biological lags in production and producers' expectations about prices. The nearly 10% expansion in Canada's cattle herd between 1987 and 1993 was a result of low grain prices in western Canada at the time (Canadian International Trade Tribunal, 1993). The cattle herd again reached a record high of 15.1 million head in 2005, which was a result of lack of export markets for cattle following the BSE crisis (Canfax Research Services, 2009). The herd has since then been declining steadily following a series of shocks that have pushed prices down, hence eroding producer margins and equity. And even though prices recovered in 2011 reaching record levels for all classes of cattle, herd expansion has not occurred (Duckworth, 2012). Canfax Research Services (2011) predicted that the higher prices would not necessarily lead to higher profitability because of increasing input prices, and therefore herd expansion would be slower than expected.

Given that cattle cycles are a permanent feature of the industry and are fundamentally driven by shocks, the rationale for the analysis of the impact of shocks on the industry may not be apparent. However, to the extent that exogenous shocks, either singularly or in combination with one another may lead to changes in cyclical features, an investigation of their impacts is warranted.

Mixed market signals, uncertainty, trade barriers, and change in consumer demand may delay or even reverse the cattle cycle (Canfax Research Services). Currently, the Canadian beef cattle industry is contracting following a lack of profitability that has caused a mass exit of cattle producers (Duckworth, 2012). Between 2006 and 2011, cattle ranching farms decreased by 34% from 75,598 to 49,613 operations (Statistics Canada, 2011). The focus of this study therefore is to investigate the impacts of shocks, and to understand how best the industry should respond to avoid plummeting deeper into unprofitability and long-term contraction.

The first problem that the study will address is that in addition to some temporary market shocks that would normally be expected to bear on the cattle cycle, the industry has experienced a permanent exogenous policy shock in the form of the United States' mandatory country of origin labeling for meat products including beef. It is plausible that this shock will negatively affect price recovery in the cattle cycle, thus prolonging the industry's recovery. The contraction in cattle and beef exports to the U.S. may lead to shock-induced changes in the structural characteristics of the beef industry. The structure of an industry refers to the characteristics of both its productive activities and the relationships between the different activities (Goddard *et al*., 1993). Therefore structural change, which is a permanent and irreversible change often associated with a permanent exogenous shock, would imply changes in what is produced, how and where, and what is traded and with who (Goddard *et al*.). In essence, structural change is change in the industry agents' preferences and expectations, and subsequently changes in their optimal decision rules. As earlier noted, structural change is the major driver of productivity growth in Canada's livestock sector (Stewart *et al*., 2009). Moreover, productivity growth may in turn have implications for herd expansion or contraction (Marsh, 1999). Therefore detecting COOL-induced structural change in the industry's economic relationships is important in understanding changes, if at all, in the industry's cyclical patterns, and formulating appropriate industry policies.

The second issue concerns the effect of some of the recent shocks on the cattle cycle and on other cyclical industry variables. Formulating appropriate policy responses to shocks on the beef cattle industry remains a difficult challenge because of the complex relationships that characterize the industry. For instance, cattle producers have been observed to supply fewer cattle in the short-run following an increase in the price of beef (Aadland and Bailey, 2001; Jarvis, 1974; Rosen, 1987), a phenomenon which partly explains the cyclical nature of the industry. Also, government transfer programs have in some cases yielded unexpected results. For example, the Federal-Provincial BSE Recovery Program, implemented from June 2003 to July 2005, was meant to compensate cattle producers but it seems to have inadvertently depressed cattle prices even further during this time (Le Roy *et al.*, 2007). This behavior suggests that perhaps any response to a shock on the industry should occur only if the shock has the potential to significantly deepen or lengthen the troughs of cycles of relevant industry variables. Otherwise, cycle peaks and troughs may be amplified by policy interventions and not necessarily by the shocks that they are meant to counteract.

The third problem is the issue of increasing cattle feeders' access to credit. The Canadian Agricultural Loans Act provides for a federal loan guarantee program for loans intended for the establishment and improvement of farms and for the processing and marketing of farm products. Also, various provincial governments provide loan guarantees to prospective cattle feeders to enable them access the capital they need to start their operations, and to existing feeders to expand their operations and remain profitable. In light of the decreased profitability and uncertainty caused by the recent market and policy shocks, it is not very clear what the cost of such guarantees would be to the tax payer and if the programs are viable. This calls for an evaluation of the cost of government-backed loan guarantee programs.

1.3 Study Objectives, Contribution and Overview of Thesis

This study examines the impact of shocks and exogenous variables on the Canadian beef cattle industry, and evaluates the cost of a government loan guarantee program. It has three specific objectives:

i. To determine whether or not there has been structural change in U.S. import demand for Canadian cattle and beef as a result of mandatory country of origin labeling.

ii. To examine the nature of and changes in cycles of cattle inventories, beef output and beef prices.

iii. To the extent that shocks create uncertainty and increase risk, the study evaluates the risk in cattle feeding, and the cost of the cattle loan guarantee provided by the Alberta government through the Feeder Association Loan Guarantee Program (FALGP).

Overall, the dissertation makes an empirical contribution to understanding: a) the effects of shocks on the Canadian beef cattle industry, and b) the value of the loan guarantee provided to cattle feeders through the Alberta Feeder Association Loan Guarantee Program. The industry has in the last decade experienced several policy and market shocks that are believed to have caused welfare losses in the industry. The introduction of mandatory country of origin labeling by the U.S. has disrupted U.S. imports of Canadian cattle, and to some extent beef. As a result, Canada has been engaged in a legal battle with the U.S. in the WTO since April 2010, and is not satisfied with the recent amendments to the law following the WTO's ruling. The case is yet to be resolved and therefore this dissertation provides *ex post* evidence of the impact of the law, which may be helpful in resolving the case or generating debate on policy options for mitigating the impacts of the law. Another contribution of this dissertation is that it provides evidence of the effectiveness of two relatively new tests of structural change – the Bai and Perron (1998, 2003) test and Andrews (2003) test.

Market shocks may affect different segments of the beef cattle industry differently, and the effects may be either short- or long-term. One way to understanding the long-term effects of shocks on the entire industry is to analyze the effects in the context of cattle cycles. The last study on Canadian cattle cycles was undertaken over forty years ago. It appears nothing has been done on the Canadian cycle since then because a lot more work has been done on the U.S. cattle cycle, which has historically been closely synchronized with the Canadian cycle as the two industries have been highly integrated. But after 1987, there was a divergence between the two cycles because of market shocks (Canfax Research Services, 2009). This dissertation therefore contributes up-to-date information to existing literature on the nature of the Canadian cattle cycle, and to the best of my knowledge, it is the first attempt at quantifying the correlation between the effect of two of the previous decade's market shocks – exchange rate appreciation and feed price escalation – and changes in the cycle.

Last but not least, the dissertation establishes the value of Alberta's Feeder Association loan guarantee provided to cattle feeders by the provincial government. This information will be helpful in the on-going review of the FALGP, which requires information on the risk that the government faces in providing the guarantee. The dissertation demonstrates how the various sources risk in cattle feeding can be used to generate a consolidated measure of risk (volatility parameter) for use in option pricing models.

The remainder of the dissertation is organized as follows: Section 1.4 gives an overview of the Canadian and U.S. beef cattle industry, and section 1.5 provides background information on the four exogenous shocks that have affected the industry in the recent past. Section 1.6 will draw upon this background information to highlight and summarize the main focus of the three papers that will emanate from this study. Chapter two forms the first of the three papers of this dissertation. It explores the existing literature on structural change, provides the theoretical and empirical framework and data that are used for testing for structural breaks, and presents the results. Chapter three focuses on the second paper, which deals with changes in cyclical patterns of the previously mentioned industry variables. Here, literature is reviewed, spectral techniques are explained, and results are presented and discussed. Chapter four concerns the third paper. It defines the economic problem associated with loan guarantees, summarizes the structure of Alberta's Feeder Association Loan Guarantee Program, reviews the literature, and provides the appropriate analytical framework and empirical results. Chapter five summarizes the dissertation.

1.4 The Canadian beef cattle industry

Operations that characterize Canadian and U.S. beef cattle industries are very similar. The beef production chain is comprised of four major operations, namely, cow-calf, backgrounding, feedlot or finishing, and beef processing and packing. Cow-calf producers (ranchers) maintain a breeding stock that produces calves. Calves are weaned at six to eight months weighing between 220 and 250 kg, and are then placed into backgrounding operations, although some may be directly placed in feedlots depending on the breed and market conditions (Athwal, 2002). Basically, backgrounding is feeding of weaned cattle on forage and grain from fall to spring in preparation for further pasturing and/or feedlot finishing. The end product is feeder cattle (steers and heifers) weighing between 350 and 450 kg, which are then placed into feedlot operations for finishing. In feedlots, feeder cattle are fed on high-energy rations of grain such as barley and corn, and silage to quickly bring them to a slaughter weight of about 550 to 600 kg at about 18 to 24 months of age. These are then referred to as fed cattle. Fed cattle as well as cows and bulls that are no longer needed for breeding (cull cattle) are processed into beef.

There is some evidence of vertical integration between different production levels. For the most part, backgrounding is undertaken by cow-calf producers (Athwal), and some beef processors own feedlot operations. Schroeder (2003) notes that Canadian beef packers tend to own more feeder cattle than their U.S. counterparts because of the seasonality of fed cattle supply in Canada relative to the U.S. On the contrary, Canada's National Farmers Union (2008) views the ownership or control of feedlots by packers as captive supply, a tactic used by packers to exert downward pressure on prices of all types of cattle. This has led to a degree of mistrust between cattle producers and beef processors, with some in the industry calling for policy intervention in the marketing of fed cattle (Schroeder and Ward, 2006). But the issue of captive supply points to an even greater challenge; the beef cattle industry is significantly less adaptable to vertical integration than the hog and poultry industries (Conner *et al*., 2000; Hayenga, *et al*., 2001; Warner, 2001). The relatively long production cycle makes it capital-intensive (Wachenheim and Singley, 1999). In addition, it has more levels of production, a wider and widening genetic base, and a wide geographic dispersion of cattle and beef production units. These factors highly constrain the ability to manage production costs and product quality along the supply chain – the major goals of vertical integration.

According to the 2011 census of agriculture by Statistics Canada, there are 49,613 cattle farming and ranching operations in Canada[1], the majority of which (25%) are found in Alberta. It is estimated that about 72% of beef cattle farms are cow-calf operations, 17% are feedlots, 4% are a combination of the two, and 7% are others (Mitura and Di Pietro, 2004). A large proportion of beef cow inventories are in western Canada; 39.4% are in Alberta and 30.4% are in Saskatchewan. But whereas Alberta accounts for 67.8% of fed cattle production, Saskatchewan together with Manitoba and British Columbia account for only 8.8% (Beef Information Centre, 2011). Ontario is the second largest producer of fed cattle (20.2%). The industry has many small farms; 61% of the farms have fewer than 47 beef cows. Together, they contribute less than 20% of the total beef cow herd. But farms with over 122 cows make up only 13% of the total number of farms, and they account for 48% of the cow herd (Beef Information Centre).

The beef processing sector comprises of federally and provincially registered and non-registered beef packers and abattoirs who slaughter fed and cull cattle to produce boxed beef and other products. About 90% of cattle are slaughtered by federally registered plants, while 4% are slaughtered by provincially registered plants (Canadian International Trade Tribunal). Beef carcasses are sold either to further processors or wholesalers and retailers. Carcasses from cull beef and dairy cattle are usually processed into manufacturing beef products.

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[1]The census of agriculture uses the North American Industry Classification System (NAICS) in which farm types are classified by both industry group (four-digit codes) and Canadian industries (six-digit codes). This figure is based on the classification by industry group. Classification by industry gives a total of 37,406 beef cattle ranching and farming operations, including feedlots (Statistics Canada, 2011).

There has been increasing concentration in the beef processing sector as measured by the four-firm concentration ratio. In 1992, the four major beef packers – Cargill Foods (High River, Alberta), Lakeside Packers (Brooks, Alberta), XL Foods (Calgary, Alberta) and Better Beef (Guelph, Ontario) – accounted for 53% of federally inspected cattle slaughter, up from 43% a year before (Canadian International Trade Tribunal). As of 2008, there were 23 federally inspected plants (Grier and Bouma, 2008). But the four plants slaughtered 93% of all cattle, with Cargill and Lakeside Packers each slaughtering over 4,500 cattle per day (Rude *et al*., 2011). Cargill Foods has since acquired Better Beef, while XL Foods now owns Lakeside Packers. However, following the discovery, on September 3, 2012, of E. coli in some of the products of XL's Lakeside operation, JBS-USA initially took over management of the plant but eventually bought it.

1.5 Background on Recent Exogenous Shocks

Exogenous shocks[2] often lead to sudden changes in demand, regulation, and cost structure (Gorbenko and Strebulaev, 2010). They may be temporary or permanent depending on their duration, and either type of shock can have both short- and long-term negative and/or positive impacts. Four exogenous shocks have threatened the Canadian beef cattle industry since the BSE crisis of 2003. The following section defines these shocks, and highlights their geneses as well as perceived and real impacts.

[2] An exogenous shock is defined as a sudden event beyond the control of authorities that has a significant impact on the economy (Varangis *et al.*, 2004), or in this particular study, the industry.

1.5.1 Mandatory Country of Origin Labeling

The final rule of the U.S. COOL legislation was implemented on March 16, 2009. It was a provision in the Farm Security and Rural Investment Act of 2002 (2002 Farm Act) that required fruits and vegetables, peanuts, fish and shellfish, beef, pork, and lamb sold at the retail level to be labeled by their country of origin (Jones *et al.,* 2009). Amendments to the 2002 Farm Act, which led to the Food, Conservation, and Energy Act of 2008 (2008 Farm Act), expanded the coverage of COOL to include poultry, goat meat, macadamia nuts, ginseng and pecans (U.S. Department of Agriculture, 2009a). It, however, does not apply to these products if they are consumed in hotels, restaurants and institutional (HRI) trade, or if they are ingredients in processed food items. Under the law, there are four meat labeling categories: meat is labeled Category A (Product of the U.S.) if it is from an animal that is born, raised and slaughtered in the U.S.; Category B (Product of U.S. and X) is meat derived from an animal born in country X, and raised and slaughtered in the U.S.; Category C (Product of X and U.S.) is meat derived from an animal born and raised in country X and slaughtered in the U.S., and Category D (Product of X) is meat imported into U.S. Also, the law provides for commingled meat. Meat from Category A that is commingled during a production day with meat from Category B may be labeled Category B (i.e., A + B = B). Meat from Category B that is commingled during a production day with meat from Category C may be labeled Category B (i.e., B + C = B).

Rude et al (2006) predicted that COOL was more apt to be one of the most controversial issues from an international trade perspective. Indeed, on April 30, 2010, Canada and Mexico petitioned the World Trade Organization (WTO) to create a dispute resolution panel to determine whether or not the law was tantamount to a violation of international trade obligations by the U.S. Ideally, international trade regulations such as product labeling are mandatory requirements meant to correct market failure due to information asymmetry (Hobbs, 2007). The WTO Technical Barriers to Trade (TBT) Agreement acknowledges the right by member governments to adopt regulations that they deem necessary and appropriate to meet consumer interests. But at the same time, it has provisions that ensure that such regulations are not deliberately used for protectionist purposes, thereby creating unnecessary obstacles to trade.

In information theory, country of origin of a product is an extrinsic informational cue that may influence the quality perception of a product (Bilkey and Nes, 1982; Elliott and Cameron, 1994). If it does, the implication is that there is imperfect information about that product, hence market failure, which then has to be addressed by voluntary or mandatory labeling (Lusk *et al.,* 2006). In a multi-product and multi-cue experiment, Wall et al (1991) find that country of origin labeling surpasses price and brand information in influencing consumers' perception of product quality. Lusk *et al*. also note that even in the absence of imperfect information, consumers' preference for country of origin labeling may stem from sheer ethnocentric tendencies.

In the case of COOL, some proponents - mainly U.S. cow-calf producers and fruit and vegetable growers - argue that most U.S. consumers prefer domestic to imported products because of the superior quality of the former, and hence labeling products by country of origin helps to allay their food safety concerns, while giving U.S. products a competitive advantage over imported ones (Krissoff *et al.*, 2004). Others argue that consumers simply have a right to know the country of origin of their food purchases (Schupp and Gillespie, 2001). From their benefit-cost analysis, VanSickle et al (2003) conclude that not only are the benefits to the U.S. of COOL significant, they outweigh its costs. Opponents of the law contend that it is a non-tariff barrier, or more precisely, a technical barrier to trade (Kerr, 2003; Vollrath and Hallahan, 2006; Grier and Martin, 2007), which imposes unnecessary and yet substantial transaction costs at all levels of the market chain (Rude *et al.*, 2006; Jones *et al.*, 2009; Carlberg *et al.*, 2009). A purely intuitive ground for this argument is that voluntary labeling by country of origin would have occurred if it were economically beneficial to do so (Lusk and Anderson, 2004; Plastina *et al.*, 2008). A summary of the costs of COOL as estimated by different studies is provided by Rude et al (2006). These costs have recently been updated by Informa Economics, Inc. (2010). U.S. importers of live animals, processors, and retailers are expected to incur costs associated with keeping records, segregating animals and meat by country of origin, verification, labeling, and certification. U.S. plants accepting only U.S. cattle will incur an additional $0.25 per head, while those accepting Canadian cattle will incur between $10 and $18 per head. Also, retailers of one or more beef labels will incur $0.15 – $0.17 per lb.

Conceptually, assuming a perfectly competitive market, the costs of COOL will shift the supply function leftward. Brester et al (2004) illustrate the resulting changes in supply and demand at each market level in a vertically linked cattle and beef industry. For simplicity, assume that there are only two market levels - retail and farm - and that the added costs of COOL are incurred at both levels. We assume that producers import *and* process cattle[3]. Figure 1 shows that the costs of COOL lead to a concurrent leftward shift in retail supply (S_r^0 to S_r^1) and farm supply (S_f^0 to S_f^1).

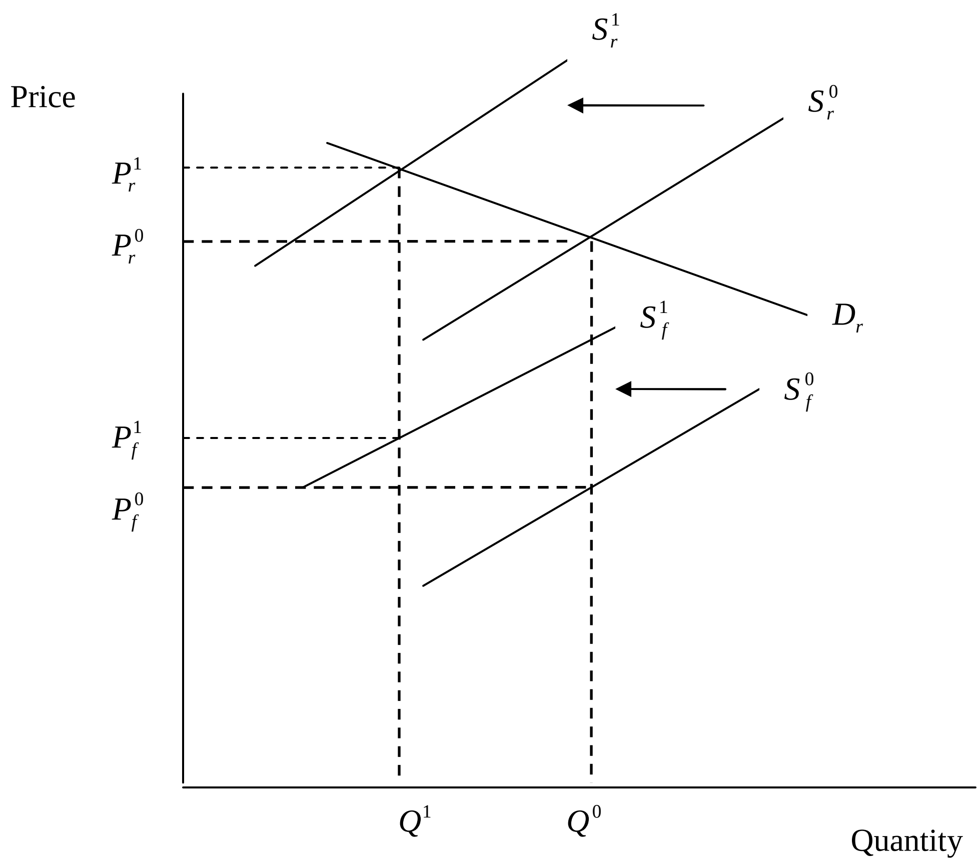

Figure 1: Effects of COOL if Costs are borne by both Producers and Retailers

[3] U.S. livestock producers who import some of their cattle maintain tax records, which are sufficient to verify the origin of the animals. Thus no additional documentation and record-keeping is required under COOL (VanSickle *et al.,* 2003). But processing would imply segregation and other costs.

The new equilibrium prices and quantity are P_r^1, P_f^1, and Q^1, giving a total of six variables and six equations including the marketing margin equation that would account for farm demand. Whereas Q^1 is unambiguously less than Q^0, P_f^1 will be greater or less than P_f^0 depending on the relative supply and demand elasticities at each level. But even if P_f^1 were to be greater than P_f^0, cattle producers would not necessarily be better-off because of a decline in farm output. If they are worse-off, then there will be a contraction in cattle imports.

At the heart of the COOL debate is the question as to whether U.S. consumers are willing to pay a premium for it; i.e., whether or not COOL will induce an increase in demand for category A beef. The numerous studies that have examined this issue have yielded mixed results. For instance, Umberger et al (2003) find that 73% of consumers are willing to pay up to 11% and 24% premium for steak and hamburger, respectively, that are labeled by country of origin. Also, they are willing to pay 19% premium for steak labeled as "U.S.A. Guaranteed: Born and Raised in the U.S." Loureiro and Umberger (2003) obtain even higher premiums of 38% and 58% for U.S. certified steak and hamburger, respectively. Considering that almost all the steak consumed in the U.S. is of U.S. origin, it is not reasonable to expect consumers to be willing to pay such a high premium just to have their steak "U.S. certified". It seems the high premiums obtained in these studies are due to hypothetical biases inherent in contingent valuation methods. In fact, in another study, Loureiro and Umberger (2005) find the premiums for certified U.S.-labeled chicken breasts, pork chops, and beef steaks to be 2.5%, 2.5%, and 2.9%, respectively, and that only 30% of consumers are willing to pay a premium of more than 5% for certified U.S. meat products. Loureiro and Umberger (2007) find that although COOL attracts a positive premium of $2.57 per pound of steak among U.S. consumers of beef, this premium is very low relative to the $8.07 per pound of steak that they are willing to pay for food safety certification by the U.S. Department of Agriculture.

Because of the lack of consensus on consumer willingness to pay for COOL, studies on the impacts of the legislation have made varied assumptions. Brester et al (2004) show that in the absence of an increase in consumer demand, COOL causes a decline in producer and consumer surplus in the U.S. beef and pork industries in both the short- and long-run. In the short-run, producer surplus declines by $647.8 million and $220.4 million in the beef and pork industries, respectively. When they assume an increase in consumer demand because of COOL, they find that one-time permanent increases of 4.05% and 4.45% in beef and pork demand, respectively, would be necessary to ensure zero losses in producer surplus in the cattle and hog industries.

Lusk and Anderson (2004) report on the impacts in the U.S. of COOL from various scenarios regarding the magnitude and incidence of the costs of compliance, and changes in consumer demand (willingness to pay). Consistent with Brester *et al*., they find that COOL leads to a reduction in beef consumer surplus in the absence of a demand increase. Results from their multi-market model indicate that a 2% increase in aggregate demand for beef and a similar increase in demand for pork would be sufficient to offset losses in beef consumer and pork producer surplus, respectively. Schmitz et al (2005) find that a 0.035%

increase in consumer demand would offset labeling costs of up to $0.05 per pound of beef in the U.S., and under this scenario, the total economic surplus accruing to U.S. producers, foreign producers, and U.S. consumers is the same as before implementation of COOL.

COOL impacts for the Canadian and U.S. hog and pork industries have been analyzed by Rude et al (2006). Their study reveals that COOL induces losses at all market levels in the U.S., while impacts in Canada depend on the level of trade in hogs and mixed supply chain pork. Specifically, U.S. consumers lose 5-6% of their consumer surplus if COOL does not stimulate demand. According to Loureiro and Umberger (2005), premiums for beef and pork are not high enough to raise the benefits of COOL above its costs. Furthermore, a study by Carter et al (2006) dismisses the claim that COOL would be an effective branding strategy even if consumers were willing to pay a price premium for it.

From the foregoing review, it appears that a lot more research is needed to fully comprehend the actual impacts of COOL. The lack of consensus on its impacts may be partly due to the fact that the studies undertaken so far were *ex ante.* This study undertakes an *ex post* evaluation of the impacts of COOL.

1.5.2 Exchange Rate Appreciation

Between 2000 and 2008, the Canadian dollar appreciated by more than 50% against the U.S. dollar (Lamoureux, 2010), reaching close to parity from mid 2007 to mid 2008 as shown in figure 2. This was due to an increase in export demand for Canada’s oil, natural gas and coal, and relatively higher interest rates that attracted substantial capital inflows (Klein *et al.*, 2006; Boyer and Irvine, 2007).

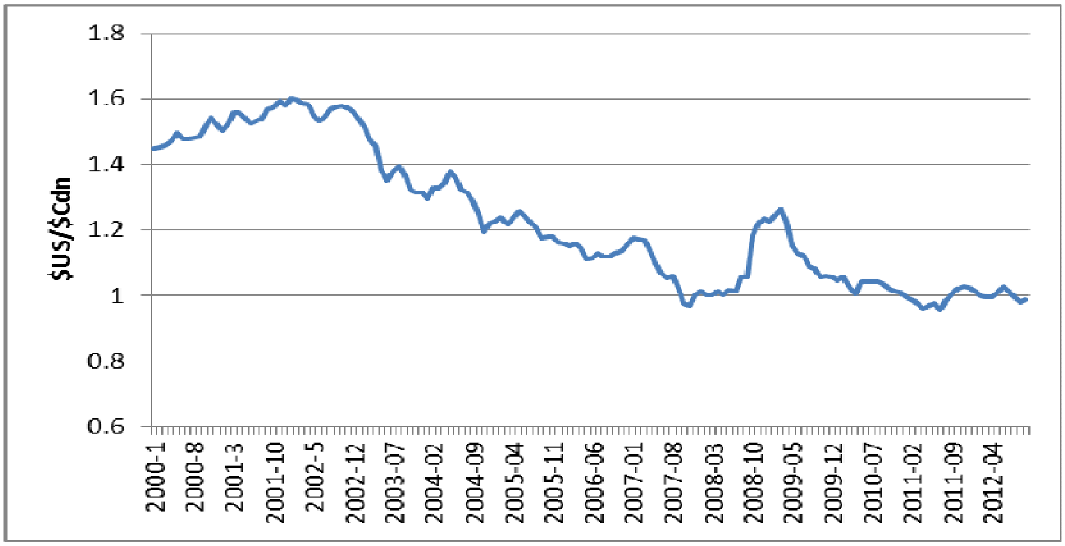

Figure 2: Exchange Rates, Jan 2000 –Apr 2012
Source: Statistics Canada (2012)

Exchange rate shocks, if sufficiently large, can have lasting impacts on trade flows, and hence lead to structural change (Baldwin and Krugman, 1989). Following Coleman and Meilke (1988), assume one commodity being traded in two perfectly competitive markets without trade barriers and transportation costs:

$$ES = ES(P_e), \qquad \frac{\partial ES}{\partial P_e} > 0 \tag{1}$$

$$ED = ED(P_i), \qquad \frac{\partial ED}{\partial P_i} < 0 \tag{2}$$

$$P_i = rP_e \tag{3}$$

$$ES = ED \tag{4}$$

where ES is the exporting country's excess supply curve, ED is the importing country's excess demand curve, P_i and P_e are importing and exporting country prices, respectively, and r is the exchange rate evaluated in terms of the units of the importer's currency per unit of the exporter's currency. Totally differentiating equation (1) through equation (4) and substituting the results from equation (1) through equation (3) into equation (4), we obtain:

$$\frac{\partial ES}{\partial P_e} dP_e = \frac{\partial ED}{\partial P_i} dP_e r + \frac{\partial ED}{\partial P_i} drP_e \qquad (5)$$

From equation (5), the exporter's price elasticity with respect to the exchange rate is:

$$E_{P_e,r} = \frac{dP_e}{dr} . \frac{r}{P_e} = \frac{E_{ed}}{E_{es} - E_{ed}} \qquad (6)$$

where E_{ed} and E_{es} are price elasticities of excess demand and excess supply, respectively. Note that $-1 \le E_{P_e,r} \le 0$, and the percentage change in equilibrium price will at most be equal to the percentage change in exchange rate. Also, the elasticity of quantity traded with respect to exchange rate is:

$$E_{es,r} = E_{P_e,r} \times E_{es} = \frac{E_{ed} \times E_{es}}{E_{es} - E_{ed}}, \qquad E_{es,r} \le 0 \qquad (7)$$

From equation (3), a depreciation of the exporter's currency (decrease in r) increases P_e, which in turn leads to an increase in quantity traded. Conversely, the condition in equation (7) derives from the fact that for any given price quoted in the importer's currency, an appreciation of the exporter's currency (increase in r) decreases the domestic currency-equivalent received by the exporter, hence a decline in quantity exported.

However, Coleman and Meilke (1988) observe that demand and supply functions contain several other prices, which are also affected by changes in exchange rate. Assuming a small exporting country, and perfect price transmission, the above model is modified as follows:

$$ES = ES(P_e, W_e), \qquad \frac{\partial ES}{\partial P_e} > 0 \text{ and } \frac{\partial ES}{\partial W_e} < 0 \qquad (8)$$

$$ED = ED(P_i, W_i), \qquad \frac{\partial ED}{\partial P_i} < 0 \text{ and } \frac{\partial ED}{\partial W_i} > 0 \qquad (9)$$

$$P_i = rP_e \qquad (10)$$

$$W_i = rW_e \qquad (11)$$

$$ES = ED \qquad (12)$$

where W_i and W_e are other prices, e.g., input prices that shift the excess demand and excess supply curves, respectively. Totally differentiating equation (8) through equation (12) and solving for the elasticity of exporter's price with respect to exchange rate, $E_{P_e,r}$ gives:

$$E_{P_e,r} = \frac{E_{ed} + E_{es,W}}{E_{es} - E_{ed}} \qquad (13)$$

where $E_{es,W}$ is the elasticity of excess supply with respect to input prices, where the change in input prices is due to a change in exchange rate. In this formulation, $E_{P_e,r}$ is larger than in the previous model, and should the excess supply curve be homogeneous of degree zero in prices, then $E_{P_e,r} = -1$. The elasticity of excess supply with respect to exchange rate is:

$$E_{es,r} = \frac{E_{ed}(E_{es} + E_{es,W})}{E_{es} - E_{ed}} \qquad (14)$$

It follows that if $E_{es,W}$ is smaller in absolute value than E_{es}, then $E_{es,r} < 0$ and $E_{es,r} = 0$ if the excess supply curve is homogeneous of degree zero in prices. The corollary is that if more prices are included in the excess supply and excess demand functions, the exchange rate effects on prices will be larger but effects on equilibrium quantities traded will be smaller than in the previous model.

Between 2002 and 2007, the Canadian dollar appreciated by 31.5%, implying an equivalent loss in the value of cattle and beef exports that is independent of losses due to BSE (Klein and Le Roy, 2010). Schaufele et al (2009) find that exchange rate fluctuations in the same time period caused far greater losses to the equity (net worth) of cattle producers than did the BSE crisis. Klein et al (2006) too reveal that appreciation of the Canadian dollar adversely affected cow-calf producers, feedlot operations, and beef packers in the short-run, with the greatest impact being felt by cow-calf producers. In the long-run, losses to cow-calf producers are expected to be reflected in lower values of their fixed assets. As feedlot operators pay a lower price for feeder cattle, beef packers will try to align their operating costs with those of their U.S. counterparts. In addition, the structural impact of the dollar appreciation will be seen in a decline in the cow herd inventory.

1.5.3 Rise in Feed Prices

Barley, corn, wheat, and oats are the common feed grains used in Canada, barley being the main one, and barley and corn being the most internationally traded. In 2009, Canada supplied 99% of U.S. barley imports (Taylor *et al.*, 2010). Canadian corn production, however, is relatively small, and therefore imports from the U.S. are used to balance the feed grain market in western Canada (Boaitey, 2010). Between 2006 and 2008, there was a large increase in global barley and corn prices as illustrated by U.S producer price trends in figure 3. Between mid 2007 and mid 2008, corn producer prices rose by about 156%. In Canada, barley prices stood at $113 per tonne in mid 2006, but by the first quarter of 2008, they had almost doubled to $216 per tonne (Grier and Bouma, 2008).

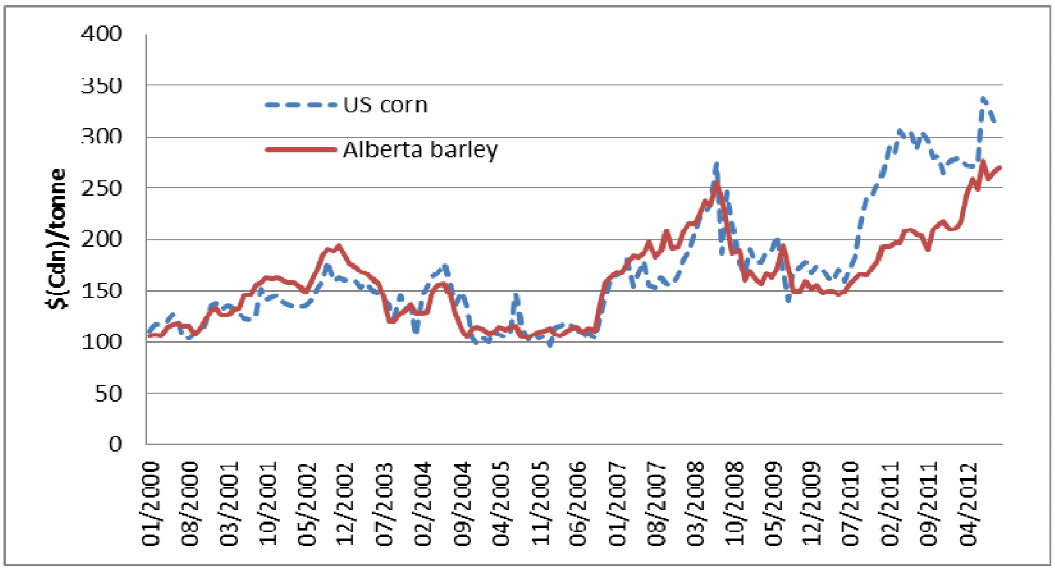

Figure 3: Feed Corn and Barley Nominal Producer Prices, Jan 2000 –Apr 2012 in U.S. dollars
Source: Agriculture and Agri-Food Canada (2012)

The rapid increase in feed grain prices has been attributed to several factors of which the single most important one is the emergence of a bio-fuels industry in North America. The increasing demand for ethanol has driven up the price of corn – since at present almost all ethanol production in the region is from corn – and hence an increase in the price of other major feed grains that closely follow corn prices. Although grain prices have trended downwards since early 2009, they are likely to remain higher than pre-2006 levels (Lawrence, 2009) because of bio-fuel consumption mandates set by Canada and the U.S. In fact, projections for the period 2005 to 2015 by Fridfinnson and Rude (2009) show corn prices remaining above baseline levels over the entire period because of these mandates.

High grain feed prices negatively impact cattle and beef production. In cattle feeding, feed grains account for as much as 70% of operating costs (Grier and Bouma, 2008), and for Canadian feedlots in particular, they account for more than 80% of the cost of gain (Canadian Cattlemen's Association, 2007), i.e., the cost of raising the weight of an animal by one unit. Thus an escalation in grain feed prices reduces profit margins of feedlot operators, who in turn respond by offering lower feeder cattle prices to cow-calf operators.

Thus far, empirical evidence suggests that the run-up in grain feed prices has significantly reduced the competitiveness of Canada's beef cattle industry relative to the U.S. (Grier and Bouma, 2008). Further, the Canadian Cattlemen's Association (2007) predicts that in the absence of a market-driven bio-fuels policy, high grain feed prices will over the long-run cause a structural shift in the industry as some feedlot operators switch to alternative feeds and/or move their operations closer to sources of cheaper feeds, while others exit the industry altogether, leading to a decline in cattle finishing capacity and hence cattle inventories.

1.5.4 Global Economic Recession

Between 2007 and 2010, there was a 3.5% decline in consumer demand for beef and veal in the world's major beef markets including the U.S. (U.S. Department of Agriculture, 2009b) to which Canada exports over 70% of its beef exports. Consumption in the domestic market, which is about 50% of domestic production, declined by 4.7% between 2007 and 2008 (Thoren, 2009). Contraction in beef demand may have been caused by a decline in real incomes following the global economic recession (U.S. Department of Agriculture, 2010b) that began in December 2007 and ended in June 2009. In 2008, Canada's real GDP per capita was $39,425, a decrease of $574 (1.4%) from the 2007 level of $39,999 (Human Resources and Skills Development Canada, 2011). In the U.S., real GDP declined 2.4% from the 2008 to the 2009 annual level (U.S. Department of Commerce, 2010). Although the recession is over, employment rates and incomes are yet to return to their pre-recession levels.

A leftward shift in retail demand decreases demand for slaughter cattle, which in turn causes a leftward shift in the derived demand for feeder cattle. The resulting changes in farm price imply lower producer profits, which induce producers to scale back production. Declining demand in the 1980s and 1990s had a structural impact on the North American industry; it contributed to industry consolidation as high cost producers exited the market (Grier, 2005). However, CattleFax (2009) disputes that beef retail prices have declined in previous recessions. They observe that in the previous recessions, Choice retail U.S. beef prices increased in year-over-year comparisons because of significant declines in beef supply, especially in the 2001 and 1990/91 recessions. It could be that the impact of previous recessions has led to leftward supply shifts. In this study, however, I conjecture that the decline in importing country consumer incomes due to the economic recession has led to a substantial reduction in Canadian beef cattle inventories.

1.6 Summary of the Three Papers

From the preceding background, it is likely that the four exogenous shocks, one of which is permanent and the others temporary have had considerable impacts on the Canadian beef cattle industry either singularly or in combination with one another. They have all occurred in the last ten years, with some occurring concurrently. Appreciation of the Canadian dollar began in mid-2002 and peaked in mid-2007, while the increase in feed prices started in early 2007 until mid-2008. The global economic recession began in late 2007 and ended in mid-2009, and the final rule of country of origin labeling was implemented in the first quarter of 2009 following an interim rule that had been introduced on September 30, 2008. So, in addition to their tangible impacts, these shocks may have generated considerable uncertainty in the industry because of their chronology. Therefore analyzing the impacts of each of these shocks and their implications for policy such as that regarding capacity expansion for beef processing would be quite informative.

However, examining the impacts of the shocks requires careful selection of an appropriate analytical framework. The first consideration is that the framework should be able to isolate the individual impacts of each shock. Second, the framework should enable the cyclical nature of the industry to be brought to bear on the analysis. But it appears that currently, there is no single framework that fits such criteria. This study uses a combination of approaches to study the impacts of three of the four shocks.

The first paper addresses structural change in U.S. import demand for Canadian cattle and beef due to mandatory country of origin labeling. Most of the previous studies on the impact of COOL have been hypothetical; they have mainly dealt with either the willingness to pay for it, or have been based on simulations. Considering that COOL is a permanent shock, analysis of COOL-induced structural change using real data would be more enlightening. In this study, reduced-form import demand equations are derived and used in the analysis. Because COOL is a relatively new law and the potential break date associated with it is not precisely known, two approaches for detecting structural change are implemented. The first one involves endogenizing the potential break date using the Bai and Perron (1998, 2003) approach, while the second approach employs Andrews' (2003) test of structural breaks occurring at the end of the sample in a small sample data set. I hypothesize that country of origin labeling has caused structural change in U.S. demand for both Canadian cattle (feeder and slaughter) and beef.

The second paper focuses on two shocks in relation to the cattle cycle, the beef cow cycle, and the cyclicality of beef output and beef prices. These shocks include appreciation of the Canadian dollar relative to the U.S. dollar and feed price escalation. This necessitates a departure from the conventional tools used in time series analysis to the powerful techniques of spectral analysis. Spectral analysis is used to estimate these cycles, and to determine whether or not they have changed over time.

The third and final paper explores the issue of cattle loan guarantees using the case of Alberta’s Feeder Association Loan Guarantee Program. Declining government budgets, industry profitability and increasing uncertainty call for an evaluation of the program. The credit risk to financial institutions, the implicit cost of the guarantee to the provincial government, and the implicit interest subsidy are estimated. A Monte Carlo cash flow model underlies the analysis, and the cost of the guarantee is determined within an option pricing framework.

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CHAPTER TWO: COOL AND STRUCTURAL CHANGE IN U.S. IMPORTS OF CANADIAN CATTLE AND BEEF

2.1 Background

Structural change in economic relationships, also known as structural break, is understood as change in the structural parameters of an economic model. Detecting structural breaks is particularly important because economic relationships may change from time to time because of change in the behavior of economic agents. The change in behavior is often associated with exogenous shocks including changes in policy regimes, tastes and preferences, institutions, technological progress, and natural disasters, and is reflected in changes in optimal decision rules upon which economic models are predicated (Chen, 2008). The presence of structural breaks, if not accounted for, inevitably increases the deviation of a model's forecast from the actual outcome (Hendry and Ericsson, 2003). Moreover, in an industry with vertically linked markets, exogenous shocks affect the way prices at different market levels relate to one another (Gardner, 1975) and therefore a structural break at one level of the market chain is likely to have welfare implications at another level of the chain. This should be of direct interest to policy makers and industry.

As mentioned previously, the Canadian beef cattle industry has experienced several shocks in the recent past, and therefore it is imperative to determine whether or not these shocks have caused any structural breaks in the industry's major economic relationships. Specifically, this chapter focuses on the impact of mandatory country of origin labeling on the stability of structural parameters of three industry equations. I conjecture that COOL has caused a structural break in U.S. import demand for Canadian beef, feeder, and fed cattle.

2.2 Testing for Structural Change: A Synopsis

The standard assumption in regression models is that the vector of parameters is constant over all sample observations of either a cross-section or time series. However, Quandt (1958, 1960) and Chow (1960) advance the notion that structural breaks are a possibility in economic relationships because of, say, non-linear interaction between a dependent and an uncontrolled exogenous variable or differential impact of an exogenous variable on distinct sub-samples within a given sample. Quandt (1960) proposes a likelihood ratio test for a change in parameters assuming that the break point is known, but the test cannot be approximated by a χ^2 distribution that he conjectures. Chow (1960) formulates what has become the most commonly used test for structural change; the so-called Chow test whose statistic follows an F distribution under the basic Ordinary Least Squares (OLS) assumptions of linearity, orthogonality, and normality. It is a simple test in which the break point is known beforehand (i.e., is exogenously determined), and basically involves testing the null hypothesis of equality of the vector of coefficients of two sub-samples or time periods against the alternative of non-equality assuming equal residual variances in both sub-sample regressions.

Since Chow (1960), a number of issues on estimation of structural breaks have arisen in the econometrics literature, the most prominent of which are the distinction between exogenous and endogenous break points, and structural breaks and unit root processes (Byrne and Perman, 2006). The Chow test assumes that any single break point is exogenous and discrete, which may be reasonable if the structural break is in relation to, for instance, a real-world event for which the date is known. But there are cases where structural change is gradual and therefore the exact break point is unknown (Greene, 2002). In essence, the data generating process, and hence the model may be unstable, pointing to the possibility of multiple breaks that are endogenously determined. Andrews (1993) proposes Wald, Lagrange Multiplier and Likelihood Ratio tests for a single structural break with an unknown (endogenous) change point. Bai and Perron (1998) build on the work of Liu et al (1997) to address multiple endogenous breaks in a linear regression model estimated by OLS. They construct hypothesis tests for the presence and number of structural breaks in the framework of a partial structural change model in which not all parameters are subject to change. Later, Qu and Perron (2007) consider multiple endogenous structural breaks still in the framework of partial structural change. They use Likelihood Ratio-type statistics for hypothesis testing of occurrence and number of structural breaks. Their formulation is particularly novel in that it allows for the determination of common breaks across equations and subsets of equations.

In the context of time series analysis, Perron (1989) has initiated the idea that tests for unit roots may be affected by the presence of structural breaks. He shows that standard tests of the null hypothesis of unit roots against the alternative of trend stationarity do not reject the null hypothesis (even if the data are in fact generated by stationary fluctuations around a trend function) as long as there is a structural break. Likewise, tests for structural breaks which assume a stationary process may yield evidence of structural change when actually it is a unit root process (Ben-David and Papell, 1995). While Perron assumes a single structural break that is exogenously determined, several authors have considered other assumptions including endogenously determined break points and multiple breaks (Christiano, 1992; Zivot and Andrews, 1992; Perron, 1997; Lumsdaine and Papell, 1997; Ohara, 1999; Kapetanios, 2005). An extensive review of the interplay between unit roots and structural breaks can be found in Perron (2006). Although results are mixed, the general consensus is that tests for structural breaks in time series models tend to be influenced by unit roots, and vice-versa.

2.3 Literature Review

There are a myriad studies in the agricultural economics literature on detection of structural breaks. Most of these studies, however, have focused their attention on structural change in retail demand for meat, motivated in part by observed changes in meat consumption in the 1970s. Given the voluminous nature of the literature, this review is limited to some of the studies that have been undertaken since 1988. A review of earlier studies is found in Dahlgran (1988).

Dahlgran (1988) analyzes structural change in U.S. demand for beef, pork and chicken using a price-dependent demand system to which he fits annual data from 1950 to 1985. He uses the Cumulative Sum of squares (CUSUM) procedure to test for structural change and finds evidence of it in 1973. The demand system used is quite appealing in terms of its data and computational requirements, but the subsystem is not integrable, and as such, the structural break cannot be attributed to any specific parameter(s) in the underlying utility function

(Dahlgran). Chalfant and Alston (1988) investigate structural change in the consumption of different types of meat including beef in the U.S. and Australia. They apply a nonparametric approach, the revealed preference method, to quarterly data for the period 1964 to 1984 for Australia and annual data from 1947 to 1983 for the U.S. They do not find any evidence of structural change in meat consumption in both countries. Their approach attempts to address the longstanding criticism of parametric approaches, which is that the results of structural change tests are conditional on the particular functional form used. However, recent improvements in diagnostic tests for parametric models are helping to address this concern. Moreover, the authors, as well as Moschini and Moro (1996) acknowledge that the power and size of the nonparametric test is unknown, which is a serious limitation of this approach.

Eales and Unnevehr (1988) test for structural change and separability in meat and meat products in the U.S. using an Almost Ideal Demand System (AIDS) with annual data for the period 1965–85. Their results indicate a structural change in aggregate beef consumption in 1974. The tests for separability are particularly illuminating as they point to a need for testing for structural change at the disaggregated product level. Structural change in aggregate beef demand is found to be driven by a decline in preference for table cuts. Atkins et al (1989) undertake a study on structural change in Canadian demand for beef, chicken and pork using single-equation demand models. Their major concern is that the use of real per capita disposable income as a covariate is the reason why the literature is awash in contradicting results on structural change. Backed by evidence of this from their initial beef regression model, they replace real per capita disposable income with the ratio of nominal expenditure on food to nominal per capita income. Using quarterly data from 1968 to 1986 and assuming a structural break in the last quarter of 1977, the Chow test reveals a structural change in the demand for beef. Undoubtedly, the study makes an empirical contribution to the literature, but the use of a proxy income variable when, in fact, per capita disposable income is observable, is questionable. Clearly, the poor performance of the conventional income variable is likely a matter of econometrics and statistics rather than economic theory, yet the authors do not attempt to undertake any model diagnostic tests that could potentially improve their initial results.

Reynolds and Goddard (1991) also analyze structural change in Canadian demand for beef, pork and chicken using quarterly data from 1968 to 1987. While previous studies have assumed an exogenously-determined change point, Reynolds and Goddard employ a gradual switching AIDS model assuming that the shift in preferences is gradual. They find evidence of structural change, and that it occurred between 1975 and 1984. A similar study is conducted by Chen and Veeman (1991) but they include turkey among the meat types, and incorporate habit formation in the dynamic form of the AIDS model. From quarterly data for the period 1967 to 1987, they find evidence of a structural shift in expenditures on Canadian meat consumption using the second quarter of 1976 as the change point. Eales and Unnevehr (1993) criticize these and other studies of structural change that have used quantity-dependent meat demand models on the premise that in meat production, especially red meat, quantity is likely to be predetermined because of the long biological lags. As such, quantity-dependent models are not appropriate for investigating structural change. In addition, they argue for the need to account for supply-side variables since changes such as the contraction of the beef herd in the 1970s due to feed price escalation, or technological improvements in production may have manifested as structural change in demand. They propose an Inverse AIDS that accounts for supply-side variables and find no evidence of structural change in meat demand in the U.S. from 1962 through to 1989 contrary to results from previous studies. From a practical viewpoint, the authors' approach is simply one of the two different demand model estimation techniques, which is appealing insofar as it improves the empirical basis for hypothesis testing (Davis, 1997a; 1997b), but from a theoretical viewpoint, price- and quantity-dependent demand models yield similar results (Davis, 1997a) and are equally applicable (Huang, 1988).

Rude et al (2010) test for structural change in U.S.-Canada bilateral hog and pork trade flows following the implementation of COOL. This study draws on their approach to model the beef cattle industry in a manner that accounts for potential product differentiation due to COOL. It then employs tests for structural breaks in U.S. import demand for Canadian feeder cattle, fed cattle and beef that are able to endogenize potential break points, and to estimate them when sample observations are few. Also, the sizes of the breaks are estimated. Finally, the study checks for the robustness of these tests by applying them to U.S. imports of Canadian breeding cattle – a commodity that was affected by the BSE crisis, but would not be significantly affected by COOL.

2.4 Method

2.4.1 Economic Model

A partial equilibrium model of U.S. and Canadian beef cattle industries underlies this study. This framework allows for the modeling of the vertical supply chain relationships that characterize the industries, and for the application of appropriate assumptions regarding the implications of COOL for demand and supply relationships. The model's structural equations are then used to derive reduced-form trade flow equations, which are used to estimate structural change. The use of reduced-form equations is particularly appealing for two reasons: first, we are able to obtain the full (direct and indirect) effects on trade flows of changes in the exogenous variables, and second, since structural break points are estimated simultaneously with the regression parameters using ordinary least squares (OLS), the use of reduced-form equations ensures that potential endogeneity problems do not arise[4].

The economic model of U.S. and Canadian cattle and beef markets is predicated on the assumptions of exchange rate parity, a fixed proportions technology for feeder and slaughter cattle, a conversion ratio of 1:1 between feeder and fed cattle, and heterogeneous beef products. Following Rude et al (2010), demand for beef in country i is $D_B^i(P_B^i, Y^i)$ where D_B^i is per capita beef demand, P_B^i is the retail price of beef, and Y^i is per capita disposable income

[4] Hall et al (2008a, 2008b) provide limiting distributions for break point estimators in linear regression models estimated using two stage least squares (2SLS). But Yamamoto (2009) and Perron and Yamamoto (2009) show that not only are the results from the 2SLS procedure similar to those in Bai and Perron (1998), the use of OLS is still preferable even in the presence of endogenous regressors.

as an exogenous demand shifter. Beef supply in country i is a function of the margin between beef price and price of slaughter cattle, P_S^i, and supply shifters, Z_B^i:

$$S_B^i = S_B^i(P_B^i - P_S^i, Z_B^i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

The supply of slaughter cattle is:

$$S_S^i = S_S^i(P_S^i - P_F^i, Z_S^i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

where P_F^i is the price of feeder cattle and Z_S^i are fed cattle supply shifters. The supply of feeder cattle is:

$$S_F^i = S_F^i(P_F^i, Z_F^i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... (3)$$

where P_F^i and Z_F^i are price of feeder cattle, and cost shifters, respectively. We assume that country of origin labeling leads to product differentiation in the U.S. market, hence the four categories of beef (A, B, C, and D), where categories B and C may be referred to as mixed supply chain beef. But markets for mixed supply chain beef are not yet established and we do not wish to contrive them for this analysis. Instead, we assume that the supply of Canadian beef and U.S.-processed Canadian beef is equal to the demand for Canadian fed cattle. Given the vertical market linkages, we obtain the following market clearing conditions in which the superscripts US and C denote U.S. and Canada, respectively:

$$S_B^C(P_B^C - P_S^C, Z_B^C) + S_B^{US}(P_B^{US} - P_S^{US}, Z_B^{US}) = D_B^C(P_B^C, Y^C) + D_B^{US}(P_B^{US}, Y^{US}) \ldots .(4)$$

$$S_S^C(P_S^C - P_F^C, Z_S^C) + S_S^{US}(P_S^{US} - P_F^{US}, Z_S^{US}) = S_B^C(P_B^C - P_S^C, Z_B^C) + S_B^{US}(P_B^{US} - P_S^{US}, Z_B^{US}) \ \ldots (5)$$

$$S_F^C(P_F^C, Z_F^C) + S_F^{US}(P_F^{US}, Z_F^{US}) = S_S^C(P_S^C - P_F^C, Z_S^C) + S_S^{US}(P_B^{US} - P_F^{US}, Z_S^{US}) \ \ldots\ldots.. (6)$$

Assuming that U.S. and Canadian cattle and beef markets are fully integrated, then $P_B^C = P_B^{US} = P_B$, $P_S^C = P_S^{US} = P_S$, and $P_F^C = P_F^{US} = P_F$. Thus the three equations, (4), (5), and (6), can be used to solve for the three equilibrium prices. The equilibrium prices are then substituted into the structural equations (1) - (3) to obtain their reduced-forms in which demand and supply are functions of exogenous variables only. Imports are obtained from excess demand equations as follows:

$$M_B^{US} \equiv D_B^{US}(P_B^{US}, Y^{US}) - S_B^{US}(P_B^{US} - P_S^{US}, Z_B^{US}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

$$M_S^{US} \equiv S_B^{US}(P_B^{US} - P_S^{US}, Z_B^{US}) - S_S^{US}(P_S^{US} - P_F^{US}, Z_S^{US}) \ldots\ldots\ldots\ldots \text{(8)}$$

$$M_F^{US} \equiv S_S^{US}(P_S^{US} - P_F^{US}, Z_S^{US}) - S_F^{US}(P_F^{US}, Z_F^{US}) \ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

where M_B^{US}, M_S^{US}, and M_F^{US} are U.S. import demands for Canadian beef, fed cattle and feeder cattle, respectively. It follows that:

$$M_B^{US} = M_B^{US}(Z_B^{US}, Z_B^C, Z_S^{US}, Z_S^C, Z_F^{US}, Z_F^C, Y^{US}, Y^C) \ldots\ldots\ldots \text{(10)}$$

$$M_S^{US} = M_S^{US}(Z_B^{US}, Z_B^C, Z_S^{US}, Z_S^C, Z_F^{US}, Z_F^C, Y^{US}, Y^C) \ldots\ldots\ldots \text{(11)}$$

$$M_F^{US} = M_B^{US}(Z_B^{US}, Z_B^C, Z_S^{US}, Z_S^C, Z_F^{US}, Z_F^C, Y^{US}, Y^C) \ldots\ldots\ldots\ldots \text{(12)}$$

Structural breaks are estimated for equations (10), (11), and (12). COOL is likely to have an indirect impact on Canadian imports of U.S. beef through its impact on Canada's beef exports to the U.S. This and any other indirect impacts can be adequately captured by the above reduced-form equations.

2.4.2 Data and Estimation

Monthly data from January 2000 to February 2011, giving a total of 134 observations, are used for estimation. Following Rude et al (2010), the beef supply shifter in U.S. and Canada is the monthly average hourly earnings in the respective meat processing sectors, data on which are obtained from the U.S. Department of Labor and Statistics Canada, respectively. The exogenous shifter of beef demand in Canada is the seasonally adjusted labour income at 2005 constant dollars obtained from Statistics Canada, while the shifter for beef demand in the U.S. is the seasonally adjusted personal income at 2005 dollars obtained from the U.S. Department of Commerce. Shifters of slaughter cattle supply in Canada and U.S are the monthly average prices of barley and corn, respectively. The price series are from the Market Analysis Group of Agriculture and Agri-Food Canada. A time trend variable capturing technical change is used as the feeder cattle supply shifter in both countries. The assumption of zero elasticity of substitution between inputs at a given market level implies that an exogenous shock at one level of the market will likely impact another level in the vertically linked industry. Ultimately, import demand equations (10) - (12) are identified by similar exogenous variables. In addition, we include the exchange rate between the Canadian and U.S. dollar in the import demand equations to capture any other exogenous factors impacting trade flows. Exchange rates are obtained from Bank of Canada. Thus the total number of exogenous variables in each equation is eight. Data on U.S. imports of Canadian beef, fed and feeder cattle were obtained from the Economic Research Service database of the U.S.

Department of Agriculture. Summary statistics of all variables are provided in table 1, and plots of U.S. imports of Canadian cattle and beef are provided in figures 4 and 5. The dramatic drop in imports in May 2003 was caused by the U.S. border closure resulting from the discovery of BSE in an Alberta cow. Thus there is likely to be a structural break in the model around that time.

Table 1: Summary statistics of structural break model variables, Jan 2000 – Feb 2011

Variable	**Mean**	**Std Dev.**
U.S. monthly imports of Canadian feeder cattle (head)[a]	6,557	8,667
U.S. monthly imports of Canadian fed cattle (head)[a]	57,061	32,921
U.S. monthly imports of Canadian beef (‘000 lb)[a]	75,699	17,598
Exchange rate (Cdn $/1 U.S. $)[b]	1.27	0.20
U.S. wages in meat processing (U.S. $/hr)[c]	12.11	0.94
Canadian wages in meat processing (Cdn $/hr)[d]	26.57	3.58
U.S. real personal income (U.S. billion $)[e]	9,429	929
Canadian nominal labour income (Cdn thousand $)[f]	58,600,000	8,957,808
Canadian nominal barley price (Cdn $/tonne)[g]	151.94	34.16
U.S. nominal corn price (U.S. $/tonne)[g]	122.16	48.52

[a] Source: U.S. Department of Agriculture (2011)
[b] Source: Bank of Canada (2011)
[c] Source: U.S. Department of Labour (2011)
[d, f] Source: Statistics Canada (2011)
[e] Source: U.S. Department of Commerce (2011)
[g] Source: Agriculture and Agri-Food Canada (2011)

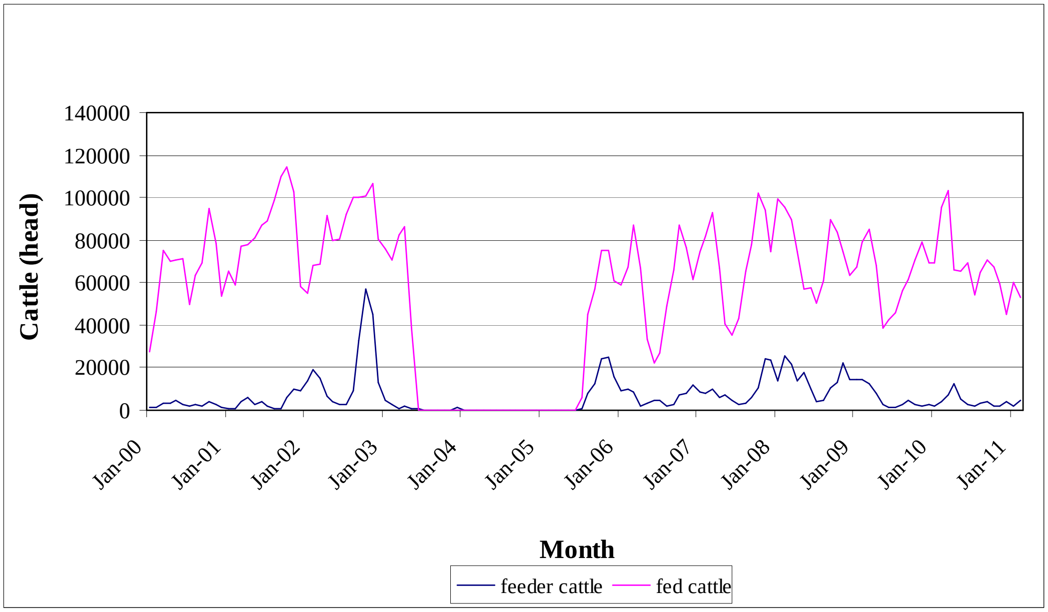

Figure 4: U.S. Imports of Canadian Cattle, Jan 2000 – Feb 2011
Source: U.S. Department of Agriculture (2011)

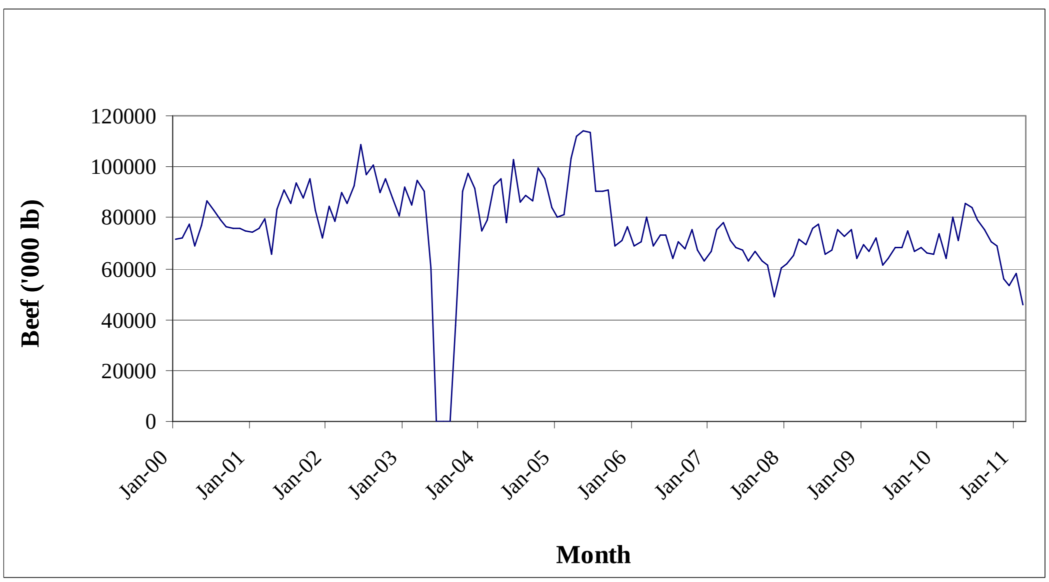

Figure 5: U.S. Imports of Canadian Beef, Jan 2000 – Feb 2011
Source: U.S. Department of Agriculture (2011)

Because the data covers the pre-BSE period, there is a possibility of having multiple structural breaks. Also, the possibility of habit persistence and dynamic behavior in consumer demand, and lagged adjustment of production and exports to exogenous shocks implies that the actual break points cannot be known with certainty, *a priori*. Therefore we employ the procedure developed by Bai and Perron (1998) and empirically implemented by Bai and Perron (2003) to analyze multiple structural changes occurring at unknown dates in the case of linear regression models. Also, considering that the Final Rule of COOL was implemented fairly recently (March 2009), there might be structural change towards the end of the sample. Therefore, Andrews' *S* test is used to detect end-of-sample structural change. Both procedures are implemented in GAUSS software.

In the Bai and Perron (hereafter BP) procedure, break dates are endogenously determined by global rather than local minimization of the sum of squared residuals. For simplicity, assume that the number of breaks, m, is known (although it is possible to treat m as unknown). Thus the number of regimes is $m+1$, and the vector of regimes, $j = 1,........,m+1$. Break points can be indexed as $T_1,........,T_m$ and are assumed unknown. In the regression model:

$$y_t = x_t'\beta + Z_t'\delta_j + u_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(13)}$$

where $t = T_{j-1}+1,........,T_j$, and x_t and Z_t are $(p\times 1)$ and $(q\times 1)$ vectors of covariates, respectively, the estimates of β and δ_j for each regime or *m*-partition are obtained by minimizing the sum of squared residuals. This is referred to as a partial structural change model because β does not change, i.e., it is the same for the entire sample. However, if *p* = 0, then $y_t = Z_t'\delta_j + u_t$, which is the special case of the pure structural change model in which all parameters are subject to change. When the optimal values of the estimates are substituted into the objective function, we obtain the sum of the squared residuals as $S_T(T_1,.......,T_m)$,

and the estimated break points $(\hat{T}_1,......,\hat{T}_j)$ are such that:

$$(\hat{T}_1,......,\hat{T}_j) = \arg\min_{T_1,..................,T_m} S_T(T_1,........,T_j) \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Other important features of this procedure are that it allows for autocorrelation and heteroskedasticity in the error terms, lagged dependent variables, trending covariates, and different distributions of errors and covariates across partitions.

In testing for multiple structural breaks, BP provide three options: (a) a test of no break versus a fixed number of breaks, (b) a test of no break versus an unknown number of breaks given some upper bound (Double Maximum tests), and (c) a test of *l* versus *l* + 1 breaks. In this study, we first employ the Double Maximum tests to determine if at least one break is present. If the null hypothesis is rejected, we employ the $\sup F_T(l+1|l)$ test of *l* versus *l* + 1 breaks to sequentially determine the number of breaks.

Andrews' *S* test (Andrews, 2003) is a variant of the F test. It is a generalization of the Chow test (Chow, 1960) in that it is also applicable to non-linear models, models with endogenous regressors, and models whose errors may be non-normal, heteroskedastic, conditionally heteroskedastic, and autocorrelated. Specifically, it is obtained by transforming a regression model to account for serial correlation, where the transformation is by the square root of the inverse of an estimator of the $m \times m$ error covariance matrix. Assume a linear regression model with *n* and *m* observations before and after the potential break point, respectively, and with *d* number of regressors:

$$Y_i = \begin{cases} X_i^{'}\beta_0 + U_i; i = 1,........, n \\ X_i^{'}\beta_{1i} + U_i; i = n+1,....., n+m \end{cases} \quad \text{.......................................} (15)$$

If the data are stationary, the null and alternative hypotheses are $H_0 : \beta_0 = \beta_1$, and $H_1 : \beta_0 \neq \beta_1$, respectively, for $i = n+1,……., n+m$. Assuming that parameters are stable over the first n observations, when $m \geq d$, the test statistic

$$S = S_{n+1}(\hat{\beta}_{n+m,} \hat{\Sigma}_{n+m}) \quad \text{...} (16)$$

where $\hat{\beta}$ is the least squares estimator of β for observations $i = 1,........, n+m$,

and $\hat{\Sigma}$ is the estimator of the $m \times m$ covariance matrix of errors. For a given observation $j = 1,........, n+1$,

$$S_j(\beta,\Sigma) = A_j(\beta,\Sigma)' V_j^{-1}(\Sigma) A_j(\beta,\Sigma) \quad \text{.......................................} (17)$$

where $A_j(\beta,\Sigma) = X'_{j,j+m-1} \Sigma^{-1}(Y_{j,j+m-1} - X_{j,j+m-1}\beta)$, and $V_j(\Sigma) = X'_{j,j+m-1} \Sigma^{-1} X_{j,j+m-1}$.

When $m \leq d$, S is the sum of the squared transformed post-change residuals:

$$S = P_{n+1}(\hat{\beta}_{n+m,} \hat{\Sigma}_{n+m}) \quad \text{...} (18)$$

where

$$P_j(\beta,\Sigma) = (Y_{j,j+m-1} - X_{j,j+m-1}\beta)' \Sigma^{-1}(Y_{j,j+m-1} - X_{j,j+m-1}\beta) \quad \text{.........} (19)$$

A parametric sub-sampling procedure as provided in Andrews (2003) is used to obtain critical values of the test statistic.

Prior to estimating the equations, all variables are checked for stationarity. Also, an appropriate functional form for each equation is established. Several tests of unit roots have been proposed [see Dickey and Fuller (1979; 1981), Phillips and Perron (1988), Zivot and Andrews (1992), and Elliot et al (1996)]. We employ the Zivot and Andrews (1992) test of unit roots in which the possibility of at least one structural break in the series is accounted for. Allowing for a break in both the drift and trend, a Bayesian (Schwarz) Information Criterion (BIC) to select the number of additional lags, and a trimming factor of 0.15, we do not reject the null hypothesis of unit root at the 5% level of significance for exchange rates, earnings in Canadian meat processing, Canadian labour income, and barley and corn prices. Therefore these variables are differenced, and all the first-differences are found to be stationary at the 5% level of significance.

Because differencing yields several negative values in some of the exogenous variables, the use of either a log-linear (double-log) or the semilog lin-log specification is automatically ruled out. Therefore the Extended Projection (PE) test proposed by MacKinnon et al (1983) is used to select between a linear specification and the semilog log-lin form. The PE test is inconclusive, so we apply Akaike (1974) and Schwarz (1978) information criteria, both of which provide support for the log-lin functional form. Therefore the empirical models for equations (10), (11), and (12) are specified as follows:

$$\ln M_B^{US} = \alpha_0 + \alpha_1 Z_B^{US} + \alpha_2 Z_B^{C} + \alpha_3 Y^{US} + \alpha_4 Y^{C} + \alpha_5 Z_S^{US} + \alpha_6 Z_S^{C} + \alpha_7 T + \alpha_8 XR \ldots \text{ (20)}$$

$$\ln M_S^{US} = \alpha_0 + \alpha_1 Z_B^{US} + \alpha_2 Z_B^{C} + \alpha_3 Y^{US} + \alpha_4 Y^{C} + \alpha_5 Z_S^{US} + \alpha_6 Z_S^{C} + \alpha_7 T + \alpha_8 XR \ldots \text{ (21)}$$

$$\ln M_F^{US} = \alpha_0 + \alpha_1 Z_B^{US} + \alpha_2 Z_B^{C} + \alpha_3 Y^{US} + \alpha_4 Y^{C} + \alpha_5 Z_S^{US} + \alpha_6 Z_S^{C} + \alpha_7 T + \alpha_8 XR \ldots \text{ (22)}$$

where T and XR are time trend and exchange rate, respectively. But the structural change tests that follow are in essence based on the notion that the assumptions of the chosen functional form may not necessarily apply to all observations in the sample (Green, 2002; Verbeek, 2008).

If any COOL-induced structural breaks are evident, this can be ascertained by extending the procedure to U.S. import demand for a related commodity, but one which is not significantly affected by COOL – Canadian breeding cattle. Beef from animals born to imported breeding cattle and raised in the U.S. would be labeled category A (product of the U.S.) Thus both tests are applied to the following import demand equation:

$$M_{BF}^{US} = \beta_0 + \beta_1 P_H^C + \beta_2 P_S^{US} + \beta_3 T + \beta_4 XR \text{ ……………………….. (23)}$$

where M_{BF}^{US} denotes monthly U.S. imports of breeding female cattle including replacement heifers and bred and unbred cows. These were obtained from the Agricultural Marketing Service (AMS) of the U.S. Department of Agriculture. P_H^C is the monthly average Alberta price of feeder heifers (601 – 700 lb) in \$/cwt (CAD) obtained from AAFC and deflated by Canada's CPI, and P_S^{US} is the monthly average Montana price of feeder steers (500 – 550 lb) in \$/cwt (USD) from the AMS and deflated by the U.S. CPI. Data were from January 2007 to February 2011, hence a total of 50 observations.

2.5 Results

In testing for structural change using the BP procedure, the upper bound, *M*, in the Double Maximum tests and the choice of trimming factor are crucial to the outcome. We set *M* = 5, which, according to BP, is sufficient for most empirical studies. A trimming factor is used to determine the size of segments in the data, where a segment is the data unit within which hypotheses for structural breaks are tested. The smaller the trimming factor, the fewer is the number of observations in a segment. The choice of a trimming factor therefore depends on the size and properties of the data. For a given sample size, testing for structural change while allowing for say, heteroskedastic errors and autocorrelation, requires a larger trimming factor than in the case with homoskedastic errors and no autocorrelation. Using both the Durbin-Watson *d* test (Durbin and Watson, 1950; 1951) and Breusch-Godfrey test (Breusch, 1978; Godfrey, 1978) of autocorrelation, for all three equations, we reject the null hypothesis of no autocorrelation in the residuals at the 5% level of significance. Also, in constructing the F-test, we allow for different moment matrices for regressors across segments and different residual variances across segments. This is done so as to avoid imposing the assumption that the distribution of the regressors is the same across segments. According to Bai and Perron (2003), even if the distribution of regressors was the same across segments, this would not guarantee more accurate estimates because the resulting asymptotic covariance matrix may be different from the exact one especially if small segments are used. Thus we use a trimming factor of 0.15, hence 20 observations per segment. This number of observations is adequate since Bai and Perron (1998) relax the assumption that estimating the break dates requires sufficient observations close to the true break dates. They note that the minimum number of observations in each segment can be equal to or greater than the number of covariates, q, and is expected to increase in proportion to sample size. In their empirical application, they use a similar trimming factor (0.15) for 120 observations.

Tables 2 and 3 summarize the results of the BP procedure for each of the three estimated equations. Starting with the Double Maximum test of the null hypothesis of no structural break in all parameters against the alternative of an unknown number of breaks, we find that test statistics of both the unweighted Double Maximum test (UDmax) and the weighted Double Maximum test (WDmax) are greater than the critical values in all three equations. Thus we reject the null hypothesis of no structural break at the five percent level of significance. The next logical step therefore is to estimate the number of breaks. The SupF test of the null hypothesis of no break against the alternative of one break indicates the presence of at least one structural break in each equation at the five percent level of significance. The SupF($l+1 \mid l$) test of the null of one break against two breaks leads to a rejection of the null hypothesis for all three equations at the five percent significance level. However, whereas we reject the null hypothesis of two breaks against the alternative of three for the beef equation, we do not reject the null hypothesis for both feeder and fed cattle export equations.

On testing the null hypothesis of three breaks against four for the beef export equation, we obtain a test statistic of 6.84 with a critical value of 28.91 at the five percent significance level (table 2). The BP procedure therefore suggests that there are two structural breaks (three regimes) in the feeder and fed cattle import equations, and three breaks (four regimes) in the beef import equation.

Table 2: Empirical results of the structural break tests using the BP procedure

Equation	Test	Test Statistic	Critical Value (5%)
Feeder cattle	Double Maximum		
	UDmax	628.34	25.81
	WDmax	628.34	27.53
	SupF		
	(1 │ 0)[a]	628.34	25.65
	SupF(*l*+1 │ *l*)		
	(2 │ 1)[b]	39.08	25.65
	(3 │ 2)	26.61	27.66
Fed cattle	Double Maximum		
	UDmax	76161.83	25.81
	WDmax	106171.24	27.53
	SupF		
	(1 │ 0)	1167.85	25.65
	SupF(*l*+1 │ *l*)		
	(2 │ 1)	86220.59	25.65
	(3 │ 2)	17.99	27.66
Beef	Double Maximum		
	UDmax	133.53	25.81
	WDmax	133.53	27.53
	SupF		
	(1 │ 0)	133.53	25.65
	SupF(*l*+1 │ *l*)		
	(2 │ 1)	39.65	25.65
	(3 │ 2)	58.77	27.66
	(4 │ 3)	6.84	28.91

[a, b] Refers to a test of the null hypothesis of no break against the alternative of one break, a test of the null of one break against two breaks, and so on. The null hypothesis is not rejected if the test statistic is less than the critical value.

The pertinent question in the context of our study is whether or not these structural breaks can be associated with COOL. Table 2 provides the estimated break dates and their 95% confidence intervals. In all three equations, the first structural change occurred in May 2003. It was at this time that the Canadian Food Inspection Agency (CFIA) announced the discovery of a single case of BSE in Alberta, which led to the immediate closure of all borders to Canadian cattle and beef exports. The second break dates occurred in 2005 in all equations, with that of the beef equation occurring a bit earlier than for the feeder and fed cattle equations.

Table 3: Break dates estimated by the BP procedure

Equation	**Break dates (95% confidence interval)**
Feeder cattle	May 2003 (April 2003 – June 2003) June 2005 (April 2005 – July 2005)
Fed cattle	May 2003 (May 2003 – June 2003) June 2005 (June 2005 – July 2005)
Beef	May 2003 (April 2003 – May 2003) January 2005 (January 2005 – February 2005) April 2008 (March 2008 – May 2008)

An explanation for the second break dates can also be found in the chronology of BSE events. In August 2003, the U.S. partially reopened its border to boneless meat from cattle less than 30 months old, while maintaining the ban on live cattle imports. But in January 2005, the CFIA announced it had detected yet another case of BSE in an Alberta beef cow. This probably affected the behavior of U.S. beef importers. The second structural break in the feeder cattle equation occurs at the same time as that in the fed cattle import equation. The breaks occur a month before the reopening of the U.S. border to live cattle imports, and therefore can likely be attributed to the BSE crisis.

While the BP procedure yields no evidence of COOL impacting U.S. feeder and fed cattle imports from Canada, there appears to be such evidence for beef imports. Structural change in the beef equation is detected in April 2008, five months before the U.S. implemented the COOL Interim Rule that henceforth included beef. Note that mandatory COOL for meat and other products was conceived as far back as 2002 in the 2002 Farm Bill but was initially applied to fish and shellfish only starting December 2004. Application to the rest of the products had been slated for September 2006 but was delayed to September 2008. Thus it seems that beef importers adjusted their behavior in anticipation of the law, and a significant part of this adjustment occurred in April 2008.

However, results of the BP test should be treated cautiously; although the test is able to detect structural breaks due to BSE, it does not provide conclusive evidence of structural breaks caused by COOL. According to Castle et al (2012), the BP test may not be robust to detecting structural breaks at or near the beginning and end of the sample. Nonetheless, given the narrow confidence intervals obtained in the BP procedure, the above break dates have been precisely estimated.

The Final Rule of COOL was implemented as late as March 2009, raising the possibility of end-of-sample structural change. Therefore we compute the critical values for Andrews' *S* statistics for each equation. The test assumes structural stability before the potential change point. But this is not the case with our data as shown by the BP test results. Since the last break date associated with BSE is June 2005, we eliminate all observations before July 2005, leaving us with 68 observations. We conjecture that an early adjustment to COOL may have occurred somewhere between January 2008 and March 2009 and therefore we obtain parametric sub-sampling critical values for observations starting from January 2008. As shown in table 4, we find evidence of COOL-induced structural change in U.S. feeder cattle imports at the 5% level of significance in February

2008, whereas structural change in fed cattle and beef imports is found later in the sample. For the fed cattle equation, we reject the null hypothesis of no structural change at the five percent level of significance in the months of February and March of 2010, while the null hypothesis in the beef equation is rejected at the same level of significance in March 2010.

Table 4: Break dates estimated by Andrews test

Equation	**Break date**	**P-value**
Feeder cattle	February 2008	0.04
Fed cattle	February 2010	0.02
	March 2010	0.02
Beef	March 2010	0.04

It is rather intriguing that feeder cattle importers, despite incurring a relatively small total outlay as a result of COOL (Informa Economics, 2010), were the quickest to adjust to the policy. Structural change in feeder cattle imports occurred before implementation of both the Interim Rule and Final Rule, and two years before structural change in fed cattle import demand. The U.S. cattle cycle was in the liquidation phase between January 2008 and December 2010 and as such, the domestic supply of fed cattle was abundant at the time (U.S. Department of Agriculture, 2010). Therefore a plausible explanation for the difference in break dates between feeder and fed cattle imports can be found in the procurement techniques for the two cattle types. Most feeder cattle are cash (negotiated) cattle procured from a rapid auction process in auction markets (Wang and Roe, 2002). But with regard to fed cattle, U.S. importers of Canadian fed cattle have increased the number of cattle purchased by contract from 6% in

2002 to 48% in 2011, while reducing the number of cash cattle from 70% in 2006 to 14% in 2011 (Canfax, 2012). As a result, it seems fed cattle importers were unable to quickly change their sources of fed cattle supply in response to COOL.

Next, we calculate the sizes of the structural breaks as the change in the level of imports between pre- and post-structural break regimes as would be predicted by the models. For each commodity, this change can be calculated simply by applying the differential intercept and slopes to the mean values of the exogenous variables prior to the structural change, since differential parameters represent parameter shifts. Alternatively, an estimate of post-structural break imports can be obtained by using the first regime parameters and differential parameters to calculate a new set of parameters for the post-structural break period, and applying it to the mean values of the exogenous variables after the structural break. This is then subtracted from the predicted pre-structural break imports. The reduction in imports caused by COOL is found to be highest for feeder cattle, and lowest for beef; on average, there was a 21% reduction in U.S. imports of Canadian feeder cattle from February 2008 to February 2011, followed by an 18% reduction in fed cattle imports from February 2010 to February 2011, while the reduction in beef imports from March 2010 to February 2011 was only 1%. These results are fairly consistent with those of Pouliot and Sumner (2012) who find that the reduction caused by COOL in the ratio of imports to domestic use is statistically more significant for feeder than fed cattle imports, and those of Rude and Twine (2012) who project that COOL would cause a 27% reduction in

Canadian feeder and fed cattle exports, and a 3% reduction in U.S. demand for Canadian beef.

To confirm the robustness of the BP test and Andrews' test in picking up COOL-induced structural breaks, we apply them to the U.S. import equation for Canadian breeding cattle. The BP test finds a structural break in October 2007, which is a month before the U.S. border was reopened, following the BSE outbreak, to Canadian live cattle including breeding cattle born on or after 1 March 1999. Andrews' test, however, does not find any structural break. Therefore the structural breaks in U.S. cattle and beef imports estimated by the Andrews procedure are likely due to COOL.

2.6 Summary and Conclusion of Chapter Two

The Canadian cattle and beef industry has had to deal with a host of market and policy shocks that have adversely affected its competiveness. Among these shocks, mandatory COOL recently implemented by the U.S. has perhaps been the most flustering to the industry as evidenced by the substantial empirical literature on its potential impacts, the legal challenge mounted by Canada and Mexico in the WTO, and the subsequent rulings by the Organization's Dispute Settlement Panel and Appellate Body that the law contravenes Article 2.1 of the TBT Agreement. The WTO gave the U.S. a deadline of May 2013 to comply with the ruling, but in August 2013, Canada and Mexico requested the WTO to establish a compliance panel to determine if the changes the U.S. has made to the law comply with the ruling. While most existing studies on COOL impacts have been *ex ante*, this study undertakes an *ex post* econometric assessment of its real impact thus far by examining structural change in the behavioral relationships governing cattle and beef trade flows.

The COOL legislation is relatively new but it has a rather long and intricate history. As such, any break points associated with it would not be precisely known. Therefore the study uses two approaches to determine structural change in U.S. import demand for Canadian feeder cattle, fed cattle, and beef. The first approach is a BP test of multiple structural breaks in which the break points are unknown, while the second approach is Andrews' *S* test that is robust to determining structural breaks in small samples, and breaks that occur at the end of the sample. Reduced-form import demand equations are derived from a partial equilibrium model of the U.S. and Canadian beef cattle industries, and are estimated using monthly data from January 2000 to February 2011. Prior to testing for structural breaks, the necessary diagnostic tests are performed.

The hypotheses of no structural break in U.S. import demand for Canadian feeder cattle, fed cattle, and beef due to mandatory country of origin labeling are rejected by the Andrews *S* test. U.S. imports of Canadian feeder cattle from February 2008 to February 2011 were 21% less than those in the preceding period, and from February 2008 to February 2011, imports of fed cattle declined by 18%. The decline in beef imports from March 2010 to February 2011 was 1%. The notion that COOL is responsible for the observed reductions in cattle and beef imports is supported by the absence of COOL-induced structural change in U.S. import demand for Canadian breeding cattle. Based on these results, we conclude that COOL has had a detrimental effect on Canada's beef cattle industry.

These findings have several implications. Structural breaks in economic relationships are indicative of changes in optimal decision criteria of agents. At the industry level, these changes may be reflected in, among other things, changes in trade flows and trading partners. So, the structural breaks revealed by this study might be a signal of structural change in the Canadian beef cattle industry as a whole.

More important, however, are the policy implications of the study's findings. First, the U.S. remains the largest importer of Canadian beef and cattle in spite of COOL. Therefore Canada's recent success in challenging the law in the WTO notwithstanding, it would be helpful in the long-run for Canada and the U.S. to work towards harmonizing beef and cattle trade regulations in a manner that benefits both countries. This will also help prevent either country from enacting regulations that act as barriers to trade.

Second, the finding that COOL has had a small impact on U.S. imports of Canadian beef relative to feeder and fed cattle imports supports the government's goals of increasing domestic beef processing capacity, and access to offshore beef markets (Agriculture and Agri-Food Canada, 2005). This will necessitate the industry to develop value chains that meet the demands of consumers in potential markets. Government support to the industry would then involve negotiating trade agreements that provide access to potential beef markets, and provision of financial support in developing the necessary value chains.

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CHAPTER THREE: CANADIAN CATTLE CYCLES AND CYCLE EFFECTS OF MARKET SHOCKS

3.1 Background

The beef cattle industry is characterized by regular and well-pronounced cycles. The theory of cattle cycles is developed by Rosen et al (1994); cyclicality in beef cattle inventories is because cattle are both capital and a consumption good, and their production is characterized by long biological lags. Rosen *et al* combine these three aspects to show how permanent shocks in demand and supply lead to cattle cycles. Assuming an AR(1) process for all shocks, they encounter the backward bending supply response to a permanent shock initially revealed by Jarvis (1974) for Argentine cattle and later confirmed by Rosen (1987) for U.S. cattle. They also find the normal positive supply response to a transitory shock; an increase in demand for beef increases current price and hence supply (Rosen, 1987), but the demand shock dissipates before the entire market responds (Rosen *et al*., 1994). Ranchers respond to a permanent increase in the demand for beef (hence its market price) by reducing the supply of slaughter heifers and cull cows opting to breed them instead so as to increase the breeding stock and thus benefit from higher future production. After about a three-year gestation and maturation period (which explains the relatively long duration of the cycle), cattle inventories and beef supplies begin to surge, leading to a decline in prices. This then precipitates a period of herd liquidation until inventories hit a trough. At low levels of cattle and beef supply, prices begin to recover, inventories build up, and the cycle is repeated. Rosen *et al*, however, find only a three-year cycle contrary to the observed ten-year cycle. Aadland (2004) builds on their work by endogenously propagating shocks to model a ten-year cycle.

The cattle cycle has been of much interest to the Canadian beef cattle industry. Gracey and Canfax research (1995) and Canfax Research Services (2009) provide a detailed description of the cattle cycle and its implications for beef cattle management. They argue that although the cycle is usually defined in terms of the total number of cattle in the national beef herd, it is better measured in terms of the yearly number of breeding females in the national breeding herd and the annual calf crop. The number of beef breeding females, however, is comprised of the total number of beef cows and replacement beef heifers. But Foster and Burt (1992) observe that heifer replacement data usually includes both one- and two-year old animals, and even though both are held for replacement, the one-year old females will not calve until one year later, which causes a measurement error in the variable. Canfax Research Services (2009) notes that the cycle can be meaningfully measured in terms of beef cow inventories. Other than the cattle cycle (total inventory) and beef cow cycle (beef cow numbers), the cycle can also be accurately described in terms of beef supply (cattle slaughtered plus fed cattle exports). Generally, it lasts 8 to 12 years and has four stages: expansion (5 years), peak (duration highly unpredictable), liquidation (2 - 3 years) and consolidation (2 - 3years). The cycle cannot be precisely predicted, but several indicators of herd expansion and contraction can be used to determine the stage of the cycle at which the industry is (Gracey and Canfax Research). These are: female to male sex ratio at disposal, heifer to steer ratio, steer to beef cow ratio, and cow culling rates.

Although the cyclical nature of the beef cattle industry has important policy implications, it is often overlooked by both researchers and policy makers. For instance, the possibility that cattle producers may respond negatively in the short-run to price incentives is highly plausible. This means that government or industry response to a shock during a downturn can inadvertently magnify its impact by exaggerating the trough of the existing cycle. Therefore it is arguable that any response to a shock to the industry should be cognizant of this cyclicality, and should probably occur only if the shock has the potential to significantly alter the existing cycles. But such an approach would require an understanding of the nature of the existing cycles, and how they have been or would be impacted by economic factors associated with exogenous shocks. This chapter estimates cycles in total cattle inventories, beef cow inventories, beef supply, and beef prices, and examines how they might have changed over time because of the various shocks the industry has experienced.

3.2 Literature Review

The study of cyclical patterns in economic time series data has proceeded mainly in the framework of harmonic motion in three fashions (Barksdale and Guffey, 1972): analysis of a single time series (spectral analysis), analysis of the relationship between two series (cross-spectral analysis), and analysis of the relationship between two or more series each associated with another variable (partial cross-spectral analysis). Most analyses have involved macroeconomic time series, especially those associated with the business cycle. The widely observed cyclicality of agricultural commodities, however, has received relatively little attention in empirical literature. Rausser and Cargill (1970) employ spectral techniques to investigate the existence of 30-month U.S. broiler cycles defined by broiler prices (I), broiler chick placements (II), broiler chick prices (III), and hatchery supply flocks (IV). Also, they use cross-spectral techniques to determine lead-lag relationships between (I) and (II), (III) and (IV), and (II) and (IV). Gelb (1979) investigates U.S. coffee price oscillations, and conducts a cross-spectral examination of prices and quantities. Griffith (1975) applies spectral and cross-spectral methods to assess pricing efficiency in the New South Wales pig meat market. Griffith (1977) and Purcell (1999) analyze the Australian pig cycle. Dawson (2009) uses spectral methods to examine cyclical patterns in prices and production of U.K. pig meat. Naylor et al (1967) analyzes cyclical patterns in the U.S. textile industry, but does so in the context of illustrating the use of spectral methods to validate an econometric model.

Studies analyzing cyclicality in cattle production include Kulshreshtha and Wilson (1973) and Mundlak and Huang (1996). Mundlak and Huang's is a comparison of cattle cycles (defined by slaughter, price, stock of cows, and total herd) of three technologically different countries namely, the U.S., Argentina and Uruguay. Spectral decomposition of the series reveals similar cycles among the three countries. Kulshreshtha and Wilson (1973) study the nature of cyclical oscillations in the Canadian hog and cattle sectors. Specifically, their interest is to determine the regularity and duration of the most prominent cycles, and estimate the short- and long-run price flexibilities. The time series of interest are slaughter output and farm prices of hogs and beef cattle for the period January 1949 to April 1972. Their spectral results show that both cattle prices and cattle slaughter exhibit short- and long-run cycles. Short-run price cycles are 12-month cycles, while long-run cycles last 114 months (9.5 years). Short-run slaughter cycles are seasonal 3- to 6-month cycles, while long-run cycles range between 108 and 120 months. Their results are consistent with those of Mundlak and Huang, who find 10-year cycles for U.S. cattle stocks and slaughter.

Since the Kulshreshtha and Wilson study, no other has been undertaken for the Canadian beef cattle industry. The existing gap in the literature is the lack of up-to-date information on the nature of cycles in the industry, as well as evidence as to whether or not they have changed because of exogenous shocks to the industry. This is the focus of the current study. The study estimates cycles in total cattle inventories, beef cow inventories, beef supply, and beef prices, and tests for changes in some of these cycles due to appreciation of the Canadian dollar relative to the U.S. currency, and feed price escalation.

3.3 Method

3.3.1 Estimating Cycles: A Spectral Analysis

This study estimates cycles in total cattle inventories, beef cow inventories, beef supply, and beef prices. An autocorrelation function of a time series variable can provide a rough indication of any cycles that may be present in the series. In this study, autocorrelation functions of the four series are derived using Bartlett's formula (Berlinet and Francq, 1997). But a more powerful technique usually used to estimate cycles in a time series variable is spectral analysis. In the strict sense, the term *cycle* implies perfect regularity or periodicity. But according to Granger and Hatanaka (1964), what is usually referred to as cycles in economic time series are simply fluctuations that may or may not exhibit regularity. For instance, as previously mentioned, the cattle cycle cannot be precisely predicted, and that is because no two cattle cycles are exactly similar in terms of duration and amplitude (Canfax Research Services, 2009). This probably explains the persistence of the cattle cycle. The lack of perfect periodicity is what underlies the spectral technique used in analyzing economic time series data.

Spectral analysis is a technique in which a time series is converted from the time domain to the frequency domain in order to examine its cyclical patterns. It is a generalization of Fourier analysis (also called harmonic analysis or periodogram analysis) initially used in the physical sciences to study the time-dependence of physical processes (Fishman and Kiviat, 1967). In Fourier analysis, any time series is assumed to contain different frequencies. When the time series is plotted against time, the time domain view is obtained, but when it is plotted against frequency, a frequency domain (or signal spectrum) view is attained (Langton, 2012). Therefore Fourier analysis with respect to a time series is the decomposition of the time series into its harmonic components, and then determining their amplitudes. The harmonic components are the different pairs of sine and cosine terms that constitute the Fourier series equation. These trigonometric sine and cosine functions exhibit complete autocorrelation, and are by definition periodic. The Fourier series equation represents the so-called Fourier decomposition, and the sine and cosine terms of each harmonic have the same frequency, and therefore their coefficients (amplitudes) can be added together to obtain the power of the harmonic (Langton, 2012).

Hamilton (1994) shows how spectral analysis is used to estimate cycles in time series data. First, he derives the population spectrum of a time series, and then the sample analog that is used to estimate the population spectrum. The value of a time series variable, Y_t, is a weighted sum of periodic functions of the form cos(ωt) and sin(ωt), where ω denotes a particular angular frequency:

$$Y_t = \mu + \int_0^{\pi} \alpha(\omega) \cdot \cos(\omega t) d\omega + \int_0^{\pi} \delta(\omega) \cdot \sin(\omega t) d\omega. \quad \ldots\ldots\ldots (1)$$

Equation (1) is the spectral representation theorem. Let $\{Y_t\}_{t=-\infty}^{\infty}$ be a covariance stationary process with mean $E(Y_t) = \mu$ and j^{th} autocovariance

$$E(Y_t - \mu)(Y_{t-j} - \mu) = \gamma_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If these autocovariances are absolutely summable[5] (i.e., $\sum_{j=-\infty}^{\infty} |\gamma_j| < \infty$), the autocovariance generating function is given by:

$$g_Y(z) \equiv \sum_{j=-\infty}^{\infty} \gamma_j z^j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where the complex scalar $z = e^{-i\omega}$. Dividing the above function by 2π (the interval over which trigonometric functions repeat themselves) and evaluating it

[5] This implies a short memory process. The counterpart is a long memory process (i.e., $\sum_{j=-\infty}^{\infty} |\gamma_j| = \infty$); its spectral density function is unbounded at the zero frequency, and therefore its autocorrelation function decays very slowly – hyperbolically rather than exponentially – and the differencing parameter, *d*, can take on a fraction (Geweke and Porter-Hudak, 1983; Janacek, 1994; Chiawa *et al*., 2010).

at some z with $i = \sqrt{-1}$ and ω a real scalar, we obtain the population power spectrum of Y:

$$S_Y(\omega) = \frac{1}{2\pi} g_Y(e^{-i\omega}) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_j e^{-i\omega j} \quad \text{………………} (4)$$

The power spectrum is a function of ω, and for any given value of ω and a sequence of autocovariances $\{Y_t\}_{t=-\infty}^{\infty}$, the value of $S_Y(\omega)$ can be calculated. Thus, the power spectrum and autocovariance functions are Fourier transforms of one another. The latter and hence variance can be recovered through an inverse transformation. Using De Moivre's theorem, which states that $e^{-i\omega j} = \cos(\omega j) - i \cdot \sin(\omega j)$, equation (4) can be rewritten as

$$S_Y(\omega) = \frac{1}{2\pi} \sum_{j=-\alpha}^{\alpha} \gamma_j \left[\cos(\omega j) - i \cdot \sin(\omega j)\right] \quad \text{…………} (5)$$

For a covariance stationary process, $\gamma_j = \gamma_{-j}$, equation (5) implies

$$S_Y(\omega) = \frac{1}{2\pi}\gamma_0\left[\cos(0) - i \cdot \sin(0)\right] + \frac{1}{2\pi}\left\{\sum_{j=1}^{\alpha}\gamma_j\left[\cos(\omega j) + \cos(-\omega j) - i \cdot \sin(\omega j) - i \cdot \sin(-\omega j)\right]\right\} \quad \text{……} (6)$$

Using the trigonometric relations: $\cos(0) = 1$, $\sin(0) = 0$, $\sin(-\theta) = -\sin(\theta)$, and $\cos(-\theta) = \cos(\theta)$, equation (6) becomes

$$S_Y(\omega) = \frac{1}{2\pi}\left\{\gamma_0 + 2\sum_{J=1}^{\infty}\gamma_j \cos(\omega j)\right\} \quad \text{…………..…} (7)$$

Thus the power spectrum is non-negative and a periodic function of ω with a period 2π; if the value of $S_Y(\omega)$ is known for all ω from 0 to π, then the value of $S_Y(\omega)$ for any ω can be inferred. In sum, the power spectrum is a Fourier cosine transformation of the autocovariance, and corresponds to particular frequencies (Naylor *et al*., 1969). It shows the contribution (power) of a particular frequency to (in) the total variance of the time series since the area under the population spectrum is the total variance of the series. And the variance of a given frequency is equal to half the square of its amplitude (Sovereign, *et al*., 1971), implying that it is directly proportional to the amplitude.

Alternatively, an autocorrelation function (which can be derived from the autocovariance function) can be used to generate what is referred to as a spectral density function (Box *et al*., 2008). And just like the power spectrum, an estimate of the spectral density measures the contribution of a particular frequency component to the total variance of a time series (Fishman and Kiviat). In essence, the spectral density is a Fourier transformation of the autocorrelation function, and may simply be calculated as the power spectrum divided by the variance (McPheters and Stronge, 1979).

From equation (5), it can be seen that generally, low frequencies yield large spectral values and therefore contribute more to the variance of the series than do higher frequencies. This leads to the typical spectral shape of an economic time series as illustrated by Granger (1966) and Naylor et al (1969), obtained by plotting the sample power spectra or spectral density estimates against frequencies. If a time series contains an important cycle, its power spectrum or spectral density function will have a peak at the frequency of the cycle (Granger, 1990) since a cycle corresponds to a specific frequency and period.

The population spectrum shown in equation (7) can be estimated using a sample periodogram. To derive the sample periodogram, we continue with the notation in Hamilton (1994). For a sample series with T observations $(y_1, y_2, ..., y_T)$, there are frequencies $\omega_1, \omega_2, ..., \omega_M$ and coefficients $\hat{\mu}, \hat{\alpha}_1, \hat{\alpha}_2, ..., \hat{\alpha}_M, \hat{\delta}_1, \hat{\delta}_2, ..., \hat{\delta}_M$ such that the value of y at time t can be expressed as the following sample analog to the spectral representation theorem shown in equation (1):

$$y_t = \hat{\mu} + \sum_{j=1}^{M} \left\{ \hat{\alpha}_j \cdot \cos\left[\omega_j (t-1)\right] + \hat{\delta}_j \cdot \sin\left[\omega_j (t-1)\right] \right\} \quad \text{.................... (8)}$$

Conceptually, an OLS regression of equation (8) leads to a perfect fit (i.e., no error term). Recall that the coefficients of this regression are the amplitudes of the sinusoid. Using these coefficients, the portion of the sample variance of the series that is due to frequency ω_j can be obtained as $0.5(\hat{\alpha}_j^2 + \hat{\delta}_j^2)$, and is proportional to the sample periodogram evaluated at ω_j. The sample periodogram, which is the sample analog of equation (7), is

$$\hat{s}_y(\omega) = \frac{1}{2\pi}\left[\hat{\gamma}_0 + 2\sum_{j=1}^{T-1} \hat{\gamma}_j \cos(\omega_j) \right] \quad \text{.. (9)}$$

This study uses equation (9) to compute sample periodogram values corresponding to all possible temporal frequencies of each time series variable. In other words, the time series are decomposed into various frequencies and equation (9) is applied to obtain $\hat{s}_y$ for each frequency ω. We then plot $\hat{s}_y$ against ω.

Estimation Issues in Spectral Analysis

Several estimation issues arise in spectral analysis, two of which are important in the context of this study. The first is the size of data sufficient for spectral analysis. According to Granger and Hatanaka (1964), the technique requires data that is at least seven times the length of the longest cycle. However, it is not always possible to know *a priori* the length of the longest cycle. The authors suggest at least 100 to 200 observations, but note that crude spectra have been estimated with as few as 80 observations. Later, Granger (1966) observes that the typical spectral shape of a time series is independent of the size of the data. In this study, total cattle inventories and beef cow inventories have 82 observations each, while beef supply and beef prices have 241 and 296 observations, respectively. Thus, the size of data used in this study is adequate for spectral analysis, and compares with that used elsewhere.

Second, the time series must be stationary (Granger, 1966). A non-stationary time series may be a pure random walk, a random walk with drift (a constant), or a random walk with both drift and a time trend that is either deterministic or stochastic. Trends in either the mean or variance or both are long-term movements in the series, and are of particular concern in spectral analysis. This is because they are low frequency components and therefore will inevitably yield large spectral values. Moreover, they also tend to positively bias spectral values of neighboring frequencies, a phenomenon called leakage (Granger and Hatanaka). In this study, all variables are visually examined for the presence of trends, and tested for stationarity using the augmented Dickey-Fuller test prior to estimation. Those found to be non-stationary are made stationary through filtering (de-trending) or prewhitening (Nerlove, 1964) using the Hodrick-Prescott (HP) high-pass filter (Hodrick and Prescott, 1997), since simple differencing may not be effective in the presence of seasonal components (Box *et al*., 2008). Analysis is then performed on the cyclical component of the data.

3.3.2 Estimating Changes in Cycles: Intervention and Spectral Analysis

To determine whether or not cycles have changed due to some of the market shocks, intervention analysis is used to estimate each variable's response to each market shock. Where the response is found to be statistically significant, the spectral procedure described in the previous section is then used to generate and compare pre- and post-intervention cycles with respect to cycle duration (period) and amplitude.

Intervention models, also known as interrupted time series models, are a generalization of the univariate Box-Jenkins approach to modeling a time series variable in that rather than assuming the time series to be a pure ARIMA (*p, d, q*) process[6], they allow its time path to be influenced by an intervention (interruption or exogenous) variable (Box and Tiao, 1975).

As in Enders (2004), consider the model

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 z_t + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

where z_t is the intervention dummy that takes on the values 0 and 1 before and after the exogenous shock, respectively, ε_t is white noise, and $|\beta_1| < 1$. Since $z_t = 0$, the intercept is β_0, and the long-run mean of the series is $\beta_0/(1-\beta_1)$. After the shock, the intercept shifts to $\beta_0 + \beta_2$. Thus the initial or impact effect of

[6] p and q denote the number of autoregressive and moving average terms, respectively, while d denotes the degree to which the variables need to be differenced. But since the data have already been made stationary, $d = 0$, which implies an ARMA (*p, q*) process.

the shock is β_2. Its long-run effect, $\beta_2/(1-\beta_1)$, is the new long-run mean less the original long-run mean. That is, $\frac{(\beta_0+\beta_2)}{(1-\beta_1)}-\frac{\beta_0}{(1-\beta_1)}=\frac{\beta_2}{(1-\beta_1)}$

In this study, a three-step procedure is used in undertaking the intervention analysis (Enders, 2004). The first step involves modeling the underlying data generating process for each variable. According to Greene (2008), finding the appropriate model is largely a trial and error process since it is not predicated on any economic theory. Consistent with Box et al (2008), Greene notes that most empirical work has been based on the AR (1) model partly because it is widely believed to be a reasonable approximation of most data generating processes, and alternative models are usually too complex to analyze. Nonetheless, there are some studies that have attempted to systematically model stochastic processes by employing the Box-Jenkins approach. The approach involves comparing the sample autocorrelation function (correlogram) and partial autocorrelation function to those of various theoretical ARMA processes to determine the appropriate lag structure for a particular variable (Box *et al*., 2008; Greene, 2008; Enders, 2004; Yaffee and McGee, 2000; Hamilton, 1994).

When the Box-Jenkins approach is applied to this study, inconclusive results are obtained; the autocorrelations and partial autocorrelations for all series do not decay in a manner similar to any of the theoretical ones. Perhaps this is due to the strong cyclicality of the variables, which cyclicality we neither want to remove nor explicitly model, since the objective is to determine how it is affected by shocks. The cyclicality may be either real as a result of the observed cattle cycle, or spurious as a result of the Slutsky-Yule effect[7]. In fact Box *et al*. caution that although the approach is very helpful, it may at times provide ambiguous results. In such cases, they suggest the use of information criteria such the Bayesian (Schwarz) Information Criterion (BIC) or Akaike Information Criterion (AIC). The AIC is used for selecting the optimal lag-order from among various AR (p) models, as well as comparing the selected AR (p) model with potential ARMA (p, q) alternatives. For all four variables, parsimonious AR (p) models have the lowest AIC values and hence are deemed to be the appropriate data generating processes.

The next step is to estimate the models, including the effect of the shocks. The autoregressive moving average with exogenous inputs (ARMAX (p, q, b)) model specification is used to implement the estimation[8]. Conceptually, beef cattle inventories, which are a function of the price of feeder cattle, fed cattle, and feed, are the major determinant of beef supply (Coleman and Meilke, 1998; Marsh, 1999). It follows that beef supply may itself be affected by these prices. This warrants estimating the effect of a feed price shock on inventories, beef supply and prices. Also, because of Canada's trade in cattle and beef with the U.S., these prices are influenced by U.S.-Canada exchange rate fluctuations, implying that an exchange rate shock may affect cattle inventories, beef prices and supply. But because of the relatively complicated nature of the beef cattle industry due in part to its multi-market character and long production lags, the exact sequence of

[7] For more details on the Slutsky-Yule effect, see Barnett (2006).

[8] p and q denote the number of autoregressive and moving average terms, respectively, while b denotes the exogenous variable. However, AIC results mean that $q = 0$.

exogenous shock effects is unclear. The study therefore separately estimates the effects of the shocks on each variable. The exchange rate shock is viewed to have started in June 2002, while the feed price shock started in January 2007, and both do not seem to have waned by the end of the sample periods of the four response variables. In essence, all shocks are modeled as pure jumps; the exogenous variable takes on the values 0 and 1 before and after the shock, respectively.

The final step in modeling the interventions is to undertake diagnostic tests of the estimated models. First, all autoregressive coefficients should be statistically significant. Second, the residuals should be white noise, that is, they should have a zero mean and constant variance, meaning that they approximate a standard normal distribution, and should be serially uncorrelated (Gujarati, 2003). In this study, all autoregressive coefficients are found to be statistically significant and the residuals are white noise.

3.3.3 Summary of Analytical Procedure for Estimating Cycles

To estimate cycles in industry variables, we begin by ensuring that all the variables are stationary. For the nonstationary variables, stationarity is achieved by filtering using the Hodrick-Prescott filter. We then generate, for each stationary variable, an autocorrelation function to get an idea of its cyclical pattern. We then subject each stationary series to equation (9) to obtain its spectral values (also called periodogram values). Plotting the spectral values against their respective frequencies, we obtain a graph known as a periodogram, which is used to determine the presence or absence of cycles in the series. A cycle is indicated by a distinctive peak in the periodogram, and the inverse of the peak's frequency corresponds to the length of the cycle.

To determine whether or not exchange rate and feed price shocks have affected the variables and hence altered the observed cycles, we use a combination of intervention analysis and spectral analysis. First, we determine the appropriate lag structure of each variable using the AIC. Equation (10) is then adjusted accordingly to estimate the impact of each shock on the variables. The results are provided in table 7. Finally, for those variables for which the shocks had a statistically significant effect and which are long enough to be subjected to pre- and post-shock spectral analysis, their periodograms for the two time periods are generated and compared.

3.3.4 Data

Four time series are used in the analysis. These include total cattle inventories, beef cow inventories, beef supply, and beef prices. Total cattle inventories and beef cow inventories are annual data for the period 1931 to 2012 (82 observations) obtained from Statistics Canada. Beef supply is calculated as a sum of three series: total monthly inspected slaughter from January 1992 to January 2012 (241 observations) obtained from the Red Meat Section of Agriculture and Agri-Food Canada, monthly fed cattle exports for January 1992 to January 2012 (241 observations), and monthly feeder cattle exports for the same period both from the Economic Research Service of the U.S. Department of Agriculture. Beef prices are analyzed using the Alberta direct to packer monthly rail steer prices for Jan. 1988 to Aug. 2012 (296 observations) from Agriculture and Agri-Food

Canada. These are found to be highly correlated with live steer prices with a correlation coefficient of 0.99. Nominal prices are used because deflating prices in spectral analysis leads to loss of information on the short-run dynamics of the data generating process (Purcell, 2001). Summary statistics for the four variables are provided in table 5.

Table 5: Summary statistics for variables used in spectral analysis

Variable	Mean	Std. Dev
Total cattle inventories (‘000 head)[a]	12,152	2,471
Beef cow inventories (‘000 head)[a]	2,858	1,552
Beef supply (head)[b]	328,204	49,422
Rail steer price (Cdn $/cwt)[c]	147.56	16.64

[a]Source: Statistics Canada (2012)
[b]Source: Agriculture and Agri-Food Canada (2012a); U.S. Department of Agriculture (2012)
[c]Source: Agriculture and Agri-Food Canada (2012b)

To investigate the data for the presence or absence of unit roots, we begin with a visual examination of the individual plots for any evidence of a trend. Where a trend is not clearly discernible, the augmented Dickey-Fuller test is applied. Further, when a variable is found to have a trend and is de-trended/filtered, the same test is performed on the de-trended (cyclical) component to ascertain if the cyclical component is significantly stationary. Figures 6 through 9 are plots of the raw data; total cattle inventories and beef cow inventories are trending. The trends are filtered out using the HP filter, leaving the cyclical components shown in figures 10 and 11. These cyclical components as well as beef supply and prices are found to be stationary.

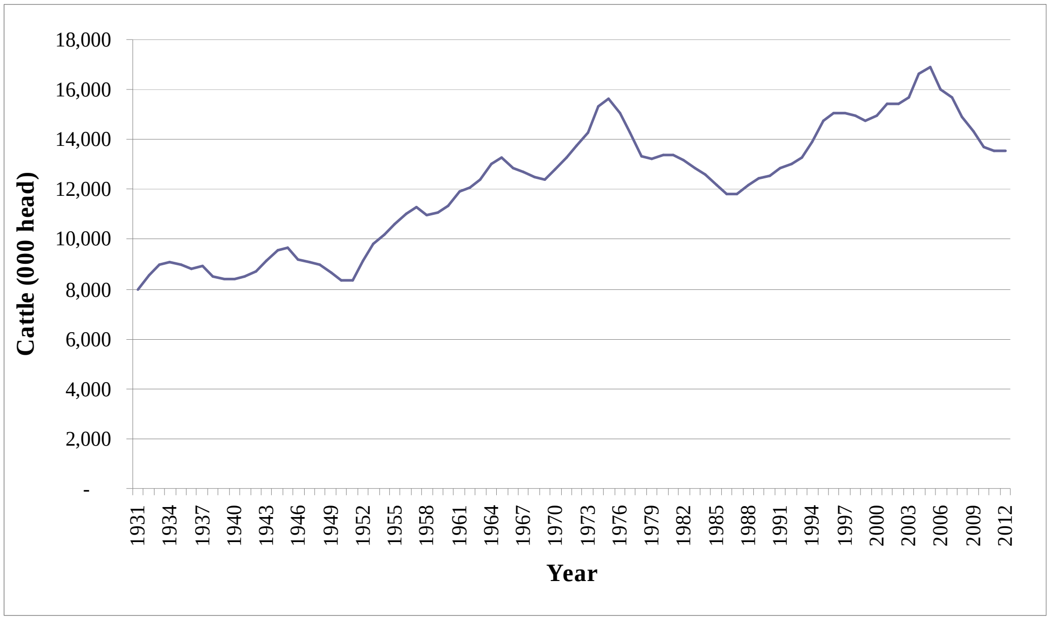

Figure 6: Canadian total cattle inventories, 1931 – 2012
Source: Statistics Canada (2012)

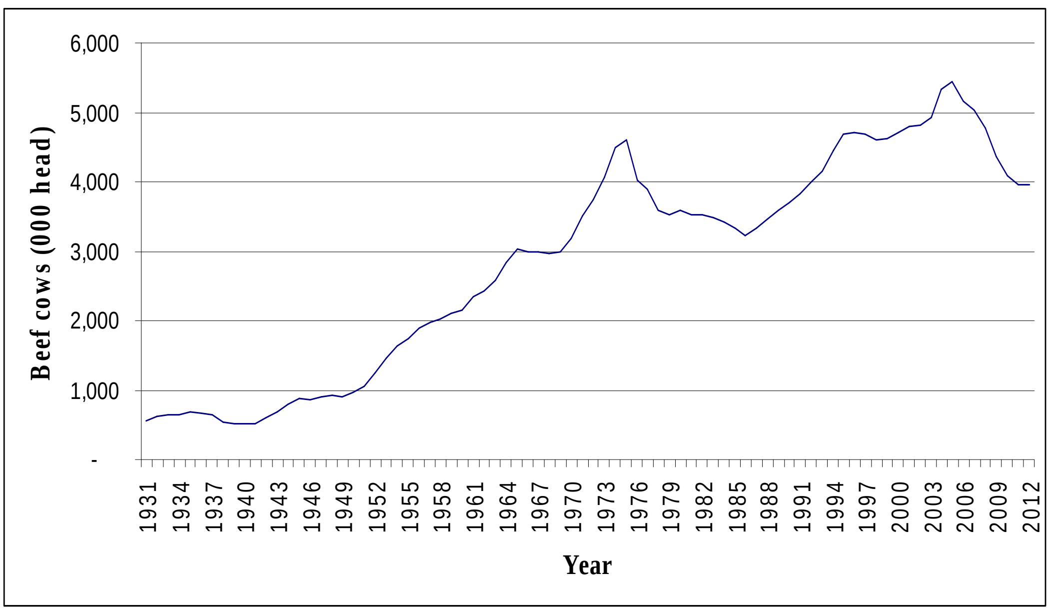

Figure 7: Canadian beef cow inventories, 1931 – 2012
Source: Statistics Canada (2012)

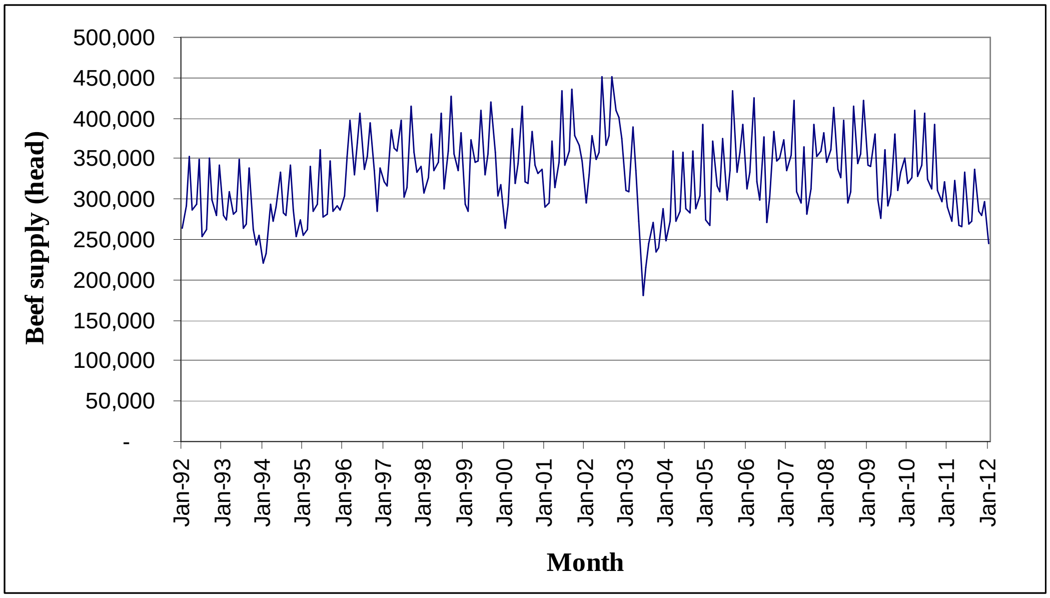

Figure 8: Monthly beef supply, Jan 1992 – Jan 2012
Source: Agriculture and Agr-Food Canada (2012a); U.S. Department of Agriculture (2012)

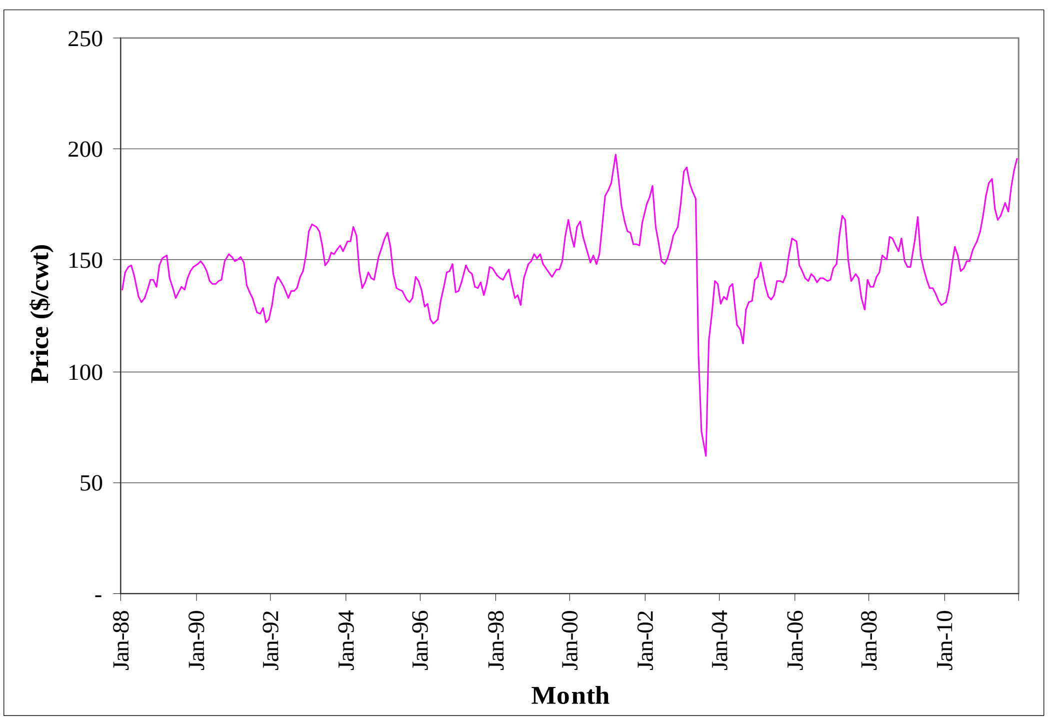

Figure 9: Monthly rail steer prices, Jan 1988 – Dec 2011
Source: Agriculture and Agri-Food Canada (2012b)

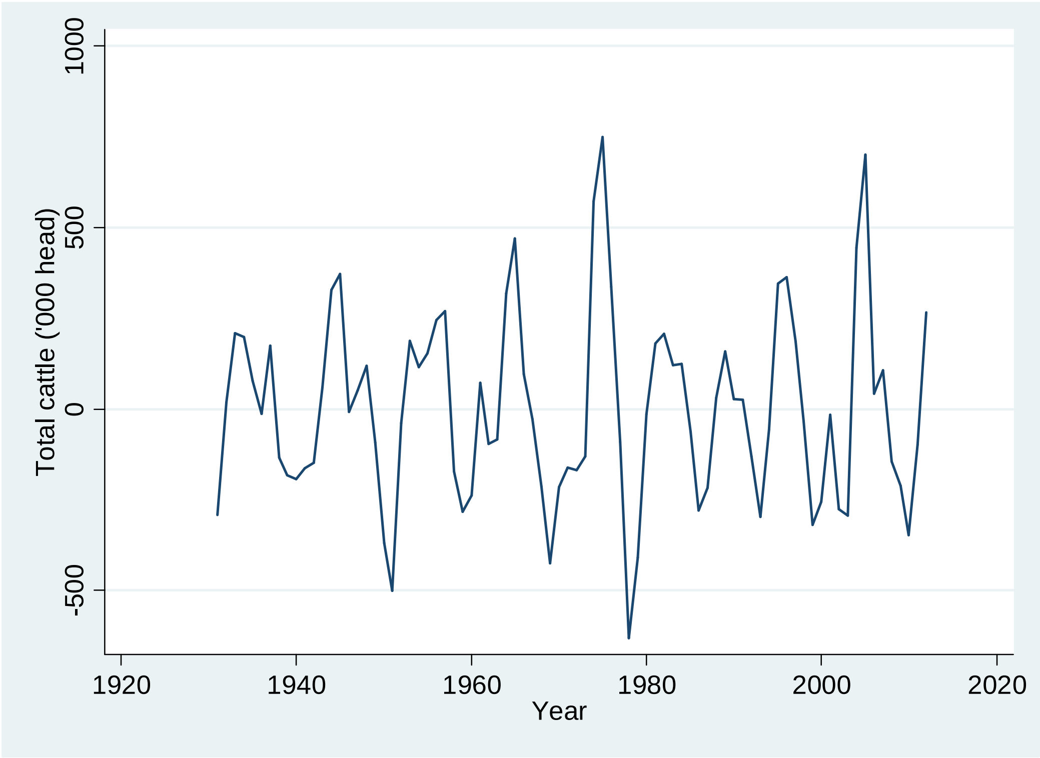

Figure 10: HP filter cyclical component of total cattle inventories, 1931 - 2012

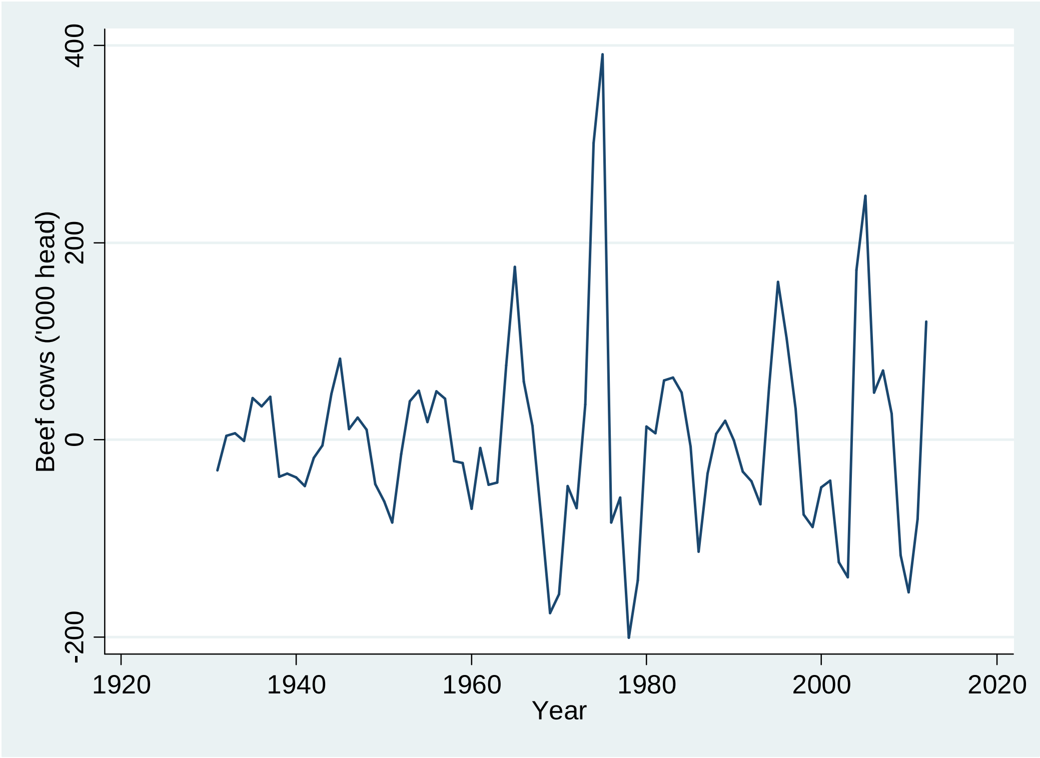

Figure 11: HP filter cyclical component of beef cow inventories, 1931 - 2012

3.4 Results

3.4.1 Nature of Cycles

Following Mundlak and Huang (1996), we begin by examining the autocorrelation function of each variable for initial clues to the nature of the cycles therein. These autocorrelations are shown in figures 12 through 15 and are derived using Bartlett's formula (Berlinet and Francq, 1997). With the length of a cycle measured from one trough to another, it is likely that total cattle inventories and beef cow inventories have one cycle almost every ten years, which is consistent with the conventional wisdom (see, for instance Gracey and Canfax Research, 1995). Beef supply has three peaks in every ten months, pointing to the possibility of a three-month seasonal variation. The autocorrelations of steer prices decline with increasing lags and seem to vary seasonally every ten to twelve months.

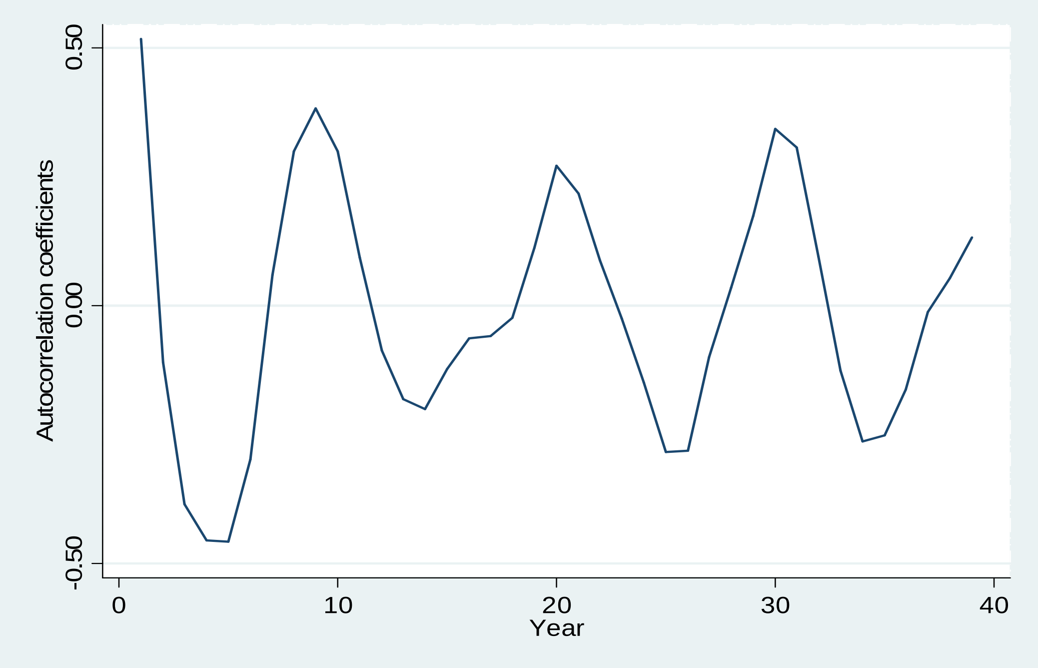

Figure 12: Autocorrelations of total cattle inventories

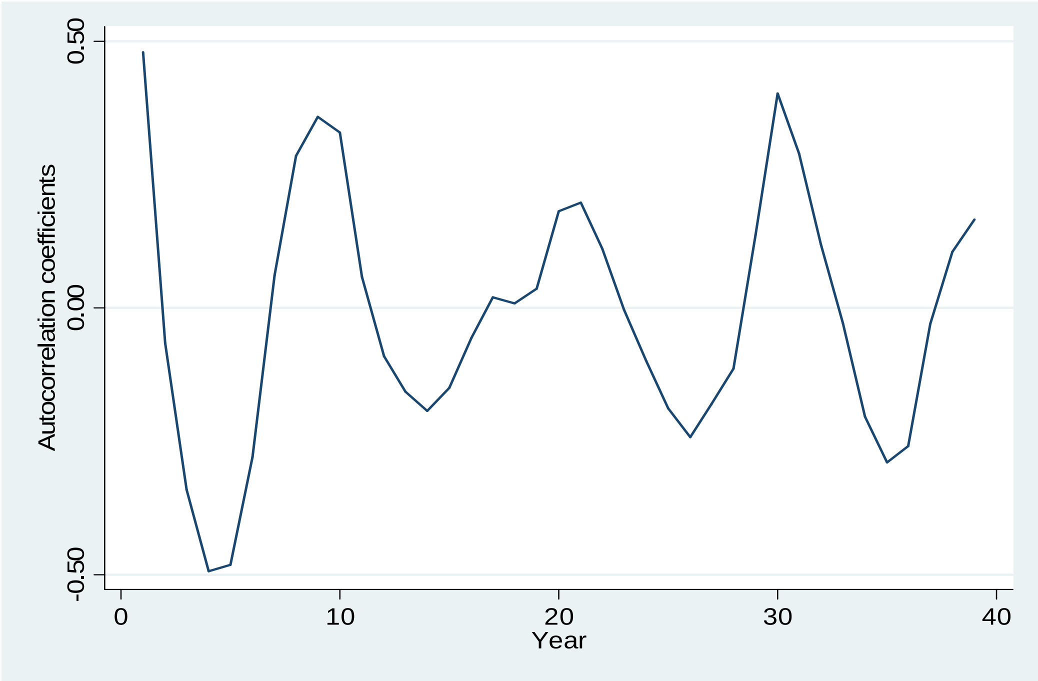

Figure 13: Autocorrelations of beef cow inventories

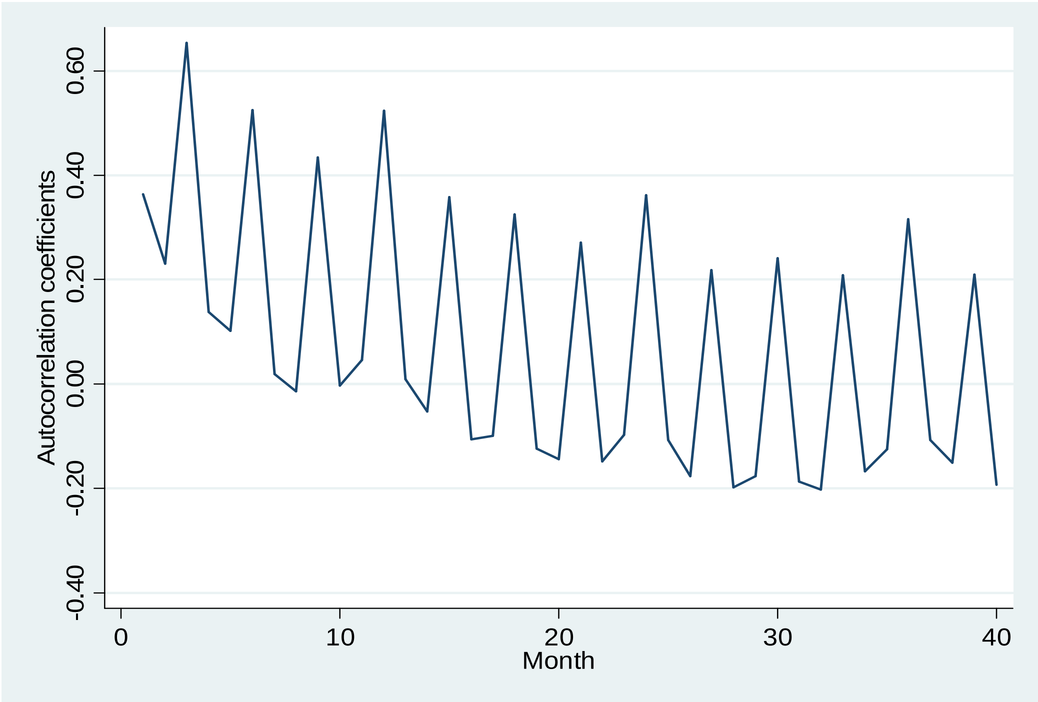

Figure 14: Autocorrelations of beef supply

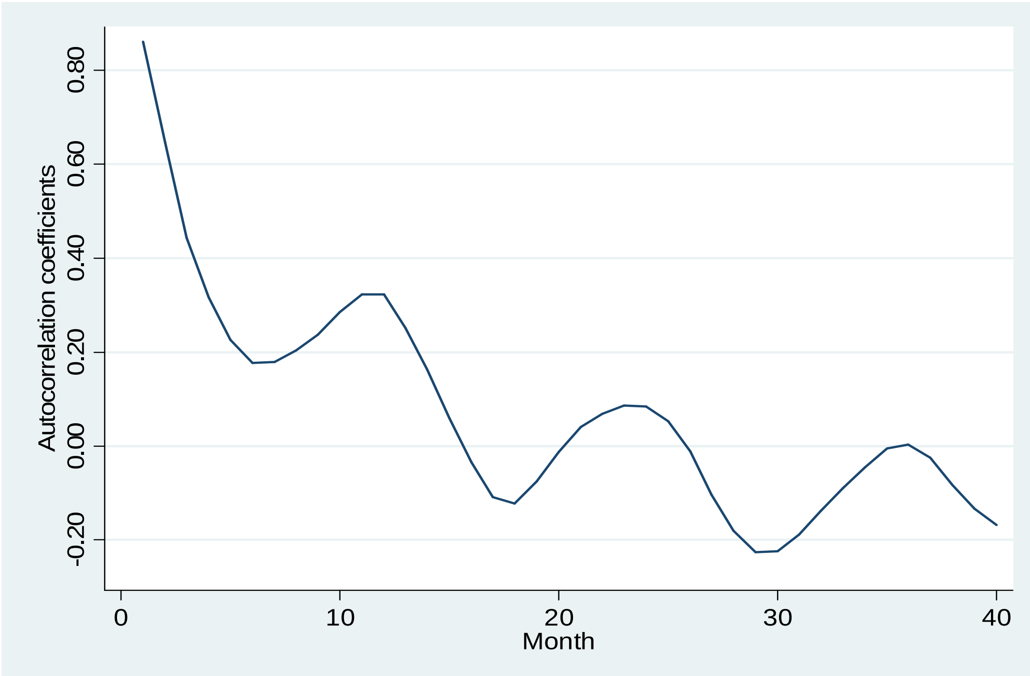

Figure 15: Autocorrelations of rail steer prices

While autocorrelation functions provide us with insights into the nature of cycles, periodogram estimates provide precise determination of important cycles. Figures 16 through 19 show the sample periodograms of the different variables, and table 6 provides a summary of the estimated cycles. For total cattle inventories, the largest periodogram value corresponds to a temporal frequency of 0.097 cycles per year. Given that the period, *T*, of a cycle is the inverse of the temporal frequency, the peak in the periodogram in figure 16 is the peak of a ten-year cycle. Similarly, a ten-year cycle is evident in beef cow inventories. These cycles are consistent with those anecdotally observed by Canfax for Canadian cattle inventories, and empirically by Mundlak and Huang (1996) for U.S. inventories. Beef supply too has a ten-year cycle as shown by the first peak, and a three-month seasonal variation indicated by the peak at a frequency of 0.33. Rail steer prices have an annual seasonal variation as seen in the autocorrelation function, and an eight-year cycle.

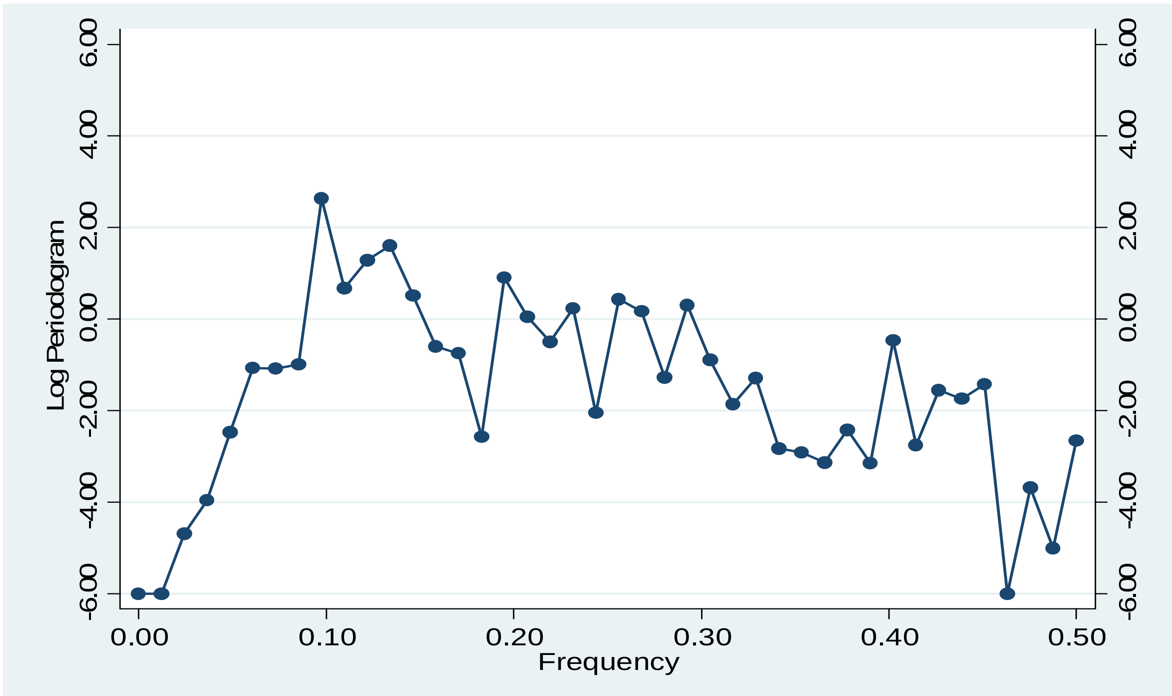

Figure 16: Periodogram of total cattle inventories

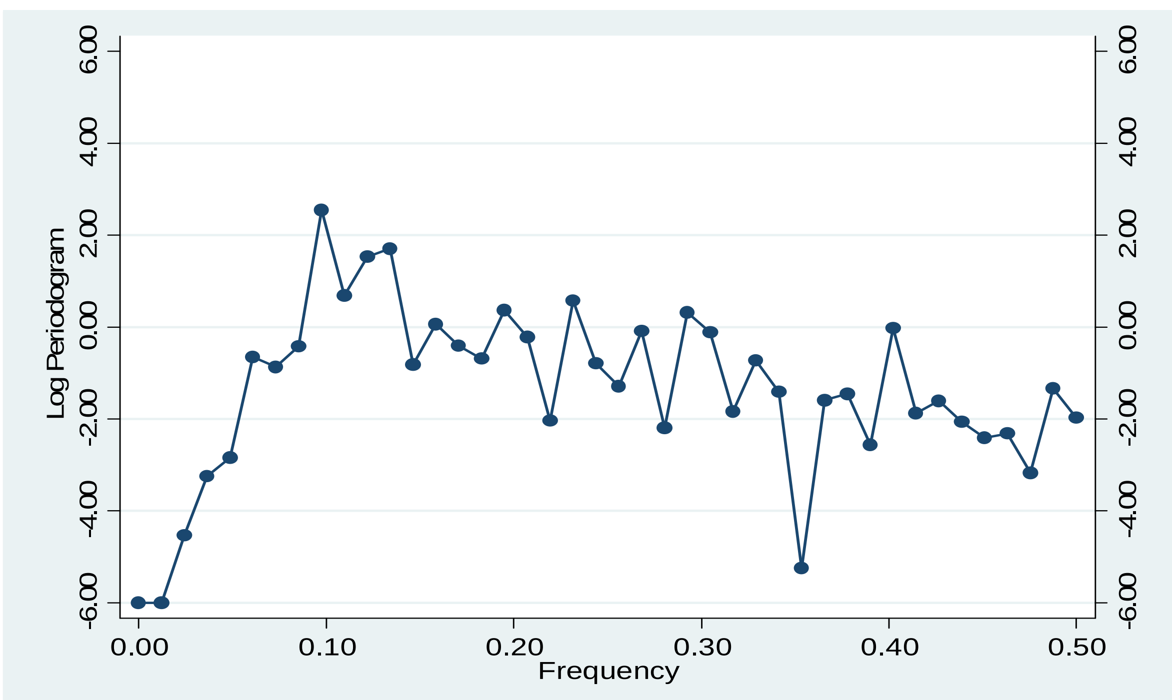

Figure 17: Periodogram of beef cow inventories

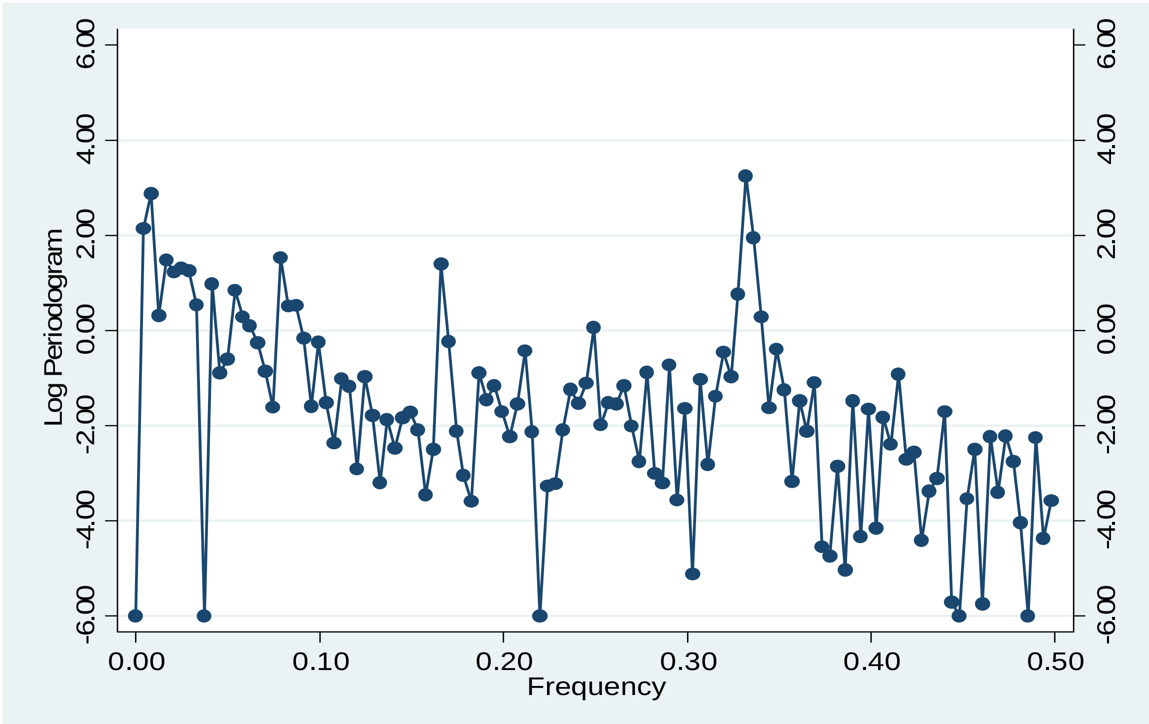

Figure 18: Periodogram of beef supply

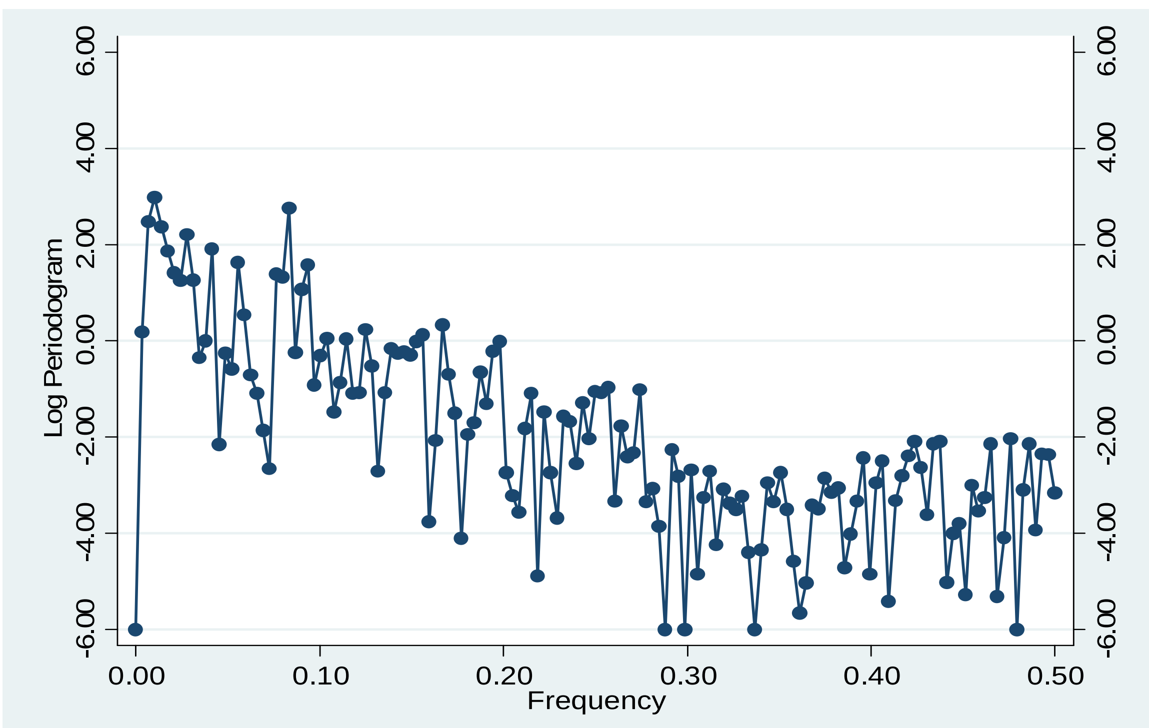

Figure 19: Periodogram of rail steer prices

Table 6: Estimated beef cattle cycles and seasonal variations

Variable	Cycle/seasonal variation
Total cattle inventories	10 years
Beef cow inventories	10 years
Beef supply	10 years; 3 months
Rail steer prices	8 years; 12 months

Overall, these results are consistent with those in most empirical studies; despite the technological and institutional changes that have occurred in the beef cattle industry, the cattle cycle, as commonly defined by cattle inventories and beef supply, is persistent and lasts ten years on average. Cattle inventory and beef supply cycles tend to move together although the latter has been observed to lag the former by about one year (Petry, 2004).

Most studies on the cattle cycle have focused on inventories and beef production, which capture mostly supply-side dynamics. However, the price cycle is perhaps more illuminating since it captures the interaction between supply and demand factors that drive the industry (Stockton *et al*., 2008). It runs counter to and leads both inventory and beef supply cycles. For instance, in the 1990-2004 U.S. cattle cycle, cattle inventories peaked five years after the price peak in 1991 (Anderson *et al*., 1996). This lag is due to the time beef production takes to respond to price changes, a result of the biological constraint inherent in beef production; a cow’s gestation period is nine months, and it takes about 18 – 24 months to bring calves to slaughter weight. This study finds, rather surprisingly, that the Canadian beef price cycle is on average eight years in duration.

Kulshreshtha and Wilson (1973) find two beef price cycles for Canada; a twelve-month cycle similar to the one obtained by this study, and a longer cycle of nine and a half years. Franzmann and Walker (1972), Mundlak and Huang (1996), and Stockton and Van Tassell (2007) find that the U.S. beef price cycle has a period of ten years, similar to the country's inventory cycle. But Mundlak and Huang also find that the beef price cycle for Argentina, whose lagged beef prices are strongly correlated with U.S. prices, lasts six years compared to the ten years for the inventory cycle. We would expect the price cycle to be of the same duration as cycles in inventories and beef supply because any difference in duration would cause the relationship between the price cycle and inventory and supply cycles that has been observed in the literature to disappear over time. Currently, it is unclear why the price cycle observed in this study is shorter than the other cycles.

3.4.2 Cycle Effects of Market Shocks

The second objective of this chapter is to examine whether or not two market shocks, namely, appreciation of the Canadian dollar relative to the U.S. dollar, and feed price escalation have altered the above cycles. These shocks have had a negative impact on the welfare of Canadian cattle producers (Twine and Rude, 2012).

As noted earlier, model selection criteria using AIC indicate that all the stationary series are generated by finite AR (*p*) instead of general ARIMA (*p*, *d*, *q*) processes with moving average terms. The absence of moving average terms means that parameter estimation is greatly simplified without considerably compromising model fit and forecasting ability (Clark, 1987). Also, the lag length for each AR (*p*) is determined using the Akaike Information Criteria. Maximum likelihood is used to estimate the resulting autoregressive models, which include exchange rate and feed prices as the intervention variables. The exchange rate shock occurred in June 2002, while the feed price shock occurred in January 2007[9]. The results are summarized in table 7. All models are statistically significant, and so are all the lagged variable parameter estimates, which are expected to approach true values as sample size increases.

Total cattle inventories and beef cow inventories follow an AR (2) process. But unlike beef cow inventories, total cattle inventories have been significantly affected by both exchange rate and feed price shocks. Beef cow inventories have not been significantly affected by either shock. All factors constant, appreciation of the Canadian dollar relative to the U.S. dollar caused substantial liquidation of herds as predicted by Klein et al (2006). Twine and Rude (2012) show that the exchange rate shock caused a decline in Canadian exports of cattle to the U.S., which consequently led to a decline in Canadian cattle and beef prices. A reduction in prices implies a decline in profitability in the industry, which may precipitate herd liquidation. But the initial effect of feed price escalation has been the opposite because the reduction in feedlot operators' profit margins following higher feed prices implies a decline in demand for feeder cattle, hence an increase in inventories in the short-run.

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[9] Since total cattle inventories and beef cow inventories are annual data, the effect of the exchange rate shock is considered to have started in 2002, while the feed price shock started in 2007.

Table 7: Maximum likelihood estimates of the intervention models

Variable	Coefficient	Z-statistic	P-value
Total cattle inventories: AR(2); N = 82, Prob > χ^2 = 0.000			
Constant	0.06	0.00	0.999
	(36.88)		
Exchange rate	-151.42	-1.99	0.046
	(75.99)		
Feed price	295.49	2.45	0.014
	(120.49)		
L1	0.91	8.36	0.000
	(0.11)		
L2	-0.58	-5.73	0.000
	(0.10)		
Beef cow inventories: AR(2); N = 82, Prob > χ^2 = 0.000			
Constant	-0.93	-0.06	0.952
	(15.35)		
Exchange rate	-2.33	-0.07	0.945
	(33.86)		
Feed price	31.43	0.71	0.477
	(44.22)		
L1	0.71	11.32	0.000
	(0.06)		
L2	-0.42	-6.50	0.000
	(0.07)		
Beef supply: AR(5); N = 241, Prob > χ^2 = 0.000			
Constant	317719.90	27.31	0.000
	(11635.10)		
Exchange rate	25922.71	2.11	0.035
	(12262.35)		
Feed price	-2372.66	-0.13	0.894
	(11763.14)		
BSE	-34449.36	-2.42	0.016
	(14251.10)		
L1	0.64	9.23	0.000
	(0.07)		
L2	-0.33	-4.79	0.000
	(0.07)		
L3	0.78	15.41	0.000
	(0.05)		
L4	-0.59	-8.40	0.000
	(0.07)		
L5	0.27	3.95	0.000
	(0.07)		

Rail steer prices: AR(5); N = 288, Prob > χ^2 = 0.000			
Constant	146.78 (4.91)	29.92	0.000
Exchange rate	-2.97 (7.97)	-0.37	0.709
Feed price	9.52 (6.91)	1.38	0.168
BSE	3.10 (6.14)	0.50	0.614
L1	1.26 (0.06)	22.61	0.000
L2	-0.38 (0.10)	-3.89	0.000
L3	-0.22 (0.10)	-2.12	0.034
L4	0.28 (0.08)	3.68	0.000
L5	-0.09 (0.05)	-1.85	0.064

Figures in parentheses are standard errors.

Beef supply and rail steer prices are generated by an AR (5) process. In determining the effect of exchange rate and feed price shocks on the two variables, the effect of the 2003 BSE crisis is accounted for since the crisis was observed to have had a direct impact on the variables. Results show a statistically significant effect of exchange rate appreciation and BSE outbreak on beef supply, but none of the three shocks is significant in the rail steer price equation. As expected, the BSE outbreak reduced beef supply, which includes beef exports. The exchange rate shock, however, has considerably increased beef supply, perhaps because it has led to herd liquidation as established in the total cattle inventory equation.

We now turn to examining the impact of shocks on cycles. From the above results, we speculate that the total cattle inventory cycle may have been altered by exchange rate appreciation or feed price escalation or both, whereas the beef supply cycle may have been altered by exchange rate appreciation, the effect of the BSE outbreak notwithstanding. Establishing these changes requires estimating and comparing the cyclical nature of the two variables before and after the respective shocks. However, the sample size of cattle inventories does not permit meaningful spectral analysis of sub-sample cycles. Therefore the analysis is restricted to beef supply. In any case, beef supply is a function of cattle inventories, and both series have a similar cycle, and have been significantly affected by the exchange rate shock.

Periodograms for beef supply showing cycles before and after the exchange rate shock are shown in figures 20 and 21[10]. The seasonal three-month cycle is evident in both time periods. But with respect to the long cycle, it was 125 months long prior to the shock, and 116 months long after the shock, implying a nine-month reduction in the duration of the beef supply cycle.

The difference in the periodogram values of the two cycles is indicative of the change in the cycle's peak amplitude. Thus we find a 58% reduction in the amplitude of the beef cycle. For a given frequency component of a time series, a contraction in its amplitude means a reduction in the component's contribution to the variance of the series. It then follows that the exchange rate shock has caused a considerable reduction in the degree of fluctuation in the beef supply cycle.

[10] The number of observations of beef supply prior to and after the shock is 125 and 116, respectively. This means that the periodogram values in the two time periods correspond to different frequencies, hence the two figures.

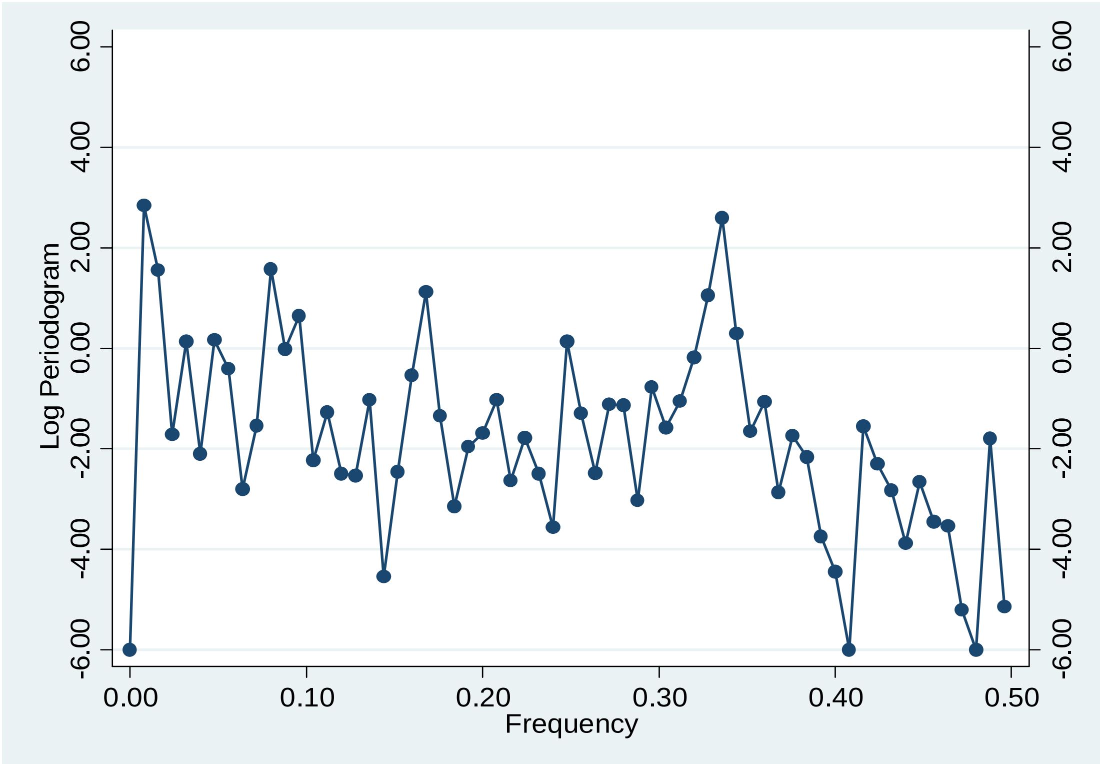

Figure 20: Periodogram of beef supply prior to exchange rate shock

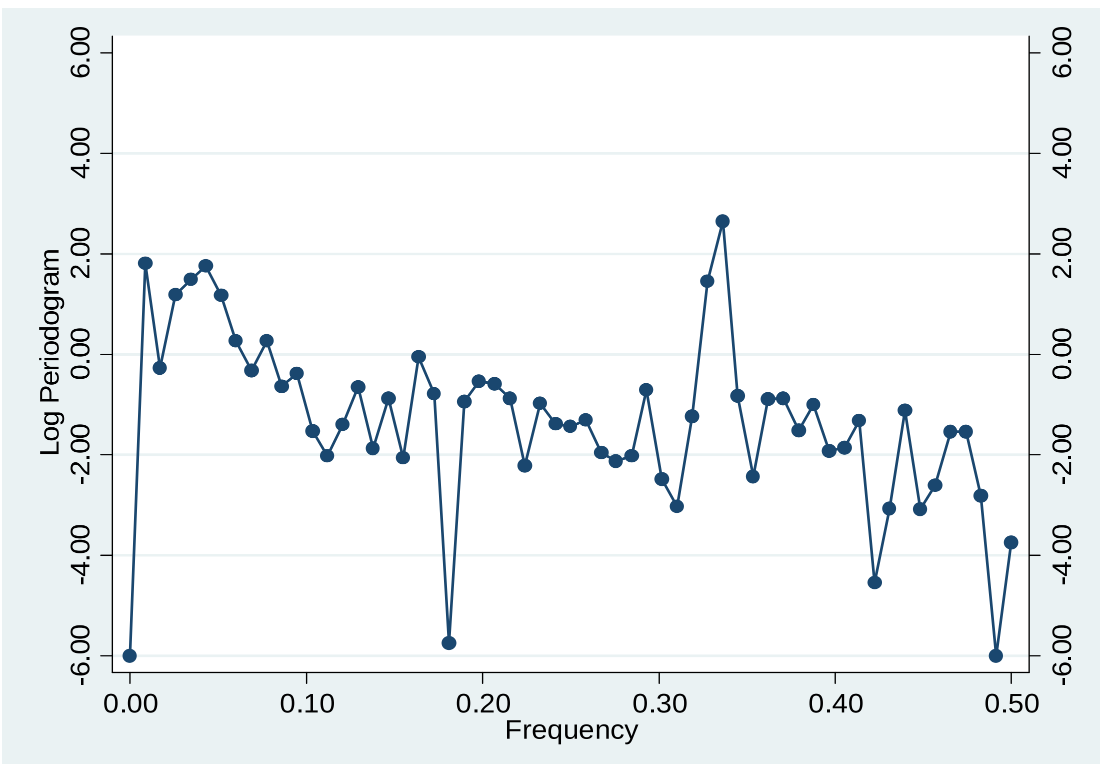

Figure 21: Periodogram of beef supply after exchange rate shock

Klein et al (2006) suggest that appreciation of the Canadian dollar would be beneficial to the beef cattle industry to the extent that it drives investments and productivity growth. Productivity growth would in turn dampen fluctuations in the cattle cycle because, according to Marsh (1999), to achieve a certain level of income, herd expansion following an increase in the price of beef would be smaller than in the case of no productivity growth. He finds that productivity growth in the U.S. beef cattle industry as measured by increases in the carcass weight of steers, heifers, and cull cows has significantly reduced the price elasticity of supply for beef cow inventories over a ten-year cycle. Productivity growth in the Canadian livestock sector in general has been reported by Stewart et al (2009), and has been attributed to both scale effects and technical change. From 1972 to 2008, beef output per cow increased by 53% from about 170 kg to about 260 kg (Canada Beef Inc. 2012). It would be helpful to empirically determine how much of this growth can be attributed to appreciation of the Canadian dollar since some of it occurred at a time when the dollar significantly depreciated against the U.S. currency.

3.5 Summary and Conclusion of Chapter Three

The existence of cattle cycles has been well-documented in the literature, but the implications of these cycles for policy are not clearly understood. In this chapter, I argue that since cycles are an important feature of the Canadian beef cattle industry, examining the impact of shocks should take into account, among other things, the extent to which they alter the cycles. This chapter recognizes cycles in not only the widely-studied cattle inventories, but also in beef supply and beef prices.

The chapter accomplishes two goals: first, it uses spectral analysis to estimate cycles in four variables, namely, total cattle inventories, beef cow inventories, beef supply, and rail steer prices. Second, it combines intervention analysis with spectral analysis to estimate the effect of two market shocks – appreciation of the Canadian dollar relative to the U.S. currency, and feed price escalation – on these cycles.

Analyses show that ten-year cycles exist in total cattle inventories, beef cow inventories, and beef supply, while an eight-year cycle exists in steer prices. Also, a seasonal three-month variation exists in beef supply, and an annual cycle exists in steer prices. Results of the intervention analysis indicate that both exchange rate and feed price shocks have significantly affected total cattle inventories, but neither shock has had an effect on beef cow inventories. Since beef cow inventories are the foundation of total cattle inventories, shocks affecting beef cow inventories are expected to affect total cattle inventories, but the reverse may not necessarily hold.

Exchange rate appreciation has caused a reduction in total inventories, but increasing feed prices have increased inventories. Also, controlling for the effect of the 2003 BSE crisis, the study finds that the exchange rate shock has significantly increased beef supply. Steer prices have not been affected by either shock even after controlling for the BSE crisis. When the beef supply series is examined for changes in the beef supply cycle following the exchange rate shock, the study finds a reduction of nine months in the duration of the cycle, and a 58% reduction in the cycle's peak amplitude. However, the seasonal three-month cycle remains intact.

From the above results, we conclude that the Canadian beef cattle cycle is on average ten years long. Beef supply and beef prices also exhibit seasonal three-month and annual variations, respectively. We also conclude that appreciation of the Canadian dollar relative to the U.S. dollar has significantly dampened fluctuations in beef supply over the ten-year cycle. The U.S. Department of Agriculture (1998) believes cattle cycles are becoming shorter, having been as long as 16 years in the early twentieth century. And according to Schulz (2003) "recent cattle cycles have become much less pronounced, with shorter periods of increase and more prolonged phases of decrease. Much of this deviation from historical trends is likely attributed to abnormal weather (leading to increased variability in stocking rates), decreases in the available land base, production being impacted by replacement rates, and input and output price variability and volatility (which affects producer's foresight of prices). Future cattle cycles likely will not have as much in common with past cycles.…." (p. 2).

These findings are important to the industry in terms of business strategy at the producer level, and policy at the industry level. Knowledge of the cycle is helpful to producers in optimally managing their herds through the different stages. Currently, the industry appears to be at the beginning of another cycle since inventories are at their lowest, with herd liquidation having begun in 2008 and continued through 2012. Regarding industry policy, it is imperative to understand the range of all possible impacts of an exogenous shock on the industry to ensure that any policy response is a result of a careful assessment of all the shock's potential effects. For instance, this study has shown that despite the observed negative impacts of the appreciation of the Canadian dollar on the industry, it has probably helped in reducing fluctuations in the ten-year beef supply cycle.

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CHAPTER FOUR: VALUING CATTLE LOAN GUARANTEES: THE CASE OF ALBERTA'S FEEDER ASSOCIATION LOAN GUARANTEE PROGRAM

4.1 Background

Financial firms are assumed to behave rationally in pursuit of their goal of profit maximization subject to capital, labour, and balance sheet constraints (Sealey, Jr. and Lindley, 1977). But even in equilibrium, credit rationing, which can be attributed to imperfect information in the credit market, is a possibility (Stiglitz and Weiss, 1981). This means that firms' optimal level of supply of credit may be less than optimal to society. As such, where credit rationing has occurred, governments have responded mainly by implementing loan guarantee schemes (Cowling, 2010). This chapter examines one such scheme – Alberta's Feeder Association Loan Guarantee Program (FALGP).

A loan or credit guarantee is an agreement in which a third party, the guarantor, promises to assume the debt obligation of the borrower in the event that the borrower defaults (Lai, 1992). It may be limited if it covers only a portion of the debt, or unlimited if it covers the entire debt. Government loan guarantees have historically been considered domestic agricultural support in Canada and elsewhere. At the federal government level, legislation such as the Farm Improvement Loans Act of 1944, and the Farm Improvement and Marketing Cooperatives Loan Act of 1987, which was amended and renamed the Canadian Agricultural Loans Act (CALA), have provided the legal framework for implementing various loan guarantees in Canada. It is believed that loan guarantees are generally motivated by perceived credit market imperfections such as information asymmetries, and the need to extend credit to disadvantaged groups of potential borrowers (Vogel and Adams, 1997; Ahrendsen *et al*., 2005). In doing so, not only do they ensure access to credit in the short-run, they also enable these borrowers to strengthen their creditworthiness in the long-run. Also, in case of unusually low product prices, loan guarantees have been deemed necessary to relieve producers of financial pressures (Lien and Hennessy, 2005). Moreover, they tend to be politically desirable in that they may lead to immediate benefits yet do not appear on the government budget since they are contingent claims (Sherrick, 1992).

However, government loan guarantees may be a cost to the government especially if they are binding (Merton, 1977). Even though they are contingent claims, the interest rate differential constitutes an implicit subsidy if no guarantee fee is charged, and therefore they require careful accounting and administration (Mody and Patro, 1996). But very rarely is the true cost of a government loan guarantee determined *a priori*. This in turn means that the government is unlikely to charge a fair market price for a guarantee if it so wished. It is therefore not surprising that government loan guarantees are generally provided free-of-charge despite the inherent cost. The implicit subsidy cost notwithstanding, failure to determine and charge a fair market price for a guarantee may also distort the benefits. Gittell and Kaen (2003) illustrate that when a high-risk borrower buys a guarantee at less than its fair market price and borrows at an interest rate that is risk-free, both the lender and borrower earn more than they should from the guarantee at the expense of the tax payer. Thus the challenge for policy makers lies in formulating and operating loan guarantee programs to achieve certain policy goals, while ensuring that the programs do not expose the government budget to a level of default risk that is way above what it can optimally manage. This issue involves knowing the guarantee's implicit interest subsidy, and setting a guarantee fee (which is equivalent to charging a premium on the interest rate differential) that reflects the cost and risk to the government of providing the guarantee. For instance, under the CALA, the borrower must pay a guarantee fee equivalent to 0.85% of the amount of the loan (Agriculture and Agri-Food Canada, 2009). In some cases, borrowers can be grouped into different risk levels and charged different guarantee fees (Kuo *et al*., 2011).

The main object of this chapter is to valuate Alberta's Feeder Association loan guarantee. The end goal is to estimate the cost to the Alberta government of the cattle loan guarantee. This would essentially be an actuarially fair premium that a cattle feeder ought to pay for the guarantee, and it would reflect the value of the guarantee to the cattle feeder. However, the challenge in estimating this value is that one has to have a precise measure of the risk involved in cattle feeding. According to Hampel et al (1998), although average returns from an investment in cattle feeding compare favorably with those from other investments, cattle feeding returns are relatively volatile. The largely sunk nature (at least over the feeding period) of investment costs in cattle feeding makes producers unable to quickly respond to new information and adverse changes in production and market conditions. This makes cattle supply, prices and hence returns highly uncertain (Hampel *et al*). Given the risky nature of cattle feeding, this study also finds it imperative to determine the likely loss to the lender (credit risk) with the aim of drawing inferences about the appropriateness of the risk (insurance) premiums charged by lenders, the five percent security deposit, and the estimated value of the loan guarantee. The study employs a Monte Carlo cash flow model to estimate cash flows, the credit risk to the lender, returns on investment, and a consolidated measure of volatility of cattle feeding returns for a typical background to finish cattle feeding enterprise. The volatility estimate obtained is then fed into option pricing models to estimate the value of the loan guarantee. Also, the study estimates the implicit interest subsidy provided by the program as a rough indication of the cost of the program to the tax payer. Results of this analysis would be helpful in determining whether or not the FALGP is desirable.

4.2 Alberta's Feeder Association Loan Guarantee Program

Alberta's FALGP is one of several provincial-level cattle loan guarantee programs in Canada. Others include New Brunswick Livestock Incentive Loan Program, Ontario Feeder Cattle Loan Guarantee Program, Manitoba Livestock Associations Loan Guarantee Program, Saskatchewan Livestock Loan Guarantee Program, and British Columbia Feeder Association Loan Guarantee Program. Established in September 1936, the FALGP has been in operation for 77 years, and has provided loan guarantees of up to $7.68 billion to members of local feeder association co-ops, financing 17-24% of the total calf crop each year (Alberta Agriculture and Rural Development, 2013a). So far, payouts have been made 17 times amounting to $3.82 million. The program is governed by the

Feeder Associations Guarantee Act of 2010, and the maximum amount of total liability of the provincial government over the program is currently set at $55 million per fiscal year. Private financing is provided for 100% of the value of cattle that a Feeder Association would want to purchase, but the government guarantee covers 15% of the total loan available to a local Feeder Association.

Loan guarantee programs are prone to informational asymmetries that may lead to both adverse selection and the Principal-Agent problem of hidden action (moral hazard). Chaney and Thakor (1984) provide an example of adverse selection, which arises prior to or at the time of contracting; firms anticipating loan guarantees may decide to take on riskier investments and thus the contingent liability of the government could be larger than expected. Principal-Agent problems arise after the guarantee has been issued. For instance, moral hazard occurs if the guarantee diminishes the private lender's incentive to adequately evaluate the borrower, and/or if it diminishes the borrower's incentive to avoid default (de Rugy, 2012). Moral hazard may also occur if the lender lends at an interest rate that is significantly above the risk-free one, thereby increasing the probability of default and counteracting the intended goal of increasing access to credit.

The FALGP has put in place some mechanisms to minimize the credit risk faced by the lenders as a result of adverse selection and moral hazard. First, although all cattle purchased through the program are managed and marketed by individual association members, the loans are provided to the local associations, which legally retain ownership of the cattle until they are sold and contracts with members are paid out. This is achieved by branding with the split bar brand unique to a Feeder Association. It is believed that branding is the most significant feature of the Feeder Associations (Mark, 2000). Second, each cattle recipient is required to submit to the association a security deposit of 5% of the total value of the cattle prior to receiving them. Third, each local association is at liberty of choosing its lender from the six participating private financial institutions, and negotiating an interest rate, total loan amount and other financing arrangements. This is intended to create competition among lenders, leading to competitive interest rates. Fourth, the program is monitored at two levels: Feeder Associations monitor loans given to their individual members, and Alberta Agriculture and Rural Development supervises and provides technical backstopping support to Feeder Associations regarding risk and loan management.

That the program has been in existence for many years may be construed as evidence of its viability. However, some in the industry are skeptical about its future mainly because of the increasing influence of government in Feeder Associations, the high cost of the program to the government, and the personnel and financial constraints faced by Feeder Associations, the latter of which is attributed to fluctuations in industry profitability (Mark, 2000). Several initiatives such as supply chain financing and equity loan pilot projects aimed at enhancing the program, and the new financing and business models aimed at increasing operational efficiency have been undertaken (Alberta Agriculture and Rural Development, 2011). The supply chain financing project aims to develop and test approaches for extending financing under the guarantee program to all levels of the beef supply chain, while the equity loan project will enable farmers to access their additional equity on a monthly basis rather than only when the cattle are sold and the entire loan paid off. In light of these changes and the uncertainty and declining profitability in the industry caused by the recent market shocks, there is need to determine the value of the program.

4.3 Literature Review

Valuing a loan guarantee requires a clear understanding of the risk associated with the enterprise for which the loan is being obtained. The value of a loan guarantee depends on, among other things, the volatility of returns on investment. As previously mentioned, there is considerable risk in cattle feeding, and the resulting probability of defaulting on a cattle feeding loan implies credit risk for the lender. Therefore as noted by Sherrick et al (2000), accurate measurement of credit risk in agricultural loans is necessary for accurate pricing of loan guarantees. Given the different sources of risk associated with cattle feeding and the risk premiums charged by lenders involved in Alberta's FALGP, this study first and foremost aims to determine the actual credit risk to a participating lender.

Credit risk is the possibility of a borrower failing to meet their loan repayment obligations in accordance with agreed terms. Zech (2003) and Kim (2005) highlight different types of credit risk models used by financial institutions to evaluate the credit risk of individual loans. The models include those based on option pricing theory, those based on econometric techniques and Monte Carlo simulation, and those based on the insurance (actuarial) approach. Conceptually, credit risk as measured by a risk premium is the difference between the return on a risky asset and the return on a risk-free investment. This is the market-based approach to evaluating credit risk (Kuo *et al.*, 2011) and it accounts for the borrower's credit status and the lender's risk preferences. Sherrick et al (2000) develop and empirically implement a theoretical model for the valuation of credit risk in agricultural mortgage loans, and their results apply to guaranteed and securitized loans as well. Credit risk is shown to be the payoff function for insurance against shortfalls in loan repayment, and is similar to the payoff function of a Put option. This approach is adapted by this study to determine the credit risk (insurance premium) on a guaranteed cattle feeding loan.

Three methods of valuing loan guarantees are described in the literature (Mody and Patro, 1996): the "rule-of-thumb" approach, the market-valuation approach, and the option pricing approach. The "rule-of-thumb" approach simply compares the market value of the loan or underlying variable with that of a risk-free asset and then bases the value of the guarantee on the difference between the two. The market-valuation approach is applied to similar assets with and without guarantees, and which are traded. The value of the guarantee would be the difference in price of the two assets. The approach is also used for assets whose market values before and after a guarantee are known. The option pricing approach, which falls in the realm of contingent claims analysis, views the payoff of a guarantee as being similar to that of a Put option. The "rule-of-thumb" approach does not account for changes in the values of assets, and the market-valuation approach makes the rather strong assumption that even when the guarantee covers only part of the debt (e.g., only interest payments), the market is able to accurately assess the coverage provided by the guarantee[11] (Mody and Patro). This study therefore opts for the option pricing approach, and the following review of empirical studies is limited to those that have applied it.

Option pricing theory has been used in the valuation of different kinds of guarantees such as guarantees of bank deposits, mortgages, agricultural price support, export credit, and sector specific loans. Within the agricultural economics literature, option pricing has been applied mostly to valuation of price support programs and export credit programs, but hardly to producer credit programs. Gardner (1977) notes that price supports that were established through the Commodity Credit Corporation loans are essentially Put options. Marcus and Modest (1986) agree that, indeed, price supports are similar to providing farmers with Put options, but they argue that because each crop unit is guaranteed and total crop size is uncertain, the Put options provided are a random number, which makes the standard Black-Scholes formula for pricing options (Black and Scholes, 1973) inapplicable to valuing agricultural price supports. Nonetheless, Bardsley and Cashin (1990) use the Black-Scholes formula to estimate the cost of the Australian government's wheat price guarantee.

Turvey (1992) uses an option pricing framework to develop formulas for computing crop, cash price, and revenue insurance premiums under Canada's agricultural stabilization and insurance policies, and applies them to corn, soybeans and wheat. Kang and Brorsen (1995) estimate the implicit premium of the U.S. deficiency payment program, a form of U.S. agricultural price support, using the Black average-option pricing model and a GARCH average-option

[11] Market prices may not be indicative of the probability of default.

model. An average-option pricing model is one that calculates the price of an option based on the average price of the underlying asset over a given time period rather than the price at a particular point in time. The authors assume wheat prices to be conditionally heteroskedastic, hence the use of the GARCH process to model wheat price changes. Modifications to the option pricing formula for evaluating agricultural support programs have been undertaken. For instance, Tirupattur et al (1997) derive theoretical models for evaluating options associated with U.S. agricultural support programs in a manner that accounts for the exotic features inherent in the programs.

Agricultural export credit guarantees have been evaluated by, among others, Dahl et al (1999), and Diersen and Sherrick (2005). Dahl *et al*. use an option pricing model to determine the value of wheat export credit guarantees for the U.S., Canada, Australia and France. They argue that interest subsidies implicit in these guarantees are not synonymous with the value (cost) of the guarantees contrary to the assertion in an earlier study by Diersen et al (1997), especially if the interest rates on the guaranteed loans are set administratively. Diersen and Sherrick extend the Dahl *et al*. study by accounting for the repayment capacity of the wheat importing countries (i.e., borrowers).

Taken together, the above literature attests to the popularity of the option pricing framework in evaluating guarantees. This is partly due to the framework's adaptability to different types of guarantees, scenarios and assumptions. It has been extended to the analysis of private loan guarantees considered to be risky as opposed to the riskless government guarantees (Lai, 1992). Also, the framework has been applied to the Farmers Home Administration and the Illinois Farm Development Authority loan guarantees in which the end-of-period distributions for the value of the firm are modeled as Burr distributions (Sherrick, 1992). Therefore this framework provides an appropriate tool for assessing the value of the FALGP.

In addition to assessing the value of the loan guarantee, this study, unlike the above studies, estimates the program's implicit interest subsidy. It would be informative to know whether or not the price of the loan guarantee covers the program's implicit interest subsidy.

4.4 Method: A Cash Flow Monte Carlo Model

4.4.1 Cash Flow Model of Cattle Feeding

A cash flow model underlies the analysis of the FALGP. A cash flow model illustrates the flow of cash in and out of the firm and can therefore be used to predict a firm's financial performance and any imminent financial constraints (Hotz, 2004). Because a cash flow statement reveals a firm's liquidity (i.e., ability to pay its bills), it is an important tool for investors and lenders to assess the short-term viability of the firm.

The cash flow model constructed for this analysis is that of backgrounding and finishing a single light steer calf with an initial weight of 350 lb at weaning[12]. It is assumed that the performance of the steer represents the average for an entire

[12] This is the case of early-weaned calves. As mentioned in section 1.4, calves are traditionally weaned at 6 to 8 months weighing between 485 and 550 lbs. But for ranchers that background calves, backgrounding early-weaned calves may be more viable (Nelson, 2013). This study undertakes a sensitivity analysis using different starting weights for backgrounding.

lot. In this scenario, a light calf purchased in the fall (say in November) is placed on pasture until the next summer (winter backgrounding) and then fed to a market weight of 1,150 lb – 1,350 lb by the next November. Thus the model tracks monthly cash flows and covers a time horizon of 12 months, six of which are spent backgrounding and the rest finishing. A farmer's potential cash flow if the steer is sold in a given month is calculated as:

$$CF = PQ - SC - \sum OC - YC - I - DL \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where CF is cash flow in dollars, P is the sale price of the steer in \$/cwt, Q is live weight of the steer in pounds, SC is the total steer purchase cost, which includes the cost of the steer and any other procurement costs. OC denotes operating costs (\$) including feed costs, cost of bedding, and cost of veterinary services and medicines. YC is yardage (overhead) costs, I is the interest that would have accrued on the loan, and DL is death loss.

4.4.2 Sources of Risk in Cattle Feeding and FALGP

Risk can be considered as the potential variance between the expected and actual cash flows of an enterprise (Clark *et al.*, 1976). This study recognizes that there are several sources of risk in cattle feeding that may significantly impact cash flows, thereby increasing the credit risk to lenders participating in the FALGP, and hence the price of the loan guarantee. Generally, there are two main sources of risk in cattle feeding, namely, *price (market) risk* caused by fluctuations in fed and feeder cattle prices and feed prices, and *production risk*, which is a function of animal health and feeding performance (Belasco *et al.*, 2009). These risks have been consistently observed in cattle feeding in western

Canada (Viney, 1995; Unterschultz, 2000; Deng, 2006), for instance, the catastrophic price risk that followed the 2003 BSE crisis. The FALGP is prone to another source of risk, moral hazard, by virtue of the Principal-Agent relationship inherent in the program. For instance, monitoring by the Feeder Associations may not sufficiently deter cattle feeders from privately selling cattle and reporting the sold cattle as part of death loss.

In light of these sources of risk, the cash flow model accounts for output price risk, production risk and moral hazard by making the variables P, Q, and DL in equation (1), and the price of barley stochastic. As shown in the next section, P is generated in a manner that accounts for the stochastic nature of feed prices. As in Belasco et al (2009), average daily gain (ADG) captures feeding performance and is used to generate Q, while DL is used as an indicator of animal health, and can also be used to simulate the effect of moral hazard.

After accounting for the different sources of risk, one then needs to select a measure that quantifies the loss to the enterprise due to the risks. The measure used to quantify the likely loss on a portfolio of financial assets is the Value at Risk (VaR); an estimate of the amount of loss in the value of a portfolio for a given probability level and time horizon (Wilmott, 2001). Manifredo and Leuthold (2001) find VaR to be applicable to estimating losses in cattle feeding margins. However, Hotz (2004) notes that financial assets are usually marked-to-market at the end of a set time horizon, but the value of non-financial assets is influenced by changes in market conditions. Therefore cash flows are the appropriate variable on which to base the measure of risk associated with non-financial assets, and VaR in the context of these assets may well be termed CFaR – Cash Flow at Risk (Hotz, 2004; Andrén *et al*., 2005).

4.4.3 Data and Model Simulation

The base model is implemented using data from various sources and by estimating price equations relevant to modeling price risk. In model implementation, it is imperative to verify and validate the model. Model verification, which is dealt with in this section, is aimed at ascertaining that the empirical model is implemented in a manner that is consistent with the conceptual framework. This is done by confirming the accuracy of the input data and by ensuring that the equations used are correctly specified. Model validation examines how accurate the model's results represent reality. It is dealt with in the results section.

The cost of the steer is the product of the purchase price and a placement weight of 350 lb. Data on ADG, death loss, operating costs and yardage for both backgrounding and finishing are from the Feedlot Investment Risk Simulation (FIR$T) tool, a tool developed by Alberta Agriculture and Rural Development (AARD) to analyze risks and returns from a cattle feeding enterprise. These data are summarized in table 8.

Table 8: Data on Costs and other Parameters used in Cash Flow Model

Parameter	**Value per steer**
Feed costs	
Backgrounding	\$0.8/day
Finishing	\$1.0/day
ADG	
Backgrounding	2.0 lb/day
Finishing	3.0 lb/day
Bedding	
Backgrounding	\$0.05/day
Finishing	\$0/day
Vet and medicines	
Backgrounding	\$0.10/day
Finishing	\$0.06/day
Yardage	
Backgrounding	\$0.45/day
Finishing	\$0.45/day
Death loss	
Backgrounding	2%
Finishing	1%
Interest on cattle	3.25% per annum

Source: Alberta Agriculture and Rural Development (2013b). Interest rate is from ATB Financial (2012).

Feed costs are the second largest expense in cattle feeding after the cost of the calf (Alberta Agriculture and Rural Development, 2004). In this study, the steer purchase cost contributes 45 to 88 percent of the total costs over the feeding period, while feed costs contribute 5 to 35 percent. This is verified by Canfax Research Services (2009) who observe the cost of the feeder animal and that of feeds to range between 50 and 70 percent and 12 and 35 percent of the total cost, respectively. Considering production costs alone, feed costs historically have contributed 50 to 70 percent (Shike, 2013). Interest charged on cattle is the ATB Financial[13] one-year fixed prime rate for 2013 (3%) plus 25 basis points. Monthly steer cash prices in \$/cwt for southern Alberta for seven weight categories starting

[13] ATB Financial is one of the financial institutions participating in the FALGP.

from 300 lbs to over 900 lbs, and monthly feed barley prices in $/tonne for Lethbridge are from Alberta Agriculture and Rural Development. Both steer and barley price series are from January 2000 to April 2013 and their summary statistics in real dollars are provided in table 9. Notice that the price per pound for lighter steers is higher relative to that of heavier steers because sellers of lighter steers are aware that the value of any additional weight (value of gain) will usually be greater than the cost of gain. This negative relationship between weight and price is referred to as the price slide (Dhuyvetter *et al*., 2002).

Table 9: Summary Statistics of Barley and Steer Prices, Jan 2000 – Apr 2013

Description	**Mean**	**Standard Deviation**
Price of barley ($/tonne)	135.91	33.46
Price of steers ($/cwt)		
900+ lbs	88.47	13.57
800 – 900 lbs	94.21	15.60
700 – 800 lbs	99.58	16.87
600 – 700 lbs	106.42	19.03
500 – 600 lbs	113.63	21.94
400 – 500 lbs	120.66	25.12
300 – 400 lbs	126.44	28.96

Source: Alberta Agriculture and Rural Development (2013c)

The presence of risk in the enterprise means that we are dealing with a stochastic rather than deterministic cash flow model. The model is simulated using Monte Carlo simulation to calculate CFaR. Monte Carlo simulation uses probability distributions of the risky variables to obtain a distribution of the possible values of the output variable. Use of probability distributions of the uncertain variables is a realistic way of accounting for risk (Palisade Corporation, 2013). Using @RISK, production risk is captured by specifying triangular distributions for ADG and death loss, while price risk is captured by systematically modeling real steer and barley prices and obtaining their forecasts using randomly generated error terms.

Modeling prices starts with the assumptions that monthly barley prices and prices of 900+ lb steers follow an autoregressive (AR) process, and the error terms of the two equations are likely correlated[14]. The Akaike Information Criteria (AIC) for lag order selection reveals that barley prices can be estimated as AR (2), and 900+ lb steer prices as AR (4). Because of the possibility of correlated error terms, the two equations are estimated using the seemingly unrelated regression (SUR) technique. The other steer prices are assumed to be determined by the current and lagged price of the 900+ lb steers and current barley price, and are estimated individually so as to maintain the price slide in the model. The price models to be estimated are shown in equations (2) – (9).

$$P_{B,t} = \delta_0^B + \delta_1^B P_{B,t-1} + \delta_2^B P_{B,t-2} + \varepsilon_t^B \quad \text{(2)}$$

$$P_{9+,t} = \delta_0^{9+} + \delta_1^{9+} P_{9+,t-1} + \delta_2^{9+} P_{9+,t-2} + \delta_3^{9+} P_{9+,t-3} + \delta_4^{9+} P_{9+,t-4} + \varepsilon_t^{9+} \quad \text{(3)}$$

$$P_{89,t} = \delta_0^{89} + \delta_1^{89} P_{9+,t} + \delta_2^{89} P_{9+,t-1} + \delta_3^{89} P_{B,t} + \varepsilon_t^{89} \quad \text{(4)}$$

$$P_{78,t} = \delta_0^{78} + \delta_1^{78} P_{9+,t} + \delta_2^{78} P_{9+,t-1} + \delta_3^{78} P_{B,t} + \varepsilon_t^{78} \quad \text{(5)}$$

$$P_{67,t} = \delta_0^{67} + \delta_1^{67} P_{9+,t} + \delta_2^{67} P_{9+,t-1} + \delta_3^{67} P_{B,t} + \varepsilon_t^{67} \quad \text{(6)}$$

$$P_{56,t} = \delta_0^{56} + \delta_1^{56} P_{9+,t} + \delta_2^{56} P_{9+,t-1} + \delta_3^{56} P_{B,t} + \varepsilon_t^{56} \quad \text{(7)}$$

$$P_{45,t} = \delta_0^{45} + \delta_1^{45} P_{9+,t} + \delta_2^{45} P_{9+,t-1} + \delta_3^{45} P_{B,t} + \varepsilon_t^{45} \quad \text{(8)}$$

[14] All price series are checked for stationarity prior to estimation. The KPSS test (Kwiatkowski *et al*., 1992) finds all series to be level stationary at the 1% confidence level.

$$P_{34,t} = \delta_0^{34} + \delta_1^{34} P_{9+,t} + \delta_2^{34} P_{9+,t-1} + \delta_3^{34} P_{B,t} + \varepsilon_t^{34} \quad \text{……………………….. (9)}$$

P_B, P_{9+}, P_{89}, P_{78}, P_{67}, P_{56}, P_{45}, and P_{34} are prices of barley, 900+ lb steers, 800 – 900 lb steers, 700 – 800 lb steers, 600 – 700 lb steers, 500 – 600 lb steers, 400 – 500 lb steers, and 300 – 400 lb steers, respectively, and ε_t^i is the error term. It is expected that the coefficients on the current and lagged price of the 900+ lb steers will be positive in the price equations of all the other steer categories; an increase in the price of 900+ lb steers would motivate cattle feeders to feed their animals to weights greater than 900 lbs to achieve higher profits. Therefore they would charge higher prices for steers weighing less than 900 lbs. But the coefficients on the price of barley are expected to be negative; an increase in the price of barley means an increase in the feed cost of gain and thus cattle feeders would bid down the price of steers.

A stochastic steer sale price for each of the 12 months is obtained by using randomly drawn errors. A standard normal distribution is used to draw the errors starting from the third lag through to the 12th month. Errors of the 900+ lb steer prices are adjusted to account for their correlation with barley price errors according to the formula in Hull (1997):

$$e_{9+} = \rho x_B + x_{9+}\sqrt{1-\rho^2} \quad \text{…………………………… (10)}$$

where e_{9+} is the adjusted error term for the price of the 900+ lb steers, ρ is the correlation coefficient between the residuals of the two equations as given by the SUR estimation, and x_B and x_{9+} are the independently drawn random errors of barley and 900+ lb steer prices, respectively. The adjusted errors of the 900+ lb steer prices and the other randomly drawn errors are each scaled by the standard deviation of their respective prices, and are then applied to equations (2) – (9) to obtain stochastic prices. Given that the price series cover the BSE period, the analysis is able to capture catastrophic price risk by specifying the observed minimum price as the lower bound when generating stochastic prices. For a given confidence level, c, CFaR of the enterprise is the probability that the future cash flow value, cf, is less than or equal to a given cash flow value, CF^*, and is at most $(1-c)$. Mathematically [see Jorion (2001)]:

$$P(cf \leq CF^*) = \int_{-\infty}^{CF^*} f(cf)dcf = 1 - c = m \quad \ldots\ldots\ldots (11)$$

Just like VaR, CFaR could be either the value CF^* at a given probability m, or the probability m for a given CF^*.

4.4.4 Estimating Credit Risk and the Value of the Loan Guarantee

Estimating Credit Risk

The approach used in this study to estimate the insurance premium or the risk to the lender of the cattle feeder defaulting on the loan draws from that used by Sherrick et al (2000) to value risk in agricultural mortgages. Assume that the total cost of the steer, SC, represents the total value of the loan, and cash flow, CF, is the only source of loan repayment. Cash flows are a stochastic variable with a cumulative distribution $P(CF)$. If $CF > SC$, the cattle feeder pays the lender SC and retains $CF - SC$. In this case, insurance against loan default has a payoff equal to zero. However, if $CF < SC$, the lender loses $CF - SC$ and the payoff from insurance would be $SC - CF$. Combining the two conditions, the insurance premium, IP, can be expressed as:

$IP = Max[0, SC - CF]$ …………………………. (12)

Estimating the Value of the Loan Guarantee

The equation used to estimate the value of the Feeder Association loan guarantee is derived by Merton (1977) based on the option pricing framework developed by Black and Scholes (1973). An option, which is a type of derivative or contingent claim, is defined as the right but not the obligation by a firm or individual to undertake a business transaction or decision. It may be real if the transaction involves a tangible asset, or financial if the transaction involves a traded asset such as a stock or bond. This analysis is based on the theory of financial options, of which there are two types: a Call option and a Put option. A Call option is a contract between two parties in which the holder has the right but not obligation to *buy* an asset known as the underlying at a specified price called the exercise or strike price, by a certain date called the expiry or maturity date. A Put option is a contract that conveys to the holder of the option the right but not obligation to *sell* a particular asset at a specified price by a certain future date. Options can be grouped into two general styles depending on when they can be exercised. A European option is one that can only be exercised at the maturity date, while an American option can be exercised any time up to the maturity date.

Assuming zero transaction costs, a log-normal distribution of possible stock prices at the end of a finite interval, a known and constant short-term interest rate and several other conditions, Black and Scholes (1973) derive a differential equation for the value of a European Call option. They also show an alternative derivation using the capital asset pricing model. Using the payoff condition of a Call option as a boundary condition, they solve the differential equation to obtain a formula for estimating the value of the option. They then specify a similar differential equation for a European Put option, and use the payoff condition of a Put option and an equation that relates the value of a European Call option to a European Put option (the so-called Put-Call parity), to obtain a formula for the value of a European Put option. However, Merton (1973) shows that the Black-Scholes model can be derived using a set of weaker assumptions than those originally used by Black and Scholes.

Let C, S and X denote the value of a Put option, stock price and exercise price, respectively. According to Black and Scholes (1973), the value of the option at maturity, t^*, will be equal to either 0 if $S \geq X$ or $X - S$ if $S < X$. In other words, the option's payoff

$C(t^*) = Max[0, X - S]$ ………………………….. (13)

where the Max function captures the holder's choice.

Merton (1977) demonstrates that the payoff structure of a loan guarantee is similar to that of a Put option. Suppose a firm acquires a debt valued at $\$B$ at maturity, with its assets, valued at $\$V$, as collateral[15]. If at maturity, $V > B$, the firm should pay off the debt. The value of the debt would be B and the value of the equity would be $V - B$. But if $V < B$, the firm would be unable to pay the debt, and the value of the debt would be equal to the collateral, V, and the value

[15] We change notation so as to demonstrate the similarity between the payoff structure of a Put option and that of a loan guarantee.

of the equity would be 0. Thus at maturity, the value of the debt would be $Min[V, B]$ and the value of the equity would be $Max[0, V - B]$.

Now, suppose the firm receives a guarantee from a third party to the effect that the guarantor pays the debt in the event that the firm defaults, but on condition that the firm relinquishes its assets to the guarantor if it defaulted. In essence, the guarantee means that the value of the firm's assets at maturity will be at least $\$B$. This represents a cost to the guarantor, but is of value to the firm. As in the case of no guarantee, the value of the debt would be B and the value of the equity would be $V - B$ for $V > B$. But if $V < B$, the value of the debt would still be B, the value of the equity would be 0, and the loss or payout by the guarantor would be $B - V$. Thus the value of the equity is $Max[0, V - B]$, the debt becomes riskless, hence remains valued at B, and the value of the guarantor's claim is the cash inflow to the firm of $-Min[0, V - B]$, which is the same as $Max[0, B - V]$. Letting G denote the value of the guarantee, at maturity, t^*,

$$G(t^*) = Max[0, B - V] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

which is similar to equation (13), with B corresponding to the exercise price and V to the stock price. Therefore the following Black-Scholes formula for valuing a Put option (Black and Scholes, 1973; Merton, 1977; Dahl *et al*., 1999) can be used to estimate the implicit cost of the FALGP guarantee.

$$G(T) = Be^{-rT}\Phi(x_2) - V\Phi(x_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

where G is the fair market value of the loan guarantee, T is the term of the loan guarantee, B is the value of the loan, V is the current value of the firm's assets[16], r is the market interest rate on riskless securities, e is the transcendental number (2.71828…), $\Phi(\cdot)$ is the cumulative normal density function, and

$$x_1 \equiv \left\{ \log\left(\frac{B}{V}\right) - \left(r + \frac{\sigma^2}{2}\right)T \right\} \Big/ \sigma\sqrt{T},$$

$$x_2 \equiv x_1 + \sigma\sqrt{T}$$

where σ^2 is the variance for changes in the value of the firm's assets.

The inputs used in calculating equation (15) are directly observable except σ. A risk-free interest rate of 6% is used[17] and the term of the loan is one year. Since there are different sources of risk in cattle feeding, σ should be a consolidated measure of risk, accounting for the fact that cattle, unlike financial assets such as shares, change form through weight gain, and the price per lb usually decreases as weight increases. Thus monthly volatility of returns to cattle feeding, σ_m, is obtained from the cash flow model as the standard deviation of the average monthly return on investment (ROI), and is converted to annual volatility using the formula $\sigma_m \cdot \sqrt{12}$ as in Copeland and Antikarov (2001) and Hull (2005). An annual volatility of 18.40% is obtained, which is comparable to 18.87% obtained by Viney (1995). Deng (2006) observes volatilities of 16.85% and 14.43% for feeder and fed cattle prices, respectively.

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[16] In this study, $B = V$

[17] This is the rate of return on Canada government bonds, which averaged 6.3% from 1985 to 2013 (Trading Economics, 2013). Deng (2006) uses the 5-year average rate on treasury bills of 3.5%.

An alternative to evaluating the payoff function in equation (14) is the Binomial option pricing method, a numerical approximation method derived by Cox et al (1979). The method involves sequentially determining the value of the enterprise in several time steps taken in up and down moves, leading to a Binomial tree structure. The value of the option is then calculated by working backwards through the tree. For a large number of time steps, the Binomial model converges to the Black-Scholes model for a European option. The Binomial model is implemented in this study and the resulting prices of European and American Put options are compared with the price obtained from the Black-Scholes model.

4.4.5 Estimating Interest Subsidy

The formula used to calculate the interest subsidy accruing to a loan guarantee is provided by Raynauld (1992). The interest subsidy (subsidy rate) is the differential interest rate between the alternative commercial rate and the Feeder Association rate. Thus the implicit guarantee subsidy is equal to the subsidy rate, S, times the loan value, and it is discounted to its present value. The subsidy rate is given as:

$$S = 100\left(1 - \frac{r/a}{d}\right)\left(1 - \frac{\dfrac{1}{(1+d)^{ag}} - \dfrac{1}{(1+d)^{aT}}}{d(aT - ag)}\right) \text{ .... (16)}$$

where r is the rate of interest on guaranteed loans, a is the number of repayments per year, g is the grace period (the time allowed after the loan repayment is due before penalties apply), T is the term of the guarantee and d

is the discount rate (reference interest rate). The reference interest rate, which is the commercial interest rate that banks would charge for lending without a guarantee, would conceptually be the rate of return on government bonds as a proxy for a risk-free interest rate, plus a risk premium associated with a risky investment. Estimates of d are found by adding the estimated risk premiums for the two feeding regimes and for the entire period to the 6% risk-free interest rate. Assuming payments on principal and interest are made on an annual basis, then $a = 1$, hence:

$$S = 100\left(1-\frac{r}{d}\right)\left(1-\frac{\dfrac{1}{(1+d)^g}-\dfrac{1}{(1+d)^T}}{d(T-g)}\right) \text{ .... (17)}$$

Also, we assume that loans are provided without a substantive grace period (i.e., $g = 0$). As indicated by Raynauld, the entire loan amount is seldom disbursed at once, and this is especially true for Canadian financing policies. Thus

$$S = 100\left(1-\frac{r}{d}\right)\left(\frac{1-\left(1-\dfrac{1}{(1+d)^T}\right)}{dT}\right) \text{ .... (18)}$$

Equation (18) is used to calculate the subsidy rate, which when multiplied by the loan value gives the interest subsidy provided by the FALGP. The interest subsidy is compared to the estimated price of the FALGP; it would be desirable, from an economic point of view, if the price of the guarantee sufficiently offsets the subsidy provided by the program.

4.4.6 Summary of Literature Review and Methods

This study analyzes three aspects of Alberta's Feeder Association Loan Guarantee Program; the credit risk faced by lenders, the value of the loan guarantee, and the interest subsidy provided by the guarantee. Cattle feeding involves different sources of risk, notably, input and output price risk, and production risk in the form of death loss and variations in average daily gain. So, a cash flow model represented by equation (1) and implemented using Monte Carlo simulation is used to calculate cash flows that would accrue to a cattle feeder from the sale of one steer in the different months of the feeding horizon. Following Sherrick et al (2000), credit risk is then calculated using equation (12).

Estimating the value of the guarantee draws heavily on the theory of option pricing. Merton (1977) demonstrates the equivalence between the payoff function of a loan guarantee and that of a Put option. The guarantee value is calculated using equation (15) as has been done for export credit guarantees by Dahl et al (1999). This equation is based on the Black-Scholes model (Black and Scholes, 1973). But Cox et al (1979) demonstrate that the payoff function of a Put option can be derived using numerical approximation. They derive an alternative model, the Binomial option pricing model, which converges to the Black-Scholes model in the case of a European Put option. This study therefore checks the accuracy of the guarantee price obtained from the Black-Scholes model by calculating the guarantee price using the Binomial option pricing model. The Binomial option pricing model is also used to calculate the price of the loan guarantee assuming that the guarantee is priced as an American Put.

Lastly, the study contends that knowledge of the interest subsidy is helpful in drawing conclusions about the appropriateness of the estimated guarantee price if the government were to charge a guarantee fee equivalent to this price. Equation (18) is used to calculate the interest subsidy provided to cattle feeders through the loan guarantee program. This formula has been used by Raynauld (1992) and Diersen et al (1997) to calculate interest subsidies provided through export credit guarantees.

4.5 Results

4.5.1 Price Model Results

All price data was checked for stationarity using the KPSS test, and all series were found to be level stationary at the 1% confidence level. The coefficients of the estimated price equations are presented in table 10. Overall, the price models are valid since they have high R-squared values with significant F-tests, and reasonably low standard errors. Moreover, all the results obtained conform to *a priori* expectations. The models are statistically significant at the 1% level with R-squared values that range between 84% and 95%. As expected, the coefficients on the current and lagged price of the 900+ lb steers in the price equations of all the other steer categories are positive and statistically significant, while the coefficients on the price of barley are negative and significant.

Table 10: Ordinary Least Squares regression results of price models

Variable	Barley	900+ lbs	800 – 900 lbs	700 – 800 lbs	600 – 700 lbs	500 – 600 lbs	400 – 500 lbs	300 – 400 lbs
Lag 1	1.25***	1.21***						
	(0.077)	(0.079)						
Lag2	-0.26***	-0.43***						
	(0.079)	(0.125)						
Lag 3		0.02						
		(0.125)						
Lag 4		0.14*						
		(0.078)						
900+ lb			0.99***	1.03***	1.04***	1.11***	1.27***	1.43***
			(0.078)	(0.088)	(0.110)	(0.125)	(0.138)	(0.164)
Lag 1 of price of 900+ lb			0.14*	0.19**	0.30***	0.44***	0.53***	0.68***
			(0.078)	(0.088)	(0.110)	(0.125)	(0.138)	(0.163)
Barley			-0.03**	-0.04***	-0.04**	-0.04**	-0.05**	-0.08***
			(0.013)	(0.015)	(0.018)	(0.021)	(0.023)	(0.027)
Constant	2.86	4.76**	-3.62	-4.44	-8.28*	-19.10***	-32.74***	-49.90***
	(2.398)	(2.336)	(3.276)	(3.713)	(4.265)	(5.268)	(5.817)	(6.873)
R-squared	0.957	0.902	0.884	0.871	0.840	0.842	0.854	0.850
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
St'd Error	6.916	4.215	5.304	6.012	7.487	8.530	9.418	11.127

Figures in parentheses are standard errors. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

Also, notice that the absolute size of the coefficients on the current and lagged price of the 900+ lb steers, and on the price of barley increases as steer weight decreases. This is because changes in these prices usually have greater implications on the cost and value of gain for lighter steers than heavier ones. For instance, holding other factors constant (including the price of barley, which captures the cost of gain), a \$1.00 increase in the current price of the 900+ lb steers will increase the price of the 800 – 900 lb steers by approximately the same amount, but by \$1.43 for the 300 – 400 lb steers. Likewise, because lighter steers have to be fed for a longer time, an increase in the price of barley, *ceteris paribus*, causes a larger reduction in their price compared to that of heavier steers.

4.5.2 Cattle Feeding Cash Flows

Assuming sale of the steer at each month, table 11 shows the average farmer's cash flows (CF) and their standard deviations for each of the 12 months as obtained from equation (1). However, lenders are unlikely to be concerned about the costs of cattle feeding. Thus their perception of cash flows (denoted by CFL in table 11) may well be approximated by the function $MIN(SC + I, REV)$ where SC is the total steer purchase cost, I is interest on cattle loan, and REV is total revenue. Both CF and CFL are noncumulative across months since the analysis is based on the sale of a single steer, which can be done only once. For instance, if the steer were to be sold in the third month of backgrounding, the farmer would realize a net cash flow of \$29.54 according to the base scenario[18]. But if the steer

[18] The three scenarios are explained later in this section.

were to be sold in the eleventh month of the feeding period (having been fed to finish for five months), the farmer would realize a cash flow of $106.37.

Validating the cash flow model would involve comparing the cash flows obtained from the model to those of a real cattle feeding operation. But cash flows of a real cattle feeding operation are difficult to find. In fact, the absence of a comparable real world system is the case in most studies involving simulation analysis (Trautman, 2012). An alternative is to validate the model using sensitivity analysis (Trautman). Essentially, this is an approach that is based on the model itself in contrast to external validation, which is based on actual data (Miller, 1974). Therefore three production risk scenarios are considered: the first scenario is the baseline, and it uses empirically observed parameters of triangular distributions for ADG and death loss, while the second and third scenarios consider a modest reduction and increase, respectively, in scenario one's parameters for ADG and death loss.

Cash flows for each scenario are obtained after 10,000 iterations. In the baseline scenario the farmer's cash flows are positive in all but the first month. But in scenario two, a small reduction in ADG leads to negative cash flows in spite of a reduction in death loss. When both ADG and death loss are slightly increased in scenario three, the farmer realizes positive cash flows, but they appear larger than what would be expected. These results do not confirm the validity of the cash flow model, but they provide support for scenario one as the more likely scenario among the three scenarios for a typical cattle feeding operation. This is further confirmed by the CFaR results in the next section.

Table 11: Cash flows for a cattle feeding operation

Month	1	2	3	4	5	6	7	8	9	10	11	12
Scen. 1	**Min**	**Exp.**	**Max**									
ADG	*1*	*2.5*	*3*	*B*								
	1	*3*	*5*	*F*								
DL	*0%*	*2%*	*6%*	*B*								
	0%	*1%*	*6%*	*F*								
CF ($)	-1.85	18.80	29.54	29.17	23.55	15.23	19.10	27.75	47.90	75.47	106.37	139.70
	(136.42)	(168.32)	(189.63)	(202.87)	(211.81)	(222.04)	(232.34)	(241.23)	(259.63)	(281.69)	(303.92	(329.88)
CFL($)	425.69	433.08	438.89	444.50	448.63	451.76	455.36	459.54	462.43	465.01	467.01	468.66
	(126.63)	(126.93)	(127.71)	(129.76)	(131.76)	(133.01)	(134.85)	(137.85)	(139.86)	(141.71)	(143.08)	(143.96)
Scen. 2												
ADG	*0.5*	*2*	*2.5*	*B*								
	0.5	*2*	*4*	*F*								
DL	*0%*	*1%*	*5%*	*B*								
	0%	*0.5%*	*5%*	*F*								
CF ($)	-8.58	-4.10	-5.90	-9.50	-19.46	-33.98	-39.35	-50.51	-59.64	-67.39	-66.79	-62.26
	(137.78)	(166.60)	(183.80)	(195.54)	(205.51)	(214.97)	(225.69)	(233.79)	(243.03)	(253.30)	(269.22)	(287.10)
CFL ($)	421.70	426.97	432.22	438.66	443.08	446.50	450.79	454.30	457.34	460.48	462.98	465.67
	(125.57)	(124.92)	(125.09)	(127.33)	(128.69)	(130.04)	(131.65)	(133.59)	(135.27)	(137.42)	(138.95)	(140.76)
Scen. 3												
ADG	*1.5*	*3*	*3.5*	*B*								
	1.5	*3.5*	*5.5*	*F*								
DL	*0.5%*	*4%*	*6.5%*	*B*								
	0.5%	*3.5%*	*6.5%*	*F*								
CF ($)	7.87	35.22	51.77	58.29	57.05	56.15	74.71	108.76	154.41	200.43	245.60	292.84
	(138.49)	(170.57)	(190.37)	(205.92)	(216.68)	(228.01)	(235.18)	(255.20)	(279.56)	(303.77)	(328.60)	(357.34)
CFL ($)	429.57	437.22	443.75	448.15	452.05	454.98	459.37	462.46	464.70	466.42	467.81	469.06
	(127.78)	(127.81)	(130.08)	(131.70)	(133.95)	(135.42)	(138.47)	(140.80)	(142.39)	(143.44)	(144.07)	(144.50)

Figures in parentheses are standard deviations. CF and CFL denote farmer's cash flow and lender's perception of cash flow, respectively. *B* and *F* denote backgrounding and finishing, respectively.

4.5.3 Cash Flow at Risk

Next, we quantify the likely loss to the cattle feeding enterprise due to the associated risks. The CFaR results reported in table 12 are obtained from the distribution of farmers' cash flows in the baseline scenario. The table shows the 5% and 20% CFaR values, as well as the probability of obtaining net cash flows less than zero. At the 5% level, we observe losses to the enterprise in each month over the entire feeding period, and the losses during backgrounding increase less gradually than those experienced during finishing. In fact there is a slight decline in losses in the last month of finishing. There is likely to be a loss of $233 or more to the enterprise if the steer is sold in the first month of backgrounding. Selling the steer in the first or even second or third month of backgrounding, however, is highly unlikely. Cattle feeders are most likely to sell after completely backgrounding the steer, or during or after finishing, depending on market conditions. There is one chance in twenty that the enterprise will realize a cash flow of $-350 or less if the steer is sold in the sixth and last month of backgrounding, or $-377 or less if sold after finishing in the 12th month.

A more realistic measure of the likely losses can be obtained by considering CFaR at a higher probability level. Whereas CFaR at 5% reveals cash flow losses likely to occur for one in twenty chances, CFaR at 20% indicates likely losses for one in five chances. Disregarding cattle feeders' risk preferences, the latter measure is undoubtedly more helpful for risk assessment and management than the former. It can be seen that the 20% CFaR values for the cattle feeding enterprise remain large but are considerably lower than those at 5% in each month. Moreover, the likely losses during finishing start to decline earlier (9^{th} month). The 20% CFaR values are comparable to losses of between \$100 and \$200 per head that have been observed in cattle feeding in western Canada in recent times (Duckworth, 2013).

Table 12: Farmer's net CFaR values for a single steer

Month	CF at 5% ($)	CF at 20% ($)	Prob CF < 0
1	-233	-109	54.3%
2	-265	-117	46.2%
3	-294	-125	44.1%
4	-306	-140	46.1%
5	-328	-152	47.9%
6	-350	-172	48.5%
7	-371	-175	48.2%
8	-371	-181	46.6%
9	-376	-174	44.3%
10	-377	-170	41.7%
11	-379	-160	38.9%
12	-377	-150	36.5%

The probability of cash flows being less than zero provides further insight into the risk associated with cattle feeding. This probability is highest at the start of backgrounding (54.3%), and it steadily declines during finishing down to 36.5% in the 12^{th} month. Note that production risk parameters for ADG and death loss only vary from one feeding regime to another but are constant within a given regime. Therefore the trend in CFaR observed within each regime is caused by the stochastic nature of prices.

Taken together, these results confirm that cattle feeding is a risky venture. CFaR as measured by the probability of zero cash flows suggests that finishing is probably less risky than backgrounding. The results have important implications for risk management in cattle feeding, and for determining the appropriate insurance premium on a cattle feeding loan.

4.5.4 Insurance Premium

Given the risk in cattle feeding, credit to cattle feeders is likely to expose lenders, both cash flow and security (cattle being the security), to considerable risk, which would in turn lead to high risk premiums and/or increased collateral requirements. The analysis of credit risk exposure in this study is predicated on cash flows perceived by the lender. These cash flows provide the lender with conjectures on the two parameters commonly used in credit risk models, namely, the probability of default and the magnitude of the loss given default (Pederson and Zech, 2009). The rationale underpinning the use of cash flows from the lender's view point is that the lender may be able to observe the relevant risk factors including stochastic asset (in this case cattle) prices as is assumed in the Merton credit risk model (Pederson and Zech) but not the operation's production costs.

Table 13 shows the average risk premiums associated with backgrounding, finishing, and both backgrounding and finishing. Percentage premiums are calculated based on an average loan amount of $455, which is equivalent to the cost of purchasing a light weight steer. CFaR results have confirmed backgrounding to be generally more risky than finishing. Therefore it is not surprising that the average risk premium for backgrounding is higher than for finishing. A more informative estimate of the insurance premium for a lender who does not know with certainty the month in which the steer is to be sold would be the weighted average premium for the entire feeding horizon. This would necessitate determining weights for each feeding regime that reflect each regime's contribution to the volatility of returns from the background-to-finish feeding operation. But for a steer fed over all the 12 months, following Elam and Njukia (1993)[19], we can calculate the insurance premium as the total of the two averages. All the premiums are greater than the 0.25% or 25 basis points charged by ATB Financial for the FALGP loans implying that the loan guarantee program and the 5% pooled security deposit have probably reduced the interest rate on cattle loans.

Table 13: Risk premiums for feeding a single steer

Regime	Premium ($)	Percentage of loan amount
Backgrounding	17.54	3.86%
Finishing	2.55	0.56%
Backgrounding and finishing	20.09	4.42%

According to Purdy (2013), there is not a set rate of interest for the industry; in the absence of the program, the rate would likely vary from one farmer to another depending on an individual farmer's risk profile, and it would certainly be above the prime rate and the program rate. Purdy notes that more importantly from the bank's risk perspective is the role of provincial supervisors in ensuring that individual Feeder Associations comply with the rules and regulations of the

[19] The authors calculate the price risk premium paid by hedgers in the live cattle futures market. Basing on the assumption that cattle are hedged when placed on feed, they calculate the risk premium per animal for a five-month feeding period as the sum of the monthly risk premiums.

program. Proper detailing of paper work, spot checks to ensure use of appropriate brands, and auditing of office procedures have been pointed out as being crucial to Feeder Associations in successfully operating the program.

4.5.5 CFaR and Insurance Premium from Conditional Standard Deviations

The preceding analysis of cash flows, CFaR and insurance premiums is based on stochastic prices generated from unconditional standard deviations of historical prices. However, the historical standard deviations are relatively high compared to the conditional standard deviations of the price models, which explains the relatively high CFaR values and insurance premiums. When stochastic prices are generated from conditional standard deviations, substantially lower CFaR values and insurance premiums are obtained as shown in tables 14 and 15, respectively.

Table 14: Farmer's net CFaR values from conditional standard deviations

Month	CF at 5% ($)	CF at 20% ($)	Prob CF < 0
1	-105	-54	50.9%
2	-112	-49	40.7%
3	-130	-52	38.1%
4	-141	-61	40.4%
5	-153	-70	42.4%
6	-171	-83	44.9%
7	-180	-82	44.0%
8	-183	-82	42.7%
9	-184	-81	39.6%
10	-189	-72	35.6%
11	-193	-63	31.0%
12	-194	-51	27.7%

Table 15: Risk premiums from conditional standard deviations

Regime	Premium ($)	Percentage of loan amount
Backgrounding	1.86	0.41%
Finishing	0.01	0.002%
Backgrounding and finishing	0.93	0.20%

The lender's risk premium of 0.20% over the entire feeding horizon compares with the 0.25% basis charged by ATB Financial for loans under the FALGP. It may well be that the level of risk and risk premium estimated with conditional standard deviations of prices are closer to the true values than those estimated using unconditional standard deviations.

4.5.6 Value of Loan Guarantee

In valuing the loan guarantee, the 5% security deposit is deducted from the total loan value. Hence the loan guarantee is valued based on a loan of $432. Table 16 shows the parameters for valuing the loan guarantee, and table 17 shows the average value (price) of the European Put option obtained from the Black-Scholes model and average values of European and American Put options obtained from the Binomial option pricing model. The three values are quite close to each other as expected since the two models provide almost similar results.

Table 16: Parameters used in valuing a loan guarantee for a single steer

Parameter	Units	Value
Loan value, *B*	$	432
Current value of assets, *V*	$	432
Term of loan, *T*	Years	1
Volatility of returns, σ	%	18.40
Risk-free interest rate, *r*	%	6.0

Table 17: Estimates of the value of a one-year cattle loan guarantee

Model	European Put ($)	American Put ($)	Percentage of loan amount
Black-Scholes	19.12		4.43% (European Put)
Binomial	18.45	21.78	4.27% (European Put) 5.04% (American Put)

According to the Black-Scholes model, cattle feeders should pay a fee equivalent to 4.43% of the face value of the loan for a one-year guarantee covering 15% of the total loan available to the Feeder Association, whereas the Binomial pricing model estimates the price of the guarantee to be 4.27% of the loan amount. Unlike a European Put, an American Put can be exercised any time, and this flexibility increases the value of the American Put. Thus cattle feeders would pay a fee equal to 5.04% of the loan for a one-year guarantee if valued in terms of an American Put option. However, according to some lenders' terms and conditions, loan repayment is made once, and does not have to be before the cattle are sold. In this case, the European Put value would be a more realistic estimate of the price of the guarantee. Generally, the values of the guarantee given by the two models do not seem to be high. In fact they are comparable to the 5% security deposit.

The price of the guarantee is a premium for the risk faced by the guarantor. The risk measure that has been used to derive the guarantee price is the volatility of cattle feeding returns. But besides the estimated guarantee price, a rough indication of the government's risk exposure is the default rate, which may be approximated by the payouts in the 77 years of the program's existence relative to the $7.68 billion that has so far been covered by the guarantee. The payouts have totaled $3.82 million, which is about 0.05% of the amount guaranteed. Given the current maximum liability of the program of $55 million, the payouts are equivalent to 6.95% of the maximum liability. Also, recall that payouts have been made 17 times, implying an average of $0.225 million per payout or 5.88% of the total payouts. These figures are generally indicative of a low rate of default on cattle feeding loans in spite of the substantial risk in cattle feeding, and therefore they support the study's finding of low values of the loan guarantee.

4.5.7 Interest Subsidy

Table 18 shows the average subsidy rates and the corresponding guarantee subsidies for the entire feeding period and for each of the two feeding regimes for a loan amount of $455. Subsidy rates approximate interest rate differentials, and the resulting guarantee subsidies represent the discounted interest savings provided to cattle feeders by the FALGP. With a subsidy rate of 4.58%, a cattle feeder would save on average twenty one dollars in interest on a loan of $455 over the entire feeding horizon.

Table 18: Subsidy rates for a one-year loan guarantee for a single steer

Period	**Subsidy rate**	**Guarantee subsidy**
Entire feeding period	4.58%	$20.84
Backgrounding	6.02%	$27.35
Finishing	3.11%	$14.12

4.6 Sensitivity Analysis

Using the baseline scenario (scenario one), three sensitivity analyses are undertaken. First, the starting weight for backgrounding is varied to assess the sensitivity of the farmer's cash flows and the credit risk to the lender. Second, volatility of returns to cattle feeding and the risk-free interest rate are varied to assess the sensitivity of the value of the loan guarantee. The third sensitivity analysis involves varying the discount rate to assess the sensitivity of the interest subsidy provided by the loan guarantee.

Changes in cash flows and risk premiums

Since the initial weight of 350 lbs is of a light calf that has been weaned early, the sensitivity analysis considers initial weights greater than 350 lbs: 400 lbs, 450 lbs, 500 lbs, and 550 lbs. The sensitivity analysis therefore includes the weight at which calves are usually weaned (485 to 550 lbs). Table 19 summarizes the results of the analysis for different starting weights. Relative to the baseline, an increase in the starting weight leads to a decline in the farmer's average cash flows in all the twelve months of the feeding horizon. While only one negative cash flow ($-1.85) was observed for the initial weight of 350 lbs, negative cash flows are realized throughout backgrounding for each initial weight, and positive cash flows are obtained only in the last 2 to 4 months of finishing. For example, in the baseline scenario, if the steer were to be sold after backgrounding in the sixth month, a cash flow of $15.23 would be realized (table 11). But for an initial weight of 400 lbs, the resulting cash flow would be $-23.97, implying a $39.20 reduction in cash flow. When the initial weight is again increased by 50 lbs (to

450 lbs), a cash flow of $-65.12 would be obtained, implying a $41.15 reduction in cash flow.

Table 19: Farmer's cash flows and lender's risk premiums, both in $/steer, for different backgrounding starting weights

Month	Farmer's cash flows ($/steer)			
	400 lbs	**450 lbs**	**500 lbs**	**550 lbs**
1	-11.33	-50.46	-64.65	-113.43
2	-10.00	-36.17	-75.13	-107.87
3	-7.10	-38.01	-80.00	-115.87
4	-9.03	-47.82	-88.00	-128.68
5	-14.98	-58.57	-99.35	-139.96
6	-23.97	-65.12	-106.47	-140.80
Risk premium for backgrounding	*$27.29 (5.26%)*	*$41.29 (7.08%)*	*$57.40 (8.87%)*	*$77.82 (10.94%)*
7	-20.28	-55.99	-87.37	-114.71
8	-5.60	-35.48	-60.89	-84.48
9	20.65	-4.27	-27.57	-50.30
10	51.22	27.97	4.94	-17.88
11	82.86	59.46	36.41	13.43
12	116.20	92.94	69.81	46.66
Risk premium for finishing	*$5.29 (1.02%)*	*$9.23 (1.58%)*	*$14.48 (2.24%)*	*$20.85 (2.93%)*

These results suggest that cash flows are sensitive to the initial weight of the steer; starting to background an animal at a relatively heavy weight may not be profitable if the backgrounding is to be done over a six-month period. As a result, the cattle loan risk premiums for both backgrounding and finishing will be relatively high, and will increase with increase in the initial weight of the animal.

Changes in the value of loan guarantee

Sensitivity of the value of the loan guarantee (for a loan amount of $432) to changes in volatility and interest rate is analyzed by considering 10%, 20% and 30% increases and reductions in both parameters. Volatility is positively related to the value of the loan guarantee, while interest rate and the value of the guarantee are inversely related. In the baseline scenario, annual volatility was 18.40%. When volatility is increased by 10% (i.e., from 18.4% to 20.24%) holding other parameters constant, the value of the loan guarantee increases by about 15% from $19.12 (table 15) to $22.01 (table 20) as per the Black-Scholes model. The value of $22.01 is 5.09% of the loan amount. The same level of sensitivity is obtained with the Binomial option pricing model; a 10% increase in volatility increases the value of the guarantee from $18.45 to $21.28 when valued as a European Put, or from $21.78 to $24.66 when valued as an American Put[20]. Therefore the greater the risk faced by the cattle feeding enterprise, the higher the implied price of the loan guarantee. It can also be concluded that the value of the loan guarantee is less for a farmer with a financially sound operation than one with financial challenges.

Increasing the risk-free interest rate decreases the value of the guarantee, and vice-versa[21]. But the value of the guarantee is not as sensitive to changes in the risk-free interest rate as it is to changes in volatility. Initially, a risk-free interest rate of 6% is used. When increased by 10%, the value of the guarantee decreases by only 1.67% from $19.12 to $18.80 according to the Black-Scholes model. A

[20] As earlier mentioned, the value of an American Put is always greater than that of a European Put. In table 18, results from the Binomial model are shown for both European and American Puts, with the larger value corresponding to the latter.
[21] For a Call option, an increase in interest rate increases the value of the option (Haug, 2007).

similar reduction in the interest rate increases the value of the guarantee by about 9% from $19.12 to $20.78.

Table 20: Estimates of the value of a one-year cattle loan guarantee for different volatility levels and risk-free interest rates

	Value of guarantee	
Volatility (%)	**Black-Scholes**	**Binomial**
20.24	$22.01 (5.09%)	$21.28 (4.93%)
		$24.66 (5.71%)
22.08	$24.93 (5.77%)	$24.12 (5.58%)
		$27.54 (6.38%)
23.92	$27.86 (6.45%)	$27.01 (6.25%)
		$30.45 (7.05%)
16.56	$16.26 (3.76%)	$15.65 (3.62%)
		$18.90 (4.38%)
14.72	$13.44 (3.11%)	$12.90 (2.99%)
		$16.07 (3.72%)
12.88	$10.69 (2.47%)	$10.21 (2.36%)
		$13.29 (3.08%)
Risk-free interest rate (%)		
6.6	$18.80 (4.35%)	$18.13 (4.20%)
		$21.55 (4.99%)
7.2	$17.86 (4.13%)	$17.19 (3.98%)
		$20.86 (4.83%)
7.8	$16.95 (3.92%)	$16.28 (3.77%)
		$20.21 (4.68%)
5.4	$20.78 (4.81%)	$20.12 (4.66%)
		$22.95 (5.31%)
4.8	$21.83 (5.05%)	$21.18 (4.90%)
		$23.69 (5.48%)
4.2	$22.92 (5.31%)	$22.27 (5.16%)
		$24.46 (5.66%)

Figures in parentheses are values of the loan guarantee expressed as a percentage of the loan amount.

Changes in Subsidy rates

Table 21 summarizes the results of the sensitivity of the subsidy rate for the entire feeding period to upward and downward changes of 10%, 20% and 30% in the discount rate. In the baseline model, a discount rate of 8.21% is used to obtain a subsidy rate of 4.58%, which, for a loan amount of $455, translates into a guarantee subsidy of $20.84. A 10% increase in the discount rate increases the subsidy rate and hence the guarantee subsidy by about 2% from $20.84 to $21.32. But a similar reduction in the discount rate would substantially reduce the guarantee subsidy by as much as 29%.

Table 21: Subsidy rates for entire feeding period at different discount rates

Discount rate	Subsidy rate	Guarantee subsidy
9.03	4.69%	$21.32
9.85	5.40%	$24.55
10.67	6.10%	$27.74
7.39	3.23%	$14.70
6.57	2.49%	$11.32
5.75	1.73%	$7.88

In summary, results of the sensitivity analysis indicate that the farmer's cash flows and the resulting risk premiums on a cattle loan are relatively sensitive to changes in the initial weight at which a steer is placed in a backgrounding program. Higher initial weights lead to lower cash flows and higher risk premiums. We also find that the value of the Alberta cattle loan guarantee program is sensitive to the volatility of returns to cattle feeding, but less so to changes in the risk-free interest rate. Consistent with the theoretical framework, higher volatility levels result in higher guarantee prices, while higher interest rates mean lower guarantee prices. A reduction in the risk-free interest rate would have a greater impact on the value of the guarantee than an increase in the rate. An increase in the discount rate leads to an increase in the subsidy inherent in the loan guarantee. But similar to the effect of a reduction in the interest rate on the guarantee price, a reduction in the discount rate would impact the guarantee subsidy more than an equivalent increase in the rate.

4.7 Summary and Conclusion of Chapter Four

Chapter four examines three aspects of Alberta's Feeder Association Loan Guarantee Program, namely, credit risk to lenders, value (price) of the loan guarantee, and guarantee subsidy. A stochastic Monte Carlo cash flow model of backgrounding and finishing a light-weight steer underlies the analysis of credit risk, and provides estimates of some of the parameters needed to determine the guarantee's price and implicit interest subsidy.

Cash flow at risk estimates show that the likely losses in cattle feeding for one in five chances range from $109 to $150, and the probability of cash flows being less than zero ranges from 36.5% to 54.3%. Given this level of risk, the insurance premiums needed to offset the credit risk to lenders participating in the loan guarantee program are on average 4.42% of the value of the loan for the entire feeding period, and 3.86% and 0.56% for backgrounding and finishing, respectively. The price of the loan guarantee as estimated by the Black-Scholes option pricing model is 4.43% of the value of the loan, and that estimated by the Binomial option pricing model is 4.27% if the guarantee is valued as a European Put, and 5.04% if valued as an American Put. The program provides a subsidy rate of 4.58%, which implies an interest saving of about $21 on a loan of $455. Note that the estimated guarantee prices are almost equal to the subsidy provided by the guarantee. Interestingly, pricing the guarantee as an American Put option ensures a price that offsets the interest subsidy.

The results have two implications for credit provision to cattle feeding enterprises. First, they suggest that both government- and market-based credit provision to cattle feeders be cognizant of the varying levels of risk exposure (to lenders) that depend on the nature of the cattle feeding operation. The risk premiums obtained in this study can be used in conjunction with the individual feeders' risk profiles to arrive at the appropriate interest rate on direct government loans, government guaranteed loans or purely private market loans. Second, the results point to the possibility of restructuring and operating the FALGP in a manner that removes the implicit guarantee subsidy. That would involve charging a guarantee fee. This is already being done under the Canadian Agricultural Loans Act although it is unclear whether or not the 0.85% fee is sufficient to offset the subsidy. To do so, however, requires information on the additionality caused by the program and the effect the change would have on it. Additionality refers to either the number of cattle feeders that were able to access credit as a result of the program, or the additional lending in terms of the volume of loans that can be attributed to the program. Additionality can then be weighed against both the financial and non-financial costs of the loan guarantee program to provide a benchmark for assessing alternatives to the program. This is a potential area for future research.

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CHAPTER FIVE: CONCLUSION

This dissertation presents findings of three studies on Canada's beef cattle industry. A common thread to the first and second studies is the analysis of the impact of exogenous shocks on important aspects of the industry. In the first study, the impact of the highly contentious country of origin labeling law on U.S. imports of Canadian beef and cattle is examined. In the second study, the impacts of two market shocks, namely, appreciation of the Canadian dollar relative to the U.S. dollar and an increase in the price of feed, on the cyclical properties of cattle inventories, beef supply and prices are examined. The third study estimates the value of the loan guarantee provided to Alberta Feeder Associations by the provincial government. Results from these studies provide insights into the nature of industry strategies and policy interventions that would help increase and sustain the industry's competitiveness. This chapter provides a summary of the three studies, the policy implications of their results, the studies' limitations, and potential areas for further research.

The first study argues that country of origin labeling (COOL) has been detrimental to the competitiveness of Canada's beef cattle industry insofar as it has caused a reduction in U.S. imports of Canadian beef and cattle. The same argument has been the basis of Canada's case against the U.S. in the WTO that the law violates Article 2.1 of the Technical Barriers to Trade (TBT) Agreement. This study develops a multi-market partial equilibrium model of the Canadian and U.S. beef cattle industries, from which it derives reduced-form U.S. import demand equations for Canadian beef and cattle. The equations are then subjected to two tests of structural change – the Bai and Perron (1998, 2003) test that addresses the fact that the exact date on which COOL caused a structural break is not known, and Andrews (2003) test that deals with the possibility that the COOL-induced break point could have occurred toward the end of our sample data. The evidence obtained strongly supports the argument that COOL has led to a reduction in U.S. imports of Canadian beef and cattle. While a 1% reduction in beef imports was observed, the reductions in fed and feeder cattle imports were as high as 18% and 21%, respectively.

These results support Canada's case against COOL in the WTO. In June 2012, the WTO's Appellate Body ruled that COOL treats imported Canadian cattle less favorably than U.S. cattle, and a WTO arbitrator set May 23, 2013 as the deadline for the U.S. to comply with the WTO ruling. The industry continues to pressure the U.S. to fully comply with the WTO ruling. This is seen in the recent application by Canada to have the WTO establish a compliance panel to assess whether or not the changes made by U.S. to the law so far are sufficient (The Globe and Mail, 2013).

However, a major policy implication of the study's results draws from the likelihood that mixed supply chain beef may cease to exist in the U.S. market if COOL is not repealed. Therefore in the long-run, the industry could aim to increase its beef processing capacity and seek offshore markets for beef owing to the law's relatively small impact on beef imports. But such a policy strategy might be limited by the potential to exercise oligopsony power by the few existing beef processors, and the industry's ability to compete with lower-cost suppliers such as Brazil, Uruguay and Argentina. Schroeder (2003) observes that COOL has motivated producers to consider better vertical coordination by investing in beef packing to obtain premiums on higher quality beef. But he notes that producer-owned processing plants may not be able to compete with existing multinational beef processing companies in the global market, and unlike the large companies, they could easily be put out of business by a single food safety event. In short, both the structural change caused by COOL as revealed by this study and the policy goal of increasing domestic beef processing capacity may have implications for the Canadian beef supply chain. But analyzing those implications is beyond the scope of this study.

A limitation of this study is that although it has been able to detect COOL-induced structural breaks using the Andrews test, it has not been able to do so using the BP test. It could be that either the time period covered by the series after the BSE crisis is not long enough for the BP test to detect structural breaks, or that the BSE shock was so big that the structural break it caused has dominated all other possible structural breaks.

The second study argues that because the beef cattle industry exhibits cyclicality, some of the recent market shocks have had an impact on the cyclical patterns of some of the industry’s key policy variables. To prove this, the study uses spectral analysis (Hamilton, 1994) to first and foremost establish the nature of cycles in total cattle inventories, beef cow inventories, beef supply and beef prices. It then combines spectral analysis with intervention analysis (Enders, 2004) to determine the impact of the appreciation of the Canadian dollar relative to the U.S. dollar, and feed price escalation on these variables. From the analyses, the study is able to conclude that total cattle inventories, beef cow inventories and beef supply are characterized by ten-year cycles, while beef prices exhibit, rather surprisingly, an eight-year cycle. In addition, seasonal three-month and annual cycles are found in beef supply and prices, respectively. Regarding the effect of shocks on cycles, the study finds evidence that the exchange rate shock of 2002 caused a 58% reduction in the peak amplitude (fluctuation) of the ten-year beef supply cycle.

The findings have implications for farm business management by individual producers as well as policy implications for the whole industry. The cattle cycle is the result of the sum of the profit-maximizing actions of individual cow-calf producers, that is, the cattle cycle is driven by the profitability of cow-calf producers. Therefore knowledge of the cattle cycle is important to especially prospective and newly established cow-calf producers in timing their production decisions. Also, the existence of the cattle cycle implies that producers need to be flexible in managing their operations to ensure they survive periods of low or no profitability during a cycle downturn.

The beef cattle industry is relatively complicated, but the existence of cycles – a long-term phenomenon that involves all market levels – provides researchers and policy makers an opportunity to better understand the effects of market shocks on the industry. The finding that exchange rate appreciation, which in most of the literature is considered to be a negative shock, is associated with a reduction in the long-term fluctuations in beef supply is informative. This result is evidence that shocks may change the cattle cycle, which means that policy interventions may be used to help the industry quickly come out of the bottom of the cycle.

The reduction in variability of beef supply may have been caused by the industry's gradual adjustment to a higher Canadian dollar, and/or productivity gains from lower costs of imported inputs. There is need to develop and empirically test a theoretical model that explains the mechanism through which exchange rate appreciation impacts the cattle cycle in the context of the entire beef supply chain.

Besides exchange rate appreciation, it is likely that COOL has had or will have a substantially large, if not larger impact on the Canadian cattle cycle. In future research, the impact of COOL on the cycle could be established by determining the margin between Canadian and U.S. steer prices due to COOL, and incorporating the margin as an exogenous variable in an ARMAX model of beef supply.

The first and second studies have been sector-level studies of the beef cattle industry. But the third study is a farm-level analysis of the value of the loan guarantee provided to cattle feeders by the Alberta provincial government. The study combines enterprise budgeting with risk analysis to determine the risk that commercial banks and other lenders would face by lending to a typical cattle feeding operation in Alberta, the value of the loan guarantee provided to cattle feeders through the FALGP, and the subsidy embodied within the FALGP. A cash flow Monte Carlo model underpins the estimation of cash flows that account for production and price risk in a backgrounding to finishing feeding operation, and option pricing models (Black and Scholes, 1973; Cox *et al*., 1979) provide the conceptual and empirical framework for valuing the loan guarantee.

This study finds that feeding cattle is, indeed, a risky venture as has been established by other studies, and the resulting risk exposure to lenders is significant. This is especially true for backgrounding. Also, the study finds that the price of a loan guarantee that covers 15% of the total loan amount available to a Feeder Association is likely to be 4% to 5% of the loan amount and this should offset the subsidy inherent in the guarantee.

These results may help generate a debate among policy makers regarding potential alternatives to ensuring access to credit by cattle feeders. These alternatives may include direct government loans, or charging a guarantee fee, or government completely divesting itself from the program. But in a related study, some program lenders have indicated that no other program would probably afford them the same level of security to be able to provide credit to cattle feeders at the prevailing interest rates (Rude *et al.*, 2013). Although the results of this study wouldn't be sufficient to gauge the feasibility of alternatives to the program, they lend support to the continuation of the FALGP in its current form. As earlier indicated, the program has been in existence for over seven decades, and appears to be beneficial to the industry as it finances 17-24% of the total calf crop annually. Moreover, in spite of the relatively high level of risk involved in cattle feeding, the default rate observed in the program has been low, and the resulting risk premium for the guarantee compares to the relatively low security deposit required of cattle feeders to access financing. In addition, the interest rate subsidy provided by the program is low, and the maximum liability of $55 million per annum in relation to the average annual payouts does not point to a large financial constraint on the part of the government.

A comprehensive evaluation of the FALGP would have to go beyond estimating a premium for the loan guarantee, to undertaking a benefit-cost analysis of the guarantee along the supply chain, and determining the implications for the whole of the Alberta and Canadian beef cattle industry. This study provides information on the value of a single steer, and an estimate of the premium that a cattle feeder would have to pay to the government for a guarantee on a loan to purchase the steer. The cash flow and option pricing models used may be expanded to form the basis of future studies.

This study, however, is not without limitations. The first limitation is that it has been undertaken at a micro level with a single animal being fed in a representative background to finish feeding operation. This means that the results obtained are based on noncumulative cash flows. It would be helpful to extend the analysis to a typical background to finish operation with more than one animal so as to base the analysis on cumulative cash flows. The second limitation is that the feeding periods for both backgrounding and finishing have each been fixed to six-month horizons. In reality, this is not usually the case; the duration of backgrounding and finishing depends on market conditions and the breed of the animal, and it has implications for risk analysis. Therefore, it might be informative to model cash flows based on varying time horizons.

An evaluation of the FALGP could benefit from, among other things, knowing the effect the program (including the associated interest subsidy) has had on the competitiveness of Alberta's entire beef supply chain. This would involve determining the extent to which the program has increased access to credit by examining the counterfactual – the behavior of lenders in the absence of the program, and the likely effects of that behavior. Also, in light of the results obtained from this study, if cow-calf operators and cattle feeders were to pay the estimated guarantee price, what effect would that have on access to financing, overall administration and operation of the program, and competitiveness of the beef supply chain? These questions could form the basis of further research.

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