“The strength of agricultural economics rests on its capacity to combine theory, quantitative methods, and data to do useful analyses of problems faced by society.”

-William G. Tomek (1993, pg. 6)

University of Alberta

Agriculture in Crisis: Policy Analysis and Cow-calf Producer Behaviour in the Aftermath of the Canadian BSE Events

by

Brandon Nicholas Schaufele

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Examining Committee

James Unterschultz, Rural Economy

Tomas Nilsson, Rural Economy

Wiktor Adamowicz, Rural Economy

Scott Jeffrey, Rural Economy

Andrew Leech, School of Business

Richard Gray, Bioresource Policy, Business and Economics, University of Saskatchewan

For Meg.

Abstract

The bovine spongiform encephalopathy (BSE) crisis was a significant shock to the Canadian agricultural sector. On May 20, 2003, it was announced that an animal infected with BSE had been identified. The economic aftermath of this discovery was described as “horrendous” (AGO, 2004).

Economic crises, such as the Canadian BSE agricultural crisis, are rare events. The rarity of these episodes supplies a unique opportunity for analysis. According to a policy review by the Alberta Auditor General (AGO, 2004), the agricultural economics discipline appeared to be of little assistance in the crisis policy design process. This research addresses this problem by exploring economic theory and policy via detailed empirical investigation. Specifically, this study evaluates agricultural support policies and producer risk preferences in the aftermath of the Canadian BSE crisis.

Three research chapters address questions related to cow-calf producer behaviour and government policy. Chapter 2 focuses on designing emergency aid programs and calculating short-run quantitative benchmarks for crisis relief at the farm-level. Chapter 3 estimates observed risk preferences for a sample of Albertan cow-calf producers. Differential risk preferences help to explain diverse production responses following agricultural crises. The final research chapter, chapter 4, examines Canada’s primary risk management program when there is potential for catastrophic price risk. In particular, vertical and horizontal equity criteria are used to scrutinize the distribution of net AgriStability benefits across a heterogeneous sample of cow-calf producers.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Economic crises, such as the Canadian bovine spongiform encephalopathy (BSE) agricultural crisis, are rare events. The rarity of these events supplies a unique opportunity for analysis. This research unifies economic theory with detailed empirical investigation to evaluate agricultural support policies and producer risk preferences in the aftermath of the Canadian BSE crisis. This research asks questions about agricultural crises and seeks durable insights into cow-calf producer behaviour and Canadian agricultural policy. Ultimately, this research aims to provide “useful analyses of problems faced by society” (Tomek, 1993, pg. 6).

Three research papers address questions related to producer behaviour and government policy following the Canadian BSE or mad-cow crisis. The BSE crisis was a significant shock to the Canadian agricultural sector. On May 20, 2003, it was announced that an animal infected with BSE had been identified.[1] Immediately, 34 countries closed their borders to Canadian exports of live cattle and beef (LeRoy and Klein, 2003). Producers experienced uncertain market conditions, as consumers faced an unfamiliar food safety situation (Veeman and Li, 2007). Carlberg and Brewin (2005) estimate the resultant losses from the crisis at $5.5 billion, while LeRoy et al. (2006) suggest a value of $4.1 billion. The overall impacts of BSE have been described as “horrendous” (AGO, 2004).

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[1] The initial animal to test positive for BSE was a six-year old downer cow, discovered near Wanham, Alberta (AGO, 2004). There have been eleven subsequent BSE discoveries (CFIA, 2008).

This chapter provides a brief introduction to the three research papers. A general definition of agricultural crises, as it applies to the Canadian BSE discovery, is reviewed. The main objectives of this research are then emphasized. Finally, each chapter is briefly introduced.

1.2 THE CANADIAN BSE CRISIS

Definitions of economic crises or catastrophes are often broad and ambiguous. For example, Duncan and Myers (2000, pg. 842) state: "a catastrophe can be defined as an infrequent event that has undesirable outcomes for a sizeable subset of the . . . population." Similarly, Schlesinger (1999, pg. 95) claims that: "Catastrophes are generally considered to be extreme events. They are often the substance of the long tails we find in many loss distributions." Bessant (2007, pg. 444, *emphasis in original*) states: "The term *crisis* is used relatively indiscriminately within various communities . . . making it difficult to establish how or when circumstances warrant its application." A stylized but likely true description of economic crises is that they are rare and have uncertain outcomes.

It is generally agreed that the discovery of an animal infected with BSE precipitated a farm financial crisis in Canada (Leroy et al., 2006; Carlberg and Brewin, 2005; AGO, 2004). For the purposes of this research, it is useful to be more precise in characterizing the general criteria associated with this economic event. With respect to the Canadian BSE crisis, there are four points to note:

1. Prices *instantaneously* and dramatically dropped;

2. Sectoral structural change occurred, with international implications (Bessant, 2007);
3. No direct precedent existed for the event (i.e., no insurance contracts were available to guard against potential losses); and,
4. Government policy response was viewed as needed to assist the sector (Brass, 1986).

These criteria are not exhaustive, but they provide an outline of the conditions in the cattle sector following the Canadian BSE crisis. Of note, environmental or animal health conditions are not included as a prerequisite for the crisis. Many livestock shocks are related to animal disease. However, while it may presage an adverse event, animal health was not a key driver of the BSE crisis (Fox and Peterson, 2004).

Some clarity is required on these primary characteristics of the BSE crisis as the topic of investigation. The Canadian BSE crisis began on May 20, 2003 with the announcement that an infected cow had been identified. Upon the discovery of a BSE-infected cow, prices declined dramatically (Canfax, 2003). International borders closed immediately (LeRoy and Klein, 2003). No direct precedent for BSE existed in Canada and producers had no explicit means of insuring against their resulting financial losses. Policy-makers reacted quickly as emergency financial aid was seen as necessary (AGO, 2004). The Albertan government implemented nine programs as a response to the discovery of an infected animal (AGO, 2004).

One infected cow triggered a crisis. This research investigates government policy and producer behaviour following the Canadian BSE crisis. The BSE crisis offers a unique perspective into agricultural crises. Additional background information is found in the three research papers.

1.3 ECONOMIC PROBLEM AND RESEARCH OBJECTIVES

The Alberta Auditor General's (AGO, 2004) review of the BSE policies noted that many theory-policy links were unknown prior to the crisis. That is, the theory developed by the agricultural economics discipline appeared to be of little assistance in the crisis policy design process. In general, agricultural economics has allocated minimal attention to understanding the quantitative impact of crises and their associated emergency relief policies. Using the Canadian BSE crisis as a case study, the economic problem addressed by this research is the lack of connection of theory to policy during periods of agricultural crisis. The specific objective is to use empirical methods to reconcile the details of the BSE events with both the predictions of economic theory and the policy responses that accompanied the crisis. Major disruptions such as the BSE outbreak are difficult for policy-makers, so shedding light on the intermediary relationships and the links between theory and reality is important.

This research presents three primary contributions to the literature. First, several models assessing producer behaviour following the BSE crisis are presented. These models examine different statistical hypotheses with respect to farmers' responses to crisis and price risk. Next, several empirical studies are completed using unique micro-datasets. Detailed firm-level results are obtained. Crises are rare events, so it is an uncommon opportunity to examine firm behaviour during adverse periods. Finally, government policy during atypical periods is investigated in depth. Minimal research has been completed on several policies including Canada's primary agricultural risk management program, AgriStability. In the aftermath of the BSE crisis, Canadian agriculture has changed. The three research chapters improve understanding of economic behaviour and policy before and after – i.e., *ex ante* (chapter 4) and *ex post* (chapers 2 and 3) – periods of agricultural crises. Consider in its entirety, this research focuses on one chief objective: to improve understanding of the economics of agriculture during periods of crisis.

1.4 SUMMARIES OF THE THREE RESEARCH CHAPTERS

Each research chapter focuses on a major theme of the Canadian BSE experience. Chapter 2 examines the implications of crisis-induced short-run technical change on the policy design process. Chapters 3 and 4 concentrate on the impact of crisis for a heterogeneous sample of firms in terms of: i) differential risk aversion levels; and, ii) treatment under Canada's primary risk management program, AgriStability. In particular, the first paper, Chapter 2, is on designing emergency aid programs and calculating short-run quantitative benchmarks for crisis relief at the farm-level. Chapter 3 estimates observed risk preferences for a sample of Albertan cow-calf producers. Differential risk preferences may explain diverse production responses following agricultural crises. The final chapter explores Canada's primary risk management program when there is potential for catastrophic price risk. Specifically, vertical and horizontal equity criteria are used to scrutinize the distribution of net AgriStability benefits across a heterogeneous sample of cow-calf producers. The main ideas of each paper are summarized next.

Paper 1: Quantifying policy targets for crisis relief programs in agriculture

Colloquially, the research in Chapter 2 is best characterized as investigating “dirty policy, done right.” The Alberta Auditor General’s (AGO) foremost criticism of the Albertan Government’s response to the BSE crisis was that the Department of Agriculture and Rural Development did not have quantitative benchmarks for their emergency relief programs (AGO, 2004). To ensure the cattle sector’s viability, policy-makers were forced to provide short-term support to primary producers. Designing emergency aid programs is challenging, however. In crisis situations there is seldom sufficient time to wait and measure final impacts. Some short-run policy is required immediately – i.e., emergency relief policy may be called “dirty policy” in that, due to time constraints, it is likely imperfect. However, while designing crisis-relief programs is difficult, economic theory does not need to be ignored. In other words, emergency relief policy can still be “done right” in the sense that the aid accounts for optimal producer behaviour.

This research provides two tools that are useful in designing crisis relief programs in agriculture. First, a conceptual policy design framework is introduced. This framework allows policy-makers to interpret the impact of a crisis at the farm-level as short-run technical change. Next, a flexible empirical framework is presented. This framework is based on generalized maximum entropy methods, a technique that permits consistent parameter estimation even when data are limited. These frameworks are then applied to western Canadian cow-calf producers’ experience with severe drought conditions in 2001 and 2002 and the bovine spongiform encephalopathy (BSE) induced farm financial crisis which began in May 2003.

Paper 2: Does experience breed confidence? Production decisions with price uncertainty and BSE

This chapter analyzes output price risk and risk aversion for a sample of Albertan cow-calf producers within a dual expected utility production model. It extends an empirical methodology introduced by Coyle (1992, 1999). Few empirical applications of this approach are found in the agricultural economics literature and none examine agricultural crises. This chapter's contribution is primarily empirical. A detailed farm-level dataset is used to estimate a series of models. Two demographic conditioning procedures are introduced to the production economics literature. Analogues to demographic scaling and translating in the consumer demand literature (Pollak and Wales, 1992), these conditioning methods enable the measurement of differential risk preferences across a sample of producers.

Paper 3: AgriStability in the aftermath of the BSE crisis: Equity implications for cow-calf producers

This paper examines the consequences of the AgriStability program for Albertan cow-calf producers when there is potential for catastrophic price risk. Two chief hypotheses are investigated. First, it is hypothesized that the AgriStability program produces an equitable distribution of benefits and costs for Albertan cow-calf producers. To state this more precisely, heterogeneous cow-calf firms are treated equitably within the structure of Canada's primary risk management program. The second hypothesis is that increased catastrophic price risk does not influence the equality of the distribution of program benefits – i.e., the relative treatment of heterogeneous producers, under

AgriStability, does not change following a catastrophic price decline. The normative economic notions of horizontal and vertical equity are used to evaluate program outcomes for cow-calf producers in the aftermath of the BSE crisis.

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CHAPTER 2: QUANTIFYING POLICY TARGETS FOR CRISIS RELIEF PROGRAMS IN AGRICULTURE

2.1 INTRODUCTION

Agricultural crises have significant impacts on the well-being of primary producers, secondary services and rural communities (Barnett, 1999). To ensure a sector's viability, crises often force policy-makers to provide short-term support to primary producers. Designing emergency aid programs is challenging, however – in crisis situations there is seldom sufficient time to wait and measure final impacts. Policy frameworks are needed to understand and address the repercussions of these short-run events. This research provides a conceptual framework for evaluating the impact of a crisis at the farm level. It then applies this framework to western Canadian cow-calf producers' experience with severe drought conditions in 2001 and 2002 and the bovine spongiform encephalopathy (BSE) induced farm financial crisis which began in May 2003.

Greater proportions of farm support are coming from sources characterized as emergency or disaster funds (Smith, 2004). Yet, the agricultural economics literature has provided little guidance on how to design short-run relief policies or how to develop quantifiable targets for temporary aid. Emergency financial aid programs should be efficient, consistent and equitable (Barnett, 1999). However, in order to achieve these goals, a consistent policy framework is required. This framework should: i) provide an *ex ante* platform for policy-makers to forecast the short-run effects of the crisis; ii) adhere to an existing and well-established economic methodology; and, iii) permit *ex post* empirical evaluation of the crisis' impacts on producer behaviour.

Chapter 1 discussed four elements of the BSE crisis. These included: i) dramatic price change, ii) structural change, iii) a lack of insurance and iv) necessity of government policy. This chapter concentrates on how the effects of i) and ii) at the farm-level influence emergency government policy, iv).

The fact that BSE changed prices is well-established. The effects of structural change are less clear. At the farm-level, structural change can be interpreted as short-run technical change. Anecdotal evidence indicates that both price and short-run technical change impacted producers. For example, newspaper stories reported farmers "having to sell because they ran out of feed" but that "feedlots [were] not interested in buying" (Duckworth, 2003, pg.1) and, even though cull cows had a positive price, the Canadian BSE crisis temporarily altered market conditions making it difficult for many producers to sell these animals *at any price* (Le Roy and Klein, 2003). Whether short-run technical change is relevant from an economic or policy perspective becomes an empirical question. Still, policy-makers should have a *quantitative* appreciation of both effects – i.e., price and short-run technical change – when devising emergency aid programs.

Western Canadian cow-calf producers experienced substantial instability in recent years. Large changes in output and input price ratios were combined with short-run technical change due to drought and BSE. To mitigate negative effects of these events, Canadian governments provided financial support to cow-calf producers as well as producers in other cattle sectors. These crisis support programs were designed to alleviate an acute, but temporary situation. Long-run stability was expected to return to the sector[2] and the primary policy goal was to keep cow-calf producers operating in the short-run.

Drought and BSE provide an opportunity to analyze short-run cow-calf producers' responses to crisis. Few attempts have been made to estimate disaggregated, short-run cow-calf output supply and input demand functions. Horbulyk (1990) examined farm-level behaviour for western Canadian cattle producers. It found that the majority of demand and supply responses are elastic with respect to within-year price changes. For example, he determined that, *in the short-run*, the own-price elasticity of cattle supply is 1.998. At a more aggregated level, Quagrainie (2000) estimated the long-run own-price elasticity of Albertan cattle production to be 0.123 and the cross-elasticity on cattle inventory to be 0.658.

These results indicate that there is a lack of consensus on these elasticities, thus increasing the challenge to establish a basis for quantifiable targets for future emergency aid programs. The paucity of estimates could be due to the short-run nature of the problem. Research on the short-run behaviour of cow-calf producers is often constrained by statistical limitations. Traditional statistical analysis of short-run models is challenging due to limited numbers of observations and many parameters. New empirical methods such as generalized maximum entropy (GME) can efficiently and consistently estimate a model using limited data.

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[2] The Alberta Auditor General report on the efficacy of the BSE programs states that in designing these programs "discussions focused on short-term solutions as they expected the border to re-open within weeks, or at worst a few months" (AGO, 2004, pg. 56).

This study uses farm-level data to estimate a set of short-run input demand and output supply relationships for Albertan cow-calf producers. Own- and cross-price elasticities of demand and Morishima input substitution elasticities are calculated. Ideally, short-run financial aid programs should recognize that short-run market prices may not fully capture all market changes – short-run technical change may also influence producer behaviour. Share biases of output supplies and factor demands capture the non-price response to two "crisis events." These short-run behavioural responses can be used to develop quantifiable measures for emergency aid programs and measure the impact of potential non-price influences.

The next section presents a conceptual framework for emergency aid programs. Revenue support is discussed in the context of two policy options, direct cash payments and price supports. Section 2.3 presents the empirical methodology. Section 2.4 contains the empirical results. Section 2.5 outlines how to calculate policy targets for crisis relief programs, using the drought and BSE crises as examples. Section 2.6 provides conclusions.

2.2 DESIGNING EMERGENCY REVENUE SUPPORT PROGRAMS

2.2.1 Short-run Technical Change

Chapter 1 identified the economic problem for this research. There is a gap between economic theory, empirical application and policy during times of crisis. Insufficient attention has been allocated to adapting current theoretical and empirical frameworks to make them useful for addressing problems such as the BSE experience.

This chapter uses the technical change literature as a framework to measure and interpret the events following a crisis.

Techniques used to assess technical change are normally applied to long run resource utilization patterns, so the logic of this paper is based on the theory described in Antle and Crissman (1988). They demonstrate that the technical change methodology can also be applied to "pattern[s] of technological change and resource utilization … in the short run" (Antle and Crissman, 1988, pg. 669). Technical change in the short-run can be brought on by a variety of factors, for example "differences in perceptions of transitory and permanent changes in resource scarcity" (Antle and Crissman, 1988, pgs. 669-670) such those that occur during multi-year droughts. Similarly, the BSE crisis may have altered production technology in the short-run as producers respond differently to transitory events compared to those that are perceived as permanent. Short-run technical change is "likely to occur when relative price deviate from their long-run trends" (Antle and Crissman, 1988, pg. 672). The reason is that producers may devote more entrepreneurial effort to seeking out cost-savings or output improving technologies during these periods. Yet, while it is impossible to directly observe or measure entrepreneurial effort, this theory does have implications for the patterns of technological change, policy and resource utilization that can be observed (Antle and Crissman, 1988) (see section 2.5.3 for additional discussion on perceptions). The observable features are embodied in short-run changes in production technology.

Several comments on this interpretation are required however. While the benefit of the technical change approach is that it is familiar and oft-used in the agricultural economics literature, it is nothing more than a tool of measurement. In fact, the “approach is sometimes disparaged as being more a measure of our ignorance than anything else” (Chambers, 1988, pg. 204). In the technical change literature, a time to index measures shifts in “technology” or the production possibility set: “Econometric necessity ... led to the wide-spread identification of technical change with a ‘time’ term in the production function” (Chambers, 1988, pg. 204). Still, two points must be emphasized. First, this time index could be a proxy for other unobservable changes. Technical change is the conventional interpretation of this time index in the production economics literature. Therefore, short-run technical change should not be distinguished from any other form of technical change. Second, whether a shift actually occurs is purely an empirical question. Theory does not provide any *a priori* guidance on this – only the data can indicate whether technology has changed.

Interpreting fluctuations in output as driven by technology factors is common in a wide range of economic models. Real business cycle theory, in macroeconomics, emphasizes the role of exogenous “technological shocks” (Kydland and Prescott, 1982). These models embody the same behaviourial postulates as production economics, namely optimization of an objective function. The premise behind real business cycle theory is that some exogenous shock affects technology which then alters the optimal allocation of the factors of production (Romer, 2001).

Still, it is useful to consider the theory of production sets and how the regularity conditions apply to agricultural production during times of crisis. Mas-Colell et al. (1995) present an exhaustive list of properties of the production set (see pgs. 130-132). Two properties are relevant to the BSE discussion: possibility of inaction and free disposal. Possibility of inaction means that “complete shutdown is possible” (Mas-Colell, 1995, pg. 130). In their discussion, Mas-Colell et al. (1995) distinguish between an intra-period PPC, or restricted PPC, and an inter-period PPC. They then state that “if some production decisions have already been made, or if irrevocable contracts for the delivery of some inputs have been signed, inaction is not possible” (pg.131). This implies that an intra-period shock such as the BSE crisis can change the producers’ decision problem – i.e., the original production set may differ from the restricted production set (for an example see Figure 5.B.3 in Mas-Colell et al., 1995, pg. 131). In Canada, it is not possible to stop production of a cow herd without facing animal welfare complaints. So a crisis such as BSE demonstrates that cattle production technology violates the possibility of inaction. This intra-period shock changes the producer’s decision problem, forcing the producer to consider two production sets. Empirically, this shift from original to restricted production set can be measured as short-run technical change. More importantly, thinking about original and restricted production sets is useful for designing crisis relief policy. Policy-makers can think of an interim “crisis technology” as well as a “normal technology”.

The free disposal property may create similar problems for cow-calf production. Due to the crisis a previously desirable output became an undesirable output. For example, if transaction (sale) prices are below transportation costs, cull cows become an undesirable output of the production process similar to pollution (Coggins and Swinton, 1996). It costs more to keep these animals alive than they are worth. In this case, cull cows would have a negative shadow price (a price of zero is a lower bound for outputs) and the PPC would be drawn as backward bending in particular sections. Undesirable outputs can affect technology by creating congestion problems, thus providing an incentive for producers to seek and adopt alternative modes of production. This, in turn, causes short-run technical change. Of course, the key point to remember is that regardless of cause – impossibility of inaction, costly disposal of outputs or some other reason – short-run technical change is fundamentally an empirical issue.

Interpreting changes in economic behaviour changes as short-run technical change is empirically convenient and intuitive for policy. However, alternative explanations may produce similar conclusions. Notably, there is the potential for misspecification of the empirical model. Most producers have both cow-calf and crop enterprises. Producers allocate scarce resources to both of these operations. Changes in cross-enterprise allocations may explain the results found in this chapter. In other words, misspecification of the empirical model could lead to erroneous interpretations of short-run technical change when in reality shifts were due to price-based allocations. Unfortunately, the data do not permit investigation of this hypothesis. As such, interpreting behaviour changes as short-run technical change is viewed as the best approach for both empirical tractability and crisis policy-making.

2.2.2 Theoretical Framework: Prices and Short-run Technical Change

It is increasingly common for policy-makers to support producers following adverse events (Smith, 2004; Barnett, 1999). Agricultural economic crises, typically associated with animal and plant disease, are unexpected phenomena which force policy-makers and primary producers to react to sudden changes in the market. Often only a brief period of time exists from the initial crisis until the point when producers need crisis relief. Consequently, it is important to have an understanding of the basic mechanics of emergency revenue support programs.

Emergency agricultural aid is defined as any program which: a) is a direct result of an adverse event; b) provides financial assistance to affected producers – e.g., offers direct cash payments or supports prices; c) is non-permanent; and d) is designed within a limited timeframe for a particular policy target. This section discusses a situation where revenue support is offered. The same framework could be applied to inputs and costs or to post-crisis stabilization policies. In the empirical and results sections (sections 2.3 and 2.4), both profit and revenue functions are discussed and estimated. Results from each are used in the examples reviewed in section 2.6. The profit function generates a set of predictions which are useful in designing future policy. The revenue function is employed in the *ex post* example policy target calculations for the Albertan cow-calf producers experiences with drought and BSE.

A producer's revenue is calculated as:

$$R = \sum_i p_i y_i^* \tag{2.1}$$

where R is revenue, p_i is the price of output i and y_i^* is the profit-maximizing supply of output i. Denote R_i as the revenue produced by output i – i.e., $R_i = p_i y_i^*$. Prices are determined by the market (i.e., producers are price takers), while output levels are chosen by producers. When examining post-crisis economic scenarios, policy-makers must recognize that profit-maximizing producers react to market signals. Producers optimally choose output levels, ensuring that the ratio of output prices equals the ratio of marginal output production (i.e., marginal physical product).

Assume that the crisis is considered a short-run event and that it is expected that in the long-run a reference level of revenue will be restored. Crisis events generally have two repercussions for producers. First, market prices change, with output prices tending to decline significantly. Second, short-run technical change, a phenomena that is not captured by prices, may occur. This technical change yields changes in output supplies. Let **(2.1)** be called the reference revenue level. Following a crisis producer revenue becomes (for the remainder of the section, subscripts are suppressed except where interpretation is unclear):

(2.2)
$$\begin{aligned} R + \Delta R &= \sum (p + \Delta p)(y^* + \Delta y^*) \\ &= \sum (py^* + \Delta py^* + p\Delta y^* + \Delta p\Delta y^*) \end{aligned}$$

where Δ represents some change (likely negative) in the variable which it precedes. Policy-makers are primarily interested in the *change in revenue* following an adverse event. Subtracting **(2.1)**, the reference revenue level, from **(2.2)** gives the change in revenue that is attributable to the crisis:

(2.3)
$$\Delta R = \sum (\Delta py^* + p\Delta y^* + \Delta p\Delta y^*).$$

There are three terms on the right-hand side of **(2.3)**. The first term indicates the change in R if y^* remains constant. It is the pure price effect of the crisis. The second term shows output decisions may change if prices remained constant but other factors influenced the market – i.e., the short-run technical change effect. The final term is the confounding effect of prices and technology.[3] Policy-makers must be cognizant of how both prices and short-run technical change affect producer decisions and, ultimately, the effectiveness and consistency of their policies.

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[3] As the changes associated with a crisis are discrete and non-marginal, the third term, $\Delta p\Delta y^*$, cannot be assumed away (i.e., while it is second-order, it may still be relevant).

Suppose the goal of emergency revenue support is to meet some pre-selected target for ΔR, farm revenue change. This target is a normative decision. There is no recipe for selecting any particular policy target, yet it is conceptually possible to understand i) how to attain this target and ii) the implications for optimal producer behaviour. For simplicity assume policy-makers target revenue-neutrality – i.e., $\Delta R=0$. Two policy options are examined: direct cash payments and price supports. Revenue support may not be the only goal of policy-makers following a crisis event: cost control or market stability may be of interest. With minor alterations, this general framework applies in these situations.

2.2.2 Policy option 1 – Direct cash payments

The most straightforward method of providing revenue support following a crisis is to make direct cash payments to affected producers. Policy-makers would pay each producer an amount equal to ΔR (revenue neutrality). This approach has several benefits: it is the easiest to understand and, *ex post*, it may be easy to calculate.

There are several challenges with this option however. If payments are urgently required to mitigate the crisis' effects – i.e., cash is provided prior to the final calculation of ΔR – policy-makers will likely over- or under-pay, implying that the target will be missed. Political conditions often make it unpalatable to provide direct cash payments to producers. Thus, there may be an unwillingness to pursue this route. Direct cash relief payments may be legally untenable also. In some instances, they contravene World Trade Organization regulations (AGO, 2004).[4]

As well, simply paying producers ignores the economic principles of the market. Producers will respond to market signals and any direct payment scheme which does not obligate farmers to enter the market may generate moral hazard. It is more difficult to predict how direct cash payments will affect producer decisions than it is with price support programs. Finally, the distribution of payments to differently sized farms and secondary operations may introduce another complication. Should all producers receive full compensation for the crisis? There is a greater chance that these questions will arise under this policy scenario versus when the market is a key component of the policy solution.

2.2.3 Policy option 2 – Price supports

Canadian policy-makers, in response to the BSE crisis, chose a market differential program as their primary source of emergency aid, as it complied with World Trade Organization restrictions (AGO, 2004). The market differential program compensated producers for output price fluctuations – i.e., it was a price support program. The government paid a portion of the difference between the price producers received upon the sale of their animals and the price they would have received had the market not been disrupted (AGO, 2004). The goals of this program were to stabilize markets and provide assistance until the crisis abated. The AGO (2004) review of the governments' responses

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[4] Direct cash payments mimic lump-sum transfers; however, they are not first-best policy options. Transaction costs, *ex ante* uncertainty and political constraints along with potential problems preventing out-transfers of funds mean that the direct cash payments option is ultimately a second-best policy.

claimed that the market differential program was successful. However, it was noted in the review that there were no quantitative benchmarks with which to evaluate success or failure.

Price supports provide incentives for producers to behave rationally when they enter the market. Profit-maximizing producers will adjust their behaviour to both price changes and any potential short-run technical change which may arise due to the crisis. Policy-makers face a challenge when developing quantitative policy targets if non-price technology effects accompany a crisis' price changes. From the producers' perspective, a new "state of technology" (Chambers, 1988) alters their optimal output ratios – i.e., one output is affected to a greater degree than another. In general, positive technical change shifts the production possibilities curves (PPC) outward (see Figure 2.1). However, following a crisis, it is possible that the PPC shifted inward as well as rotate slightly, comparatively favouring one output. The precise size and direction of a change is an empirical question. Yet, when designing emergency price support programs, policy-makers should consider both post-crisis effects: price changes and short-run technical change. Overlooking either may lead to missed policy targets and unintended market equilibria.

Figure 2.1 provides an illustration of the impact of a crisis on a producer in output space. A similar description applies on the input side of production. Let BB denote an initial PPC. The isorevenue line, P_1, is tangent to BB at point E_1. Suppose that a crisis occurs in this market. This event has two repercussions. First, prices decrease. Next, consider what happens when short-run technical change occurs. The crisis will cause the

PPC to shift inward. It may also alter its shape – i.e., rotate the PPC. The crisis alters both the prices received from selling animals and the ability of producers to sell and produce outputs. For example, the BSE crisis decreased the prices for all animals. Many producers also found that, *even after accounting for the price drop*, it was more difficult to sell cull cows than calves at any price – i.e., shifting the PPC inward. This implies that the production of one output, cull cows, was affected more than another, calves – i.e., the BSE crisis altered the shape of the PPC, leading to a greater inward shift for the cull cow output than for the calves output. In Figure 2.1, the post-event PPC is shown by curve DD, where the shift in y_1 is greater than y_2.

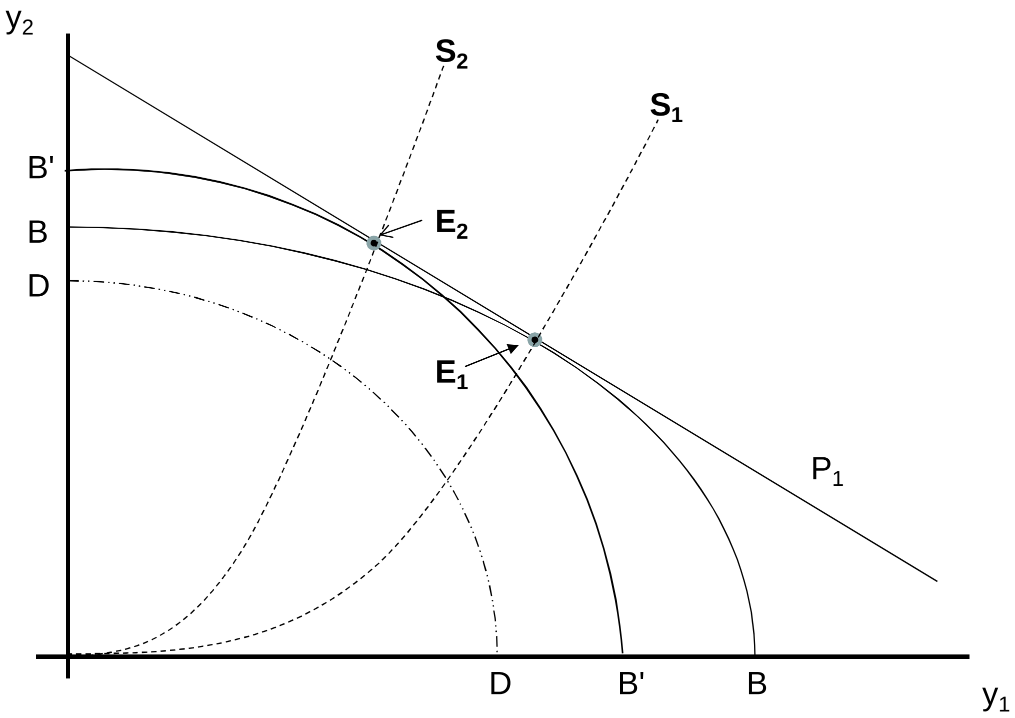

Figure 2.1: Short-run Technical Change with Rotation of Production Possibilities Curve

The market differential program is designed to reduce the revenue lost due to a crisis. Assume that the policy target is revenue-neutrality. The crisis has affected outputs

y_1 and y_2 in different proportions. This implies that a price support program which maintains constant relative prices is not share neutral due to the short-run technical change. Understanding that there has been a change in optimal production mix is important when establishing quantifiable program targets – i.e., a price support program may be revenue neutral while not being share neutral. Paths S_1 and S_2 represent the expansion paths for the initial and post-crisis PPCs respectively. Share bias due to short-run technical change is measured by the temporary shift of this expansion path that is attributable to the crisis at points E_1 and E_2.

Measurement of the magnitude of the bias can only be completed after the crisis. However understanding that some shift has occurred is vital for hitting policy targets and historical events provide guidance for program projections. The method for calculating targets is discussed in section 2.5. In the following sections, empirical results are estimated and discussed for two examples of events that constitute crises; one that primarily affected inputs (drought) and another that chiefly impacted outputs (BSE).

2.3 EMPIRICAL FRAMEWORK

The conceptual policy framework requires an empirical framework to estimate the effects of price and short-run technical change. Two empirical models are presented. First, a restricted profit function is discussed. Second, the revenue function is presented. Both models are estimated to provide baseline elasticities along with estimates of share biases, which may be useful in the event that future emergency relief programs are needed. Parameters from these models are used in the example calculations described in section 2.5.

2.3.1 Restricted Profit Function

Assume that the farms, cow-calf producers in this paper, exhibit profit maximizing behaviour. Lau (1976) defines a short-run, restricted profit function as the difference between total revenue and total variable costs. Letting π^* represent maximum restricted profit of a multi-output, multi-input cow-calf enterprise, the dual profit function is given by:

(2.4) $$\pi^* = \pi(\mathbf{p}, \mathbf{w}, \mathbf{c})$$

where **p** is a vector of output prices, **w** is a vector of input prices and **c** are exogenous crisis events. The profit function permits output to vary endogenously with factor and output prices. Linear homogeneity is imposed via the normalization of output and input prices. The second-order partial derivatives are restricted to ensure symmetry. Curvature and monotonicity can be empirically checked. Output supply and input demand equations are determined using Hotelling's lemma:

(2.5) $$y_j^* = \partial\pi^* \big/ \partial p_j$$

(2.6) $$-x_i^* = \partial\pi^* \big/ \partial w_i$$

where y_j^* is the optimal quantity produced of output *j* and x_i^* is the optimal quantity demanded of input *i*. Revenue and cost share of profit equations, derived from the profit function, can then be defined over prices and crisis events:

(2.7) $$\begin{aligned} S_j &= S(\mathbf{p}, \mathbf{w}, \mathbf{c}) \\ S_i &= S(\mathbf{p}, \mathbf{w}, \mathbf{c}) \end{aligned}$$

where S_j is output *j*'s revenue share of profit and S_i is input *i*'s variable cost share of profit.

2.3.2 Revenue Function

A dual revenue function represents the maximum value that can be produced by a given input endowment (Chambers, 1988). A revenue function corresponds to a scenario where a producer has committed her inputs to production in a given year, but has not yet determined the mix of outputs. This set-up is particularly useful when discussing livestock producers' experiences with drought and BSE – these crises occurred once most input decisions had been made. Producers were constrained to altering their output mix for a given input bundle – i.e., when the crisis materialized, producers could not reduce their input costs. In some senses, "revenue maximization [is] . . . a true economic problem" (Chambers, 1988, pg. 262).

Let R^* represent maximum revenue of a multi-output cow-calf operation. The dual revenue function is then given by:

(2.8) $$R^* = R(\mathbf{p}, \mathbf{x}, \mathbf{c})$$

where **p** is a vector of output prices, **x** is a vector of fixed inputs and **c** are exogenous crisis events. In the revenue function formulation, output supplies endogenously vary with output prices only. Symmetry restrictions are imposed during estimation. Curvature and monotonicity can be empirically checked. An analogue to Hotelling's lemma for the profit function is the Samuelson-McFadden lemma (Chambers, 1988):

(2.9) $$y_j^* = \partial R^* \big/ \partial p_j$$

which gives a revenue maximizing output supply, y_j^*, for a given input vector. Similar to the profit function, share of maximum revenue equations can be derived for the revenue function (see **(2.7)**).

2.3.3 Substitution Elasticities

After estimation of the profit function, Morishima elasticities of substitution (MES) are calculated. The MES "(i) *is* a measure of curvature, or ease of substitution, (ii) *is* a sufficient statistic for assessing – quantitatively as well as qualitatively – the effects of changes in price or quantity ratios on relative factor share, and (iii) *is* a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio" (Blackorby and Russell, 1989, pg. 883, *emphasis* in original). The formula for the gross MES is (Blackorby et al., 2007):

(2.10) $$M_{ik} = \varepsilon_{ik} - \varepsilon_{kk}$$

where ε_{ik} is the price elasticity of demand for the *i*th factor with respect to the *k*th factor, and ε_{kk} is a typical own-price elasticity of demand. An MES is interpreted as the effect of a one percent change in the optimal input ratio x_i/x_k, allowing only the *k*th price to vary (Wohlgenant, 2001). As only a single price is changing, these elasticities are "inherently asymmetric" (Blackorby and Russell, 1989; pg. 885). Formulae for the price elasticities are given when the functional form is specified.

2.3.4 Measuring Bias due to Short-run Technical Change

Bias associated with post-crisis short-run technical change can also be measured. These biases are calculated under the assumption of constant revenues (costs). This assumption provides a reference to measure the change in optimal output and input ratios that can be attributed to the event. Profit maximizing farmers produce at the point where their ratio of marginal outputs equals the price ratio. Bias captures the change in the "state of technology" that is due to the crisis.

The bias effect of a crisis on the output or input shares is determined by differentiating the logarithm of **(2.7)** with respect to the crisis event variable:

(2.11) $$B_j = {\partial \ln S_j}\big/{\partial c_t}$$

where B_j indicates the bias of either output or input share. If B_j is greater than zero, the crisis is said to be positively biased towards share *j*. If B_j is less than zero, the crisis is negatively biased towards the share. Finally, if B_j equals zero, the crisis is share neutral. These are often referred to as "factor using", "factor saving" and "factor neutral" technical change. Similarly, the pairwise bias of a crisis is computed as in Kuroda (1988) and Karagiannis and Furtan (1993):

(2.12) $$B_{ji} = {\partial \ln S_j}\big/{\partial c_t} - {\partial \ln S_i}\big/{\partial c_t}$$

If B_{ji} is greater than zero then the crisis generated a bias towards *j* and against *i* – i.e., the rotation of the PPC or isoquant is measured by B_{ji}. These bias measures are output-output and input-input only. There are no cross output-input biases.

2.3.5 Translog approximation – Restricted Profit Function

The dual profit function (**(2.1)**) is assumed to be translog:

(2.13)
$$\begin{aligned}\ln \pi = {} & \alpha_0 + \sum_{j=1}^{2} \beta_j \ln p_j + \sum_{i=1}^{3} \beta_i \ln w_i \\ & + \frac{1}{2}\left(\sum_{k=1}^{2}\sum_{j=1}^{2} \gamma_{kj} \ln p_k \ln p_j + \sum_{h=1}^{3}\sum_{i=1}^{3} \gamma_{hi} \ln w_h \ln w_i \right. \\ & \left. + \sum_{j=1}^{2}\sum_{i=1}^{3} \gamma_{ji} \ln p_j \ln w_i \right) \\ & + \sum_{j=1}^{2}\sum_{t=1}^{2} \theta_{jt} \ln p_j c_t + \sum_{i=1}^{3}\sum_{t=1}^{2} \theta_{it} \ln w_i c_t\end{aligned}$$

This equation contains two outputs, calves and cull cows, and three variable inputs, capital, materials and feed. Output prices, input prices and crisis dummies are defined as above – **p**, **w** and **c** respectively – while *α*, *β*, *γ* and *θ* are parameters to be estimated. All output and input prices are divided by the (log) price of labour. This normalization imposes linear homogeneity on the function. Similarly, cross-price derivatives are restricted to be symmetric – i.e. $\gamma_{kj} = \gamma_{jk,}\, \gamma_{ih} = \gamma_{hi}$ and $\gamma_{ji} = \gamma_{ij}$. The profit maximizing output and variable input share equations, derived from **(2.13)**, are:

(2.14) $$S_j = \beta_{j0} + \sum_k \gamma_k \ln p_k + \sum_i \gamma_i \ln w_i + \sum_t \theta_t c_t + e_j$$

(2.15) $$S_i = \beta_{i0} + \sum_j \gamma_j \ln p_j + \sum_h \gamma_h \ln w_h + \sum_t \theta_t c_t + e_i$$

The five equations in this system become the data consistency constraints on the generalized entropy function. Using the coefficients from **(2.14)** and **(2.15)**, the own- and cross-price elasticities of output supply and input demand are given by (e.g., Sidhu and Baanate, 1981):

(2.16) $$\varepsilon_{jj} = \frac{\gamma_{jj} + S_j^2 - S_j}{S_j}$$
$$\varepsilon_{ji} = \frac{\gamma_{ji} + S_j S_i}{S_i}$$

These elasticities are evaluated at the sample means. They are also used to compute the MES (**(2.10)**).

2.3.6 Translog approximation – Revenue Function

Similar to the profit function, let the revenue function (**(2.8)**) be represented by a translog approximation:

(2.17)

$$\begin{aligned}\ln R = \alpha_0 &+ \sum_{j=1}^{2} \beta_j \ln p_j + \sum_{i=1}^{4} \beta_i \ln x_i \\ &+ \frac{1}{2}\left(\sum_{k=1}^{2}\sum_{j=1}^{2} \gamma_{kj} \ln p_k \ln p_j + \sum_{h=1}^{4}\sum_{i=1}^{4} \gamma_{hi} \ln x_h \ln x_i \right. \\ &\left. + \sum_{j=1}^{2}\sum_{i=1}^{4} \gamma_{ji} \ln p_j \ln x_i \right) \\ &+ \sum_{j=1}^{2}\sum_{t=1}^{2} \theta_{jt} \ln p_j c_t + \sum_{i=1}^{4}\sum_{t=1}^{2} \theta_{it} \ln x_i c_t \end{aligned}$$

.

This equation contains two outputs, calves and cull cows, and four fixed inputs, capital, labour, materials and feed. Output prices and crisis dummies are defined as above, while x_i represents fixed input quantities. Identical symmetry restrictions are placed on the revenue and profit functions. The revenue maximizing output share equations, derived from **(2.17)**, are:

(2.18)

$$S_j = \beta_{j0} + \sum\nolimits_k \gamma_{jk} \ln p_k + \sum\nolimits_i \gamma_{ji} \ln x_i + \sum\nolimits_t \theta_{jt} c_t + e_j \,.$$

2.3.7 Generalized Maximum Entropy Estimation

GME is an efficient approach for estimating a system of equations (Golan et al., 2001). Based on the principle of maximum entropy (see Jaynes, 1957a,b), GME converts a deductive mathematical problem (e.g., linear programming) into one of inference (Golan et al., 1996a). Recently, it has received substantial attention in the agricultural economics literature (see, for example, Bailey et al., 2004; Fraser, 2000; Gardebroek and Oude Lansink, 1999; and, Stokes and Frechette, 2006). The main benefit of this method is its ability to consistently estimate under-defined problems, which are otherwise infeasible to estimate via standard econometric techniques. Maximum entropy methods still work when there are insufficient or negative degrees of freedom. GME is used to estimate the parameters of the share equations **(2.14)**, **(2.15)** and **(2.18)**, as data are limited and only short-run behaviour is relevant for this study.

The share equations are linear in parameters, so consider a general linear model (Golan et al., 1996b):

(2.19) $$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{e}$$

with n observations – **y** is a $(n \times 1)$ vector of dependent variables, **X** is $(n \times k)$ matrix of exogenous variables, **β** is an $(k \times 1)$ vector of parameters and **e** is an $(n \times 1)$ vector of errors. GME involves specifying a discrete probability distribution for each parameter, β_k, to be estimated. In fact, β_k becomes the central moment of these distributions (Oude Lansink, 1999). This is achieved by reparameterising each β_k as the expected value of a set of M probabilities (q_{km}) and M support values (z_m):

(2.20) $$\beta_k = \sum_{m=1}^{M} q_{km} \cdot z_m \quad \forall k$$

where k indexes the parameter. Correspondingly, the error terms, e_i, are reparameterised as the expected value of H probabilities (ω_{ih}) and H support values (v_h):

(2.21) $$e_i = \sum_{h=1}^{H} \omega_{ih} \cdot v_h \quad \forall i$$

where i indexes the equation (i.e., observations are indexed by $i = 1, \ldots, n$). No distributional assumptions are required for the error terms. Substituting **(2.20)** and **(2.21)** into **(2.19)**, the general linear model becomes:

(2.22) $$\mathbf{y} = \mathbf{XZq} + \mathbf{V}\boldsymbol{\omega}$$

where **Z** and **V** are $(k \times km)$ and $(n \times nh)$ block diagonal matrices respectively and **q** and $\boldsymbol{\omega}$ correspond to $(km \times 1)$ and $(nh \times 1)$ probability vectors. Based on information theory, the entropy function transforms data into a distribution of probabilities describing our state of knowledge (Golan et al., 1996b). It is given by:

(2.23) $$H(\mathbf{q},\boldsymbol{\omega}) = -\mathbf{q}'\ln\mathbf{q} - \boldsymbol{\omega}'\ln\boldsymbol{\omega}$$

This function is then maximized over a set of constraints. These constraints consist of the data conditions – the reparameterized share equations represented by **(2.14)**, **(2.15)** and **(2.18)** – and the symmetry restrictions. As a GME approach is used, both output supply share equations can be simultaneously estimated. The imposition of a set of supplementary adding-up and non-negativity constraints on the probabilities is also required:

(2.24) $$\begin{array}{ll} \sum_{m=1}^{M} q_{km} = 1, \forall k & \sum_{n=1}^{N} \omega_{ih} = 1, \forall i \\ q_{km} \geq 0, \forall k, m & \omega_{ih} \geq 0, \forall h, n \end{array}$$

The support vectors in **(2.20)** and **(2.21)** must be specified by the researcher. The dependent variables are shares, so the error terms' support point interval is logically (-1, 0, 1) (Golan et al., 2001). Assigning the corresponding support points for the parameters requires more deliberation. Golan et al. (1996b, pg.88) suggest a three standard deviations rule (3σ) – i.e., let the bounds of the support vector be three standard deviations away from the mean of the data and then space the other support points equally along that interval. Some researchers have found that parameter values are sensitive to support vector specification (Paris, 2001). Consequently, alternative ranges were tested. The resulting estimates were consistent across various support points. All parameters presented in results section employ the 3σ rule. Finally, the GME model is estimated using GAMS software.

2.3.8 Data

The Government of Alberta’s Department of Agriculture and Rural Development (AARD, 2006) collects and organizes data from an annual farm survey of cow-calf producers across different regions in the province of Alberta. This farm survey is an unbalanced panel dataset. Annual average financial data on profits, variable costs and shares were retrieved for ten years, 1996 to 2005. The cow-calf information was separated from the crop information. This adjustment implicitly assumes that there is no joint production between crops and cattle. Over the span of the data collection period, the average number of cows wintered per farm was 172. Also, there were an average of 158 calves and 17 cull cows sold per year per farm.

Inputs are grouped into four categories: feed, materials, capital and labour following Adamowicz (1986) and Stewart (2006). Aggregate input price indices are used in the model. These indices are taken from Statistics Canada’s Farm Price Index publication (Statistics Canada, 1996-2005). Alberta annual average steer (5-600 lbs.) and D1-2 slaughter cow prices are used for calves and cull cows respectively. These data are from Canfax (1996-2005). Dummy variables are used to represent crises. These are short-term variables indicating that producers revert to previous behaviour following the crisis. A drought dummy takes the value of 1 for 2001 and 2002, while a BSE dummy takes the value of 1 for the years 2003 and 2004.

2.4 RESULTS AND DISCUSSION

2.4.1 Restricted Profit Function

Parameter estimates for the five share equations (**(2.14)** and **(2.15)**) are presented in Table 2.1. Due to negative degrees of freedom, standard parametric testing of these estimates is not possible. Similarly, the usual goodness of fit measures do not apply. Soofi (1992) and Golan et al. (1996c) did develop an information index to measure reduction in uncertainty. Analogous to McFadden's R-squared for maximum likelihood estimation, it involves subtracting from one the ratio of the value of constrained over the unconstrained entropy functions (**(2.23)**). However, this index is not independent of the number of support points specified. For example, if three support points are stipulated in **(2.20)** and **(2.21)**, the information index for this system of equations equals 0.033.[5] Instead, if twelve support points are used, the index equals 0.439. The estimated parameters of both formulations are identical to three decimal places. Due to this problem, the information index is not considered a reliable goodness of fit statistic.

Table 2.1: Parameter Estimates for Output Supply and Input Demand Share Equations from Restricted Profit Function

	Supply Equations		Demand Equations		
Parameter	Calves	Cull Cows	Feed	Capital	Materials
Intercept	0.222	0.026	0.131	0.033	0.054
Calves	0.263	0.107	0.052	0.126	0.104
Cull Cows	0.107	0.051	-0.044	0.000	-0.009
Feed	-0.052	0.044	-0.164	-0.105	-0.112
Capital	-0.126	-0.000	-0.105	-0.042	-0.055
Materials	-0.104	0.009	-0.112	-0.055	-0.066
Drought	-0.004	0.016	0.083	-0.017	0.003
BSE	0.083	-0.036	0.078	-0.013	-0.009

---

[5] Compared to previous research using the GME approach, this is a reasonable "fit" (Golan et al., 1996a; Fraser, 2000).

The output supply equations for calves and cull cows are both non-decreasing in output prices. The input demand equations are non-increasing in input prices. Concavity holds at the sample means for calves, feed, capital and materials. The cull cow output supply function contravenes this condition. Also, using the implied parameters, labour demand violates the concavity condition. As cull cows comprise a comparatively small proportion of output and the focus is on the short-run, this is not seen as a major violation of economic theory. In fact, a negatively-sloped short-run supply curve for Canadian cattle has been previously hypothesized in the literature (Horbulyk, 1990). Finally, monotonicity holds at every data point as the predicted shares have the appropriate sign. Homogeneity and cross-price symmetry were imposed in estimation.

The negative cross-price derivatives of the factor demand equations with respect to each feed, capital and materials indicates that they are gross complements. In contrast, all three inputs are gross substitutes to the labour input. Next, taking the derivative of the input demands with respect to the output prices suggests that at the farm level all factors are normal inputs for calf production. Feed and materials, however, are inferior inputs for cull cow production.

Table 2.2 presents the short-run own- and cross-price elasticities of demand, calculated at the sample means. These values are calculated using the equations in **(2.16)**. Derived from the share equation parameters, these elasticities are valuable for assessing the impact of price support policy proposals on farmers' decisions.

Own-price elasticities of demand for feed, capital and materials are all negative and correspondingly equal to -1.192, -0.745 and -0.865. The feed input is the most responsive to price changes. This result likely reflects two farm decisions. First, producers may opt to leave their herd on pasture for longer durations. They may be willing to trade-off some short-term pasture degradation in order to offset increased feed prices. Second, managers may take their animals to market at lower weights. Both options are viable alternatives to increasing feed purchases. The own-price elasticity for labour is positive and relatively large. Much of the hired farm labour is temporary and transient for an individual cow-calf producer. Consequently, it is possible that, in some years, the demand for hired labour is greater than the supply at the market rate. That is, short-run labour market frictions and difficulties arising when farmers attempt to substitute family labour for hired workers may force farmers to concurrently increase the wage paid to hired labour and the number of hours demanded. It is expected that, in the long-run, labour would have a negative own-price elasticity of demand.

Table 2.2: Short-Run Own- and Cross-Price Elasticities of Output Supply and Input Demand for Albertan Cow-Calf Producers[a]

	Quantities					
	Calves	Cull Cows	Feed	Capital	Materials	Labour
Calves	0.178	1.750	0.979	1.986	1.401	1.382
Cull Cows	0.244	-0.461	0.037	0.123	0.078	1.319
Feed	-0.571	-0.154	-1.192	0.410	0.051	-2.725
Capital	-0.258	-0.115	0.091	-0.745	0.165	-1.986
Materials	-0.316	-0.126	0.020	0.287	-0.865	-2.065
Labour	-0.276	-1.894	-0.934	-3.060	-1.831	3.076

a. – Elasticities are calculated at the sample means.

The own-price elasticity of calf supply is positive and inelastic. Equal to 0.178, it is comparable to the aggregate estimates found in other studies (e.g., Quagrainie), but much lower than that reported by Horbulyk (1990). Cull cows have a negative own-price elasticity of supply. There are several potential explanations for this anomaly. It could be due to the short-run nature of the model. It may also indicate that farm decisions are based primarily on the price of calves. Farmers may alternate between treating cull animals as an output and an input. Retaining a greater number of cows implies that there will be more calves in the next season. Overall, as is expected in the short-run, the majority of cross-price input elasticities are inelastic.

The Morishima input substitutability elasticities are presented in Table 2.3. With output constant, a 1 percent increase in the price of feed would lead to a 1.155, 0.916 and -5.801 percent change in the demand for capital, materials and labour respectively. This indicates that feed is substitutable with capital and materials, but that labour and feed are complements. In contrast, if the price of capital, materials and labour increases by 1 percent, the corresponding demand for feed changes by 1.284, 1.212 and 0.258 percent.

Table 2.3: Morishima Elasticities of Input Substitution

	Quantities			
	Feed	Capital	Materials	Labour
Feed		1.284	1.212	0.258
Capital	1.155		1.033	-2.315
Materials	0.916	1.030		-0.966
Labour	-5.801	-5.062	-5.141	

This purports that capital, materials and labour are substitutable with feed at the farm level. Examining these values, the inherent asymmetry of the MES is clear. Overall, this table demonstrates that feed, capital and materials are substitutable with each other. As the price of labour increases though, the capital-labour and materials-labour ratio declines.

Given the crises which occurred in the Albertan cattle sector, some short-run non-price changes in the shares of output supply and input demand are to be expected – i.e., producers experienced short-run technical change. The share biases associated with this technical change are useful for developing quantitative targets for crisis relief policy. Using **(2.11)**, Table 2.4 presents the single factor biases that resulted from the Albertan drought and BSE crisis. For the outputs, the drought was negatively biased for calves and positively biased for cull cows. The reverse is true for the BSE crisis: the share of calves produced had a positive response, while cull cows had a negative reaction. Considering that several months following the initial BSE discovery the US reopened the border to beef imports from animals less than 30 months in age only, this result matches expectations. Both the drought and the BSE crisis negatively biased capital and labour factors. Feed, on the other hand, responded positively to the crises. As a short-run remedy to the drought, farmers may have altered their production techniques reacting to a lower quality of pasture. That is, they may have started their herd on feed earlier in the production cycle. The responsiveness of materials was relatively small. Nevertheless, it responded negatively to the BSE crisis and positively to the drought.

Table 2.4: Share Bias due to Crises in the Albertan Cow-Calf Sector: Drought and BSE

Outputs	Drought	BSE
Calves	-0.004	0.094
Cull Cows	0.131	-0.293
Inputs		
Feed	0.162	0.152
Capital	-0.152	-0.114
Materials	0.015	-0.045
Labour	-0.392	-0.318

Pairwise non-price, crises response biases are presented in Table 2.5 (see **(2.12)**). On the output side, the drought biased production by 13.6 percent towards cull cows and away from calves. The BSE crisis, however, was biased towards calf production by nearly 39 percent. So, on the output side, there was a greater rotation of the PPC due to BSE than drought. All inputs – capital, materials and labour –were substantially biased towards feed for both events. Similarly, all inputs were biased away from labour for both crises. The drought generated a 16.6 percent bias towards materials from capital, yet the shift resulting from BSE was only 6.9 percent. In general, the pairwise input biases are larger for the drought than for the BSE crisis. The only exception is the bias towards feed and away from materials – feed gained more from materials as a result of BSE, than due to the drought. Overall, the drought had a larger impact on the optimal input ratios, while BSE had a greater effect on output mix.

Table 2.5: Pairwise Measures of Share Bias due to Crisis (shift towards quantity in column from quantity in row)

	Pairwise Bias due to Drought				
	Cull Cows	Feed	Capital	Materials	Labour
Calves	-0.136				
Feed		-			
Capital		-0.314	-		
Materials		-0.148	0.166	-	
Labour		-0.554	-0.240	-0.407	-
	Pairwise Bias due to BSE				
	Cull Cows	Feed	Capital	Materials	Labour
Calves	0.388				
Feed		-			
Capital		-0.266	-		
Materials		-0.197	0.069	-	
Labour		-0.469	-0.204	-0.273	-

2.4.2 Revenue Function

Table 2.6 displays the parameter estimates from the revenue function model (**(2.18)**). A detailed discussion of technological relationships is contained in the profit function section (section 2.4.1), so will not be reviewed again. The primary comparative static prediction of the revenue function relates to the outputs supplied. Calves and cull cows both have positive own price supply response, agreeing with the theoretical predictions.

Table 2.6: Parameter Estimates for Revenue Function Output Supply Share Equations[a]

	Calves	Cull Cows
Intercept	7.670	1.062
Calves	0.816	0.320
Cull Cows	0.320	0.366
Feed	4.578	0.272
Capital	3.908	0.388
Materials	3.529	0.613
Labour	3.977	0.984
Drought	-1.312	0.482
BSE	1.023	-1.112

a – All values multiplied by *10^{-2}

Table 2.7 presents the output supply elasticities calculated at the data means. The own-price supply elasticity for calves is 0.113, while the cull cow own-price elasticity equals 0.852. The cull cow output is more elastic than the calves output. Cull cows can be “stored” as cull cows, while calves, as an output, cannot be considered inventory. That is, if a cow-calf producer is going to sell calves as calves, there is a limited interval available before calves become mature animals (e.g., cows). Accounting for this constraint on the calves output, the inelasticity of the price response accords with intuition. The calves output has a similar own-price elasticity for both the revenue and profit functions. Finally, the cull cows comparative static prediction matches theory for the revenue function, while with the profit function a negatively slope supply curve was predicted.

Table 2.7: Own- and Cross-Price Elasticities of Output

	Quantities	
	Calves	Cull Cows
Calves	0.113	-0.904
Cull Cows	-0.127	0.852

Tables 2.8 and 2.9, respectively, provide the single share and pairwise biases due drought and BSE. Biases represent shifts in output that are not captured by changes in prices. Drought led the calves' share of output to decrease by 1.5 percent, while the increase in its own-share bias due to BSE was 1.1 percent. Conversely, the drought led producers to increase their share of cull cows supplied by 3.2 percent and BSE caused a 17 percent decline in the cull cow share. The comparative statics of the bias results match the predicted values from the profit function. However, the magnitude of the short-run technical change effects calculated from the revenue function are smaller.

Table 2.8: Output Share Bias Due to Drought and BSE

	Drought	BSE
Calves	-0.015	0.011
Cull Cows	0.032	-0.170

Following the BSE crisis, the revenue function predicts a pairwise bias towards calves of 18 percent which is less than the 39 percent derived from the profit function model. Similarly, the drought estimates shift away from calves of 4.7 percent for the revenue function compared to the 13.6 percent calculated using the profit function. For both events, drought and BSE, it is likely that many producers had allocated their inputs prior to the crisis. As a consequence, following these incidents, the revenue function may be a better reflection of producer behaviour and more confidence is placed in the bias estimates presented in Tables 2.8 and 2.9.

Table 2.9: Pairwise Bias Towards Calves Due to Drought and BSE

	Bias
Drought	-0.047
BSE	0.180

2.5 QUANTIFIABLE POLICY TARGETS

Policy-makers can use the elasticity and bias values to develop approximate quantifiable targets for price support emergency aid programs in the event of another agricultural crisis. A mathematical description of a crisis' price and bias effects on optimal output ratios is straightforward. Let ε_{ii} and ε_{ij} be the partial own- and cross-price elasticities of supply for output *i* with respect to prices p_i and p_j respectively. The effect of a crisis on output y_i can be approximated with the formula (assuming two outputs):[6]

$$\textbf{(2.25)} \qquad \Delta y_i^* \approx \Delta p_i \varepsilon_{ii} \frac{y_i}{p_i} + \Delta p_j \varepsilon_{ij} \frac{y_i}{p_j} + B_i y_i$$

where B_i summarizes the per unit effect of short-run technical change and y_i and p_i correspond to a reference period's outputs and prices. Strictly speaking, ε_{ii} and ε_{ij} relate marginal changes in prices and quantities. However, for crisis situations, this approximation affords a clear understanding of the magnitude of a producer's response to a change in price.

Three predictions can be made by using **(2.25)**. First, this expression can be substituted into **(2.3)**. After inserting the appropriate elasticities and forecasted biases, support levels may be calculated for any pre-specified policy target using approaches

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[6] This equation is derived from the total price elasticity of output, which is the sum of the partial elasticities. Bias, B_i, in terms of percent change per unit output is then appended to that equation to capture the short-run technical change effects of the crisis.

such as a goal programming model. Next, if a single factor is of primary interest, it is possible to rewrite **(2.25)** as:

(2.26) $$\frac{\Delta y_i^*}{y_i} \approx \frac{\Delta p_i}{p_i}\varepsilon_{ii} + \frac{\Delta p_j}{p_j}\varepsilon_{ij} + B_i\,,$$

giving the predicted percent change in the output of interest as a function of the percent change in prices, elasticities and biases. Finally, if predictions of the change in optimal output shares are desired, it is possible to take this approximation a step further. For simplicity, assume that $\frac{\Delta y_i^*}{y_i} \approx \ln y_i$ and $\frac{\Delta p_i}{p_i} \approx \ln p_i$. Then **(2.26)** can be written as: $\ln y_i = \ln p_i \varepsilon_{ii} + \ln p_j \varepsilon_{ij} + B_i$. Subtracting this expression for output *i* from the equivalent expression for output *j* and rearranging the difference, results in the following (Chambers, 1988):

(2.27) $$\ln\left({}^{y_i}\!/_{y_j} \right) = \ln p_j \left(\varepsilon_{ij} - \varepsilon_{jj}\right) - \ln p_i \left(\varepsilon_{ji} - \varepsilon_{ii}\right) + \left(B_i - B_j\right).$$

Define a Morishima elasticity of output transformation as: $T_{ij} = \varepsilon_{ji} - \varepsilon_{ii}$ and a pairwise bias as $B_{ij} = B_i - B_j$. One can then write:

(2.28) $$\ln\left({}^{y_i}\!/_{y_j} \right) = \ln p_j T_{ji} - \ln p_i T_{ij} + B_{ij}\,.$$

This expression, **(2.28)**, can be used to forecast the effects of both changes in price and non-price technology effects on optimal output shares.

Two examples, using the information presented in the previous section, highlight the approach for formulating quantifiable policy targets for crisis relief. The first example uses the BSE crisis where the emergency aid program is targeting both revenue and output share neutrality. This calculation uses the first method, where **(2.25)** is substituted into **(2.3)**, and the predictions from the revenue function to predict the relative change in prices (i.e., rotation of the isorevenue line) necessary to keep production at its reference equilibrium. Along with the information from the profit function, the second example uses the second and third methods to predict the single factor change and the changes in optimal input ratios when the price of feed is subsidized during the drought. While these targets are calculated *ex post*, these two events supply baseline information and the approach can be readily applied in future crisis relief situations. Appendix 2A contains the goal programming specification used to make the quantitative crisis-policy predictions for example 1.

2.5.1 Example 1: BSE crisis with a policy target of revenue- and share-neutrality

Assume that both revenue- and share-neutrality were desired policy targets during the BSE crisis. Figure 2.2 provides an illustration of this policy outcome. Similar to Figure 2.1, the initial PPC is given by *BB*. Revenue- and share-neutrality implies that the policy goal is to maintain equilibrium point E_1. Therefore, any subsidized PPC must pass through that point. Short-run technical change will alter the shape of the original PPC, so the original isorevenue line, P_1, would not be share neutral. Thus, in order to achieve the policy target, output prices must be supported disproportionately, leading to a new rotated isorevenue line, P_2, that is tangent to the supported PPC, $D'D'$. If the reference equilibrium is to be maintained, the bias estimates dictate that cull cow prices must be subsidized more than calf prices in order to maintain share neutrality.

Using the year 2000 as a reference period – i.e., the crisis relief program's goal is to match the post-crisis revenues and output shares to those in 2000 – and assuming that policy-makers accurately predicted the short-run technical change in the output market, then any price support policy must support cull cow prices more than calf prices. Goal programming models allow policy makers to quickly predict the necessary rotation of the price supported isorevenue line. In the case of the BSE crisis, the optimal revenue- and share-neutral price support policy dictates that for every dollar that calf prices are supported cull cow prices must receive \$2.14 in support to recover the initial equilibrium following the BSE crisis. As a comparison, assume that the forecasted bias away from cull cows were not the 17 percent that was measured *ex post* but: a) twice that amount (34 percent); and, b) half the effect (8.5 percent). Assume the overall price supports required to achieve the revenue- and share-neutral policy target are identical for calves. The supports needed to achieve a revenue- and share-neutral support policy in these alternative scenarios are: a) a 64 percent increase for cull cows to \$3.55 for every \$1 of calf support; and, b) a 32 percent decrease to \$1.45 for every \$1 of calf support. Regardless of prediction, cull cow prices require greater support than calf prices in order to hit the policy target.

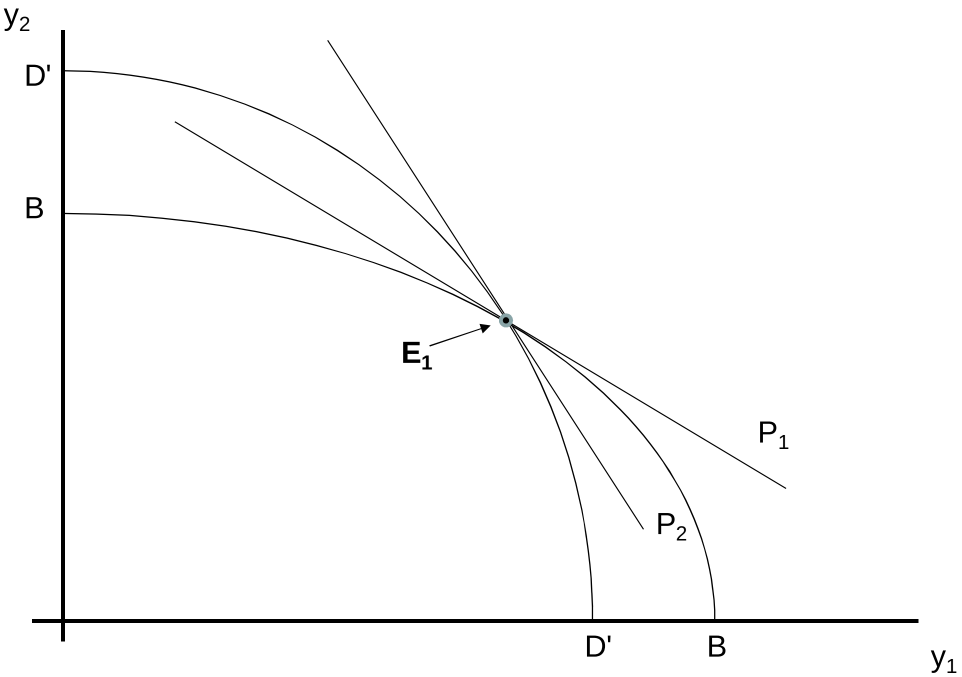

Figure 2.2: Achieving a Revenue- and Share-Neutral Policy Target

2.5.2 Example 2: Predicting the input bias due to drought

Severe drought conditions in 2002 led the Albertan government to provide support to primary producers. While the majority of this support went to crop enterprises, assume that, for cow-calf producers, a 10 percent subsidy is offered on the price of feed. Policy-makers who ignored the effect of short-run technical change (i.e., assumed that $B_i = 0$ in **(2.26)**) would forecast that the increase in demand for feed would be 12 percent. Short-run technical change is important, however. Incorporating short-run technical change yields a much larger predicted increase of 28 percent in quantity of feed demanded. Similarly, forecasting the effect of the support on optimal input share ratios (using **(2.28)**), without considering the effect of technical change, leads to predicted changes of 12 percent, 9 percent and -58 percent for the feed-capital, feed-materials and feed-labour ratios respectively. When bias is considered, the corresponding percent of the optimal ratios are -20 percent, -6 percent and -113 percent. Clearly, bias due to short-run technical change plays a major role in achieving policy targets and in understanding optimal behaviour at the producer level. Policy targets that do not account for temporary short-run technical change may be missed by a substantial margin.

2.5.3 Government policy and producer expectations during crises

These two examples provide a systematic method for making quantitative forecasts on the effects of *ad hoc* policy. Implicit in this framework is the assumption that producers cannot *ex ante* predict that the government will introduce policy. If farmers correctly predict government intervention, then this approach will not generate accurate approximations. Moreover, if producers had *ex ante* expectations that a crisis was imminent, they would have altered their production plans, hedged their risk and accounted for government action. An entirely different framework would then be required to generate quantitative predictions under these alternative assumptions (see, for example, Quiggin and Chambers, 2004).

Short-run, crisis policy is the focus of this chapter. For BSE-type events, the approach outlined in this chapter is useful. The reason is this: a “crisis” cannot occur if it is accurately forecasted. If a crisis is accurately forecasted, then producers would have already altered their productions plans, implying observable *ex ante* changes (provided that producers did not make “errors” in their optimization problem) and the government or private sector should have introduced products enabling producers to hedge the downside risks of the crisis. Therefore, in most actual crisis situations, the government can plausibly expect that producers’ subjective probabilities of the event are negligibly different from zero. With respect to the BSE crisis, neither producers nor the government accurately forecasted event (AGO, 2004). As a result, some government intervention was viewed as necessary in order for the cattle industry to survive (AGO, 2004). There was a perception that without government support the industry would collapse, but the final form of that support was unknown *a priori* (e.g., would it be lump-sum transfers, price supports, etc.?). Moreover, the Canadian Agricultural Income Stabilization (CAIS) program was new and untested (AGC, 2007). Therefore, caution should be exercised in attributing too much confidence to producers' accurately forming expectations regarding government programs in the period immediately before and following the BSE crisis. Depending on the specific context of future events, the assumption on producer expectations may or may not hold.

2.6 CONCLUSION

Western Canadian cow-calf producers experienced significant market volatility recently. They suffered through a drought and the BSE crisis. Emergency government support assisted producers through these challenging periods. This type of support is becoming increasingly common in both Canada and the United States (Smith, 2004). This paper investigated some of the economic responses occurring at the farm level during adverse events. More importantly, it provides a framework for policy-makers to understand and formulate forecasts about the relative impacts of financial aid programs on this behaviour. These forecasts provide *quantitative* benchmarks for designing relief programs.

There has been minimal research on disaggregated output supply and input demand relationships for the cattle sector. In this respect, this paper addresses a gap in the literature. Farm level elasticities and biases provide new insights on the short-run behaviour of cow-calf producers. Further, this research highlights the two implications of crises on agricultural markets. Both price and short-run technical change are critical to understanding post-crisis producer behaviour.

Two final comments are required. First, caution should be exercised when interpreting the short-run technical change and biases. These could be capturing model misspecification or some alternative effect. Transactions costs and fixed inputs – namely, land – may generate temporary share biases. Also, particularly following the BSE crisis, the Alberta cattle industry may have experienced other structural changes – notably, export markets disappeared. The share biases may suggest that farmers had a lag in adjusting to this new market structure – i.e., the short-run technical change is measuring an adjustment or equilibration process rather than a change in the production possibilities set. Ultimately, when it comes to the policy design process, short-run technical change offers an established and intuitive framework, yet it should be used for short-run policy only. Second, Goodwin and Rejesus (2008) find an inverse relationship between the government's provision of disaster relief and farm-level risk mitigating behaviour. It warns that emergency relief is becoming common and therefore producers have a disincentive to insure against adverse events. It states: "critics of *ad hoc* disaster relief have argued that its continual provision . . . results in a form a free insurance and thus reduces incentives to participate in insurance programs" (pg. 416). This chapter addresses methods to design one-time, temporary crisis aid programs. It neglects the dynamic interactions between these policies and producer behaviour. These dynamic interactions however yield an interesting avenue for future research.

APPENDIX 2A: GOAL PROGRAMMING FORMULATION FOR EXAMPLE 1

The assumed policy target is revenue neutrality with share neutrality. Define a set of deviational variables corresponding to negative and positive deviations, s_i^- and s_i^+ (Taha, 2007). Let **s** be a column vector which represents these deviation variables and **b** be a vector of weights. In the program below, the first constraint, (i), states that the first policy goal is revenue neutrality ($\Delta R = 0$ as given by **(2.3)** and **(2.25)**). The second constraint, (ii), states that the second policy goal is share neutrality where $\bar{S}_i$ and $\hat{S}_i$ are the reference and post-crisis shares of output *i* respectively. From **(2.3)**, $\Delta p_i = \hat{p}_i - \bar{p}_i$ where $\bar{p}_i$ is the reference price and $\hat{p}_i$ is the post-crisis price. Government price subsidies, p_i^s, are added to this equation, so: $\Delta\tilde{p}_i = \hat{p}_i - \bar{p}_i + p_i^s$. The goal programming problem minimizes the deviations or penalties from the policy goals by choosing price support subsidies, p_i^s. (*n* represents the number of outputs)

$$\min_{p^s} \mathbf{b}'\mathbf{s}$$

subject to

(i) $\Delta R + s_1^- - s_1^+ = 0$

(ii) $\bar{S}_i - \hat{S}_i + s_i^- - s_i^+ = 0 \ \forall i = 2,...,n$

(iii) $s_i^-, s_i^+ \geq 0 \ i = 1,...,n$

where

$$\Delta R = \sum_i \left(\Delta\tilde{p}_i y_i^* + p_i \Delta y_i^* + \Delta\tilde{p}_i \Delta y_i^*\right)$$

$$\Delta y_i^* = \Delta\tilde{p}_i \varepsilon_{ii} \frac{\bar{y}_i}{\bar{p}_i} + \sum_j \Delta\tilde{p}_j \varepsilon_{ij} \frac{\bar{y}_i}{\bar{p}_j} + B_i \bar{y}_i$$

$$\Delta\tilde{p}_i = \hat{p}_i - \bar{p}_i + p_i^s$$

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CHAPTER 3: DOES EXPERIENCE BREED CONFIDENCE? PRODUCTION DECISIONS WITH PRICE UNCERTAINTY AND BSE

3.1 INTRODUCTION

Assessing the impacts of risk aversion and price uncertainty has traditionally been considered a weakness in production economics, particularly within duality theory (Shumway, 1995). Most studies either identify risk attitudes without determining the source of randomness or estimate the cause of uncertainty without ascertaining the concomitant risk preference structure (Moschini and Hennessy, 2001). The 2003 Canadian BSE crisis introduces additional complications. Economic crises are unpredictable and lead to dramatic financial repercussions for producers. The BSE crisis highlights the combined influence of both price uncertainty and risk preferences in production decisions. Traditional models that treat uncertainty and risk preferences independently may overlook important elements of producer behaviour during agricultural crises. This paper advances a duality based approach, originally developed by Coyle (1992, 1999), which overcomes this weakness. Simultaneous examination of price uncertainty and risk preferences is completed within an empirically tractable framework. A farm-level application is completed for Albertan cow-calf producers, with particular attention paid to the consequences of the BSE farm financial crisis on risk aversion.

Following the May 2003 BSE announcement, it is reasonable to ask whether risk preferences changed – i.e., did producers alter their levels of risk aversion? At the same time one would expect that production decisions be affected by increased price uncertainty. Extending Coyle’s (1992, 1999) approach to duality with uncertainty, this paper presents a framework that integrates risk preferences, conditioning procedures and the effects of BSE.

This research makes two chief contributions to the literature. First, it is a new empirical study. Few empirical investigations have employed this methodology and no Canadian research has used farm-level data. This is primarily an exploratory study. This chapter formulates and tests four statistical hypotheses. These hypotheses are not predictions from economic theory; rather, they are empirical conjectures used to find patterns in the data. If substantial empirical patterns are found, it is at that stage that theory may be developed to explain these phenomena. For the patterns that are found in this study, several potential rationalizations are presented, yet these are limited as the focus of the study is on exploratory and empirical themes. In order to achieve the objectives of this empirical goal, new techniques are required. The second contribution, then, is to introduce conditioning methods used to incorporate additional explanatory variables within a theoretically consistent model of producer behaviour that accounts for price randomness. These conditioning methods are new to the production economics literature.

This study investigates the behaviour of Albertan cow-calf producers. Cow-calf producers are an important component of the Albertan agricultural sector. From 2000 to 2004, cattle and calves comprised an average of 35.3 percent of the total value of agricultural production (AARD, 2005). Alberta has the largest number of cow-calf enterprises in Canada. Approximately, 37 percent of beef cattle firms, consisting of 39.3 percent of Canadian herd, are located in the province (Canfax, 2006; Samarajeewa et al., 2006). Substantial instability has stressed the industry following the BSE announcement in May 2003. More than 34 countries enacted import restrictions (Le Roy and Klein, 2003). The United States, which had previously accounted for over 70 percent of Canada's exports, refused to accept any Canadian ruminant meat products (Grier, 2005). Alberta was clearly the most affected of all Canadian provinces (Poulin and Boame, 2003; Maynard et al., 2008).

Four research hypotheses are examined in this paper. (a) First, it is hypothesized that farmers are risk averse. That is, production models which include risk aversion fit the data better than risk neutral models. This premise is evaluated via a nested statistical test within a parametric model. Let this hypothesis be known as *farmers are risk averse*. If the hypothesis is not rejected, several additional economic measures will be calculated – namely, price and substitution elasticities along with producers' observed risk premiums. (b) Second, it is conjectured that producers with more years of experience have lower overall levels of risk aversion or greater confidence. Confidence is assumed to be inversely related to risk aversion – i.e., greater risk aversion implies less confidence and vice versa. This is called the *experience breeds confidence* hypothesis. (c) The third hypothesis states that the BSE crisis led to a statistically significant change in risk attitudes. Producers, likely in accordance with the cattle sector's uncertainty, may have increased their aversion to output price risk. This is called the *BSE increased aversion to risk* hypothesis. (d) The final hypothesis relates risk aversion to short- and long-run leverage ratios – to be precise, the firm-level current and debt-to-equity ratios. Firms may have differential risk preferences depending on the attributes of the firm or manager. Each farm's current and debt-to-equity ratio is ranked relative to other operations in the sample. Firms are then classified according to this ranking as having low, medium or high risk tolerance in the short- and long-run. Categorization of the sample is done in thirds – for example, firms with high current ratios are classified as having low risk tolerance. The main thrust of this hypothesis is that either higher current liabilities (i.e., low current ratios) or long-run debt levels may suggest greater willingness to accept risk in either the short- or long-term. This in turn implies lower levels of risk aversion. Firms' relative rankings are assumed to be indicators or proxies of risk tolerance. Risk preferences, hence output supply and input demand decisions, are conditioned on these variables.[7] Consequently, the final hypothesis is that aversion to output price risk within firms that have displayed risk tolerant behaviour may be smaller. Let this be known as the *risk tolerance* hypothesis.

To summarize, the four main hypotheses of this research are:

a. Farmers are risk averse;
b. Experience breeds confidence;
c. BSE increased aversion to risk; and,
d. Risk tolerance.

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[7] While absolute financial performance and risk preferences are likely endogenous, emphasis is placed on choices relative to the sample. This approach avoids direct endogeneity problems, permitting the risk tolerance variables to be uncorrelated with the error term. Relative risk tolerance variables are best categorized as "weakly exogeneous" (Gujarati, 2003). Testing and estimation are valid with weakly exogenous variables, however caution should be exercised when expressing causal explanations (Gujarati, 2003). It is believed that risk tolerance is an informative hypothesis to formulate and examine. As such, it is included in this analysis.

Economic theory does not make any *a priori* predictions with respect to these hypotheses. As stated, this is an exploratory analysis and these conjectures must be empirically tested. If patterns are discovered in the data, economic theory should be developed to explain these results. In order to assess the final three hypotheses within dual production theory, extensions to existing models are needed. Production models have typically found few applications for specifications that contain firm-specific variables (except in efficiency research). Drawing on the consumer demand literature, two procedures for incorporating firm- and manager-specific variables into a duality based model with risk are presented. These two procedures, analogues to the techniques developed by Pollak and Wales (1978, 1981, 1992), are: risk scaling and risk translating. These approaches, within an empirically tractable formulation, augment the risk model permitting risk preferences to be conditioned on exogenous explanatory variables. Introducing these methods into agricultural economic production models is a contribution to the literature.

Output price risk refers to the uncertainty in prices. Profits are affected by price movements – i.e., when prices are unpredictable, farm profits are also uncertain. This study assumes that there is no output risk. Price uncertainty is the only form of risk examined. For cow-calf enterprise, this assumption is not unrealistic. Hart et al. (2001) state: “For most livestock producers, production risk is relatively small compared to price risk. Relative to crop production, livestock production risk is much smaller because livestock are more adaptable. Most production risk can be attributable to disease, mechanical failure, or variability in weight gain” (pgs. 555-6).

This chapter contains seven sections. Section 3.2 describes the conceptual model and conditioning procedures. Dual production theory for constant absolute risk averse (CARA) and decreasing absolute risk averse (DARA) preferences is reviewed and the risk scaling and risk translating techniques are introduced. The literature review comes in section 3.3. This organization is unorthodox; however, this arrangement highlights gaps in the literature which are addressed in this paper. Section 3.4 contains the empirical models, data and econometric methods. Section 3.5 presents the empirical results and discussion. Suggested extensions are discussed in section 3.6. Section 3.7 concludes.

3.2 CONCEPTUAL MODEL

Following the approach of Moschini and Hennessy (2001, pg. 91), the notions of risk and uncertainty are used interchangeably. In general, the term “uncertainty” describes the economic decision-making environment, while risk applies to the relevant implications of uncertainty.

Coyle (1992, 1999) developed a cogent, duality based framework of producer behaviour under uncertainty. This framework incorporates empirically tractable conditions from economic theory (e.g., symmetry, homogeneity and curvature). Sub-sections 3.2.1 and 3.2.2 review the main contributions of the Coyle papers.

A dual expected utility model is derived for two familiar forms of risk aversion. Models for constant absolute risk aversion (CARA) and decreasing absolute risk aversion (DARA) under price uncertainty are presented. Constant relative risk aversion (CRRA), a class of DARA preferences, is also considered. It is a stylized fact that aversion to risk declines with wealth – i.e., producers exhibit DARA or CRRA preferences (Saha, 1993).

It must be clearly stated however that economic theory does not make any predictions with respect to risk preferences and the potential for DARA is merely an expected pattern in the data. For each type of risk preferences, a set of economic theoretic model restrictions are derived.

3.2.1 CARA Preferences

3.2.1.1 Dual Expected Utility Model

Following Coyle (1992), assume that cow-calf producers' exhibit expected utility maximizing behaviour under price uncertainty. A utility function that is linear in the expectation and variance of profits is:

(3.1) $$U = \bar{\pi} - (\alpha/2)\mathbf{V}_{\pi}$$

where $\alpha > 0$ is the coefficient of absolute risk aversion. Let expected profits, $E[\pi] = \bar{\pi}$, be given by:

(3.2) $$\bar{\pi} = \bar{\mathbf{p}}\mathbf{y} - \mathbf{wx}$$

where $\bar{\mathbf{p}}, \mathbf{y}, \mathbf{w}\ \text{and}\ \mathbf{x}$ are respectively vectors of expected prices, outputs, input prices and inputs. As mentioned only output price risk is considered. The variance-covariance matrix of profits, $\mathbf{V}_{\pi}$, equals:

(3.3) $$\mathbf{V}_{\pi} = \mathbf{y}^T \mathbf{V}_p \mathbf{y}\,.$$

Where $\mathbf{V}_p$ is the (symmetric) variance-covariance matrix of output prices. Substituting **(3.2)** and **(3.3)** into **(3.1)** gives:

(3.4) $$U^*(\bar{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p) = \{\max U(\mathbf{y}, \mathbf{x}) \equiv \bar{\mathbf{p}}\mathbf{y} - \mathbf{wx} - (\alpha/2)\mathbf{y}^T \mathbf{V}_p \mathbf{y}\}.$$

This is the producer's dual indirect utility function. Maximum indirect utility, U^*, with CARA is a function of prices and the variance of uncertain output prices: $\bar{\mathbf{p}}, \mathbf{w}\ \text{and}\ \mathbf{V}_p$.

3.2.1.2 Properties

Proposition 1 in Coyle (1992) presents a set of properties for **(3.4)**. Assuming U^* exists and is differentiable, then (i) the dual indirect utility function is increasing in $\bar{\mathbf{p}}$, decreasing in **w** and decreasing in elements of $\mathbf{V}_p$; (ii) is linearly homogeneous in $\bar{\mathbf{p}}, \mathbf{w} \text{ and } \mathbf{V}_p$; (iii) is convex in $\bar{\mathbf{p}}, \mathbf{w} \text{ and } \mathbf{V}_p$; and (iv) has the following derivative properties:

(3.5a) $$y_j^* = U_{\bar{p}_j}^*; \quad j = 1, \ldots, n$$

(3.5b) $$y_j^* = -(1/\alpha)\frac{U_{\bar{p}_j V_{p_{jj}}}^*}{U_{\bar{p}_j \bar{p}_j}^*}; \quad \mathrm{j} = 1, \ldots, \mathrm{n}$$

(3.6) $$-x_i^* = U_{w_i}^*; \quad i = 1, \ldots, m$$

where the subscript of U^* refers to the derivative of the indirect utility function, **(3.4)**, with respect to that variable. Double subscripts refer to the second derivative – e.g., $U_{\bar{p}_j V_{p_{jj}}}^*$ represents the derivative of U^* with respect to the expected price of *j* and then the variance of that price. Optimal output supplies and input demands, the functions that will be estimated, are represented by y_j^* and x_i^* respectively. It is clear that **(3.5a)** and **(3.6)** are CARA analogues to Hotelling's lemma, whereas **(3.5b)** does not have an equivalent representation in risk neutral production theory – **(3.5b)**, however, is needed to incorporate the risk translating procedures into the model (see section 3.2.4.2). An implication of these properties is the matrix of second derivatives (i.e., $\nabla^2 U^*$) is positive semi-definite. Further, via Young's Theorem, symmetry relationships can be derived, e.g.:

(3.7) $$\begin{aligned} \partial y_j / \partial \overline{p}_i &= \partial y_i / \partial \overline{p}_j \\ \partial x_i / \partial w_j &= \partial x_j / \partial w_i \qquad \forall i, j \\ \partial y_j / \partial w_i &= -\partial x_i / \partial \overline{p}_j \end{aligned}$$

Symmetry and homogeneity restrictions are imposed during estimation. Proofs of these properties are found in Coyle (1992).

3.2.2 DARA Preferences

3.2.2.1 Dual Expected Utility Model

Assume that cow-calf operators exhibit expected utility maximizing behaviour under price uncertainty and that they have nonlinear mean-variance preferences. Let $\overline{W}$ and V_W denote the mean and variance of wealth respectively. Mean wealth is defined as: $\overline{W} = W_0 + \overline{\pi}$, where $\overline{\pi}$ is expected profit and W_0 is initial wealth. Output prices are the only random variable, so expected profits are defined as in **(3.2)**. Next, $\mathbf{V}_W$ equals $\mathbf{V}_\pi$, hence **(3.3)** applies. Again let U^* represent the certainty equivalent dual, indirect expected utility function (Coyle, 1999):

(3.8) $$\begin{aligned} U^*(\overline{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p, W_0) &= \{\max U(\mathbf{y}, \mathbf{x}) \\ &\equiv \overline{W} - \frac{\alpha(\overline{W}, V_W)V_W}{2} \\ &= W_0 + \overline{\pi} - \frac{\alpha(\overline{W}, V_W)V_W}{2} \\ &= W_0 + \overline{\mathbf{p}}\mathbf{y} - \mathbf{w}\mathbf{x} - \frac{\alpha(\cdot)}{2}\mathbf{y}^T\mathbf{V}_p\mathbf{y}\} \end{aligned} .$$

The measure of risk aversion is given by $\alpha(\cdot)$. Under DARA preferences, CRRA risk aversion – a special case of DARA – can be modelled as (Sckokai and Moro, 2006):

(3.9) $$\alpha(\cdot) = \alpha_R / \overline{W}$$

where α_R can be interpreted as a coefficient of constant relative risk aversion.[8] Risk aversion declines as expected wealth (i.e., $E[W]=\overline{W}$) increases in **(3.9)**. Note that an implicit, simplifying assumption in **(3.9)** is that variance of wealth (price risk) does not impact a producer's level of risk aversion. Substituting **(3.9)** into **(3.8)** gives the dual indirect utility function under CRRA preferences:

$$\begin{aligned} U^*(\bar{\mathbf{p}}, \mathbf{w}, \mathbf{V_p}, W_0) &= \{\max U(\mathbf{y}, \mathbf{x}) \\ &\equiv W_0 + \bar{\pi} - \frac{\alpha(\overline{W}, V_W)V_W}{2} \\ &= W_0 + \bar{\mathbf{p}}\mathbf{y} - \mathbf{w}\mathbf{x} - \frac{\alpha(\cdot)}{2}\mathbf{y}^T\mathbf{V}_p\mathbf{y} \\ &= W_0 + \bar{\mathbf{p}}\mathbf{y} - \mathbf{w}\mathbf{x} - \frac{\alpha_R}{2(W_0 + \bar{\mathbf{p}}\mathbf{y} - \mathbf{w}\mathbf{x})}\mathbf{y}^T\mathbf{V}_p\mathbf{y}\} \end{aligned} \tag{3.10}$$

The producer's dual indirect utility function (i.e., either **(3.8)** or **(3.10)**) depends on initial wealth, W_0, expected output prices, $\bar{\mathbf{p}}$, input prices, **w**, and output price variance, $\mathbf{V}_p$. This expression, as compared to **(3.4)**, permits DARA risk preferences but includes substantial nonlinearity in its formulation.

3.2.2.2 Properties

Following Proposition 2 in Coyle (1999), the following properties can be established: (i) if a producer has CRRA preferences (i.e., **(3.10)**), then the homogeneity property of U^* entails that $U^*(\lambda W_0, \lambda\bar{\mathbf{p}}, \lambda\mathbf{w}, \lambda^2\mathbf{V}_p) = \lambda U^*(W_0, \bar{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p)$ for $\lambda > 0$; (ii) under DARA **(3.8)** and **(3.10)** are quasi-convex in $\bar{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p$ and W_0; (iii) assuming that

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[8] See section 3.2.4.2 for additional discussion on this interpretation. In the empirical specification (section 3.4.1), the parameter α_R actually plays a slightly different role.

U^*, the dual expected utility function, is differentiable, then the following envelope relations hold:

(3.11) $$y_i^*\left(\bar{\mathbf{p}}, \mathbf{w}, \mathbf{V}_\mathbf{p}, W_0\right) = U^*_{\bar{p}_i} \big/ U^*_{W_0} \; ; \quad i = 1, \ldots, n$$

(3.12) $$-x_j^*\left(\bar{\mathbf{p}}, \mathbf{w}, \mathbf{V}_\mathbf{p}, W_0\right) = U^*_{w_j} \big/ U^*_{W_0} \; ; \quad j = 1, \ldots, m$$

(3.13) $$\partial U^* \big/ \partial W_0 = 1 + \frac{\alpha_R}{2\bar{W}^2} \mathbf{y}^T \mathbf{V}_p \mathbf{y} \; ;$$

and, (iv) the matrix of second-order derivatives is symmetric positive semi-definite in $\bar{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p$ and W_0. Property (iii) can be compared to Roy's Identity, where y_i^* and x_j^*, respectively, are output supplies and input demands – i.e., the functions to be estimated. This specific formulation places a restriction **(3.11)** however. It is assumed that variance of output prices is unaffected by a change in expected prices. This condition is required to enable the model to remain empirically tractable. As the focus of this study covers a short period of time, this assumption is mild. Property (iv) implies symmetry of the second-order partial derivatives with respect to $\bar{\mathbf{p}}$ and $\mathbf{w}$ hold via Young's Theorem (i.e., the cross-price derivatives of **(3.11)** and **(3.12)**). It must be noted that **(3.13)** only exists when the dual indirect utility function is specified as in **(3.10)**. Restricting preferences to CRRA, **(3.13)** is an important formulation of this model: previous research has required that preferences be restricted to CRRA to enable the estimated likelihood and objective functions to converge (Coyle, 1999; Sckokai and Moro, 2006). Proofs of these properties are found in Coyle (1999).

3.2.3 Comparative Statics

Several papers have presented the comparative static predictions of the mean-variance expected utility framework (e.g., Pope, 1980; Just and Zilberman, 1986; Robison and Barry, 1987). There are four comparative static predictions which are important in this chapter. The first three relate prices and risk levels to output supply and input demand decisions and are testable properties of the dual indirect utility function:

$$\partial y_j / \partial \overline{p}_j \geq 0$$

$$\partial y_j / \partial V_{p_{jj}} \leq 0$$

$$\partial x_i / \partial w_i \leq 0$$

while, the fourth, under the maintained hypothesis of non-increasing absolute risk aversion (i.e., CARA or DARA), links the output supply decision to risk preferences:

$$\partial y_j / \partial \alpha \leq 0 .$$

The empirical ramifications of these predictions are examined in section 3.5.

3.2.4 Incorporating Firm-specific Variables into the Models

Coyle (1992, 1999) does not address methods for incorporating exogenous variables into production theory. This sub-section provides this extension to the methodology.

Just and Pope (1999) suggests that many of the theoretical properties of risk neutral production models (i.e., homogeneity, curvature and symmetry) are rejected in empirical analysis due to heterogeneity across firms. A maintained hypothesis of most risk neutral production models is that distinct profit-maximizing firms, facing the same price conditions, will make identical output supply and factor demand decisions (assuming efficiency). Similarly, under price uncertainty, firm homogeneity with respect to risk preferences is often assumed (e.g., Coyle, 1992; Oude Lansink, 1999; Abdulkadri et al., 2006). The assumption of homogeneous risk preferences across firms is unnecessary however. It can be relaxed and formulated as a testable hypothesis. This research introduces two procedures which permit heterogeneous producer risk attitudes.

It is possible that firms may have differential risk preferences. Differential risk preferences suggest that two producers (i.e., risk averse producers), even with identical production conditions, may make different decisions. These differences are due to disparate aversions to risk. The issue then becomes whether firms grouped by some similar characteristic (e.g., experience of the primary operator) have similar levels of risk aversion. Manager- and firm-specific variables could be determinants of risk preference patterns.

Two methods are discussed for introducing exogenous variables into the dual production framework: risk translating and risk scaling (Pollak and Wales, 1978, 1981). As in demand analysis, several additional conditioning techniques are available (see Pollak and Wales, 1992). The focus of this research is on scaling, due to its intuitive appeal, and translating, due to its presence in the literature. It is hypothesized that additional explanatory variables may account for patterns of differential risk preferences and hence diverse economic decisions. While in consumer demand theory demographic translating and scaling can be generally incorporated into any system of equations, this is not the case for production models under risk. Risk scaling is a general procedure, however risk translating is not. The selection of scaling or translating depends on the specific functional form employed by the researcher. For example, the empirical formulation may explicitly include an estimable risk aversion parameter (e.g., as in **(3.5b))** or the analyst may be forced to calculate the implied level of risk aversion (e.g., as in **(3.5a)**). Risk translating, in the empirical CRRA models, does not have a straightforward "risk aversion" interpretation.

3.2.4.1 Risk Scaling

Let $m(z)$ be a modifying (scaling) function, where *z* are exogenous explanatory variables. Risk scaling applies this modifying function to the variance and covariances of output prices. The main difference between risk neutral and risk averse production theory is with respect to how producers treat risk. Risk is measured by variance of output price. The role of the modifying function is to scale this measure of risk (i.e., scale output price variance) by a set of firm- or manager-specific variables. This process adjusts output price variance, so it reflects the level of risk faced by "equivalent cow-calf operations" – i.e., equivalent production conditions. Consequently, this procedure can be thought of as treating risk for all firms as comparable while allowing the levels of risk aversion to vary. Output supply and input demand decisions are transformed from decisions under risk to decisions under risk per equivalent production unit. With this formulation, the risk aversion parameters must adjust to reflect the differential risk preferences of the manager.

To maintain tractability, only linear modifying functions are considered in this paper. Let the scaling function be:

(3.14) $$m(z) = 1 + \sum_{i=1}^{K} \phi_i z_i$$

where there are K exogenous variables included (e.g., experience and farm size) and ϕ are parameters to be estimated. Scaled output price variance, then, is given by:

$$\textbf{(3.15)} \qquad \mathbf{V}_p^* = \mathbf{V}_p \cdot m(z)$$

This approach adds, at most, $(n \times K)$ parameters to the system of output supply and input demand equations. The scaled variance, $\mathbf{V}_p^*$, can be incorporated into any of the above formulations.

3.2.4.2 Risk Translating

A form of risk translating was used in Sckokai and Moro (2006). Risk translating simply augments the estimated risk aversion parameter with a function of exogenous variables. That is, the risk aversion coefficient is translated by a function which depends on additional explanatory factors. Translating does not however imply that an intercept is shifted – risk coefficients enter the models nonlinearly. Translating refers to a shift in the risk aversion coefficient. This procedure is not general however. In the CARA formulation there is a single risk aversion coefficient with straightforward connotation. Interpreting the translating procedure for the CRRA model is less obvious. Previous literature has conveyed the CRRA risk aversion parameter, α_R, as capturing the full effect of a producer's preferences (Sckokai and Moro, 2006). This interpretation may misconstrue the role of α_R however. Risk preferences, in the empirical CRRA model, are not completely captured by this single parameter; other coefficients are required to calculate the risk premium. Rather the translating procedure reflects how additional variables alter the “wealth effect” of the CRRA model (Mas-Colell et al., 1995), not how *risk* affects the model.[9]

In general, greater confidence is placed on the results derived from the risk scaling method. Translating maintains some appeal for the nonlinear CARA model and, as mentioned, has been employed in the literature for the CRRA model (i.e., in Sckokai and Moro). For these reasons, the risk translating conditioning procedure is introduced and applied in this research. Yet, less confidence is placed in the CRRA models that employ this technique. Let:

(3.16) $$d(z)=\sum_{i=1}^{K}\varphi_i z_i$$

be the translating function, where φ_i are parameters to be estimated.

First, consider the CARA case. Assume that the analyst specified her output supply function as in **(3.5b)**. To include exogenous factors using translating, simply specify the risk aversion parameter as:

(3.17) $$\alpha^* = \alpha_0 + d(z) = \alpha_0 + \sum_{i=1}^{K}\varphi_i z_i$$

where α^* is the modified CARA coefficient. Incorporating the translating function **(3.17)** into **(3.5b)** then gives the following output supply function:

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[9] This can be seen by examining **(3.11)** and **(3.13)**. Assume preferences are restricted to CRRA and replace with denominator in **(3.11)** with **(3.13)**. If α_R is set to zero – i.e., wealth does not play a role in production decisions – the problem reduces to the CARA model. In other words, the producer can still have a non-zero risk production premium, so α_R does not fully capture risk aversion.

(3.18)

$$\begin{aligned} y_j^* &= -\left(1/\alpha^*\right)\frac{U^*_{\bar{p}_j V_{p_{jj}}}}{U^*_{\bar{p}_j \bar{p}_j}} \\ &= -\left(\frac{1}{\alpha_0 + \sum \varphi_i z_i}\right)\frac{U^*_{\bar{p}_j V_{p_{jj}}}}{U^*_{\bar{p}_j \bar{p}_j}}; \quad \mathrm{j} = 1, \ldots, \mathrm{n} \end{aligned} .$$

This translating procedure cannot be applied if the output supply equation is specified as in **(3.5a)**.

Next, consider DARA preferences. In this instance, specify the output supply as in **(3.11)** and the input demand as in **(3.12)**. Let the denominator be as in **(3.13)** however. Replacing the denominator of **(3.11)** and **(3.12)** with **(3.13)** is suggested by Coyle (1999) and employed by Sckokai and Moro (2006). These output supply and input demand functions restrict risk preferences to being CRRA. Similar to **(3.17)**, α_R,can be translated via **(3.16)**, taking the form:

(3.19) $$\alpha_R^* = \alpha_0 + d(z) = \alpha_0 + \sum_{i=1}^{K} \varphi_i z_i .$$

Finally, **(3.19)** is then inserted into the alternative specifications of **(3.11)** and **(3.12)**. The parameter α_R^* is interpreted in this chapter as a pseudo-relative risk aversion coefficient, as it does not fully capture the risk preferences of producers. Both translating procedures incorporate, at most, $(n \times K)$ additional parameters into the system.

Risk scaling and translating allow for the inclusion of exogenous explanatory variables into production models. These additional variables and conditioning procedures permit greater understanding of the patterns of differential risk preferences across a sample of farms.

3.3 RELATED LITERATURE

There is a vast production economics literature on the implications of risk and uncertainty. This chapter however is only interested in duality-based models that integrate uncertainty and testable (or imposable) conditions from economic theory (e.g., homogeneity, symmetry, curvature). For reviews of the general literature on risk in production economics, see Moschini and Hennessy (2001) and Robison and Barry (1987).

3.3.1 Recent Theoretical Literature on Duality under Uncertainty

This research expands on the framework developed by Coyle (1992, 1999). The Coyle approach is selected as it is amenable to empirically assessing multi-output, multi-input firms under price uncertainty. It contains important refutable economic theoretic hypotheses which apply to dual models with risk as well as with certainty (Shumway, 1995). Saha (1997) derives similar conditions and shows that ignoring risk may yield over-estimates of output supply and input demand elasticities. Importantly, the Coyle methodology allows for the simultaneous examination of risk attitudes and price uncertainty.

Other recent research examining production risk within a duality framework includes Appelbaum and Ullah (1997) and Alghalith (2001). Appelbaum and Ullah studies the effects of higher moments of the output price distribution on production decisions. It employs a framework which is similar to Coyle’s DARA model, but replaces initial wealth with fixed costs. Alghalith presents results for a firm facing both price and output uncertainty. It extends results of Dalal (1990) in an effort to reduce the “complexity” of empirically modelling firms under uncertainty. Comparing how different specifications of output uncertainty affect a firm's decision, Alghalith's approach shows promise for empirical research where both price and output risks are significant. Both studies highlight the dearth of empirical research into the repercussions of uncertainty on firm behaviour.

3.3.2 Empirical Applications of the Coyle Framework

Coyle's duality approach has received limited application in the agricultural economics literature. Oude Landsink (1999) is the initial paper to empirically employ this framework. For a sample of Dutch farms, it investigates crop-area allocations with CARA and a nonlinear mean-variance model. The stated purpose of the article is to test curvature conditions under risk (i.e., the second-order conditions of the dual indirect utility function). These conditions are rejected. Even so, a model, which is restricted to ensure convexity in prices, finds that Dutch farmer have a low degree of risk aversion with a risk premium of approximately 3 percent.

Abdulkadri et al. (2006) uses a nonlinear CARA model to assess how price uncertainty and risk aversion modifies the measurement of economies of scale and scope. The analysis examines, over a five-year period (1995-1999), farm-level data on joint wheat and beef-cow enterprises in Kansas. It finds that "estimates . . . may be significantly altered when risk and risk aversion are ignored" (pg. 192). Not accounting for risk leads to over-estimation of product-specific economies of scale and under-estimation of both economies of scope and multi-product economies of scale. Abdulkadri et al. also claims that the results which incorporate risk are more reliable than conventional estimates.

Sckokai and Moro (2006), while allowing for risk aversion, scrutinize the European Union's Common Agricultural Policy Framework with respect to farming. Employing a nonlinear model with initial wealth, it models price uncertainty under CRRA. In its empirical application, Sckokai and Moro test the hypothesis that the CRRA coefficient (pseudo-relative risk aversion coefficient) may depend on farm size (small, medium, large), effectively using the translating procedure described above. Italian data demonstrate that risk preferences play a major role in farmer decision-making. Moreover, the pseudo-relative risk aversion coefficient declines with farm size, virtually becoming zero for large farms. "This means that wealthier farmers are intrinsically more willing to bear risk" (pg. 50).

The literature review and preceding theory section underline two gaps in the literature. First, there are few empirical applications of the duality under uncertainty approach – particularly, within a Canadian context. Empirical evidence on Albertan cow-calf producers, especially during the period of the BSE crisis, should produce new insights into economic behaviour. Next, including exogenous explanatory variables has only been completed in a single instance; even then, it is only applied to the special case of risk translating and CRRA preferences. The conditioning procedures address this gap. The three hypotheses relating firm- and manager-specific variables to risk attitudes initiate a new research direction for production economics.

3.4 EMPIRICAL SPECIFICATIONS

This research is chiefly interested in assessing four empirical hypotheses: farmers are risk averse, experience breeds confidence, BSE increased aversion to risk, and risk tolerance. The theory and related literature sections highlighted how these hypotheses contribute to the production economics literature. The empirical models and data that are employed to test these hypotheses are introduced next.

3.4.1 Empirical Models: Quadratic Approximations

The dual expected utility function must be specified in two different fashions to accommodate both the risk scaling and risk translating methods. First, the empirical model that incorporates scaling for CARA, CRRA and DARA preferences is presented. The same functional form, shown after the scaling models, can integrate translating for CRRA preferences. Finally, the translating formulation for the CARA model is given. To employ the translating approach in this model, a different form of the dual expected utility function is needed.

Let the dual expected utility function (**(3.4)**, **(3.8)** or **(3.10)**) be a generalized quadratic (Chambers, 1989). Sckokai and Moro (2006) and Coyle (1999) also use this functional form. This specification accommodates the scaling method and translating under the assumption of CRRA. The quadratic allows for negative profits and has a Hessian matrix of constants, so curvature properties hold globally. Its general form is given by:

$$\textbf{(3.20)} \qquad U^* = a_0 + \mathbf{a}\overline{\mathbf{q}} + \overline{\mathbf{q}}\mathbf{A}\overline{\mathbf{q}}$$

where **a** and **A**, respectively, are a vector and matrix of estimable coefficients and $\overline{\mathbf{q}}$ represents the variables (e.g., $\overline{\mathbf{q}}^{CARA} = \left(\overline{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p^*\right)$ and $\overline{\mathbf{q}}^{DARA} = \left(\overline{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p^*, W_0\right)$). Under the CARA assumption with the scaling procedure, $\overline{\mathbf{q}}^{CARA} = \left(\overline{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p^*\right)$ and the output supply and input demand equations take the form:

(3.21) $$y_i^* = \beta_i + \sum_j \beta_{ij} \overline{q}_j^{CARA}$$

(3.22) $$-x_h^* = \gamma_h + \sum_j \gamma_{hj} \overline{q}_j^{CARA}$$.

These correspond to **(3.5a)** and **(3.6)**. Assuming DARA preferences, $\overline{\mathbf{q}}^{DARA} = \left(\overline{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p^*, W_0\right)$ and the corresponding output supply and input demand formulations are:

(3.23) $$y_i^* = \left(\beta_j + \sum_j \beta_{ij} \overline{q}_j^{DARA}\right) \Big/ \left(\alpha_k + \sum_j \alpha_{kj} \overline{q}_j^{DARA}\right)$$

(3.24) $$x_h^* = -\left(\gamma_h + \sum_j \gamma_{hj} \overline{q}_j^{DARA}\right) \Big/ \left(\alpha_k + \sum_j \alpha_{kj} \overline{q}_j^{DARA}\right)$$

which agree with **(3.11)** and **(3.12)**. If aversion to risk is restricted to be CRRA preferences, then the translating procedure can be incorporated into the output supply and input demand equations as ($\overline{\mathbf{q}}^{DARA} = \left(\overline{\mathbf{p}}, \mathbf{w}, \mathbf{V}_p, W_0\right)$):

(3.25) $$y_i^* = \left(\beta_j + \sum_j \beta_{ij} \overline{q}_j^{DARA}\right) \Big/ \left(1 + \frac{\alpha_R^*}{2\overline{W}^2} \mathbf{y}^T \mathbf{V}_p \mathbf{y}\right)$$

(3.26) $$x_h^* = -\left(\gamma_h + \sum_j \gamma_{hj} \overline{q}_j^{DARA}\right) \Big/ \left(1 + \frac{\alpha_R^*}{2\overline{W}^2} \mathbf{y}^T \mathbf{V}_p \mathbf{y}\right)$$

where $\alpha, \beta \, \text{and} \, \gamma$ are parameters to estimated – i.e., the elements of **a** and **A**. The denominators of **(3.23)** and **(3.24)** are replaced with **(3.13)**, giving **(3.25)** and **(3.26)**.

To use risk translating with CARA preferences, an alternative specification is required. Let the dual utility function be given by:

(3.27) $$U^* = \overline{\mathbf{p}}\mathbf{y} - C\left(\mathbf{y}^*, \mathbf{w}\right) - \frac{\alpha}{2} \mathbf{y}^T \mathbf{V}_p \mathbf{y}$$

where $C(\mathbf{y}^*, \mathbf{w})$, the dual cost function, is assumed to be generalized quadratic. In this case, the output supply equation that corresponds to **(3.21)** is (Oude Lansink, 1999; Abdulkadri et al., 2006):

(3.28)
$$y_i^* = \frac{1}{\alpha^* \operatorname{var} p_i + \beta_{ii}} \left(\overline{p}_i - \beta_i - \sum_j \beta_{ij} y_j - \sum_j \gamma_{ij} w_j - \alpha^* \sum_j y_j \operatorname{cov} p_{ij} \right)$$

while the input demand equation which matches **(3.22)** is:

(3.29)
$$-x_h^* = \gamma_h + \sum_j \gamma_{hj} w_j + \sum_j \beta_{hj} y_j \ .$$

Each empirical formulation contains two output supply equations, calves and cull cows, and three input demand equations, capital, materials and feed. All output and input prices are divided by the price of labour. The variance and covariance terms are normalized according to property (ii) for the CARA models and property (i) for the CRRA formulations. This normalization imposes linear homogeneity on the dual expected utility functions. Cross-price derivatives are restricted to be symmetric – i.e. $\alpha_{kj} = \alpha_{jk,}\, \beta_{ih} = \beta_{hi}$ and $\gamma_{ji} = \gamma_{ij}$. Firm- and manager-specific effects are included in these models by using **(3.15)** for scaling, **(3.18)** for translating in the CARA model and **(3.19)** for translating in the CRRA model. These procedures incorporate additional parameters into these systems of equations. A chief testable hypothesis is whether the parameterized models display risk neutrality. Risk neutrality implies that all of the coefficients on the variance-covariance terms equal zero for **(3.21)**, **(3.22)**, **(3.23)** and **(3.24)**. Similarly, if the risk aversion parameter (i.e., α or α^*) equals zero in **(3.28)**, then the hypothesis of risk aversion is rejected.

It should be made clear that this empirical formulation has a maintained hypothesis of constant risk perceptions. Risk preference parameters adjust to accommodate the changes in production decisions, yet risk perceptions remain fixed. This assumption is made to ensure the tractability of the empirical models as the number of permutations of alternative risk perception models is large. Just (2008) argues that it is not feasible to jointly identify risk preferences and risk perceptions. It warns that the assumption of fixed perceptions should not be used to measure welfare changes for normative and policy purposes. This chapter focuses on four positive hypotheses however and the assumption of fixed risk perceptions does not pose a substantial problem. Nonetheless, there is one exception where invoking this assumption is questionable. It is discussed at that point (section 3.5.3).

3.4.2 Elasticity and Risk Aversion Coefficient Calculations

Using the coefficients from **(3.21)-(3.24)**, the own- and cross-price elasticities of output supply and input demand are given by:

(3.30)
$$\varepsilon_{ij} = \frac{\partial g_i}{\partial \bar{q}_j} \cdot \frac{\bar{q}_j}{g_i}; \quad \forall i, j$$

where $g = \left(\mathbf{y}^*, \mathbf{x}^*\right)$ and $\bar{\mathbf{q}}$ represents the variables. These elasticities are evaluated at the sample means. They are also used to compute selected Morishima elasticities of substitution (MES). The MES "(i) *is* a measure of curvature, or ease of substitution, (ii) *is* a sufficient statistic for assessing – quantitatively as well as qualitatively – the effects of changes in price or quantity ratios on relative factor share, and (iii) *is* a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio" (Blackorby and Russell, 1989, pg. 883, *emphasis* in original). The formula for the MES is (Wohlgenant, 2001):

(3.31)
$$M_{ij} = \varepsilon_{ij} - \varepsilon_{jj}$$

where ε_{ij} is the price elasticity of demand for the *i*th factor with respect to the *j*th factor, and ε_{jj} is a typical (Marshallian) own-price elasticity of demand. An MES is interpreted as the effect of a 1 percent change in the optimal input ratio x_i / x_j, allowing only the *j*th price to vary (Wohlgenant, 2001). As only a single price is changing, these elasticities are “inherently asymmetric” (Blackorby and Russell, 1989; pg. 885).

CRRA risk aversion coefficients are normalized by decision-maker wealth, unlike their CARA counterparts, and are more comparable across studies (Babcock et al., 1993). Calculating CRRA coefficients for the CARA models is useful for comparison with the literature. Using **(3.4)**, a CARA coefficient is computed as:

(3.32) $$\alpha^{CARA} = \frac{2(\hat{U} - \hat{\pi})}{-V_{\pi}} = \frac{2(\hat{U} - \hat{\pi})}{-y^T V_p y}$$

where a hat (“^”) indicates the predicted utility and profit level. Constant relative risk averse and constant absolute risk averse coefficients are connected via the identity (**(3.9)**):

(3.33) $$\alpha^{CRRA} = \hat{W} \cdot \alpha^{CARA}.$$

Information on initial wealth is available in this study. If these data do not exist, this calculation would not be possible.[10] It should be emphasized that this is an *ex post* calculation of the CRRA coefficients from the CARA models. The CRRA coefficients derived from the CARA models are not estimated parameters –wealth is not a component of the estimating equation. Moreover, the CARA and CRRA coefficients along with the risk premiums do not directly correspond to each other. They are derived from

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[10] Estimation of a DARA or CRRA would also not be possible.

fundamentally different models. It may even be the case that one model, say the CRRA, has a lower risk premium but a higher CRRA coefficient than an alternative formulation.

3.4.3 Estimation Methods

3.4.3.1 Output Price Equations: Expectations and Variances

Producers' price expectations are a key component of this research. Based on past prices, producers are assumed to form their best statistical forecast of the next period's prices. Cattle prices are assumed to follow a discrete stochastic process. Estimation of the statistical properties of this process is required to determine a price forecasting model and establish a model of producer price expectations.

Previous research has simply assumed a price expectation model. Oude Lansink (1999) and Abdulkadri et al. (2006) estimate an autoregressive price model, whereas Coyle (1992) uses a naive expectations model. To contrast, this chapter ensures that the model selected is statistically appropriate. Output price data for the prices for weaned steers, weaned heifers and cull cows are tested for stationarity.[11] If the stochastic process satisfies the conditions for covariance stationarity (Judge et al., 1985), then the price expectation model should be represented by an autoregressive price process – i.e., the autoregressive model is a statistically appropriate forecast of future cattle prices. If the price series are found to be non-stationary, then prices follow a random walk and a naive expectations model is a producer's best forecast of future prices.

Prices differ across the province, so three price series, representing the northern, central and southern regions of Alberta, are used for steers and heifers. Only province-

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[11] The price data used in chapters 3 and 4 are from different sources. As result, one should not expect *a priori* the series to have identical properties.

wide cull cow prices are available however. Data are from Canfax (1996-2006). The most common form of non-stationarity is due to unit roots. Statistical tests for unit roots include the Augmented Dickey Fuller (ADF) (Dickey and Fuller, 1981) and the Kwiatkowski, Phillips, Schmidt and Shin (1992) (KPSS) test. The ADF and KPSS statistics, when tested separately, are generally considered weak (Verbeek, 2004). Considered together however these tests provide more robust evidence of whether a price series is stationary.

The ADF tests have null and alternative hypotheses of:

$$\begin{aligned} &H_0 : \text{non-stationarity due to unit root} \\ &H_1 : \text{stationarity} \end{aligned}$$

These tests require substantial evidence supporting stationarity to reject the null. Inability to reject the null hypothesis could be due to insufficient information in the data rather than a true unit root. This test is based on a t-test, but critical values do not follow a standard t-distribution.

A KPSS (Kwiatkowski et al., 1992) test – where $KPSS = N^{-2} \cdot \sum_{t=1}^{N} S_t^2 \Big/ \hat{\sigma}^2$, $S_t = \sum_{j=1}^{t} e_j$ are the partial sums of the errors (e_j are the errors of a regression of the price on a time-trend and a constant (or just a constant for a no trend test)), $\hat{\sigma}^2$ is the Newey-West corrected the error variance of the regression and *N*, the number observations, is used to normalize the statistic – has a null hypothesis of stationarity:

$$\begin{aligned} &H_0 : \text{stationarity} \\ &H_1 : \text{non-stationarity} \end{aligned}$$

This test is based on a Lagrange Multiplier test, but does not have a standard chi-squared distribution.

Table 3.1 provides the test statistics and critical values for steer and cull cow monthly price data. Tests were also run for heifers as well as at the weekly and annual levels. All series are non-stationary. Thus using an autoregressive forecast as a price expectation model is inappropriate.

Table 3.1: Test Statistics for Monthly Albertan Cull Cow and Steer Prices, 1996-2005

	Cull Cows	Steers Southern Alberta	 Central Alberta	 Northern Alberta	5% Critical Value
ADF test					
Trend	-1.838	-1.786	-2.464	-1.643	-3.410
No Trend	-1.371	-1.671	-2.582	-1.510	-2.860
KPSS test					
Trend	1.945	1.919	2.026	1.938	0.146
No Trend	4.706	3.361	3.124	3.390	0.463

Cattle prices – cull cows, steers and heifers – follow a random walk. Therefore, producers' price expectations for cull cows and calves take the form:

(3.34)
$$\begin{aligned} \overline{p}_t^{cull} &= Ep_t^{cull} = p_{t-1}^{cull} \\ \overline{p}_t^{calf} &= Ep_t^{calf} = p_{t-1}^{calf} \end{aligned}$$

There is only a single calf price presented as the dataset contains composite weaned calf output – i.e., heifer and steer prices are combined (see the description of the data below).

Variance and covariance values are calculated using the approach of Chavas and Holt (1990). This method is employed by Sckokai and Moro (2006), Abdulkadri et al. (2006), Oude Lansink (1999) and Coyle (1999). Variances and covariances are calculated according to:

(3.35a)
$$\mathrm{var}(p_{i,t}) = \sum_{j=1}^{3} \omega_j \left[p_{i,t-j} - E_{t-j-1}(p_{i,t-j})\right]^2$$

(3.35b)
$$\mathrm{cov}(p_{i,t}, p_{k,t}) = \sum_{j=1}^{3} \omega_j \left[p_{i,t-j} - E_{t-j-1}(p_{i,t-j})\right] \times \left[p_{k,t-j} - E_{t-j-1}(p_{k,t-j})\right]$$

where ω_j, the weights, equal 0.50, 0.33 and 0.17 (Chavas and Holt, 1990). Expected prices in the variance and covariance calculations are from **(3.34)**. These calculations require three successive years of price data. As in Sckokai and Moro (2006), if an observation had missing on-farm price data for any year, the average regional price was used – i.e., if the cow-calf operation was located in the Northern part of the province, the variance and covariance was calculated with the Northern Albertan price.

It should be noted that the term variance is used only to maintain consistency with the theoretical models presented in section 3.2. A more accurate term to describe **(3.35a)** and **(3.35b)** may be price variability. The reason for this is that prices are non-stationary and variances do not exist for non-stationary distributions. An extension to this research is to investigate how different risk assessment models (e.g., alternatives to **(3.35a)** and **(3.35b)**) affect the risk premium results.

3.4.3.2 Estimation and Testing Procedures for Models

Previous attempts to elicit risk aversion from observed data have used several procedures to estimate model parameters. Coyle (1992, 1999) employed seemingly unrelated regression (SUR) and three-stage nonlinear least squares (3SNLS) techniques. Abdulkadri et al. (2006) used nonlinear regression and maximum likelihood techniques. Oude Lansink (1999) and Sckokai and Moro (2006) estimated parameters via full information maximum likelihood (FIML) methods.

The estimation of the nonlinear simultaneous equation models requires several comments. For this class of models, Amemiya (1985) presents an extensive discussion of the merits of the 3SNLS and FIML estimation procedures. There are three points to note. First, there is no guarantee that a unique solution exists for a system of nonlinear equations unless several stringent assumptions are made on the form of the estimating equations and the density of the error terms. To avoid the problem of local minima, sensitivity analysis is performed on the “starting values” of each model’s optimization procedure. In most cases, identical parameter estimates are found. In the exceptional cases, where there is sensitivity to starting values, the results presented are those for which confidence is highest. Next, the likelihood function in FIML is the product of the error term’s density and the Jacobian. This implies that, if the errors are not distributed jointly normal, then the resulting parameters estimates *may not* be consistent. 3SNLS and FIML are asymptotically equivalent under normal residuals. Even if the errors are not normally distributed however, FIML may still be asymptotically efficient. The advantage of 3SNLS over FIML is that the estimates are consistent even when the disturbances are non-normally distributed. In fact, 3SNLS retains consistency regardless of whether or not there are multiple solutions (Amemiya, 1985). Still, 3SNLS procedures require selection of a set of instrumental variables. Due to limited data, most variables must act as their own instruments, implying that coefficient estimates may be biased. There is a robustness-efficiency-biasedness trade-off between the two estimation methods (FIML and 3SNLS): FIML achieves higher efficiency, while 3SNLS generates consistent but potentially biased estimates. The final point is that, even when the errors are normally distributed, “the [3SNLS] and FIML estimates are usually quite different numerically” (Greene, 2003, pg. 409). Ultimately, FIML is a fully specified data generating process and is the preferred approach in this research. The results presented in section three employ this estimation method under the assumption that the error terms are normally distributed.

Five equations are estimated, two output supplies and three input demands. These equations are given in **(3.21)-(3.26)** and **(3.28)-(3.29)**. In each case, two-stage least squares is exploited to determine the initial starting values for the optimization algorithms of the likelihood functions – as stated, sensitivity analysis is performed around these starting values in an attempt to ensure robust estimates for the nonlinear models.

Many of the research hypotheses of this paper can be formulated as nested statistical tests. Likelihood ratio (LR) tests are used for all FIML results (Greene, 2003; Davidson and MacKinnon, 2004). Tests of the FIML results are "checked" using different statistics and alternative estimation procedures (SUR and 3SNLS). For the linear CARA models, when parameters are estimated using the SUR method, Wald statistics are used (Greene, 2003). Tests of hypotheses for the 3SNLS model are formulated as quasi-likelihood ratio (QLR) tests (Gallant and Jorgenson, 1979; Amemiya, 1985) – i.e., $QLR = n(Q_0 - Q_1)$, where n is the number of observations, Q_0 is the value of the minimum distance function for the unrestricted model and Q_1 is the value for the restricted model. In general, the checks either agreed with the results of the LR test or the model, estimated via the alternative procedure, would not converge to reliable estimates. Little insight is gained from these supplementary models and tests, so they are not discussed further.

3.4.4 Data

3.4.4.1 Farm-level Data

The Government of Alberta's Department of Agriculture and Rural Development collects and organizes data from an annual farm survey (AARD, 1996-2005). This farm survey, known as AgriProfit$, contains detailed farm-level cow-calf information. It is an unbalanced panel dataset which includes income statements, balance sheets, production data – e.g., output and input quantities, conception rates, number of cows-wintered, acres farmed, etc. – and additional personal explanatory variables – e.g., age and experience of the primary farmer. Information is available for ten years, 1996 to 2005. While many firms are involved in both livestock and crop enterprises, the cow-calf information was adjusted for and separated from the crop information prior to obtaining the data. This adjustment implicitly assumes that there is no joint production between crops and cattle. A subset of these data, for the years 1996 to 2002, was also used in Samarajeewa (2007) to examine relative efficiencies of Albertan cow-calf enterprises.

Farmers are assumed to form price expectations according to **(3.34).** Only operations that have at least two consecutive observations are used. This is the minimal requirement for generating the price expectations at the farm-level. There are 173 observations across 81 firms. Firm-specific observations are often not in sequence – for example, a farm may have a datapoint for 1998 and then not reappear until 2004. Due to the high number of parameters in the model and unbalanced nature of the panel, firm-specific fixed effects are not used. A true fixed-effects panel model would require too many degrees of freedom. Rather than firm-specific fixed effects, dummy variables were employed to capture other “group effects” (Davidson and MacKinnon, 2004) – namely, provincial region (Northern, Central or Southern Alberta) and soil type (Brown, Black or Grey). Upon testing however, these group effects were not found to be statistically significant and are excluded from the models. A time trend is included as it was found to be statistically significant for most models.

3.4.4.2 Output Data

Pounds of weaned calves and cull cows sold are the two outputs in this research. For both outputs, the dataset contains these values as physical quantities. It does not differentiate between steers and heifers, however – weaned calves are treated uniformly. As in Samarajeewa (2007), feeder calves and bulls are not considered as they comprise a small share of output value. This assumption is not viewed as restrictive: in each year, the combined value of weaned calves and cull cows production comprise greater than an 88 percent share of total cattle production value. Per pound prices unique to each farm for the outputs are also retrieved from the AgriProfit$ data. These are farm-specific and represent annual averages. All prices are multiplied by 100 and treated as hundred weight (cwt) prices. Price expectations, variances and covariances are calculated via **(3.34)**, **(3.35a)** and **(3.35b)**.

3.4.4.3 Input Data

Inputs are grouped into four categories: feed, labour, capital and materials. These categories were employed by Adamowicz (1986) and Stewart (2006). Table 3.2 lists the disaggregated inputs which comprise each category.

Feed costs strongly influence cow-calf enterprises. Feed consists of winter feed, bedding and pasture. Physical quantities of each component are available in the data. Quantities were aggregated using a Divisia value-weighted index procedure (Coelli et al., 1998). The total dollar value of winter feed, pasture and bedding was then divided by the quantity to obtain the implicit on-farm per unit price of feed.

Table 3.2: Categories of Input Aggregation

Variable Name	
Feed	Winter feed
	Bedding
	Pasture
Labour	Hired labour
	Unpaid Labour
Capital	Machinery and equipment
	Repairs – machine
	Repairs – corrals and buildings
	Equipment and buildings – depreciation
	Paid capital interest
Materials	Fuel
	Veterinary and medicine
	Breeding fees/bull rental
	Taxes, water rates, licencing and Insurance
	Trucking and marketing charges
	Utilities and miscellaneous expenses

Materials, often called supplies and services, consist of expenditures on veterinary services, breeding, trucking, fuel, utilities and taxes. Annual quantities were derived as in Sckokai and Moro (2006) by using a Divisia index and aggregate price indices for each component of the input. These indices, representing Albertan farms, were retrieved from Statistics Canada's (1996-2006a) Farm Price Index publication. Once a quantity of "materials" was determined, then the summed farm-level value of materials was divided by the quantity to obtain the price of materials.

The components of capital include machinery depreciation and repairs and building depreciation. Enterprise-specific quantities and prices of capital, similar to the materials input, were calculated using the Divisia index procedure. Livestock inventory is not treated as an element of capital.

Total quantity of labour is measured in hours and is comprised of hired labour plus family labour. The price of labour is calculated as a weighted average of the hourly price of hired and family labour. The hourly price of hired labour is provided in the AgriProfit$ data. Family labour is assumed to be remunerated at its opportunity cost, where the opportunity cost of labour is taken to be the median hourly wage in Alberta. Data on Alberta's median hourly wage is from Statistics Canada (1996-2006b). These data are divided into two age brackets, 18 to 54 years and 54 years and older. The owner of the enterprise was assumed to be the primary supplier of family labour, thus the opportunity cost of labour was based on her reported age. This procedure assumes that age-adjusted family labour has a fixed quality, which may not be true. Other quality issues are not discussed for practical reasons.

3.4.4.4 Producer Wealth

The AgriProfit$ dataset contains financial statements for each observation. Farm balance sheet equity is used to proxy producer wealth. While farm balance sheet equity is believed to comprise the largest share of farmer wealth, it likely underestimates producers' actual wealth. Two factors must be mentioned. First, medium- and long-term assets, most notably land and buildings, are not usually documented at their fair market value in financial statements. Often the recorded value of these assets is less than would be received upon their sale – this is particularly important for land values in Alberta (see Schaufele et al., 2009). Second, a farmers' portfolio may include additional assets (e.g., nonfarm pensions and investments) which would not be listed on their farm balance sheets. Due to these two factors – i.e., non-fair market valuation of farm assets and extra-farm portfolios – farm equity is an underestimate of producer wealth.

The implication of using an underestimate of producer wealth in the models is that the risk aversion levels estimated from the CRRA models will over-estimate actual aversion to risk. Expected wealth normalizes the production response. Larger expected wealth yields a smaller production response. Risk premiums calculated using farm equity as a proxy for producer wealth must be considered an upper bound estimate of producers' level of risk aversion.[12]

3.4.4.5 Additional Information

The dataset contains several additional variables which are used in the risk aversion conditioning procedures. This information, needed to test three of the research hypotheses, includes experience and age data as well as leverage and current ratios. Dummy variables are used to represent the BSE crisis. The BSE dummies take the value of one for all years 2003 and after. Means, minimums, maximums and standard deviations for all data are in Appendix 3A, Table 3A.1.

3.5 RESULTS AND DISCUSSION

A duality based approach is used to examine the combined influence of price uncertainty and observed risk preferences in cow-calf production decisions. The underlying premise is that a firm's profit maximization goal is modified in response to the decision-maker's attitudes towards risk. Four research hypotheses are investigated:

a. Farmers are risk averse;

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[12] A terminological distinction must be made between the concepts of balance sheet equity and economic equity. This chapter uses the term equity to denote balance sheet equity – i.e., equity is the residual that completes the accounting identity: Total Assets = Total Liabilities + Firm Equity – whereas economic equity refers to a set of concepts related to the equality of the distribution of economic benefits and costs. Economic equity is discussed in Chapter 4.

b. Experience breeds confidence;

c. BSE increased aversion to risk; and,

d. Risk tolerance.

These are empirical conjectures: economic theory does not make any predictions with respect to these hypotheses.

Each hypothesis is discussed in sequence. This is followed by an examination of the comparative statics and elasticities of the base models. Models are referred to by their preference structure and a Roman numeral. Table 3.3 lists the models, conditioning procedures and the associated research hypotheses. CARA I and CRRA I are considered the base models as they do not include any conditioning variables.

No DARA models are listed in Table 3.3. Coyle (1999) and Sckokai and Moro (2006) found that these models would not converge. Coyle used 3SNLS methods, while Sckokai and Moro employed FIML estimation techniques. Similar problems exist in this research. After extensive effort, it was determined that these models would not converge

Table 3.3: Summary of Models and Hypotheses

Model	Conditioning Procedure	Research Hypothesis
CARA I	Base Model	Farmers are Risk Averse
CRRA I	Base Model	Farmers are Risk Averse
CARA II	Risk Scaling	Experience Breeds Confidence
CRRA II	Risk Scaling	Experience Breeds Confidence
CARA III	Risk Translating	Experience Breeds Confidence
CRRA III	Risk Translating	Experience Breeds Confidence
CARA IV	Risk Scaling	BSE Increased Aversion to Risk
CRRA IV	Risk Scaling	BSE Increased Aversion to Risk
CARA V	Risk Translating	BSE Increased Aversion to Risk
CRRA V	Risk Translating	BSE Increased Aversion to Risk
CARA VI	Risk Scaling	Risk Tolerance
CRRA VI	Risk Scaling	Risk Tolerance
CARA VII	Risk Translating	Risk Tolerance
CRRA VII	Risk Translating	Risk Tolerance

to stable estimates. Analysis therefore concentrates on the CARA and CRRA preference structures.

Parameter values and t-statistics for the base models are given in Appendix 3B, Table 3B.1. Statistical significance of individual parameters is not the main focus of this study. Factors related to risk aversion within fully specified models are more relevant – i.e., the changes in observed risk preferences and risk premiums. Nonetheless, several comments are mandated. In terms of individual parameter statistical significance, the translating CARA models tend to outperform the scaling CARA, while the scaling CRRA procedure outperforms the translating CRRA – i.e., there are more individually statistically significant parameters in the translating CARA and scaling CRRA models relative to the scaling CARA and translating CRRA models respectively. In general, the statistical significance of the models' parameters is lower than in previous research (e.g., Abdulkadri et al., 2006; Sckokai and Moro, 2006). The data transformations employed in these studies are the likely explanations for this outcome. This paper's analysis is based on farm-level data and statistically accurate price expectation models. Abdulkadri et al. use an autoregressive price expectation model, but do not test whether it is a statistically appropriate formulation. Sckokai and Moro take regional prices as proxies for farm-level prices. These two tactics enhance statistical significance of model parameters while sacrificing farm-level accuracy.

3.5.1 Hypothesis 1: Farmers are Risk Averse

The first research hypothesis is known as farmers are risk averse. It states that production models which include risk aversion have a statistically significantly better fit of the data than risk neutral models. Results from Oude Lansink (1999), Abdulkadri et al. (2006) and Sckokai and Moro (2006) support models which include risk aversion parameters. This conjecture is evaluated via a nested likelihood ratio test for the base models, CARA I and CRRA I. Average risk premiums as a percent of expected utility (profit) and CRRA coefficients are also calculated.

Table 3.4 presents the results of a test of a null hypothesis of risk neutrality. At a five percent level of significance, the null is rejected. Incorporating risk aversion statistically improves upon a model which omits this information. Consequently, the first research hypothesis of this paper cannot be rejected: risk aversion is supported by the base models.

Table 3.4: Farmers are Risk Averse – Test of the Null of Risk Neutrality

Model	Statistic	p-value
CARA I	30.378	0.011
CRRA I	30.272	0.017

The next step is to calculate the unconditional risk premium for cow-calf producers. Risk may be viewed as an additional cost in the certainty equivalent formulation of the firm's maximization goal. The risk premium is the value that leaves a producer indifferent between the certainty equivalent and risky outcomes. Risk premiums are presented in Table 3.5. The CARA I model has a risk premium of 11.25 percent calculated at the data means. With CRRA preferences, the average observed risk premium is 10.72 percent. The only paper in the literature to calculate risk premiums, after estimating a similar dual production model, is Oude Lansink (1999). It found a risk premium of approximately 3 percent of annual profit. The CARA I and CRRA I premiums for Albertan cow-calf producers are higher. However, Oude Lansink estimated a CARA model with alternative specification – a formulation that is used in the

CARA translating models below. As is seen in the discussion of hypotheses two through four, the CARA translating model predicts lower levels of risk aversion.

Table 3.5: Calculated Risk Premiums for Base Models[a]

Model	Risk Premium
CARA I	11.25%
CRRA I	10.72%

a. Values are calculated at the means of the data

The risk premiums in Table 3.5 imply CRRA coefficients of 0.274 for the CARA I model and 0.798 for the CRRA I model. Hardaker et al. (2004) classify levels of risk aversion by the magnitude of relative risk aversion coefficients. It lists five categories of risk preference (pg.109):

- $\alpha_R = 0.5$, hardly risk averse at all;
- $\alpha_R = 1.0$, somewhat risk averse (normal);
- $\alpha_R = 2.0$, rather risk averse;
- $\alpha_R = 3.0$, very risk averse; and,
- $\alpha_R = 4.0$, extremely risk averse.

A wide range of values (from 0 to 7), derived via alternative estimation methods, is found in the literature (see Saha et al. (1994) for a discussion). Using this classification the CARA I model entails that the producer is “hardly risk averse at all”, while the CRRA I coefficient approaches the category “somewhat risk averse (normal)”. These coefficients correspond to those calculated by Oude Lansink. It found a constant relative risk coefficient of 0.31 for a translating CARA model. Additional discussion of risk aversion coefficients is contained in section four (see Table 3.13).

Estimated risk aversion levels appear to be sensitive to model specification – i.e., the scaling and translating formulations result in different risk premiums. Yet, despite the disparity between model specification and calculated risk premiums, several consistent trends emerge in the analysis of the next three hypotheses. Risk aversion levels are not constant across different characteristics of a sample. For example, experience does have an effect on observed risk aversion as does the level of risk tolerance. However, section 3.5.3 demonstrates that the BSE crisis did not statistically significantly alter risk preferences.

3.5.2 Hypothesis 2: Experience Breeds Confidence

The experience breeds confidence hypothesis postulates a negative relationship between the number of years that a manager has operated her farm and her level of risk aversion. To assess this conjecture, three steps are necessary. First, experience must be incorporated into the base models via risk translating and risk scaling. Then a likelihood ratio test is computed to evaluate whether these are statistically relevant variables. The third step is to calculate producers' risk premiums at different years of experience. This determines whether experience breeds or erodes confidence. As seen in Appendix 3A, Table 3A.1, the minimum and maximum number of years of experience is 4 and 62 years respectively with a sample mean of 27 and a standard deviation of 11.7.

Table 3.6 provides the test statistics. Experience is a statistically significant variable at a 10 percent level in three out of four models. The exception is the CRRA model which uses the translating procedure, CRRA III. As discussed in section 3.2.4.2, the translating procedure in the CRRA model is both less reliable than the scaling technique and more difficult to interpret.

Two additional factors must be mentioned. First, it was initially believed that the age of the producer may be an important element in these models. Age, however, was found to be a statistically insignificant and had little impact on the risk premium calculations.[13] These results do not control for farmer age. Next, experience is included in these models both linearly and as a quadratic term. Including a squared term was found to economically and statistically significantly improve the models.

Table 3.6: Experience Breeds Confidence – Test of the Null Hypothesis of that Experience is Unrelated to Risk Aversion

Model	Statistic	p-value
	Risk Scaling	
CARA II	28.400	0.002
CRRA II	16.179	0.095
	Risk Translating	
CARA III	76.592	0.000
CRRA III	0.804	0.669

Figure 3.1 illustrates the relationship between a producer's years of experience and her risk premium for the CARA preferences. The CARA II plot of years of experience against risk premium illustrates a clear "half frown" shape. New producers display increasing risk aversion levels. After approximately 15 years however, managers gain sufficient confidence and begin reducing their risk premiums. Experience does seem to breed confidence with a qualification – i.e., experience breeds confidence *after the producer has been in business for several years*. A farmer with five years of experience has a risk premium of approximately 25 percent, while after 35 years at the

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[13] Age and experience were not as closely correlated as expected with a correlation coefficient of 0.646. Still, 3SNLS models were run using age as an instrument for experience. Calculations using the 3SNLS parameters yielded risk premiums that were not economically meaningful.

job her risk premium falls below 10 percent. Producers even appear to be risk loving once they have greater than 38 years of experience.[14] The CARA III model has a similar inverted parabolic shape, but the influence of experience is mild. The main result from this model is the low observed risk premiums. These values are similar to the equally low premiums found in Oude Lansink (1999) which employs a similar specification. Regardless of years of experience, the risk premium implied by the translating model is less than one percent. While the trend between years of experience and risk aversion is consistent across CARA II and CARA III, it is important to note that these models are fundamentally distinct and should not be directly compared.

The relationship between risk premium and years of experience for CRRA preferences is displayed in Figure 3.2. Recall that the CRRA II scaling model finds that experience is a statistically significant variable, while the translating model (CRRA III) does not. A clear upside-down u-shape (inverted parabola) relationship between the

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[14] This result is believed to indicate that a more complex modifying function is required (i.e., one that incorporates additional parameters). This is a topic which can be explored in future research.

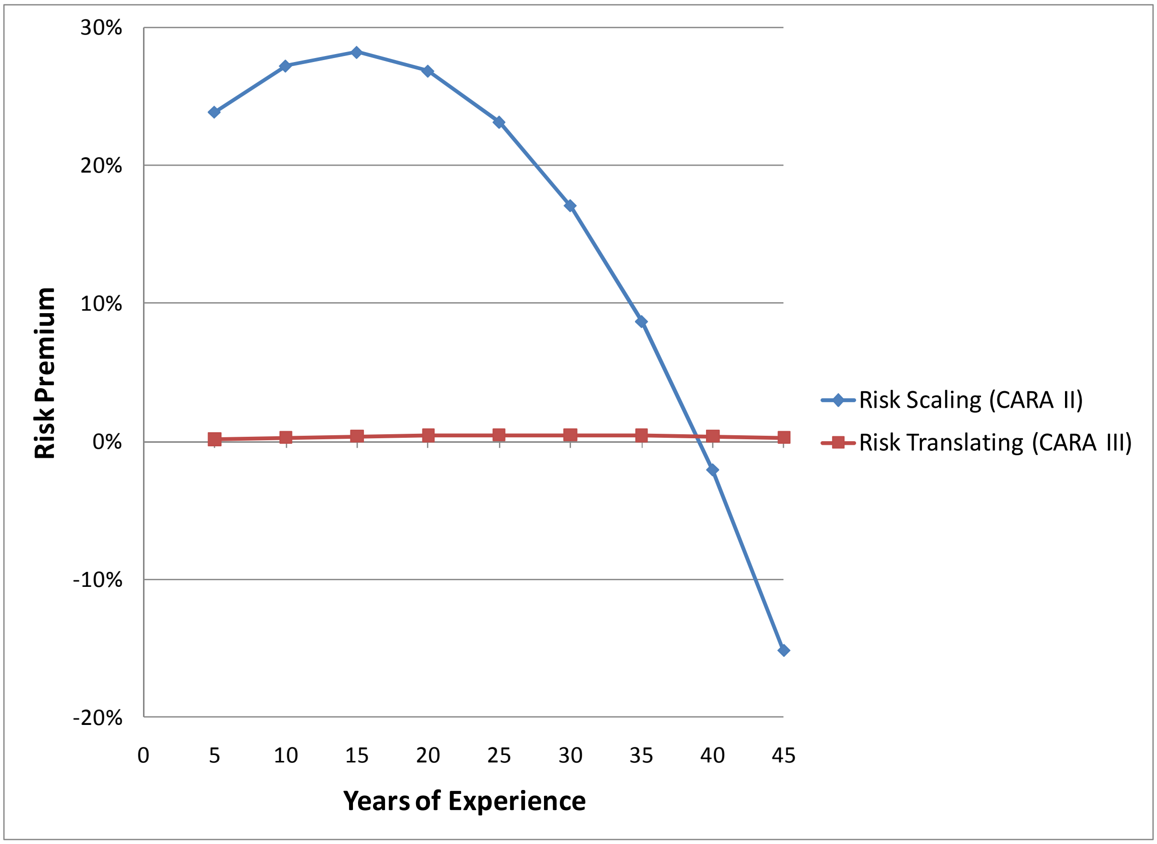

Figure 3.1: Relationship between Risk Premium and Cow-calf Producers' Years of Experience for CARA Preferences

number of years of experience and the risk premium is evident for CRRA II. This pattern is compatible with the results of the CARA models. Still, the risk premiums differ. As an example, with scaling CRRA preferences, a farmer who has been in the business for 15 years has a risk premium of approximately 10 percent, whereas the CARA II model indicates that the same producer's premium is nearly 30 percent. Nevertheless, it seems that experience does breed confidence *after several years in business*. In the CRRA II model it takes longer for managers to gain confidence. A producer does not become confident until she has 26 years of experience. The translating CRRA III model, in contrast to its scaling and CARA counterparts, has a slight smile shape. To reiterate, this

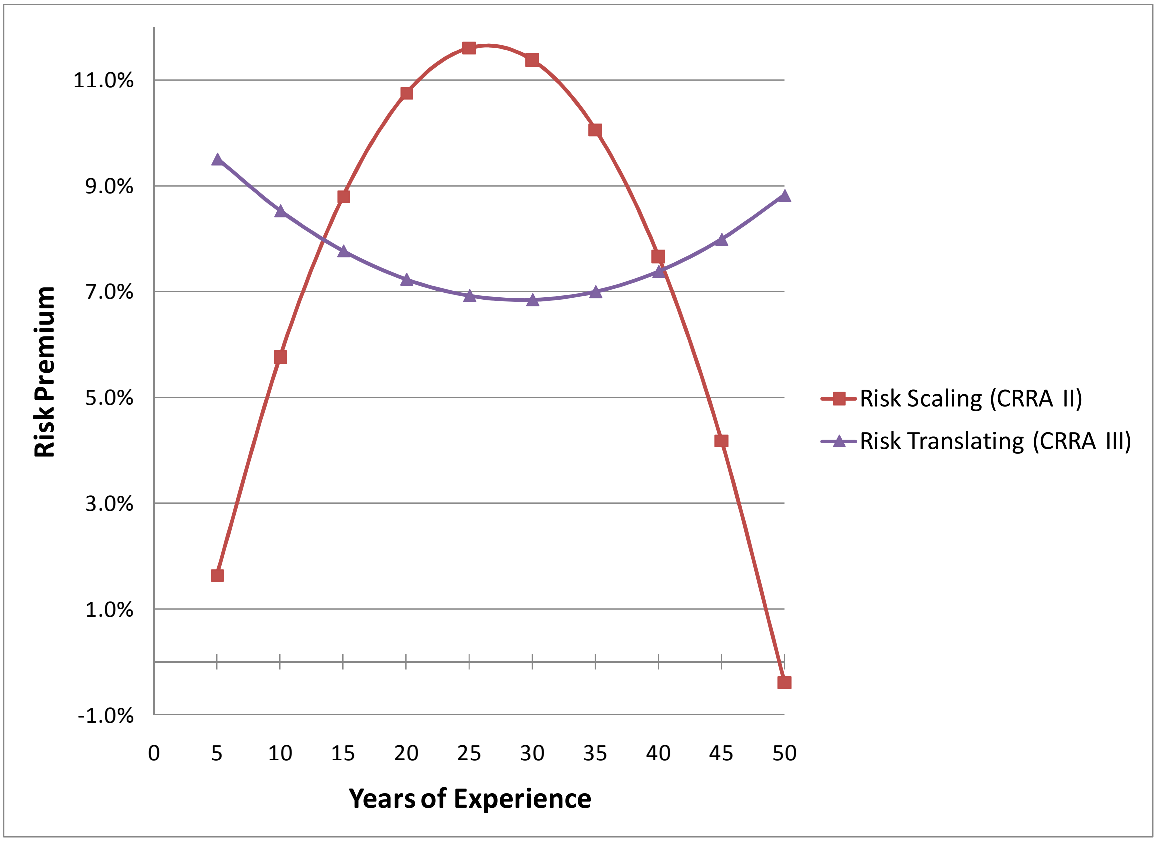

Figure 3.2: Relationship between Risk Premium and Cow-calf Producers' Years of Experience for CRRA Preferences

relationship is not statistically significant and the method is not easily interpreted. The average risk premium for this specification is approximately 8 percent.

The inverted parabolic relationship between experience and risk aversion is an interesting empirical regularity. The general shape is consistent across all models for which experience is a statistically significant variable. This regularity suggests several lifecycle features of the models and it is possible to speculate about relationships between non-farm obligations and management decisions. For example, middle-aged producers may have families that influence their production plans. Greater aversion to risk due to family or other non-farm responsibilities may imply that producers view profit (wealth) variability differently at different points in their lives. Once children have left home, say, producers may be willing to engage in riskier businesses. Regardless of cause, differential risk preferences across managers and firms exist and deserve study. Depending on a particular characteristic – experience, in this case – producers' risk preference can range from "barely risk averse at all" to "rather risk averse."

The risk aversion coefficients corresponding to the scaling models, CARA II and CRRA II are 1.308 and 1.912 (see Table 3.13). The respective values for the CARA III and CRRA III translating models are 0.075 and 1.279. Values are calculated for a manager with twenty years of experience – i.e., near producers' point of maximum aversion to risk. With the exception of CARA III translating model, producers are in Hardaker et al.'s "normal" to "rather risk averse" range.

3.5.3 Hypothesis 3: BSE Increased Aversion to Risk

The third hypothesis of this paper is that the BSE crisis increased producers' aversion to risk. This increase, akin to a structural change in a risk neutral model, would be evident from a statistically significant change in risk premium. Table 3.7 presents the results from a likelihood ratio test of the null that the BSE crisis had no effect on producers' risk aversion levels. BSE dummies are included in the models via risk scaling and translating. The null cannot be rejected at a 10 percent level of significance in three out of four models. In only a single case does the BSE crisis have a statistically significant impact on risk preferences.

As the hypothesis is rejected in three out of four cases when risk scaling and translating methods are used, a second formulation, where BSE dummy variables were simply additively included on the end of each equation, is also tested. These supplementary models are used as a "check" on the previous results. Likelihood ratio tests found, for all four models, no statistically significant effect due to the inclusion of BSE dummy variables.

There are three possible explanations for why BSE does not seem to increase producers' aversion to risk. First, estimation of risk preferences requires a model for risk assessment or risk perceptions. A maintained hypothesis of the empirical model is that risk perceptions are fixed. The risk perception model used in this paper covers three years of data (see Section 3.4.3.1). Following the BSE crisis price variation noticeably increased – as an example, using **(3.35a)** to calculate price variance, the annual Albertan variance for weaned heifer prices in 2002 equalled \$199.90/cwt while by 2005 this had increased to\$563.52/cwt (Canfax, 2002-2004). This implies that the actual risk, measured by price variance, faced by producers increased, but aversion to risk remained stable. The results of Table 3.7 imply that preferences did not experience a statistically significant shift, which is plausible result. It is also plausible however that producers' perceptions of risk changed following the BSE crisis. Testing this hypothesis is beyond the scope of this chapter. Next, the data employed in the risk assessment model ends in 2005, only two years following the initial announcement of an infected animal. With additional data (i.e., a period of more than three years), it is possible that

Table 3.7: BSE Increased Aversion to Risk – Test of the Null Hypothesis of that BSE Did Not Affect Risk Preferences

Model	Statistic	p-value
Risk Scaling		
CARA IV	0.076	0.783
CRRA IV	2.693	0.747
Risk Translating		
CARA V	62.533	0.000
CRRA V	2.706	0.100

producers may display signs of preference shifts. Yet, Chapter 2 found that the BSE crisis only affected cow-calf production decision for two years, 2003 and 2004. Alternative time frames were tried in the models, but were also not found to be statistically significant. Finally, intra-farm substitution effects between livestock and crops may have dampened the influence of the BSE crisis on producers' preferences. While cattle prices were falling, crop prices were increasing. Examined from a "whole-farm" perspective, the BSE crisis may not have had as large an impact on farm profits as when the cattle enterprise is independently investigated. The dataset did not permit detailed scrutiny of this possibility.

Despite the lack of statistical significance, Table 3.8 presents the implied change in producers' risk premiums due to the BSE crisis. The sign on these values accords with the research hypothesis that BSE increased risk aversion – i.e., producers displayed greater aversion to risk following the BSE crisis. For the CRRA IV model, BSE led to a 7.80 percent increase, while for CARA IV there is only a 0.81 percent gain. The model where BSE did have a statistically significant effect is CARA V. This model purports a

Table 3.8: Increase in Risk Premium Attributable to the BSE Crisis

Model	Risk Premium Increase
Risk Scaling	
CARA IV	0.81%
CRRA IV	7.80%
Risk Translating	
CARA V	1.29%
CRRA V	2.52%

a. Values are calculated at the means of the data

1.29 percent increase in the risk premium following the 2003 announcement. Increases of these magnitudes, in terms of economic significance, do not suggest a major shift in producer’s risk preferences.

A final comment should be made on these results. Government support programs are not captured in these models. Nine BSE-related relief programs were introduced following the May 2003 announcement. Over $500 million dollars was allocated to the cattle sector as relief for the crisis. Producer risk preferences may be conditioned on an expectation of government disaster relief and these expectations may provide a disincentive for producers to guard against catastrophic price risks. Goodwin and Rejesus (2008) argue that continual provision of *ad hoc* disaster relief is equivalent to “a form of free insurance” (pg. 416) which may reduce producers’ aversion to risk. In other words, producers only need to focus on “normal” risks as the expectation is that any “catastrophe” will trigger emergency government payments. The government’s prevalence to provide disaster relief payments acts a hedge for producers against potential catastrophic risks. If operations face small policy risk – i.e., farm managers know that the government will provide emergency payments – then altering risk preferences in response to crisis-events is unnecessary. In this description of events, the fact that BSE appears to have a minor and statistically insignificant effect on risk preferences would be in accordance with expectations. See Chapters 2 and 4 for additional discussion of policy and catastrophic price risk.

3.5.4 Hypothesis 4: Risk Tolerance

The dual certainty equivalent models are augmented with two variables for the fourth hypothesis. Risk tolerance hypothesizes a relationship between variables, which are assumed to proxy a producer's willingness to bear short- and long-run financial risk, and her risk premium in production decisions. Similar to analysis of the experience breeds confidence hypothesis several steps are required to evaluate this proposition.

First, a current ratio is calculated for each farm.[15] Firms are then grouped into three categories based on this value. For example, if a firm's current ratio is in the upper third of the sample – i.e., the current ratio was higher than at least two thirds of the other current ratios – the firm is considered to have low short-run risk tolerance. Similarly, if a firm's current ratio fell in middle or bottom third, the manager is considered to have medium or high risk tolerance. The willingness of a firm to incur short-run liabilities relative to current assets, *as reflected in its current ratio relative to the sample*, is used to proxy a manager's short run risk tolerance. The use of relative rankings helps to avoid potential endogeneity problems in estimation. The current ratio cut-offs for low, medium and high risk tolerances correspond to: greater than 4.8, between 1.7 and 4.8 and less than 1.7.

Using a similar strategy, the debt-to-equity ratio is exploited to approximate long-run risk tolerance. Ratios less than 0.1 are considered low risk tolerance; values between 0.1 and 0.3 are medium tolerance, while greater than 0.3 is high risk tolerance.

It must be emphasized that firms are classified according to their risk tolerance relative to the sample. Sckokai and Moro (2006), assessing differential risk premiums across firm sizes in Europe, performed a similar relative ranking. In this case, the majority of the firms in this sample are in a strong financial position. For example, Risk Management Association (2004) classifies the current and debt-to-equity ratios for a

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[15] The current ratio is defined as total current assets divided by total current liabilities.

sample cattle farms. Collecting income statements and balance sheets from across the United States, they catalogue, based on quartiles, ratios into superior, good, fair and poor. Superior current ratios are in the upper quartile and above 2.1; a good current ratio value are between 1.2 and 2.1; fair values are between 0.8 and 1.2; and, the bottom quartile is ratio values below 0.8. For a superior debt-to-equity ratio the value should be less than 0.5; good ratios lie in the interval 0.0 to 1.8; fair ratios must be less than 9.7 but greater than 1.8; finally, a poor debt-to-equity ratio is greater than 9.7. Mitura and Di Piètro (2004), in a Canadian context, categorize current ratios in the agricultural sector according to (pg. 33):

- Superior – more than 1.5;
- Good – between 1.2 and 1.5;
- May constitute risk – between 1.1 and 1.2;
- Low – between 1.0 and 1.1;
- Inferior – less than 1.0.

For the sample used in this analysis, 73.0 percent of the firms have superior current ratios (greater than 1.5), while only 14.5 percent have low or inferior ratios. For the debt-to-equity ratio, a business such as a beef farm which has high income variability, would want to have a ratio of "significantly less than 1" (Mitura and Di Piètro, 2004, pg. 34). Only 1.9 percent of operations in this sample have a debt-to-equity ratio of greater than one. Refer to Table 3A.1 in the Appendix for additional information. The firms in this sample have better than average balance sheet positions. As a result, caution must be exercised when interpreting this section's results in terms of absolute risk tolerance. Explicit premiums at different risk tolerance levels should not be compared across studies. Focus should be placed on the trends in the data and empirical regularities rather than the specific parameter values.

Table 3.9 presents the results from likelihood ratio tests of the risk tolerance hypotheses. The risk scaling procedure demonstrates that short-run risk tolerance has a statistically significant effect on the risk preferences at a one percent level. Long-run risk tolerance does not statistically significantly alter risk preferences. When these variables are included via the risk translating procedure, the parameters for both short- and long-run risk tolerances are not statistically distinct from zero with the CRRA model (CRRA VII). At a one percent level of significance, both risk tolerance variables do influence CARA VII however.

Table 3.9: Risk Tolerance – Test of the Null Hypothesis of that Risk Tolerance does not affect Risk Aversion

Model		Statistic	p-value
	Risk Scaling		
CARA VI	Short-run	30.523	0.001
	Long-run	15.887	0.103
CRRA VI	Short-run	40.549	0.000
	Long-run	13.245	0.210
	Risk Translating		
CARA VII	Short-run	315.742	0.000
	Long-run	91.568	0.000
CRRA VII	Short-run	0.972	0.615
	Long-run	0.435	0.805

Table 3.10 presents the risk premiums for all eight specifications. As mentioned, premium values are less relevant than trends across risk tolerance levels. The short-run CARA VI (risk scaling) model shows an inverse relationship between the risk premium and the risk tolerance proxy. As willingness to bear risk increases, the risk premium decreases. This result agrees with the hypothesized relationship. Indeed, hypothesis four, where the risk premium is expected to decrease as relative risk tolerance increases,

holds for six of the eight models. Moreover, hypothesis four cannot be rejected for all of the models where the risk tolerance variables are statistically significant, with the only exception being the short-run CRRA VI model. Prudence is required when interpreting the CRRA preference structure in the short-run. CRRA formulations include a wealth variable and the underlying utility maximization problem deals with optimizing over

Table 3.10: Risk Premium at Low, Middle and High Risk Tolerance Levels[a]

Model			Risk Premium
		Risk Scaling	
CARA VI	Short-run	Low	10.45%
		Middle	3.49%
		High	2.21%
CARA VI	Long-run	Low	14.08%
		Middle	10.42%
		High	2.23%
CRRA VI	Short-run	Low	-13.91%
		Middle	5.90%
		High	-17.26%
CRRA VI	Long-run	Low	48.86%
		Middle	13.48%
		High	-9.71%
		Risk Translating	
CARA VII	Short-run	Low	2.62%
		Middle	1.13%
		High	0.53%
CARA VII	Long-run[b]	Low	0.00%
		Middle	0.00%
		High	0.00%
CRRA VII	Short-run	Low	11.96%
		Middle	12.05%
		High	12.25%
CRRA VII	Long-run	Low	11.33%
		Middle	11.18%
		High	10.93%

a. Values are calculated at the means of the data
b. Risk premiums for CARA VII are 0.82E-2%, 0.24E-2% and 0.18E-2%, for low, middle and high, respectively

terminal wealth. Terminal wealth is a long-run variable. Thus, there may be some feedback between the short-run risk tolerance and the long-run wealth variables with CRRA preferences.

The risk tolerance results require one additional caution. This analysis makes an implicit assumption that production and financial decisions are independent. The models measure the impact of price risk on outputs produced. Financial risk, on the other hand, is reflected in the firms' income statements and balance sheets. In this framework, financial risk is treated as exogenous. It is only a proxy for relative risk tolerance. This is a strong and unrealistic assumption. Financial structure and financial constraints have a real influence on production decisions. Moreover, a farm's financial performance may be a better proxy for relative firm-level efficiency rather than risk tolerance. Despite this caveat however, the general trend accords with expectations. Higher relative risk tolerance tends to be related to decreased risk premiums, supporting hypothesis four.

3.5.5 Comparative Statics, Price and Substitution Elasticities

This section outlines the comparative static results along with the price and substitution elasticities for the base CARA and CRRA models (CARA I and CRRA I). Parameter values for these models are presented in Appendix Table 3B.1.

The theoretical comparative static relationships are outlined in section 3.2.3. All input demands have the correct signs on own-price responses for both CARA and CRRA preference structures. The quantity demanded of each input is non-increasing in its price. When the producer is modelled as having CRRA preferences, own-price risk (i.e., variance of own price) has the predicted sign for both calves and cull cows. Cull cows also have the expected response on its risk variable for CARA preferences, however additional calves are supplied as its own-price risk increases – i.e., weaned calves price risk has the incorrect sign on its parameter. The cull cow output has the appropriate sign for price changes – i.e., cull cows supplied increases with an increase in the expected price of cull cows – yet both CARA and CRRA models have the incorrect comparative static prediction for the calves output. An increase in the expected price of weaned calves leads to a decrease in output supplied.

Even though the predicted comparative static relationship for calves output does not hold, this is not viewed as a major flaw in the models. Rather, this is seen as indirect evidence that the supply of calves involves significant dynamics that are not captured by the current specifications (Chavas, 2008). Weaned calves cannot be "stored" as calves – i.e., as calves age they become cows or feeder animals – and, while the naive expectation models that are used are statistically appropriate, producers likely have more complex price forecasting methods. A simple example illustrates the challenge in correctly determining dynamics for the calves output. Consider two three year periods. In the first period assume that calf prices have small fluctuations around constant mean price. In the second situation, assume sizable price increases for three successive years and that producers believe that prices will continue to rise. Measured risk may be noticeably greater in the second instance even though increasing prices benefit producers. In the second case, producers would likely retain more heifers, reducing supply and growing their herd, while the first period could be considered a steady-state. This simple example highlights the joint role of risk assessment and risk preferences (Chavas, 2008) in combination with herd dynamics. This chapter's treatment of producer decisions with respect to herd dynamics is essentially the steady-state case. The empirical models are conditioned on cattle inventory – i.e., herd size is not included as "capital" – and, effectively, this is an assumption that can be considered equivalent to a "steady-state" herd replacement rule. The assumption is made to maintain tractability and is supported by two features of the problem: i) the relatively short data sampling period – i.e., data are available from 1996 to 2005 only; and, ii) the revenue share of cull cows is stable.[16] Moreover, the focus of this study is on risk preferences. Nevertheless, accurately determining how producers forecast prices – i.e., risk perceptions – and herd dynamics are important future research topics. Further discussion on the joint estimation of risk preferences and risk perceptions can be found in Lence (2009) and Just (2008).

Saha (1997) and Pope and Just (1998) demonstrated that ignoring risk yields biased, over-estimates of output supply and input demand elasticities. Thus, price elasticities from models that include risk may be more accurate than values from models that assume risk neutrality (Abdulkadri et al., 2006). Table 3.11 displays the short-run price elasticities of output supply and input demand calculated at the data means. Values are for the base models, CARA I and CRRA I. Own-price elasticities of demand for feed, capital and materials are all negative and equal to -0.528, -0.514 and -0.895 for the CARA I model and -0.864, -1.005 and -0.119 for the CRRA I model. The own-expected price output supply elasticity for cull cows is positive and inelastic. Equal to 0.100 for CARA I and 0.016 for the CRRA I model, this value is less than elasticities from risk

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[16] The stability of the cull cow revenue share is taken as evidence that producers, on average, are using a steady-state herd replacement rule. The coefficient of variation of the cull cow revenue share is less than one (i.e., low variance) at 0.90. Mean revenue share of the cull cow output is 0.13 percent with a standard deviation of 0.12.

neutral models (Quagrainie, 2001; Chapter 2). Weaned calves have a negative own-expected price of supply. A one percent increase in the expected price of weaned calves leads to a 0.082 percent and 0.263 percent decrease in the output for CARA I and CRRA I respectively. This result contravenes economic intuition. Two potential explanations for this result, already discussed above, are: i) the suitability of the price expectation models; and, ii) the dual role of weaned calves in the production process. First, naive

Table 3.11: Price Elasticities of Base Modelsa,b

CARA I

	Expected Calf	Expected Cull	Materials	Feed	Capital
Expected Calf	-0.082	0.042	0.057	-0.062	0.037
	(0.012)	(0.024)	(0.009)	(0.017)	(0.008)
Expected Cull	0.245	0.100	-0.026	0.173	-0.046
	(0.017)	(0.031)	(0.003)	(0.022)	(0.006)
Materials	0.450	2.167	-0.895	0.166	0.278
	(0.005)	(0.122)	(0.014)	(0.004)	(0.005)
Feed	-0.076	0.036	0.026	-0.528	0.031
	(0.044)	(0.033)	(0.015)	(0.668)	(0.020)
Capital	0.298	-0.063	0.007	0.205	-0.514
	(0.005)	(0.005)	(0.006)	(0.006)	(0.015)

CRRA I

	Expected Calf	Expected Cull	Materials	Feed	Capital
Expected Calf	-0.026	-0.014	0.028	-0.132	-0.008
	(0.014)	(0.016)	(0.007)	-0.020	(0.009)
Expected Cull	-0.043	0.016	-0.047	0.013	-0.046
	(0.069)	(0.036)	(0.002)	(0.031)	(0.015)
Materials	0.026	-0.014	-0.119	0.026	-0.094
	(0.004)	(0.001)	(0.010)	(0.025)	(0.006)
Feed	-0.242	0.007	0.052	-0.864	0.074
	(0.906)	(0.294)	(0.167)	(6.838)	(0.268)
Capital	-0.080	-0.151	-0.053	0.409	-1.005
	(0.009)	(0.005)	(0.007)	(0.001)	(0.014)

a. Values are calculated at the means of the data

b. Standard errors in parentheses

expectations models were used to develop producer price expectations as they were statistically appropriate models. Farm managers may generate expectations using an alternative procedure however. If this process were known, the models' comparative static predictions may change. Next, weaned heifers, in particular, may serve as either an output or as retained heifers – i.e., as both an output and a capital investment. Weaned calves were grouped into a single composite output in the data, so disaggregating steers from heifers was not possible. Future extensions of these models should include herd dynamics. All other results from these models agree with the comparative static predictions, so the anomaly of the negative weaned calves supply elasticity is not seen as a major defect in the approach.

Even though a dual framework is used, technological relationships are recoverable from the estimated parameters (Oude Lansink, 1999). Table 3.12 provides the MES for the inputs of the production process. Recall that the MES is interpreted as the effect of a one percent change in the optimal input ratio x_i / x_j allowing only the *j*th price to vary (Wohlgenant, 2001). With output constant, a one percent increase in the price of feed would lead to a 0.694 and 0.889 increase in the demand for materials, for CARA and CRRA respectively. A similar one percent change in the price of feed would lead to yield a 0.733 and 1.273 percent increase in the demand for capital. The optimal feed-capital input ratio is more elastic than the feed-materials ratio. On the whole, these values suggest a technology that has low substitutability between inputs – i.e., most of the substitution elasticities are less than one in absolute value. For cattle production, minimal substitutability in the production process is plausible result. High levels of production flexibility likely do not exist. For example, it is difficult to determine effective substitutes for feed when the objective is encouraging weight gain in calves.[17] Examining these values, the inherent asymmetry of the MES is evident.

Table 3.12: Morishima Elasticities of Substitution for Base Modelsa,b

CARA I

	Materials	Feed	Capital
Materials		0.694	0.792
		(0.671)	(0.020)
Feed	0.921		0.546
	(0.023)		(0.030)
Capital	0.902	0.733	
	(0.019)	(0.673)	

CRRA I

	Materials	Feed	Capital
Materials		0.889	0.911
		(7.004)	(0.017)
Feed	0.171		1.079
	(0.027)		(0.015)
Capital	0.065	1.273	
	(0.012)	(7.105)	

a. Values are calculated at the means of the data

b. Standard errors in parentheses

3.6 EXTENSIONS

There are three main advantages to the Coyle methodology. First, econometric estimation of the CARA and CRRA models is straightforward. Estimating models which accommodate the "joint importance of risk assessment and risk preferences" (Chavas,

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[17] This statement is focused on conditions in winter months. Pasture is a substitute for feed in summer. Land is not considered a variable input in the empirical models, however – i.e., the models are conditioned on a given land input. The justification for this is that land is not a binding constraint for the mean producer, as the animal unit months (AUM) of pasture available to the mean producer are significantly greater than the AUMs used.

2008, pg. 435) is tractable. More flexible DARA preferences pose a challenge. However, CARA and CRRA formulations provide a credible first approximation to producer preferences. Next, the flexibility of this framework makes it amenable to policy analysis. For example, results from this chapter are used in Chapter 4 to assess the Canadian AgriStability program. Finally, the duality-based certainty equivalent formulation is more general than static models but retains the ease of application, empirical tractability and intuitive appeal of the static multi-input, multi-output dual production models. Still, while the Coyle methodology does open new research directions for production economics, several limitations and extensions are discussed.

Hardaker et al. (2004) identify two main drawbacks of duality based models for assessing risk: theoretical basis and model specification. First, the models depend on the assumption that the producers observed behaviour is aligned with the analyst's view of uncertainty. Most empirical studies, including consumer demand and static production models, rely on a maintained hypothesis of objective function optimization.[18] Several papers, including Fox and Kivanda (1994) and Clark and Coyle (1994), have discussed this criticism. Hardaker et al.'s second critique can be framed as an open research question. Functional form and risk assessment are two ways that specification errors can enter the empirical models. This paper's choice of functional form appealed to the literature to ensure greater comparability between the few existing studies. Prior to establishing consensus on the appropriate model specification, it is acknowledged that

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[18] The relevance of the integrability conditions – i.e., symmetry, homogeneity, curvature – was not explored. The primary hypotheses were not concerned with these topics. Previous literature has briefly discussed these issues (Coyle, Oude Landsink). This avenue may prove fruitful for future research.

further research on various model formulations is needed. Similarly, alternative measures of risk and risk assessment – i.e., different methods of calculating price variance and covariance – may yield new insights. While this technique for calculating the variance and covariance of output prices is oft-used in the literature, it is largely arbitrary and likely does not accurately reflect a producers' actual or perceived price risk. Space constraints limit the study of alternative specifications in this chapter.

Next, distinguishing between first- and second-order effects of a particular research question is necessary when determining the final purpose of a model. For instance, risk and risk preferences may not be optimal predictors of future behaviour – i.e., risk may only have a "second-order" impact on forecasting producer decision-making (Moschini and Hennessy, 2001). Factors such as herd dynamics and crop rotation may explain changes in farm output to a greater extent than risk aversion. Alternatively, if an analyst is examining risk-mitigating policy, then understanding risk preferences is of paramount importance. For example, it is difficult to conceive of an analysis of production insurance where risk and risk preferences do not have a prominent role. This research focused on evaluating risk preferences and the results are used in Chapter 4 to evaluate a revenue insurance program. If accurately predicting producer output in the years following the BSE crisis was the main aim of this chapter, explicitly modelling herd dynamics may have been more appropriate.

The final limitation is the interpretation of the "cost function specification", **(3.27)**. This formulation was applied in Oude Lansink (1999) and Abdulkadri et al. (2006). This specification may not be consistent with the expected utility framework. Cost functions traditionally treat output as fixed; however, **(3.27)** allows output j, say, to both vary with own-expected price, but remain fixed in the determination of output *i* and the input demand equations. An idiosyncratic explanation on the "timing" of production decisions or of output expectations may help avoid explicit contradictions, yet this formulation still generates some confusion. Ultimately, the convenience of cost function estimation may outweigh its theoretical drawbacks, but caution should be exercised with its interpretation.[19]

The most obvious extension to this research is further investigation into modifying functions and supplementary explanatory variables. Only two modifying functions are examined and they are used to answer a precise set of questions. Novel conditioning methods for firm- and manager-specific variables may open a range of new research questions for production economics. Likewise many potential empirical relationships conceivably exist between demographic and farm specific variables and production decisions. This is an under-researched area that could yield a bounty of interesting research applications – notably with respect to the adoption of new technologies or the purchase of agricultural insurance.

Another extension to the empirical results deserves comment. Data for crop and cattle operations were separated prior to this investigation. Many Albertan firms have both grain and livestock enterprises. Diversification of farming operations provides a natural risk dissipation mechanism. This hedge is relevant when one is considering the

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[19] A similar warning is valid for all of the models examined in this paper. Had the estimating equations been risk neutral, they would likely be considered short-run models – i.e., they are conditioned on land and cattle inventory. Whether a short-run interpretation is valid within the confines of the expected utility framework is unclear.

role of risk and risk preferences. The neglected role of crop and livestock price covariance may have a larger role in assessing producer risk preferences than is demonstrated in these results. This is a clear opportunity for future research.

A chief attraction of duality based methods is the ability to infer observed, as opposed to assumed, risk aversion results. Table 3.13 provides the CRRA coefficients for the models listed in Table 3.3. Discussion of calculation methods for the coefficients is in section 3.4.2. Several of these coefficients are used along with a simulation model in Chapter 4. These risk aversion values provide a valid range within which to perform extended policy analysis. Chapter 4 examines the Canadian AgriStability program and the equity of benefit distribution when there is the prospect of catastrophic price risk.

One final comment is warranted on the theoretical foundation of this chapter. The methodology is based on the canonical expected utility framework. Many non-expected utility alternatives have also been developed (see Machina, 1989). However, this research supports the conclusion of Machina (1989): ultimately, the expected utility framework is still the best choice for applied work, primarily due to the lack of widespread acceptance of an alternative model.

Table 3.13: Constant Relative Risk Aversion Coefficients Implied by the Models

Model	CRRA Coefficient
CARA I	0.549
CRRA I	1.595
CARA II[a]	1.308
CRRA II[a]	1.912
CARA III[a]	0.075
CRRA III[a]	1.279
CARA IV[b]	0.489
CRRA IV[b]	2.085
CARA V[b]	0.286
CRRA V[b]	1.711
CARA VI – Short-run[c]	0.175
CARA VI – Long-run[c]	0.523
CRRA VI – Short-run[c]	0.778
CRRA VI – Long-run[c]	1.791
CARA VII – Short-run[c]	0.203
CARA VII – Long-run[c]	0.000
CRRA VII – Short-run[c]	2.225
CRRA VII – Long-run[c]	2.091

a. Calculated at 20 years of experience

b. Post-BSE risk aversion coefficient

c. Middle risk tolerance level

3.7 CONCLUSIONS

This paper contributes to a small but growing literature on duality based models that incorporate risk aversion. Advantages of the duality framework include computational convenience, estimation efficiency and the ability to use a broader range of functional forms (Oude Landsink, 1999). There are two primary contributions of this research. First, this is a new empirical study. There is no directly comparable research with which to compare the observed risk premiums of cow-calf producers. These results therefore form a base-line for these measures. Second, methods for introducing additional variables into this class of models were introduced. These conditioning procedures allow for differential risk preferences across some firm- or manager-specific characteristic. Empirical focus was placed on four hypotheses:

a. Risk aversion versus risk neutrality;
b. Experience breeds confidence;
c. BSE increased aversion to risk; and,
d. Risk tolerance.

Evidence was found to reject only a single hypothesis and several novel empirical regularities were uncovered. The Canadian BSE crisis did not have a statistically significant impact on Albertan cow-calf producers risk preferences. Finally, there are numerous interesting extensions to this research which could be undertaken.

APPENDIX 3A – SUMMARY STATISTICS FOR COW-CALF DATA

Table 3A.1: Summary Statistics for Cow-calf Data

	Mean	Std Dev	Minimum	Maximum
CALF OUTPUT (cwt)	934.13	555.12	74.00	4075.50
CULL COW OUTPUT (cwt)	301.86	299.88	0.00	2142.00
EXPECTED CULL COW PRICE ($/cwt)	60.51	51.40	0.00	407.61
EXPECTED CALVES PRICE ($/cwt)	116.55	20.64	74.05	163.27
PRICE PER UNIT MATERIALS	432.65	95.01	195.35	666.04
PRICE PER UNIT CAPITAL	277.97	77.33	123.20	489.62
PRICE PER UNIT FEED	45.20	15.83	22.92	102.45
PRICE PER HOUR LABOUR	12.83	1.52	8.13	17.21
VARIANCE OF CULL COW PRICES	3033.10	9590.89	10.92	86758.56
VARIANCE OF CALF PRICES	315.90	356.13	13.31	3067.54
COVARIANCE OF PRICES	70.49	533.12	-2643.42	1904.50
WEALTH	1,631,210.23	1,623,178.73	138,400.52	17,417,000.00
EXPERIENCE (YEARS)	27.12	11.70	4	62
CURRENT RATIO	7.39	13.26	0.10	93.11
DEBT-TO-EQUITY RATIO	0.29	0.35	0.00	2.93

APPENDIX 3B – ESTIMATED PARAMETERS AND T-STATISTICS OF BASE MODELS

Table 3B.1: Parameter Values and t-Statistics for Base CARA and CRRA Models (CARA I and CRRA I)

CARA I			CRRA I		
	Parameter Value	t-statistic		Parameter Value	t-statistic
Cull Cow_Constant	1524.960	0.830	Cull Cow_Constant	1246.450	0.671
Cull Cow Price	-8.364	-0.400	Cull Cow Price	-9.535	-0.552
Cull Cow_Calf	8.056	0.502	Cull Cow_Calf	11.296	0.837
Cull Cow_Materials	1.583	1.324	Cull Cow_Materials	1.543	1.350
Cull Cow_Capital	-16.054	-0.524	Cull Cow_Capital	-23.979	-0.807
Cull Cow_Feed	1.575	1.039	Cull Cow_Feed	2.264	1.464
Cull Cow_VCull Cow	-0.638	-0.149	Cull Cow_VCull Cow	-2.422	-0.064
Cull Cow_VCalf	0.041	0.170	Cull Cow_Vcalf	-0.016	-0.007
Cull Cow_Cov Cull-Calf	-0.129	-0.064	Cull Cow_Cov Cull-Calf	-4.181	-0.223
Calf_Constant	706.368	0.388	Cull Cow_Wealth	0.003	4.546
Calf Price	6.300	0.498	Calf_Constant	637.232	0.336
Calf_Materials	-0.232	-0.323	Calf Price	6.453	0.449
Calf_Capital	14.516	0.504	Calf_Materials	-0.118	-0.163
Calf_Feed	-0.639	-0.777	Calf_Capital	14.074	0.513
Calf_VCull Cow	1.372	1.049	Calf_Feed	-0.822	-0.892
Calf_VCalf	-0.007	-0.045	Calf_VCull Cow	14.798	1.132
Calf_Cov Cull-Calf	0.665	0.512	Calf_VCalf	-0.266	-0.139
Materials_Constant	608.405	0.343	Calf_Cov Cull-Calf	8.063	0.520
Materials Price	-0.853	-2.951	Calf_Wealth	0.001	1.019
Materials_Capital	1.487	1.129	Materials_Constant	644.507	0.355
Materials_Feed	0.408	1.661	Materials Price	-0.857	-3.109
Materials_VCull Cow	0.006	0.045	Materials_Capital	1.038	0.717
Materials_VCalf	0.002	0.124	Materials_Feed	0.514	1.969
Materials_Cov Cul-Calf	0.004	0.054	Materials_VCull Cow	0.231	0.224
Capital_Constant	3562.890	1.945	Materials_VCalf	0.009	0.054
Capital Price	-283.421	-2.557	Materials_Cov Cul-Calf	-0.032	-0.044
Capital_Feed	2.762	1.497	Materials_Wealth	0.000	4.686
Capital_VCull Cow	-3.420	-0.398	Capital_Constant	3152.460	1.691
Capital_VCalf	0.109	0.231	Capital Price	-287.497	-2.270
Capital_Cov Cull-Calf	-1.281	-0.296	Capital_Feed	2.415	1.322
Feed_Constant	615.031	0.347	Capital_VCull Cow	-23.305	-0.281
Feed Price	-1.136	-3.196	Capital_VCalf	0.640	0.114
Feed_VCull Cow	-0.125	-0.657	Capital_Cov Cull-Calf	-21.329	-0.388
Feed_VCalf	0.009	1.020	Capital_Wealth	0.004	2.954
Feed_Cov Cull-Calf	-0.003	-0.026	Feed_Constant	647.472	0.356
Time Trend	-0.288	-0.326	Feed Price	-1.165	-3.089
			Feed_VCull Cow	-1.260	-0.532
			Feed_VCalf	0.109	1.031
			Feed_Cov Cull-Calf	-0.067	-0.049
			Feed_Wealth	0.000	1.263
			CRRA	431.614	0.041
			Time Trend	-0.311	-0.343

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CHAPTER 4: AGRISTABILITY IN THE AFTERMATH OF BSE: EQUITY IMPLICATIONS OF CATASTROPHIC RISK

4.1 GENERAL OVERVIEW

This paper examines the consequences of the AgriStability program for Albertan cow-calf producers when there is potential for catastrophic price risk. The concepts of inducement subsidies and pure wealth transfers are introduced. Actuarial techniques and indifference pricing methods are employed in combination with a simulation model to calculate: i) actuarially fair insurance premiums; ii) the upper bounds on premiums that Albertan cow-calf producers are willing to pay for the insurance contract; and, iii) several inequality measures such as Gini coefficients and Suits indices for the distribution of net AgriStability benefits. The concepts of horizontal and vertical equity are used to evaluate program outcomes for cow-calf producers in the aftermath of the BSE crisis. Most research focuses on the differential welfare effects from agricultural policy on a homogeneous group of producers relative to a homogenous group of consumers (e.g., Gardner, 1983; Schmitz et al., 2002). This chapter takes an alternative approach. It concentrates on how AgriStability treats heterogeneous firms *within* the group of cow-calf producers.

AgriStability is Canada’s primary government support and risk management program. The objective of the program is “to provide Canadian agricultural producers with an ongoing whole-farm *risk-management tool* that provides protection against both small and large drops in income” (AFSC, 2003, pg. 1, *emphasis added*). In its current form, AgriStability mimics a net revenue insurance program; hence, program enrolment fees are treated as premiums and program payouts as indemnities. Moreover, asset pricing models which are used to calculate insurance premiums can be applied to AgriStability. The program does not actually charge “premiums”. Rather there is a participation fee that producers must pay. For the purposes of this chapter, the terms fee and premium are considered synonymous.[20] Relevant features of the program are discussed in section 4.2.

This paper contributes to an on-going policy discussion by examining the AgriStability risk management program when the prospect of a bovine spongiform encephalopathy (BSE)-like price shock exists. Recent experience with BSE in the cattle sector demonstrates that output prices are susceptible to both “normal” risk and sudden, “catastrophic” declines. Large price shocks are often linked with animal disease. For instance, a discovery of Foot-and-Mouth disease (FMD) would immediately close Canadian cattle export markets. These markets would not reopen until, at the very least, three months after the disease had been eradicated. “Consequential losses associated with an animal disease always occur but risk management strategies to deal with their impact are underdeveloped” (Grannis et al., 2004, pg. 2).

Two chief hypotheses are investigated. First, it is hypothesized that the AgriStability program produces an equitable distribution of benefits and costs for Albertan cow-calf producers. Distributional equality is measured using two statistics: the Gini coefficient and an adapted Suits index. The second hypothesis states that increased

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[20] There is some debate about whether it is valid to consider the fee and the premium as equivalent, as the fees are much lower than the actuarially fair premiums (see sections 4.4.4 and 4.5). AgriStability is treated as an insurance program throughout this chapter, so the term premium is appropriate.

catastrophic price risk does not influence the equality of the distribution of program benefits. The motivation for these hypotheses is derived from how AgriStability was launched. Specifically, it was introduced as a “targeted, equitable, whole-farm” program (AAFC, 2009). Moreover, “Canadian public policy has historically placed an emphasis on fairness” (Freshwater and Hedley, 2005, pg. 25). The intention of this chapter is to empirically measure the AgriStability’s degree of equity. A farm-level simulation model is developed to perform *ex ante* analysis of the program at the level of an individual producer.[21] Price risk for a sample of Albertan whole-farm businesses is considered. Producers’ willingnesses to pay for this form of revenue insurance are calculated using indifference pricing techniques. Actuarially fair premiums, from the insurer’s perspective, are computed using an actuarial model. Five price risk scenarios are explored. Finally, after these hypotheses are empirically evaluated, the AgriStability program is scrutinized according to the normative concepts of vertical and horizontal equity.

AgriStability’s influence on livestock farms is the primary concern. Detailed data are available for a sample of cow-calf enterprises. Limited information on these firms’ crop enterprises is contained in the dataset however. Each firm is therefore modelled

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[21] The results of this chapter would be identical if the analysis were completed *ex post*. The reason is this. The model described in this chapter assumes fixed behaviour. Agents don’t optimize or alter their decisions after the state of the world has been revealed. Therefore, ex ante and ex post predictions are the same. For *ex post* measurements to differ from *ex ante*, the model must explicitly allow the producer to alter his behaviour once he knew what the output price actually is. This model does not permit such changes. A model that did include changes in behaviour would imply some form of renegotiation, moral hazard or adverse selection.

with an identical crop enterprise while the livestock enterprise is reproduced according to the data in the sample. This approach focuses analysis on the effect of AgriStability on the cow-calf business. It is assumed that there is no output risk. As the focus is on livestock producers, this assumption is not unrealistic. Hart et al. (2001) state: “For most livestock producers, production risk is relatively small compared to price risk. Relative to crop production, livestock production risk is much smaller because livestock are more adaptable . . . Most production risk can be attributable to disease, mechanical failure, or variability in weight gain” (pgs. 555-6). Alberta has the greatest number of cow-calf enterprises in Canada, so Albertan producers were selected for analysis.

4.2 THE AGRISTABILITY PROGRAM

Income variability is a persistent challenge facing cow-calf producers. Unstable returns can have large negative impacts on the well-being of risk-averse farmers. Producers may reap significant benefits from income stabilization (Hennessy, 1998). Introduced in 2003, the Canadian Agricultural Income Stabilization (CAIS) program was designed to mitigate the downside risks of the agricultural sector. CAIS has recently been replaced by AgriStability and AgriInvest. AgriStability is intended to protect against both ordinary production and price risk and the prospect of catastrophic shocks. It “integrates stabilization and disaster protection into a single program” (AAFC, 2006).

The agricultural economics literature considers insurance, stabilization and support programs as distinct. In general, an income stabilization program is designed to smooth cyclical fluctuations in farm income (Freshwater and Hedley, 2005), while income support programs include any policy that yields higher incomes than would be generated by the market (Dewbre and Short, 2002). Yet, even the simplest farm programs are never as straightforward as the textbook definitions suggest. For example, traditional crop insurance includes subsidies and does strictly adhere to the requirements of a competitive insurance contract (Turvey and Amanor-Boadu, 1989). The CAIS program was initially designed as a deposit-based “stabilization” program but was reformulated using an entirely different enrolment structure (Jeffrey and Unterschultz, 2007). In practice, regardless of the label used to describe the program, it is challenging to precisely distinguish between agricultural support, stabilization and insurance policies.

The theoretical and empirical methods used for analyzing insurance products are advanced and mature however. As such, AgriStability is discussed using the language of insurance economics. If any differences exist between treating the program as insurance versus stabilization or support, they are viewed as minor. See Freshwater and Hedley (2005) for a historical overview of Canadian agricultural policy.

Mussell and Martin (2005) completed an early assessment of CAIS. Using National Income Stabilisation Account (NISA) data from 1994-2001, it modelled Ontario agriculture as if CAIS had existed. They concluded that CAIS favourably affected farm margins and did stabilize income. Jeffrey and Unterschultz (2007), on the other hand, argued that CAIS was structured more for disaster relief rather than income stabilization. As a disaster relief program however, it qualitatively determined that it was successful.

CAIS experienced several administrative problems when it was introduced in 2003 (AGC, 2007). Thus, it is uncertain whether the program provides adequate disaster protection from catastrophic price risks such as those experienced during the BSE crisis. Moreover, it is possible that distinct livestock operations may have been treated inequitably even if CAIS had functioned correctly – i.e., the current AgriStability program design may lead to unbalanced outcomes or generate unintended incentives.

AgriStability is a federal and provincially funded agricultural risk management program open to livestock and crop enterprises. The administration of the program in 2008 is a federal responsibility for the provinces of British Columbia, Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Newfoundland and Labrador and Yukon. Ontario, Prince Edward Island, Quebec and Alberta manage the program provincially.

AgriStability payments are based on historical returns, so the program is path-dependent. Program payments are built on two margins: the production and reference margins. The production margin is calculated annually (fiscal year) and determined by subtracting allowable expenses from allowable income (AFSC, 2008). The production margin is tantamount to the net enterprise cash flows after excluding unallowable expenses (i.e., expenses subject to moral hazard). The reference margin is path-dependent and calculated as an Olympic average of the five previous production margins – i.e., the reference margin excludes the previous five years' highest and lowest production margins and then takes an average of the remaining three.[22]

Figure 3.1 depicts the payment structure of AgriStability. There are two primary tiers in the program (tiers 2 and 3). First, if a producer's production margin is less than 70% of her reference margin, AgriStability payments equal 80% of the margin decline – for example, if a farmer's reference margin equalled $100,000 and she experienced a

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[22] In Alberta the reference margin is allowed to be the greater of the Olympic average and the average of the previous three years' production margins. As it is more applicable country-wide, only the Olympic average calculation is considered in this paper.

100% margin decline, the tier 3 payment would equal (70% * $100,000) * 80% = $56,000. For the next tier (tier 2), the 70%-85% protection level, the subsequent income protected, over the original 70% of the reference margin, receives 70% coverage – i.e., the total AgriStability payment is tier 2 plus tier 3: (70% * $100,000) * 80% + (15% * $100,000) * 70% = $66,500. Let *RM* be the reference margin and *PM* be the production margin. Then AgriStability payments for tiers 2 and 3 are calculated via:

$$\text{Payment} = \begin{cases} 0, \text{if } PM \geq 85\%RM \\ 70\%(85\%RM - PM), \text{ if } 70\%RM \leq PM < 85\%RM \\ 80\%(70\%RM - PM) + 70\% \cdot 15\%RM, \text{ if } PM < 70\%RM \end{cases}$$

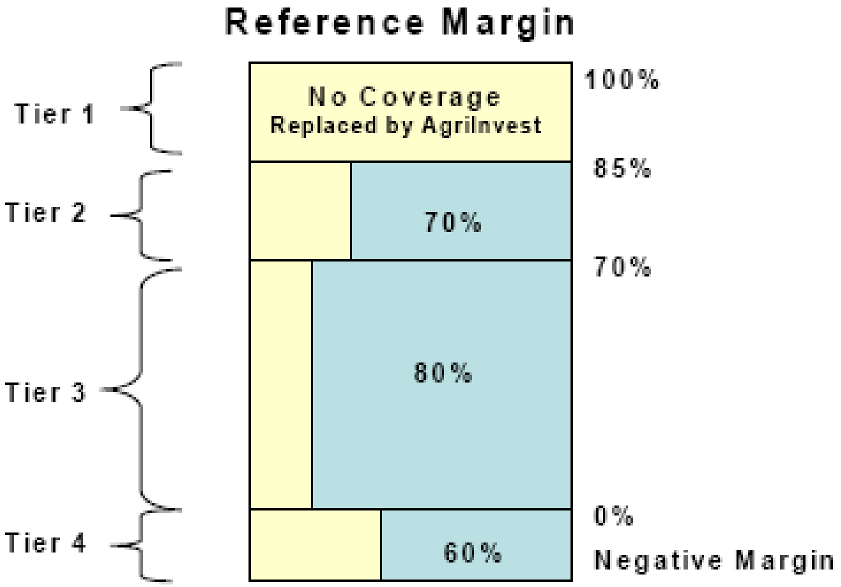

Figure 4.1: AgriStability Payment Tiers

Source: AFSC (2008), pg. 1.

Producers must pay a participation "fee" of $4.50 for each $1000 of their reference margin multiplied by 85% (AAFC, 2009). An additional $55.00 fixed "administrative cost share" fee is also levied. Together these fees grant access to the program. Producers are not obligated to participate in AgriStability however. They can opt out (not enrol) and not pay the fees. While that actual enrolment costs are labelled as “fees”, the term “premium” is used in the empirical section of this chapter. This is to maintain consistency with the terminology used in the theoretical literature. It should be emphasized however that these fees are low and likely below the actuarially fair costs.

AgriStability includes a provision for production margin declines of greater than 100% as illustrated by tier 4 in Figure 3.1. This provision for payouts on negative margins was added to the CAIS program in 2005. Provided that the operation’s reference margin is greater than $0 and that the enterprise has not received negative margin contributions for greater than two of the previous five years, the program pays $0.60 for each dollar of negative margin.

4.3 RELATED LITERATURE

4.3.1 General Agricultural Insurance Valuation Methods

AgriStability mimics a net revenue or portfolio insurance program. An extensive literature exists on agricultural insurance along with methods for its valuation or pricing. The term valuation refers to a method of assigning a dollar “value” to a set of random payoffs. Valuation methods differ based on their underlying assumptions, which may or may not apply in certain circumstances. Alternative pricing techniques often generate vastly divergent estimates (e.g., Turvey and Amanor-Boadu, 1989). Myers et al. (2005) provides a critique of three common valuation methods: expected value approaches, option pricing methods and general equilibrium models.

First, the expected value approach determines the price of an insurance contract by computing the present value of the expected loss and then multiplying this expected value by a “loading factor.” The loading factor is an arbitrary parameter which represents the insurer’s risk premium and other transactions costs. The primary advantage of the expected value approach is its ease of computation for almost any loss distribution. Moreover, this method is the preferred method in the actuarial sciences (Klugman et al., 1998). Myers et al. however critique the need to exogenously specify the loading factor – i.e., it is a “free parameter” that must be set by the analyst. Yet, while Myers et al. see the loading factor as a weakness in actuarial models, for this paper, it allows for additional analysis on the equity features of government provided insurance, as is seen in section 4.4.5.2. Further, the expected value approach is extensively employed in the literature (e.g., Vedenov and Power, 2008; Skees and Nutt, 1988).

The Black-Scholes framework is often used to estimate agricultural insurance premiums (e.g., Turvey and Amador-Boadu, 1989; Turvey, 1992a, 2003; Richards and Manfredo, 2003). Insurance contracts are written based on an operation’s underlying farm revenue. Insurance takes the form of a contingent payoff that can be replicated as a put option. This option is then priced using some variation of the Black-Scholes formula. The advantage of the Black-Scholes model is that it is “a fully articulated equilibrium asset pricing model, and so it will . . . value options (and hopefully insurance contracts) at what their equilibrium value would be in competitive financial markets” (Myers et al., 2005, pg. 6). However, several restrictive assumptions must be satisfied to ensure the accuracy of a Black-Scholes priced contract. These assumptions include that: i) the underlying index be continuously traded in a liquid market; ii) there are no transactions costs; and, iii) the stochastic process driving the underlying index is a geometric Brownian motion. In most cases, assumption iii) will not be restrictive for pricing agricultural insurance as Brownian motion is the limit of a large set of stochastic processes (Roberts, 2009). However, conditions i) and ii) pose a greater problem. Agricultural insurance markets have transaction costs and are likely incomplete (Duncan and Myers, 2000). Thus agricultural insurance markets do not explicitly meet the strict requirements of the Black-Scholes model. The model can be adjusted to compensate for these restrictions. Yet, it is unclear whether these modifications sufficiently overcome the drawbacks and, at the very least, engender the model with greater complication than the expected value approach. Nonetheless, the Black-Scholes framework provides a theoretically consistent method to approximate insurance premiums.

The third agricultural insurance valuation technique considered by Myers et al. is the Lucasian model of intertemporal consumption. In this model, investors are compensated for taking the risk of issuing an insurance contract. The factor which determines the required compensation for bearing this risk is measured by the intertemporal rate of substitution of consumption. This model requires that a utility function be assumed and Myers et al. critique the approach as it is unclear whose consumption should be used. Lucas' model also implies that no trades occur in equilibrium, which is an unrealistically strict condition.

This review of valuation methods is not exhaustive. Several alternative techniques have also been proposed. For instance, Chambers (2007) prices insurance in a "state-contingent" framework. This pricing method is based on a theoretically distinct framework than the previously described methods. This framework is new to the literature. As a consequence, research is still required to fully develop its practical applicability to a range of insurance contexts.

The calculations in this research use an expected value or actuarial model to value AgriStability from the insurer's perspective and indifference pricing techniques to capture the producers' upper bound on her willingness to pay for the contracts. These are discussed below.

4.3.2 Livestock and Revenue Insurance Programs

Several studies have compared outcomes under revenue insurance policies to those under US farm programs (Harwood et al., 1994; Hennessy et al., 1997). The general conclusion is that a revenue insurance program would have been more effective – i.e., it would have provided greater benefits at a lower cost – than the actual farm programs that were enacted. On a similar note, Paulson and Babcock (2008) examine the new Group Risk Income Protection program in terms of comparable revenue insurance protection. It finds that government provision of agricultural risk management programs threatens to crowd-out private or quasi-public insurance. The majority of analyses focus on the impacts of a homogeneous group of producers (see Coble and Knight (2002) and Glauber and Collins (2002) for reviews). Minimal research has been completed on the equity impacts of publically provided insurance within a particular group of livestock producers.

Demanders of revenue insurance may have a distinct demographic profile from producers purchasing traditional crop insurance. Vedenov and Power (2008) found that farmers who purchase revenue insurance tend to be younger, less experienced and more highly leveraged. General agriculture insurance demand increases with leverage, risk and farm size but decreases with wealth. Additionally, some producers may still choose to not purchase a given insurance product, even under circumstances when premiums are subsidized or other contract terms are in their farm's favour (Vedenov and Power, 2008).

Research on livestock insurance, particularly for cattle producers, is less developed than for crop insurance. Beef cattle producers are exposed to price risks resulting from several factors including: beef imports, food safety issues and demand (Fields and Gillespie, 2008). Consequently, some form of insurance is warranted for livestock producers. Hart et al. (2001) outline a potential structure for livestock revenue insurance. It proposes that livestock revenue insurance take the form of an Asian basket option for which a numerical technique, combining approximation and Monte Carlo methods, is developed to calculate actuarially fair premiums.

Producers in the US can currently purchase a combination of futures and options on the Chicago Mercantile Exchange to form a position that would behave like price insurance. However, revenue insurance may be a superior option due to several reasons. First, more producers would likely use insurance than those who currently use futures and options. Only 1.5% of US beef cattle producers currently exploit futures strategies (Fields and Gillespie, 2008). Similarly, Unterschultz et al. (1999) found that only 4.5% of Albertan cow-calf producers used any form of hedging to mitigate risk on their farms. Next, specialized knowledge required to use futures and options would be transferred to the insurance companies rather than being required by producers. The majority of producers likely do not have the ability to fully exploit derivatives whereas revenue insurance is more accessible. Finally, insurance products can be tailored to individual farms. It is probable that more producers will take advantage of insurance risk-reduction mechanisms than have employed alternative financial tools (Fields and Gillespie, 2008).

4.3.3 Valuing Canadian Agricultural Insurance

Sigurdson and Sin (1994) provide an overview of the history and evolution of Canadian crop insurance policy. Crop insurance programs in Canada have transformed into income support programs. Sigurdson and Sin asserts that this is a direct result of premium subsidies. These premium subsidies were originally intended to induce program participation – i.e., they were inducement subsidies. Sigurdson and Sin find that inducement subsidies did increase program participation, but the effect was small – e.g., “an increase in the expected rate of return [from crop insurance] of 10 percent would increase participation by 1.85 percentage points” (pg. 65).

Turvey and Amanor-Boadu (1989) calculated premiums for “portfolio” or revenue insurance using an actuarial model and the Black-Scholes framework. Premiums are calculated for an Ontario cash crop farm. The paper makes several notable contributions to the Canadian insurance policy discussion, building on earlier research by Finkle and Furtan (1988). First, it employs techniques from financial mathematics to value agricultural insurance and compares these values to ones computed from actuarial methods. It claims that premiums from the distinct pricing methods “may act as lower and upper bounds boundaries within which the actuarially fair premiums fall” (pg. 240), however no justification is given for this assertion. These computations highlight the problem of assuming a normally distributed underlying index when an alternative distribution is more appropriate (as in the expected value model) – e.g., if the underlying distribution is positively skewed, then assuming normality will lead to overestimates of the actuarially fair premiums (Hart et al., 2001). Turvey and Amanor-Boadu (1989) states that “to avoid *ad hoc* premium setting, it is necessary to relate insurance premiums with portfolio risks associated with farm production” (pg. 234). The range for the results that Turvey and Amanor-Boadu presents is broad however. “For example, a 90% coverage on expected net farm income of $120 per acre (i.e., $108 per acre) will cost $1.89 per acre and $17.86 per acre under the Black-Scholes model and crop insurance model, respectively” (pg. 244). The paper claims that “the probability distribution of farm income is extremely crucial in the determination of the premium” (pg. 245). Despite the unreliability of the premium estimates, Turvey and Amanor-Boadu introduced advanced techniques and is an influential paper in assessing Canadian whole-farm or portfolio agricultural insurance.

Turvey (1992a, b) extend the analysis of Turvey and Amanor-Boadu (1989), examining revenue insurance using both expected value and the Black-Scholes models. Turvey (1992a) structures government insurance payments as contingent claims against farmers’ revenue from commodity production. It then employs option pricing methods to generate *ex ante* contract values. The main conclusion is that “mispricing agricultural insurance can lead to problems of adverse selection” (pg. 195). Further, it highlights the importance of moral hazard: “That farmers can either alter the probability of insured outcomes, or optimize according to the parameters of the policy is undisputed” (pg.195). Turvey (1992b) presents an in-depth investigation of revenue insurance on farm-level decisions. It notes that for an Ontarian crop enterprise “substantial acreage response could result from . . . revenue insurance” (pg. 422).

Minimal research has been completed on the new Canadian business risk management suite. Further, there is a dearth of attention paid to the equity implications of government provided programs, particularly when these programs include subsidies. This research aims to fill this gap.

4.4 THE MODEL

This chapter's analysis of AgriStability with the potential of catastrophic risk requires a model with three components. First, the insurer's premium valuation problem is considered. Actuarially fair premiums are computed using an expected value model. Next, the producer's problem is developed. Indifference pricing techniques are discussed and two calculations are compiled: i) upper bounds of producers' willingnesses to pay for program premiums; and, ii) the program's actual costs. Finally, the premium valuations, actuarially fair and indifference prices, are connected through a series of linkage relationships, referred to as models (I) and (II). The parameters of these linkage equations are the primary artefact of interest for this research. The underlying equity implications of the AgriStability program within a sample of Albertan cow-calf producers are elicited via these relationships. The operationalization of the analytical model requires the construction of a simulation model which is also reviewed. Before the discussion on pricing AgriStability, the concept of catastrophic price risk and the five scenarios examined in this research are introduced.

4.4.1 Catastrophic Price Risk

A stylized but likely true characterization of catastrophic events is that they are rare – i.e., low probability, high impact events. "Catastrophes are generally considered to be extreme events. They are often the substance of the long tails we find in many loss distributions" (Schlesinger, 1999, pg. 95). Duncan and Myers (2000, pg. 842) state: "From an insurance perspective, a catastrophe can be defined as an infrequent event that has undesirable outcomes for a sizeable subset of the . . . population."

Two fundamental features of catastrophic risk are considered: probability of event occurrence and magnitude of impact. Probability of event occurrence refers to the chance that a catastrophic level disaster could occur within a defined period of time. Magnitude of impact refers to the size of the price shock if an event occurs. Catastrophes are rare and reliable estimates are unavailable for both frequency (probability) and magnitude.

Five scenarios, a combination of catastrophic price risk probability and impact, are considered. Table 4.1 presents the probability of a catastrophic event and size of its impact for each scenario. Actuarially fair premiums and indifference prices along with the equity calculations in models (I) and (II) are determined for each scenario. A primary research question of this chapter is how these values change with the introduction of catastrophic risk.

Table 4.1: List of Probabilities and Magnitudes of Catastrophic Price Drop for Five Scenarios

	Probability of Event Occurrence	Magnitude of Price Drop
Scenario 1	No Catastrophic Risk	
Scenario 2	2%	60%
Scenario 3	2%	80%
Scenario 4	4%	60%
Scenario 5	4%	80%

4.4.2 The Insurer's Problem

4.4.2.1 Actuarially Fair Premiums

AgriStability can be treated as a net revenue insurance contract for which actuarial methods can be used to determine premiums. Assume that the insurer views an individual firm's production margin as composed of two distinct components. First, examine $PM > RM$. Let x^{+} be a random variable that represents the production margins under this condition and denote the AgriStability payment associated with that variable as A^{+}. Next, assume that $PM < RM$. Let x^{-} be the production margin in this case and A^{-} be the AgriStability payment. Assume that the insurer forms a 2-point mixture between distinct distributions and calculates the expected loss from the mixed distribution. The actuarially fair premiums for AgriStability can be calculated via:

(4.1) $$\pi_{fair} = (1-\mu)\cdot\int A^{+} f(x^{+})dx^{+} + \mu\cdot\int A^{-} g(x^{-})dx^{-}.$$

The distributions $f(\cdot)$ and $g(\cdot)$ represent the "gain" and loss distributions respectively (Klugman et al., 2004). Each distribution integrates to one and reflects the probability that the random variable, which meets a particular condition (resp. $PM > RM$ or $PM < RM$), deviates from the reference margin at particular magnitudes. The parameter μ represents the probability that $PM < RM$. If the reference margin is near its long-run mean and realized production margins are independent through time then it is reasonable to set μ equal to 0.50.[23]

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[23] In the simulations a value for μ was always within the interval (0.48, 0.52). Therefore μ=0.50 is a reasonable value to assume for the premium calculations.

The actuarially fair premium is calculated using a 2-point mixture, rather than using a single revenue distribution, because this approach requires less information and is more adaptable to differing institutional frameworks. Whenever an x^+ is realized the production margin is greater than the reference margin and A^+ equals zero. This means that the first right-hand side term of **(4.1)** disappears. Only information on the loss distribution, $g(\cdot)$, is required to determine the actuarially fair premium. While the government, acting as insurer, likely has access to information of the complete revenue distribution of a farm, this may not be the case if insurance is provided through a private or quasi-public organization. If insurance is privately provided, the insurer will only have access to information on the loss probability and loss distribution, μ and $g(\cdot)$. Thus, modelling the actuarially fair premiums as a 2-point mixture permits greater flexibility in applying the approach to settings where the revenue insurance is not provided by a public agency.

The particular parameters of the AgriStability program were discussed in section 4.2. The actuarially fair premiums for this contract are calculated via:

(4.2)
$$\pi_{fair} = \mu \cdot \begin{bmatrix} \alpha \cdot \int_{\theta \cdot RM}^{\varphi \cdot RM} (\varphi \cdot RM - x) g(x) dx \\ + \beta \cdot \int_{0}^{\theta \cdot RM} (\theta \cdot RM - x) g(x) dx \\ + \gamma \cdot \int_{-\infty}^{0} x \cdot g(x) dx \end{bmatrix}$$

where the “-” superscript on x is repressed here forward. The random variable x therefore represents the producer’s production margin under the condition that it is less than her reference margin ($x = PM$, if $PM < RM$) – i.e., an eligible “loss” within the AgriStability structure. The producer’s loss distribution is still given by $g(x)$. There are two sets of parameters in **(4.2)**: α, β and γ correspond to the payout rates, 70%, 80% and 60% for AgriStability tiers 2, 3 and 4 of Figure 4.1, while φ and θ are the cutoffs for tiers 2 and 3 respectively (i.e., 85% and 70% of *RM*).

Figure 4.2 presents a graphical depiction of the AgriStability payout structure. The random loss variable, *x*, is represented on the horizontal axis. Any realized loss is translated into an AgriStability payment by first moving vertically until the curve is reached and then by moving horizontally to the payment level. The kinks in the curve correspond to the reference margin cutoffs specified by the programs parameters. Actuarially fair premiums are calculated by summing (integrating) the area under the curve where loss values are weighted by their probability of occurrence.

Equation **(4.2)** is a mathematical translation of Figures 4.1 and 4.2 from the Government or insurer's perspective. The first two right-hand side terms in **(4.2)** correspond to tiers 2 and 3. This is the AgriStability program in its basic form. The third term captures tier 4, the additional payments for negative producer margin.

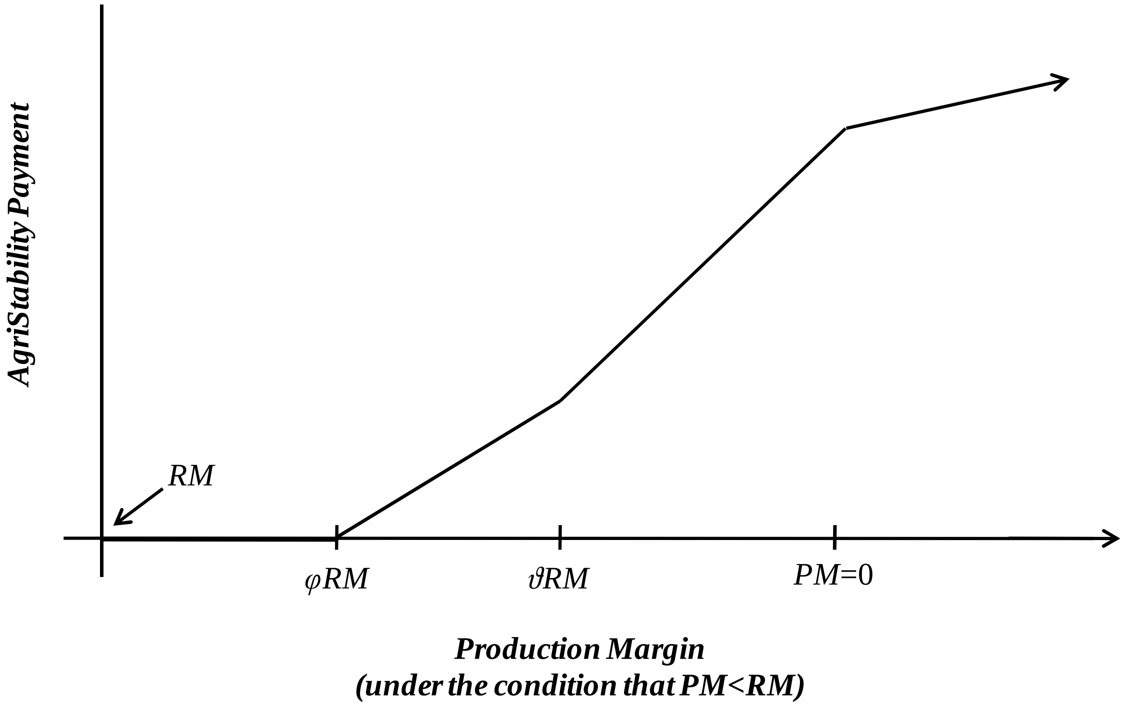

Figure 4.2: Relationship between Loss and AgriStability Payments

4.4.2.2 Loss Distribution

The loss distribution, $g(\cdot)$, is a key component for calculating actuarially fair premiums. The sample contains 76 unique cow-calf firms (see sections 3.4.4 and 4.4.7 for detailed descriptions of the data). Simulations for each firm and scenario are run (section 4.4.7 contains a discussion of the simulation model). The generated data on reference and production margins are used to determine the loss distribution. A set of familiar parametric distributions[24] are fit to the data and then ranked according to three goodness-of-fit statistics. These statistics – the chi-squared, Anderson-Darling and Kolmogorov-Smirnov – are generally considered weak tests and many appropriately

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[24] Examples of the distributions include: Normal, Lognormal, Inverse Gaussian, Weibell, Exponential, among others.

parameterized distributions adequately fit the data. Overall, the exponential distribution consistently ranked highest.

A convenient feature of the exponential distribution is that it depends on a single parameter, enabling greater flexibility in the modelling process. The loss distribution, $g(\cdot)$, for equation **(4.2)** is modelled as:

(4.3)
$$\begin{aligned} & x \sim Exp(\lambda) \\ & \text{where} \\ & \lambda = \lambda_0 + \lambda_1 \cdot (\text{Herd Size}) \cdot \end{aligned}$$

The exponential probability distribution – which is specified as $g(x;\lambda) = -\,{}^{1}\!/_{\lambda}\, e^{-\frac{x}{\lambda}}$ – depends on the parameter λ. Mean loss, equal to λ, is assumed to be linearly depend on a firm's herd size, measured in cows-wintered. The rationale for this extension is that, even if an insurer does not have historical information on a specific firm's potential loss, it can generate an estimate based on that farm's herd size. In this application, as crops are held constant across firms, their effect is captured in the constant term. The distribution featured in **(4.3)** is one of many potential specifications. Additional explanatory variables or even alternative distributions may be appropriate in varied empirical circumstances.

Cash flow simulation models are developed using historical input costs, price forecasting equations and firm-specific output information. Section 4.4.7 describes the simulation model. Output data from these models are used to calculate λ from the loss distribution. Once all simulations were completed, a linear regression of a constant and firm herd-size was run, with λ as the dependent variable. A regression was run for each of the five scenarios (see Table 4.1). Table 4.2 presents the results from these regressions. This approach implies that each firm's loss distribution, and consequently their actuarially fair premium, is determined by their herd size.

Table 4.2: Regression results of Exponential Distribution Parameter on Herd Size

	Scenario				
	1	2	3	4	5
Constant	7160.4	6805.3	6554.6	6339.8	5917.7
	(15.26)	(14.93)	(14.38)	(13.76)	(13.05)
Herd Size	62.697	72.386	80.173	82.657	97.878
	(29.13)	(34.63)	(38.35)	(39.12)	(47.08)
R-squared	0.913	0.942	0.952	0.954	0.968

* - t-statistics in parentheses

4.4.3 The Producer's Problem

The indifference pricing methodology is applicable to any asset pricing problem. As this research's application deals with agriculture, discussion focuses on farming and the purchase of a revenue insurance contract that mimics AgriStability. To start, a general overview of the underlying concepts of indifference pricing is introduced. Then the general pricing framework and specific model formulations are presented.

4.4.3.1 Indifference Pricing: Introduction

The basic premise of indifference pricing is that an agent has an incentive to purchase revenue insurance if owning the insurance contract increases her wealth. More precisely, if F_b is the upper bound indifference price, then F_b is the maximum price where a producer, *i*, is indifferent between: a) paying F_b now to obtain margin coverage via AgriStabilty; and, b) having no revenue insurance – i.e., not being covered by AgriStability. Xu et al. (2008) state: "Indifference pricing starts with the appealing idea that the amount of money at which a potential buyer . . . of . . . insurance is indifferent, in terms of expected utility between buying . . . and not buying constitutes an upper . . .

limit for the contract price. *Such an approach can take into account the particular economic situation of individual buyers*" (pg. 980, *emphasis* added). The appeal of indifference pricing over alternative financial economic methods, when dealing with agricultural insurance, is derived from the relaxation of a key assumption. Most models in financial economics require the assumption of continuous trading on a liquid market. Indifference pricing avoids this restriction. Moreover, there is the appealing feature that the pricing of agricultural financial products is relevant in discrete time settings – i.e., where positions are retained once a sell or buy decision has been made (Xu et al., 2008).

Indifference pricing is used to value AgriStability revenue insurance contracts. There are three key features of the indifference pricing method that are germane to this application. First, indifference prices are derived from an individual agent's utility maximization problem, which implies that individual agents are optimizing over their choice sets. The risk aversion parameters estimated in Chapter 3 are used to calculate producers' maximum willingnesses to pay for AgriStability revenue insurance. Next, the indifference pricing methods "prices-in" both systematic and idiosyncratic risk. That is, individual firms can incorporate risks which are specific to their businesses. This is a relevant feature for agricultural finance, as farm-specific risks can play a substantial role in decision-making. Finally, unlike the option pricing framework or the Lucasian model, the indifference pricing method is not an equilibrium approach. Individuals are assumed to maximize their utility of terminal wealth, so the model appeals to individual rationality conditions. As no equilibrating relationship is imposed *a priori* on the model, several of the more restrictive assumptions of the alternative pricing methods are removed, making the approach more flexible and amenable to the particular characteristics of agricultural finance.

Agricultural insurance is frequently provided by the government. As such, markets for risk management products are often incomplete or distorted by subsidies and regulations. Consequently, it is often easier and more appropriate to work with distributions of relevant random variables rather than stochastic processes in continuous time (Xu et al., 2008). Relaxing the equilibrium requirement enables a more realistic characterization of the market for agricultural financial products. A series of linkage relationships are developed which connect the actuarially fair premiums to inducement subsidies, pure wealth transfers and producers' upper bound indifference prices (see section 4.4.5). The derivations of the indifference pricing models follow the general approach of Xu et al. (2008).

4.4.3.2 General Indifference Pricing Approach

The value F_b^i indicates the maximum price that the agent *i* is willing to pay for a product (the firm index, *i*, is suppressed for this subsection). Let $V(W,0)$ and $V(W-F_b,1)$ be the maximal expected utility of initial wealth, *W*, without and with a financial product – i.e., if an individual does not purchase insurance (or other risk mitigating financial derivative) it is denoted by a "0"; purchasing the product is given by a "1". Maximal expected utility in these two scenarios corresponds to:

(4.4) $$V(W,0)=\sup_{\vartheta} E\left(U\left(W+\int_0^T \vartheta\cdot dS\right)\right)$$

and

(4.5) $$V(W-F_b,1)=\sup_{\vartheta} E\left(U\left(W+\int_0^T \vartheta\cdot dS-F_b+A^-\right)\right).$$

Where ϑ represents any financial asset (farm profit in this application), dS represents any stochastic process (can be discrete or continuous), E is the expectation operator and T represents the terminal period. The other variables, W, F_b and A^-, are defined as above.

The point of indifference – i.e., the point where a producer is indifferent between owning and not owning the insurance contract – gives a condition for the maximum price that a producer is willing to pay for the financial product. This *indifference pricing condition* is given by:

(4.6) $$V(W,0) = V(W - F_b, 1)$$

where F_b is the indifference price of the product. To solve for the indifference price in **(4.6)** either an exponential expected utility function must be assumed or numerical methods are required. Both approaches are employed below. CARA preferences are consistent with exponential utility functions and an explicit AgriStability pricing formula is derived in this case. The drawback from using an exponential utility function is that it is only exact when the underlying index is normally distributed, a condition which is violated when there is catastrophic price risk. A larger deviation from normality generally implies less reliability in the results. Alternatively, numerical methods are used with the power utility function, which represents a CRRA preference structure.

Becherer (2003) demonstrated that in the absence of dynamic trading strategies (i.e., trading strategies are restricted in the initial period to the set *{buy, do not buy}*), as is the case when producers decide whether to enrol in AgriStability, the indifference pricing condition, **(4.6)**, reduces to the actuarial principle of equivalent expected utility:

(4.7) $$E[U(W,0)] = E[U(W,1)].$$

The indifference price F_b should not be interpreted as the market price for a product (Xu et al., 2008). It is an upper bound which acts as a starting place for further analysis. Alternatively, it is a threshold in negotiations between buyers and sellers. In the analysis of AgriStability with the potential for catastrophic risk, producers' indifference prices are used to calculate inducement subsidies under the five scenarios. Indifference prices are not equilibrium prices in the sense that they do not provide sufficient market clearing conditions for the insurance market.

4.4.3.3 Utility Functions and Pricing Models: Pricing AgriStability

Characterize the farm production decision in the same manner as Chapter 3. Assume a two period horizon. At period *t=0*, the producer makes a decision to maximize terminal wealth at time *T*. Planned farm production in the initial period, *t=0*, leads to farm profits, π, which is a random variable due to price uncertainty. The producer also has an initial level of wealth, W_0. Terminal wealth, in period *T*, is given by the sum of initial wealth and profits:

(4.8) $$W_i = W_0^i + \pi^i .$$

Initial wealth influences production decisions under risk when preferences are consistent with constant relative risk aversion (CRRA). Wealth drops out of the constant absolute risk aversion (CARA) pricing condition. The mean and variance of terminal wealth, respectively, are defined as:

(4.9) $$\overline{W_i} = W_0^i + \overline{\pi}^i$$

and

(4.10) $$\sigma_{Wi}^2 = \sigma_{\pi i}^2$$

where $\overline{W}_i, \overline{\pi}^i, \sigma^2_{Wi}$ and $\sigma^2_{\pi i}$ represent expected wealth, expected profit, variance of wealth and variance of profit respectively for firm *i*.

Including revenue insurance in the wealth calculation involves the inclusion of two components in **(4.8)**. First, a constant contract price, F_b^i ,must be subtracted from terminal wealth. Next, a random insurance payout must be added, A^i (the "-" is suppressed). Wealth with AgriStability is defined as:

(4.11) $$W_i = W_0^i + \pi^i - F_b^i + A^i .$$

Taking the expectation of **(4.11)** gives expected terminal wealth for producer *i*:

(4.12) $$\begin{aligned} E[W_i] &= E\left[W_0^i + \pi^i - F_b^i + A^i\right] \\ &= W_0^i - F_b^i + E\left[\pi^i + A^i\right]. \end{aligned}$$

Assume a producer's expected utility can be represented by exponential or power functional form. These are consistent with CARA and CRRA preferences, respectively. First, the exponential utility function for producer *i* takes the form:

(4.13) $$U_i(W_i) = -e^{-\gamma_i \cdot W_i}$$

where γ_i is the constant absolute risk aversion parameter. The exponential functional form coincides with mean-variance preferences. Next, if preferences are described by CRRA, then the power utility function takes the form:

(4.14) $$U_i(W_i) = \begin{cases} \dfrac{W_i^{1-R_i}}{1-R_i}, \text{if } R_i \neq 1 \\ \log W_i, \text{if } R_i = 1 \end{cases}$$

where the coefficient of relative risk aversion is R_i. Certainty equivalent formulations of each class of preferences are required. Let *CE* refer to the certainty equivalent version of the exponential functional form and $\hat{W}$ denote the certainty equivalent representation of **(4.14)**.

The coefficients of risk aversion, γ_i and R_i, are farm-specific in this analysis. Rather than assuming *ad hoc* aversions to risk, each firm's risk aversion parameter is calculated based on the number of years of experience of the primary operator. Specifically, risk aversion parameters are derived from models CARA II and CRRA II in Chapter 3 (see Table 3.3). Using these firm-specific values links the results of Chapters 3 and 4.

A producer is indifferent between her uncertain expected wealth and certainty equivalent wealth, so a change in the certainty equivalent wealth is a direct reflection of a change in the utility function (Pope and Chavas, 1985). When preferences are exponential (i.e., as in **(4.13)**), the certainty equivalent takes a mean-variance form. When producer *i* does not enrol in AgriStability, this gives:

(4.15)

$$\begin{aligned} CE_i^{wihtout} &= E[W_i] - \frac{\gamma_i}{2}\sigma^2(W_i) \\ &= W_0^i + E[\pi^i] - \frac{\gamma_i}{2}\sigma_{\pi i}^2 \end{aligned}$$

The certainty equivalent formulation with AgriStability then takes the form:

(4.16)

$$\begin{aligned} CE_i^{with} &= E[W_i] - \frac{\gamma_i}{2}\sigma^2(W_i) \\ &= W_0^i - F_b^i + E[\pi^i] + E[A^i] - \frac{\gamma_i}{2}\left[\sigma_{\pi i}^2 + \sigma_{A^i}^2 + 2\operatorname{cov}(\pi^i, A^i)\right] \end{aligned}$$

where $\sigma_{A^i}^2$ is the variance of AgriStability payments. The indifference pricing condition states that a producer's upper bound indifference price for the AgriStability contract is determined when **(4.15)** is equated to **(4.16)**. This gives:

(4.17) $$CE_i^{without} = CE_i^{with}.$$

This is equivalent to the condition **(4.7)**. After rearranging and simplifying, **(4.17)** gives a closed form pricing formula:

(4.18) $$F_b^i = E\left[A^i\right] - \frac{\gamma_i}{2}\sigma_{A^i}^2 - \gamma_i \operatorname{cov}\left(\pi^i, A^i\right)$$

The pricing equation, **(4.18)**, is used to explicitly calculate the maximum willingness to pay for each firm and scenario with simulated data. This formula has three components. First, the price of AgriStability depends on the expected payout. A higher expected payout implies a higher indifference price. Next, **(4.18)** states that even though producers are willing to pay more for higher expected payouts, there is a cost to variability in those benefits – as the variance of AgriStability payments increases, the indifference prices of risk averse producers declines. Indeed, it is possible to simultaneously have the expected value of the AgriStability program to increase while a producer’s indifference price decreases. Finally, it is likely that there is a negative covariance between farm profits and AgriStability payments. The purpose of revenue insurance is to guard against declines in farm income, so higher AgriStability payments are expected with lower profits. Greater negative covariance between profits and payments yields higher willingnesses to pay to participate in the AgriStability program.

Rearranging **(4.14)** gives the certainty equivalent version of the CRRA function:

(4.19) $$\hat{W}_i^{without} = \left\{(1-R_i)E\left[U_i(W,0)\right]\right\}^{1/(1-R_i)}$$

when the producer does not enrol in AgriStability. Participating in the program gives a certainty equivalent wealth of:

(4.20) $$\hat{W}_i^{with} = \left\{(1-R_i)E\left[U_i(W,1)\right]\right\}^{1/(1-R_i)}.$$

This indifference pricing condition, **(4.7)**, states that the upper bound indifference price is found by equating **(4.19)** and **(4.20)**:

(4.21) $$\hat{W}_i^{without} = \hat{W}_i^{with}.$$

No closed form expression for the indifference price can be derived using **(4.21)**. Each producer's indifference price is calculated numerically for each scenario.

4.4.4 Actual Enrolment Costs of Current AgriStability Program

The actual cost of enrolling in AgriStability is a key element is evaluating the economic equity of the program. For firm *i*, the cost of obtaining AgriStability benefits is given by:

(4.22) $$\eta_i = {0.85 \cdot RM_i}/{\$1000} \cdot \$4.50 + \$55.00$$

where RM_i is the reference margin for the firm and η_i represents the actual cost paid by the firm. A producer can obtain coverage for 85 percent of her reference margin at a cost of \$4.50 per \$1000 plus a \$55 administrative cost share fee.

The heart of the research problem is embodied in **(4.22)**. The AgriStability premium is represented by η_i. For any given reference margin, the program premium is identical across firms. Neither risk nor randomness enters into the actual AgriStability cost calculation. Enrolment costs depend on a firm's reference margin only. In other words, **(4.22)** represents the premium calculation for a net revenue insurance contract but it does not contain any measure of risk. According to the current design of the program, the only relevant characteristic, for the purposes of the AgriStability program, of a firm is its reference margin.

The reference margin mimics a farm's long-run gross margin and does not explicitly contain any adjustment for the riskiness of the underlying production processes.

Two firms with vastly different risk profiles could have identical reference margins and pay the same enrolment costs. The riskier firm would receive superior risk protection than the less risky farm. In effect AgriStability distorts producer incentives by encouraging producers to engage in riskier enterprises. Moreover, as program premiums are based on **(4.22)**, only by coincidence would AgriStability generate an equal distribution of net benefits to a sample of producers. Whether the *ex ante* inequitable benefit distribution increases with catastrophic risk is a primary question of the chapter.

4.4.5 Linkage Relationships

Three distinct AgriStability prices have been established. First, actuarially fair AgriStability premiums from the insurer or government's perspective are calculated. Next, producers' maximum willingnesses to pay to participate in the program are determined. Finally, the actual costs to enrol in AgriStability are recovered. Two stylized models, referred to as models (I) and (II), connect these three prices.

Figure 4.3 illustrates how the three prices are connected. The actuarially fair premium, π^i_{fair}, for producer *i* is linked to a producer's indifference price, F^i_b, via the inducement subsidy, Γ_i. Inducement subsidies are discussed in section 4.4.5.1. Next, the actual costs of the program, η_i, link with the actuarially fair premium via the total farm subsidy, Ω_i. Finally, from the inducement and total subsidy, the pure wealth transfer is calculated, Δ_i. *Ex ante* program equity under the prospect of catastrophic price risk is determined by examining the statistical dispersion of the total subsidy and the pure wealth transfer across the sample of cow-calf operations.

The next subsection introduces inducement subsidies. Following this discussion, models (I) and (II) along with definitions of the total subsidy and pure wealth transfer are addressed.

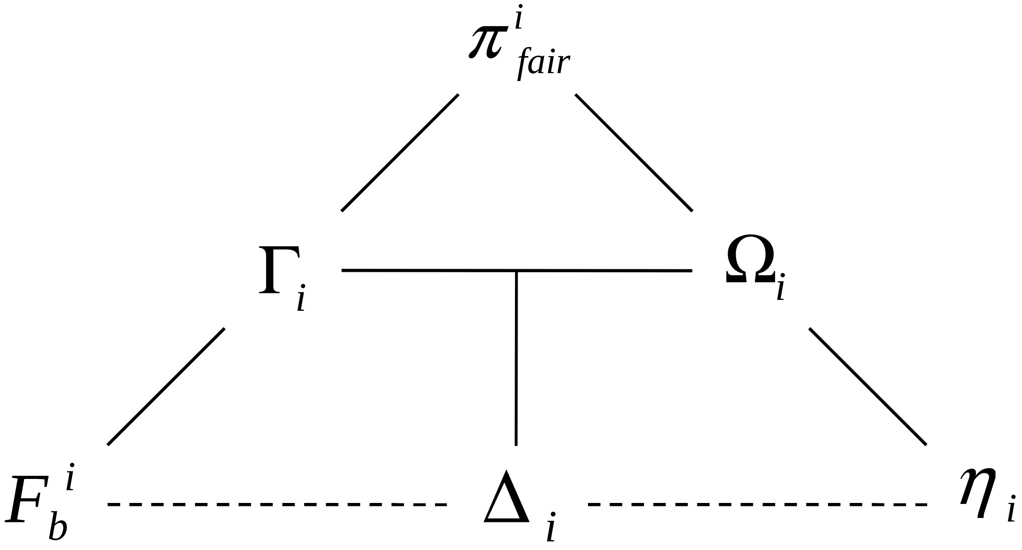

Figure 4.3: Linkage Relationships between Actual Costs, Indifference Prices and Actuarially Fair Premiums

4.4.5.1 Inducement Subsidies

An inducement subsidy is defined as a subsidy which is provided by the government to encourage producers to enrol in the AgriStability program. If a producer's maximum indifference price is less than the actuarially fair premium, then the government may subsidize program participation costs. This inducement subsidy induces the producer to enrol in AgriStability whereas without it she would not participate in the program.

There are three potential justifications for providing inducement subsidies. The first rationale is derived from a market stabilization argument. Policy-makers may be willing to subsidize the purchase of farm-level revenue insurance because stable producer income is seen as having positive supply-chain effects. For example, if a producer does not insure, she may have a more volatile output supplied. Additional volatility at the farm-level could be transmitted along the value chain, potentially affecting processors, retailers and consumers. The second rationalization is that producers will increase output supplied if their incomes are more stable. Increased output supplied may lead to lower consumer prices and an increase in total social surplus (Just, 1974). Finally, Schmitz et al. (2002) claim political factors may validate the provision of inducement subsidies. According to this argument, society may be willing to support the institutional arrangement of the family farm. As such, offering inducement subsidies sustains the socially and politically desirable family business. Whether the costs and benefits from these three explanations – supply-chain spill-overs, increased social welfare and political factors – justify the government's role in inducing producer participation in stabilization and insurance programs is still an open question. However, for the purposes of this chapter, it is assumed that in some subset of circumstances inducement subsidies are valid and justifiable.

An inducement subsidy must be distinguished from a total subsidy. Total subsidies and pure wealth transfers are discussed in the next section. Inducement subsidies refer to the amount needed to encourage program participation at the actuarially fair program premiums. Any transfer beyond this amount serves an alternative purpose.

Models (I) and (II) deal with dollars and rates respectively. Thus, distinct inducement subsidy calculations must be defined for each. In model (I), the minimum inducement subsidy for the AgriStability revenue insurance contract is defined as:

(4.23) $$\Gamma_i^I = \max\left[\left(\pi_{fair}^i - F_b^i\right), 0\right].$$

Model (II) defines the inducement subsidy as:

(4.24) $$\Gamma_i^{II} = \max\left[\left(\frac{\pi_{fair}^i}{F_b^i} - 1\right), 0\right]$$

where Γ_i is the minimum inducement subsidy, π_{fair}^i is the actuarially fair premium and F_b^i is producer *i*'s maximum willingness to pay for the contract. **(4.23)** calculates the minimum inducement subsidy in dollars, while **(4.24)** determines the subsidy as a percent of the actuarially fair premium. The inducement subsidy is defined to be a minimum, as the producer's indifference price is computed as a maximum.

Table 4.3 illustrates the share of the sample requiring an inducement subsidy to enrol in AgriStability at the actuarially fair premium. Using **(4.23)** and **(4.24)**, inducement subsidies are determined, using each firm's indifference price and actuarially fair premium, for all five scenarios (see Table 4.1). In scenario 1, for example, if all producers have CRRA preferences, 53.9 percent of farmers would require a subsidy in order to enrol in AgriStability at the actuarially fair cost of the program. Conversely, in scenario 5, when there is a 4 percent chance of an 80 percent price drop, only 2.6 percent of the sample needs an inducement subsidy. The general pattern, for both CARA and CRRA preferences, is similar: as probability and impact of catastrophic risk increases, willingness to purchase revenue insurance increases. The exception is scenario 5 under CARA. When calculating producers' indifference prices, added volatility due to increased price risk is not offset by AgriStability payments – i.e., variance of payments increased more than expected payments.

Table 4.3: Share of Sample Requiring an Inducement Subsidy in Each Scenario

	Scenario				
	1	2	3	4	5
CARA Preferences	57.9%	34.2%	31.6%	22.4%	25.0%
CRRA Preferences	53.9%	28.9%	14.5%	9.2%	2.6%

Table 4.3 highlights an important feature of any revenue insurance program: the number of producers requiring an inducement subsidy declines as risk increases. Therefore, if producers misperceive their actual level of risk, they may not fully protect against adverse events – i.e., even though producers would be better off enrolling in AgriStability, a distorted perception of their outcome probability distribution may lead to an erroneous decision (not participating). As an example, assume that the "true" distribution is reflected by scenario 3. However, assume that producers believe that the distribution is given by scenario 1. In this situation, over 20 percent of the sample would not purchase the revenue insurance contract, despite the fact that, even without an inducement subsidy, it would improve their welfare. This underlines the importance of understanding basic probability and statistics of events for both policy-makers and primary producers. Effective policy therefore should i) have a clear understanding of the outcome distribution; and, ii) communicate relevant information in a comprehensible manner. It should be mentioned that it may be challenging to generate accurate outcome distributions for rare events like the BSE crisis. By definition, rare events happen infrequently and much of statistics is not equipped to deal with sporadic data.

4.4.5.2 Linkage Models

Two approaches, referred to as models (I) and (II), link the producers' indifference pricing models, actual AgriStability costs, actuarially fair premiums and inducement subsidies. Model (I), on both a whole-farm and per cow-wintered basis, calculates values in *dollars*. Model (II) focuses on subsidy and transfer *rates* from the program.

Model (I)

Model (I) connects the actual program costs to actuarially fair premiums and inducement subsidies in actual dollars. The total subsidy provided to a cow-calf producer is defined as the difference between the governments actuarially fair cost of providing risk protection and a producer's actual cost of enrolling in the program. This difference is given by:

(4.25) $$\Omega_i^I = \pi_{fair}^i - \eta_i$$

where Ω_i^I is the total subsidy provided to producer *i* for model I. The total subsidy, Ω_i^I, then is the sum of two components. The first component of the total subsidy is the inducement subsidy, Γ_i^I, as defined in **(4.23)**. The difference between a producer's total and inducement subsidies is defined as a pure wealth transfer. This dollar amount is not required to encourage enrolment in AgriStability. Rather, it is a direct money transfer from the government to cow-calf producers which is embedded in the program's design. In model (I), a pure wealth transfer for producer *i* is calculated as:

(4.26) $$\Delta_i^I = \pi_{fair}^i - \left(\eta_i + \Gamma_i^I\right) = \Omega_i^I - \Gamma_i^I$$

where Δ_i^I is the pure wealth transfer.

Net benefits from AgriStability are measured via **(4.25)** and **(4.26)**. Both the total subsidy and the pure wealth transfer are computed for each farm in the sample. The two primary motivations for this research are to investigate: i) whether there is an unequal distribution of benefits in the sample; and, ii) whether the inequality increases with the introduction of catastrophic risk. Analysis focuses on the distribution of the total subsidy and pure wealth transfer.

One final point should be mentioned for model (I). The transfers in **(4.25)** and **(4.26)** are denominated in dollars. As such they depend on the scale of the operation. It is not clear whether the herd size should alter the AgriStability benefits to which a producer has access. Consequently, as model (I) is not independent of scale, both the total subsidy and pure wealth transfer are calculated on a whole-farm and a per cow-wintered basis. In general, dollars are relevant to producers, while rate calculations are pertinent for policy-makers.

Model (II)

Model (II) links actual AgriStability costs to the actuarially fair premiums via subsidy rates and loading factors. Unlike model (I), the total subsidy and pure wealth transfer rates determined by model (II) are scale-free. This implies that both the inequality of the distribution of rates across the sample and the structure of the rates, as reference margins change, must be examined. Akin to **(4.25)**, the actuarially fair premium and actual program costs are used to determine the total subsidy rate, Ω_i^{II}:

(4.27) $$\pi_{fair}^{i} = \left(1 + \Omega_i^{II}\right)\eta_i$$

where if $\Omega_i^{II} < 0$, it is referred to as a loading factor (the loading factor is the "free parameter" discussed in Myers et al. (2005)), and if $\Omega_i^{II} > 0$, it is known as a total subsidy rate for firm *i*. Similar to model (I), the total subsidy rate can be separated into two components: the inducement subsidy rate and pure wealth transfer rate. Combining **(4.27)** with **(4.24)**, it is possible to calculate the pure wealth transfer rate:[25]

(4.28) $$\Delta_i^{II} = \Omega_i^{II} - \Gamma_i^{II}$$

where Δ_i^{II} is firm *i*'s pure wealth transfer rate. As in model (I), the inequality of model (II)'s distribution of net benefits for both the total subsidy and pure wealth transfer rates is examined.

4.4.6 *Ex ante* Program Equity: Measuring the Distribution of Net Benefits

Two indices are used to evaluate the equity of the distribution of net AgriStability benefits. The Gini coefficient is calculated for both models (I) and (II). An adapted or modified Suits index (Suits, 1977) is also introduced. This index is applied to model (II) and determines, as firms' reference margins increase, the progressivity or regressivity of the structure of total subsidy and pure wealth transfer rates. It should be noted that the Gini and modified Suits indices are two choices from a large set of potential measures of inequality and progressivity. The theoretical backgrounds of these coefficients are not discussed. See Pauw (2003) and Suits (1977) for references.

The Gini coefficient is a well-known statistic in economics. Frequently employed to measure income inequality, it is a measure of statistical dispersion in an ordered sample – i.e., the Gini coefficient measures the inequality in a distribution of data that are ranked from smallest to largest. In the agricultural economic literature, El-Ostra and Morehart (2002) use the Gini ratio to examine the dynamics of the distribution of wealth

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[25] An alternative method for calculating the pure wealth transfer is according to: $\pi_{fair}^{i} = (1 + \Gamma_i + \Delta_i)\eta_i$.

in US farm operators and El-Ostra and Mishra (2005) employ it to investigate the role of subsidies in US farm household wealth.

This chapter hypothesizes an equal distribution of net benefits from the AgriStability program. A Gini coefficient is a statistic that yields a straightforward interpretation of the magnitude of equality in an ordered distribution of data. If a distribution is perfectly equitable – i.e., each producer obtains the same benefits from AgriStability – then the Gini coefficient of the net benefits distribution will equal zero. Conversely, if a single producer receives all program payments – i.e., AgriStability is perfectly inequitable – then the benefit distribution will produce a Gini coefficient of one.

Let y_i represent net AgriStability benefits (e.g., total subsidy or pure wealth transfer) and *i* = 1 to *n* be an ordered ranking of the size of benefits received by each firm in the sample (either more dollars or a greater subsidy rate). The ranking must have a non-decreasing order (i.e., $y_i \le y_{i+1}$). The Gini coefficient is an average which weights the benefits received by each firm by the share of total benefits received by that producer. Specifically, it is calculated as (Duclos et al., 2008):

(4.29)
$$\hat{G} = 1 - \frac{\sum_{i=1}^{n} h(y_i)(V_{i-1} + V_i)}{V_n}$$

where $h(y_i)$ is the distribution of benefits, $V_i = \sum_{j=1}^{i} h(y_j) y_j$ and $V_0 = 0$.

Gini coefficients are statistics that describe data. While often couched in a discussion of equity, these statistics do not have any explicit equity connotations. In section 4.6 however, these statistics are used in conjunction with equity criteria to evaluate the AgriStability revenue insurance program. Model (I) calculates Gini coefficients for the total subsidy and pure wealth transfer (including both CARA and CRRA preference structures) for each scenario at that whole-farm and per cow-wintered levels. Ginis are calculated for total subsidy and pure wealth transfer rates in all five catastrophic risk scenarios for model (II). If the coefficient increases as the scenarios move from one through five, then catastrophic risk exacerbates the inequality of the distribution of AgriStability benefits.

The Suits index (Suits, 1977) was introduced to measure the progressivity or regressivity in a tax schedule. An adapted Suits index is employed in this study to examine the degree of progressivity in the subsidy rate of the AgriStability program.[26] The index measures the degree that the structure of subsidy rates deviates from proportionality (Duclos, 1998). The Suits index was "inspired by and [is] related to the Gini ratio" (Suits, 1977, pg. 747).

The true adapted Suits index is computed from the subsidy concentration curve, which is a plot of the accumulated subsidy benefits against the accumulated reference margin. In this chapter, deciles are calculated for producer reference margins. The adapted Suits index is then approximated by (Suits, 1977):[27]

(4.30) $$\hat{S} \approx -\sum_{j=1}^{10} \frac{1/2\left(W\left(RM_j\right)+W\left(RM_{j-1}\right)\right)}{RM_j - RM_{j-1}}$$

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[26] The terms "adapted" and "modified" refer to the application to a subsidy rate structure rather than a tax rate structure and the sign change which accompanies the alternate interpretation.

[27] Reference margin deciles are used rather than actual references margins because several firms have identical reference margins. This leads to undefined values in **(4.30)**.

where $W(RM_j)$ is the subsidy rate for a producer with reference margin RM_j. The adapted Suits index varies from +1 at the extreme of progressivity where the entire subsidy is received by farms in the lowest reference margin bracket, through 0 for a proportional subsidy, to -1 at the extreme regressivity at which the entire subsidy is given to members of the highest reference margin decile (Suits 1977, pg. 747).

The index measures the average progressivity or regressivity of the subsidy system across the reference margin range. It is calculated for each scenario in model (II) for both the total subsidy and pure wealth transfer rates.

4.4.7 Data and Simulation Model

4.4.7.1 Capital Budgeting Cash Flow Model

A whole-farm capital budgeting simulation model is developed to generate the indifference prices, AgriStability costs and payments for individual firms. Each farm is comprised of a cow-calf enterprise and a crops enterprise. Firms are defined by three characteristics: initial wealth, experience of primary operator and herd size. Farm balance sheet equity is used to proxy initial wealth (see Chapter 3, section 3.4.4.4 for discussion on using balance sheet equity to proxy producer wealth). Wealth is required to calculate the CRRA indifference price. Risk aversion is a key variable in the indifference price calculations, so the use of differential risk aversion levels based on farm-specific variables is a contribution to the literature. The farm manager’s years of experience in combination with the results of the Chapter 3 is used to infer observed risk aversion levels for each firm. Finally, farms are differentiated by their herd size measured in terms of cows-wintered. Due to lack of data and as the focus is on the cow-calf enterprise, each farm is assumed to have an identical crop enterprise.

Information on these firm-specific characteristics is from the detailed cow-calf AgriProfit$ production data, described in Chapter 3 (AARD, 1996-2005). Chapter 3 contains 173 observations in an unbalanced panel dataset. These data are collected via an annual survey using actual farm records. Unique farms are required for this analysis as the focus is on the distribution of benefits and costs of AgriStability across individual units. For firms that had multiple observations – i.e., firms that had observations in greater than one year – a random number generator was used to select the year used in this analysis. In total, data for 76 unique farms are used in the simulation model.

All input costs except winter feed are assumed to be non-stochastic. The majority of winter feed is supplied internally. The farm is assumed to have five quarter sections in crop. These crops are on a four year rotation, with three fields in forages (alfalfa/grass hay) and one in each barley and wheat. Wheat is a revenue crop and is not used in the livestock enterprise. Winter rations are derived from AARD (2006). The model assumes that the pasture land has sufficient carrying capacity for the herd. Tables 4A.1 and 4A.2 in Appendix 4A contain additional information on the cash flow model and the unit costs for inputs.

4.4.7.2 Price Models

Uncertainty enters the model via stochastic price equations for both livestock and crops. Price movements are often closely related and a relationship between the output price paths is necessary. Estimated cattle price equations using inflation-adjusted semi-annual data from 1976-2000 and seemingly unrelated regression (SUR) methods were used to obtain coefficient estimates and error correlations. These price models take the form (Miller, 2002):

$$
\textbf{(4.31)}\qquad
\begin{aligned}
p_t^{steer} &= (1-\lambda_t D)\cdot(49.447 + 0.444\,p_{t-1}^{steer} + 0.554\,p_{t-2}^{steer} - 0.384\,p_{t-3}^{steer} + \varepsilon_t^{steer})\\
p_t^{heifer} &= (1-\lambda_t D)\cdot(47.007 + 0.405\,p_{t-1}^{heifer} + 0.568\,p_{t-2}^{heifer} - 0.379\,p_{t-3}^{heifer} + \varepsilon_t^{heifer})\\
p_t^{bred} &= (1-\lambda_t D)\cdot(56.056 + 0.799\,p_{t-1}^{bred} + 0.288\,p_{t-2}^{bred} - 0.436\,p_{t-3}^{bred} + \varepsilon_t^{bred})\\
p_t^{cull} &= (1-\lambda_t D)\cdot(17.621 + 0.319\,p_{t-1}^{cull} + 0.719\,p_{t-2}^{cull} - 0.317\,p_{t-3}^{cull} + \varepsilon_t^{cull})\\
p_t^{bull} &= (1-\lambda_t D)\cdot(43.288 + 0.259\,p_{t-1}^{bull} + \varepsilon_t^{bull})
\end{aligned}
$$

where steer, heifer, bred, cull and bull indicate the dollars per hundred-weight prices for weaned steers, weaned heifers, bred heifers, cull cows and slaughter bulls respectively. The variable *D* is the price drop, equalling 0.6 or 0.8, of a catastrophic price event and λ_t is generated from a Poisson distribution. The estimated coefficients and errors (ε) are from Miller (2002). The error terms (ε) for steers, heifers, bred heifers and cull cows are correlated across equations (Hull, 1997) and, for each series, *i*, and time period, *t*, take the form $\varepsilon_t^i = \upsilon_i^t \sigma_i$ where $\upsilon^t \sim N(0,1)$ and σ_i is the standard deviation. Table 4A.3 in Appendix 4A contains the error correlations. As in Turvey (2003), occurrences of disasters are modelled as a Poisson jump process within stochastic price equations. A Poisson distributed random variable is the "catastrophic" shock that causes an immediate downward jump in prices (see Merton, 1990, pgs. 311-317 for further discussion) where $\lambda_t = 1$ if there is a catastrophic price shock and $\lambda_t = 0$ otherwise. After a single catastrophic price shock, prices return to the long-run mean in about three years, all else constant. The normal and catastrophic shocks are uncorrelated.

Annual wheat, feed barley and forages price data for the years 1977 – 2005 for Alberta were used to estimate crop price path equations. Stationarity was tested using Augmented Dickey-Fuller and KPSS (Kwiatkowski et al., 1992) unit root tests (see Chapter 3, section 3.4.3.1 for discussion on these tests). Based on these tests, stationarity was not rejected and the time series have a stable data generating process. To determine the appropriate number of lags for the crop equations, the Akaike Information Criterion and Schwartz Criterion are used (Judge et al., 1985). Appendix 4A contains the stationarity and information criterion test statistics, Tables 4A.4 and 4A.5 respectively. Wheat is estimated with two lags, while barley and forages are estimated with a one period lag. A SUR approach was used to obtain model coefficients and error correlations. The crop price equations measured in dollars per metric tonne are:

$$\begin{aligned} p_t^{wheat} &= 73.832 + 0.622\, p_{t-1}^{wheat} - 0.277\, p_{t-2}^{wheat} + \xi_t^{wheat} \\ p_t^{barley} &= 51.601 + 0.475\, p_{t-1}^{barley} + \xi_t^{barley} \\ p_t^{forage} &= 33.026 + 0.553\, p_{t-1}^{forage} + \xi_t^{forage} \end{aligned} \tag{4.32}$$

As with the livestock price path equations, the errors of the crop prices are correlated, with $\xi_t^j = \varphi_j^t \sigma_j$ and $\varphi^t \sim N(0,1)$. Table 4A.6, in Appendix 4A, contains the error correlations. As the focus is on the implications of disaster protection in the livestock sector, no catastrophic risk is considered for crops.

Net enterprise cash flow is determined by deducting fixed per unit input costs from random revenues for both crops and the cow-calf operations. Net enterprise cash flows are then adjusted, according to AgriStability rules, to obtain a firm's production margin, and subsequently, its reference margin. The reference margin is obtained by running the simulation for ten years prior to the year of interest. In total 760 distinct cash flow simulations are run – there are 76 producers, two preference structures and five scenarios (76x2x5=760). The number of iterations for the each simulation is 5000.

4.5 RESULTS

This section presents the empirical Gini coefficients and modified Suits indices. These results gauge the inequality and progressivity of the distribution of net

AgriStability benefits. Discussion of the implications of these statistics and an evaluation of the vertical and horizontal equity features embedded in the program is contained in section 4.6.

Table 4.4 presents the quartiles from the indifference price models. Risk aversion coefficients are calibrated based on producers' years of experience. Recall that more inexperienced producers' risk premiums under CARA preferences are notably higher than under CRRA (see Chapter 3, section 3.5.2). Producers modelled using a power utility function have indifference prices which tend to increase with risk. For example, for each quartile, a producer has a higher maximum willingness to pay for AgriStability in scenario five than in scenario two (risk is greater in scenario five than scenario two). The CARA model, on the other hand, does not display a clear-cut relationship between indifference prices and increasing potential of catastrophic risk. Increases in payment variances outweigh the increases expected payments – i.e., variability in AgriStability payments have a negative influence on producer utility.

Table 4.4: Quartiles of the Sample's Indifference AgriStability Prices for the Five Scenarios – Annual Dollars

	Scenario				
CARA Preferences	1	2	3	4	5
Minimum	4,037	4,152	4,122	4,267	4,197
First Quartile	4,669	4,747	4,774	4,781	4,813
Median	5,211	5,430	5,482	5,590	5,600
Third Quartile	7,235	7,262	7,208	7,399	7,084
Maximum	17,937	17,829	17,810	17,654	17,465
CRRA Preferences					
Minimum	4,092	4,296	4,399	4,377	4,414
First Quartile	4,633	4,782	4,943	4,908	5,177
Median	5,409	5,764	5,978	5,949	6,296
Third Quartile	7,941	8,545	8,880	8,874	9,444
Maximum	18,044	19,433	20,550	20,324	23,435

* Values should be compared horizontally across scenarios, not vertically across quartiles

In scenario one, the lowest indifference price that any producer in the sample is willing to pay for AgriStability risk protection is $4037 for CARA preferences and $4092 in the CRRA model. To illustrate the discrepancy between the actual and actuarially fair premiums, one can take these values and calculate the implied reference margins as if the actual AgriStability enrolment costs equalled the actuarially fair values. Using **(4.22)** the producers would have reference margins corresponding to $1,041,046 and $1,055,425. These reference margins are nearly ten times greater than the highest reference margin in the sample, so clearly AgriStability costs are subsidized. The maximum that a producer is willing to pay for revenue protection is $23,435 for CRRA preferences. This maximum occurs in scenario five. If preferences have a CARA specification, then the maximum premium that occurs in scenario one and equals $17,937.

The Gini coefficients from model I's total subsidy are presented in Table 4.5. Model I calculates total subsidies and pure wealth transfers in terms of dollars, while model II (Table 4.6) deals with subsidy and transfer rates. A Gini coefficient of zero implies that each producer receives an identical payment. A value of one indicates that a single producer received the entire subsidy of the sample. Coefficients are calculated on both a whole-farm and per cow basis. For all five scenarios, the whole farm Gini estimate is approximately 0.18. The confidence intervals for these estimates overlap as well. When measured in terms of dollars, catastrophic risk does not affect the level of inequality in benefit distribution. The per cow-wintered values demonstrate parallel results. The Gini is roughly 0.23 in every scenario and the confidence intervals correspond.

Hypothesis one is rejected for the total subsidy of model (I). AgriStability generates an unequal distribution of net benefits. This inequality is higher when calculated on a per cow versus a whole-farm basis. While hypothesis one does not hold, hypothesis two is not rejected in model (I). The distribution of AgriStability's total subsidy is not impacted by catastrophic price risk.

Table 4.6 presents the Gini coefficients for the total subsidy computed from model (II). Comparing these values to those from model (I), there are two points of interest. First, the Gini ratios are lower when calculated as rates than in dollar amounts. The more relevant factor however is that a trend emerges. As the level of risk increases, the distributional inequality of total subsidy rates increases. In scenario one, the Gini equals 0.047. While in scenario five, the value is 0.076. Moreover, the confidence intervals on these estimates have only minor overlap – i.e., the confidence intervals on the coefficients differ as the prospect of catastrophic risk increases (e.g., as one moves

Table 4.5: Gini Coefficient of the Total Subsidy from AgriStability – Model (I)

Panel A – Whole Farm Estimate

		95% Confidence Interval	
	Mean Coefficient	Lower	Upper
Scenario 1	0.178	0.154	0.201
Scenario 2	0.177	0.154	0.201
Scenario 3	0.181	0.157	0.205
Scenario 4	0.179	0.155	0.203
Scenario 5	0.187	0.161	0.210

Panel B – Estimate per Cow-Wintered

		95% Confidence Interval	
	Mean Coefficient	Lower	Upper
Scenario 1	0.232	0.143	0.320
Scenario 2	0.233	0.143	0.323
Scenario 3	0.229	0.139	0.318
Scenario 4	0.232	0.142	0.323
Scenario 5	0.224	0.135	0.314

from scenario 1 to scenario 3 to scenario 4). Model (II) appears to demonstrate that following a crisis AgriStability becomes a less equitable program, thus rejecting hypothesis two.

Table 4.6: Gini Coefficient of the Total Subsidy from AgriStability – Model (II)

Panel A – Whole Farm Estimate

	Mean Coefficient	95% Confidence Interval Lower	95% Confidence Interval Upper
Scenario 1	0.047	0.041	0.053
Scenario 2	0.056	0.049	0.063
Scenario 3	0.061	0.053	0.069
Scenario 4	0.066	0.057	0.074
Scenario 5	0.076	0.066	0.085

The total subsidy is defined as the sum of inducement subsidies and pure wealth transfers. Examining the effect of pure wealth transfers independently generates similar results for model (I). Table 4.7 displays the Gini coefficients for model (I)'s pure wealth transfers when preferences are CARA. Table 4.8 presents the same coefficients when producers are assumed to have CRRA preferences. The whole farm Gini estimate for all scenarios is about 0.18 for the CARA model. The per cow-wintered estimate is also consistent across scenarios at 0.25. For the CRRA model, the whole farm Gini is slightly higher than in the CARA model. The reverse is true when coefficients are calculated on a per cow basis. The CRRA model's Gini ratio is approximately 0.23. Catastrophic price risk does not influence distributional equality in either the CRRA or CARA models when values are calculated in terms of dollars, so hypothesis two cannot be rejected when only pure wealth transfers are considered.

Table 4.7: Gini Coefficient of the Pure Wealth Transfers from AgriStability with CARA Preferences – Model (I)

	Mean Coefficient	95% Confidence Interval	
Panel A – Whole Farm Estimate			
	Mean Coefficient	Lower	Upper
Scenario 1	0.179	0.150	0.205
Scenario 2	0.175	0.150	0.200
Scenario 3	0.177	0.151	0.203
Scenario 4	0.174	0.149	0.199
Scenario 5	0.179	0.152	0.205
Panel B – Estimate per Cow-Wintered			
	Mean Coefficient	Lower	Upper
Scenario 1	0.255	0.162	0.347
Scenario 2	0.250	0.160	0.341
Scenario 3	0.250	0.160	0.340
Scenario 4	0.247	0.156	0.338
Scenario 5	0.246	0.157	0.336

Table 4.8: Gini Coefficient of the Pure Wealth Transfers from AgriStability with CRRA Preferences – Model (I)

	Mean Coefficient	95% Confidence Interval	
Panel A – Whole Farm Estimate			
	Mean Coefficient	Lower	Upper
Scenario 1	0.189	0.166	0.211
Scenario 2	0.182	0.158	0.205
Scenario 3	0.183	0.159	0.207
Scenario 4	0.180	0.156	0.204
Scenario 5	0.186	0.161	0.210
Panel B – Estimate per Cow-Wintered			
	Mean Coefficient	Lower	Upper
Scenario 1	0.236	0.141	0.330
Scenario 2	0.233	0.141	0.324
Scenario 3	0.229	0.138	0.319
Scenario 4	0.232	0.141	0.323
Scenario 5	0.224	0.135	0.314

The coefficient values calculated for the pure wealth transfers under model (II) are lower than those for model (I). Tables 4.9 and 4.10 display the Ginis for the pure wealth transfer rates under CARA and CRRA respectively. Values for the two preference structures correspond. For instance, with both CARA and CRRA preferences scenario three's estimated Gini equals 0.06. However, while the distributional inequality values for pure wealth transfers for model (II) are lower than those for model (I), hypothesis two cannot be rejected and a trend emerges. Similar to the total subsidy results, increasing catastrophic risk increases inequality in the distribution of AgriStability benefits. For instance, the 95 percent confidence interval on the Gini estimate in scenario 5 is (0.066, 0.085). In scenario two, these values are (0.049, 0.063), implying that there is a statistically significant difference in the mean inequality estimates

Table 4.9: Gini Coefficient of the Pure Wealth Transfers from AgriStability with CARA Preferences – Model (II)

		95% Confidence Interval	
	Mean Coefficient	Lower	Upper
Scenario 1	0.047	0.041	0.053
Scenario 2	0.055	0.048	0.062
Scenario 3	0.060	0.053	0.068
Scenario 4	0.065	0.057	0.073
Scenario 5	0.075	0.066	0.084

Table 4.10: Gini Coefficient of the Pure Wealth Transfers from AgriStability with CRRA Preferences – Model (II)

		95% Confidence Interval	
	Mean Coefficient	Lower	Upper
Scenario 1	0.048	0.041	0.054
Scenario 2	0.056	0.049	0.063
Scenario 3	0.061	0.053	0.069
Scenario 4	0.066	0.058	0.074
Scenario 5	0.076	0.066	0.085

between the scenarios. In model (II), the potential for catastrophic price risk increases the inequality of the benefit distribution for both the total subsidy and the pure wealth transfer rates.

Additional insights can be drawn from model (II) by combining the structure of subsidies, reference margins and the effect of catastrophic price risk. Table 4.11 presents the adapted Suits index values for the total AgriStability subsidy structure. This statistic measures the progressivity or regressivity of the structure of total AgriStability subsidies as producers' reference margins increase. An index value of zero indicates that the subsidy rate associated with AgriStability does not depend on a cow-calf producer's reference margin. Alternatively, if the subsidy rate increases as producers' reference margins increase, then the subsidy structure is regressive and a negative Suits index is calculated. If the Suits index is positive, then subsidy rate declines as references margins increase and the structure can be called progressive.

Table 4.11: Adapted Suits Index used to Measure the Progressivity of the Total AgriStability Subsidy

Scenario	Index Value
1	-0.0688
2	-0.0698
3	-0.0718
4	-0.0763
5	-0.0820

The total subsidy rate structure of AgriStability benefits is regressive. Producers with higher reference margins receive a greater subsidy rate from the program. Both hypotheses one and two can be rejected by examining the results of Table 4.11. Benefits are not uniformly distributed and catastrophic price risk increases the regressivity of the total subsidy rate structure. In scenario one, the Suits index is -0.069. In scenario four, regressivity has increased and the index equal -0.076.

Figure 4.4 provides an illustration of scenario 1's structure of total subsidy rates. This figure reveals a clear picture of regressive nature of AgriStability subsidy rates. Firms are grouped into deciles based on their reference margin, from smallest to largest. These deciles are plotted along the horizontal axis. The average total subsidy rate for each bracket (decile) is then plotted vertically. As firms' reference margins increase, the subsidy rate curve slopes upward. A positive sloping subsidy curve indicates a regressive rate structure. Firms with larger reference margins – i.e., cow-calf producers with higher gross margins – obtain a higher subsidy rate. A progressive program would have a downward sloping curve.

Once the inducement rate is removed from the total subsidy rate, the pure wealth transfer rate is the remainder. Table 4.12 presents the modified Suits index, calculated for the pure wealth transfer rate of AgriStability. The results in this table are consistent with the total subsidy values. First, there is a regressive pure wealth transfer rate structure. Second, the regressivity of the AgriStability benefit distribution increases with the prospect of catastrophic risk. These figures suggest that if another BSE-type event occurred, firms with larger reference margins would receive greater wealth transfers from AgriStability than smaller producers.

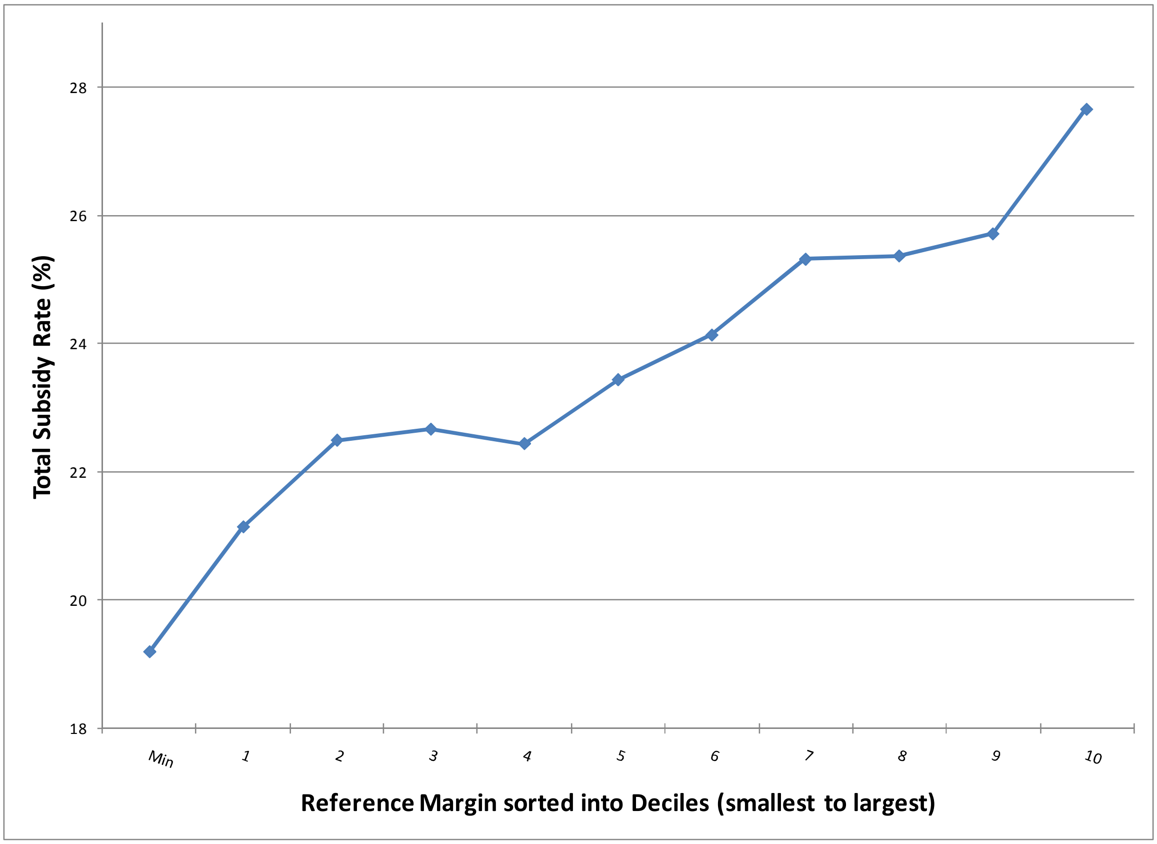

Figure 4.4: Structure of Total Subsidy Rates with Reference Margins sorted into Deciles – Scenario 1

Table 4.12: Suits Index Measuring the Progressivity of the Pure Wealth Transfer Rate

CRRA Preferences	
Scenario	Index Value
1	-0.0686
2	-0.0695
3	-0.0718
4	-0.0763
5	-0.0820
CARA Preferences	
Scenario	Index Value
1	-0.0686
2	-0.0695
3	-0.0717
4	-0.0762
5	-0.0819

4.6 DISCUSSION AND EXTENTIONS

4.6.1 Vertical and Horizontal Equity Criteria

The concept of equity needs some clarification. Section 4.5 presents statistical results on the distribution of net benefits from AgriStability for a heterogeneous sample of cow-calf producers. These are positive empirical results. Discussion of program equity, in contrast, applies normative criteria to evaluate these empirical results. AgriStability is a redistributive program – enrolment costs are less than its actuarially fair premiums – so the government transfers funds from alternative uses to farmers via this program. Two primary principles are used to assess redistributive government policies (Duclos, 2008). The first concept, vertical equity, evaluates the distributive equity of a policy's impact on individuals who differ in initial welfare levels. The second equity criterion is known as horizontal equity. Horizontal equity evaluates a policy's impact across individuals who are similar in all relevant ethical aspects – including their initial level of welfare. Atkinson and Stiglitz (1980) state: "It is conventional to distinguish between vertical and horizontal equity, the latter being concerned with the treatment of people who are in all relevant aspects identical, and the former with the treatment of unequals" (pg. 350). In this context, horizontal equity refers to treating similar producers equally, while vertical equity then deals with the unequal treatment of cow-calf producers who differ is some meaningful aspect. In this study, the most relevant characteristic differentiating producers is their reference margin, with a larger reference margin implying a wealthier farmer.

The statistical results on the distribution of net AgriStability benefits demonstrate that not all producers are treated equally. Some cow-calf producers receive more program benefits than others. This section discusses several implications from this conclusion. First, several features of the program are reviewed in light of vertical and horizontal equity. Next, a brief discussion on agricultural risk management policy is undertaken. Finally, several potential extensions to the above analysis are presented.

It should be noted that the following discussion does not specify an explicit social welfare function. Relative changes in welfare within the sample of heterogeneous firms are the focus. It is acknowledged that policy design under uncertainty is challenging. However, limited research has been completed on the distributional features of most agricultural policies (Moreddu, 2008). Therefore, providing direct comparisons with the literature is not possible. Instead, the values calculated in this chapter are useful as reference points for which to gauge future research. Moreover, if prospective Canadian risk management programs are going to consider equity criteria, it is important to understand the distribution of outcomes from the current program.

4.6.2 Structure of AgriStability: Equity Implications

The current design of the AgriStability program violates the criteria of horizontal and vertical equity. Inequities arise due to the structure of the program. First, regressivity and vertical equity are discussed in light of the payout scheme and catastrophic price risk. Then, the horizontal inequity and distorted incentives which arise due to the enrolment costs are reviewed. Finally, the potential for moral hazard is considered in connection with the payout tier configuration.

AgriStability is a regressive government program, yielding more benefits to larger firms. Tables 4.11 and 4.12 in combination with Figure 4.4 demonstrate that as a firm’s reference margin grows government transfers increase. For example, the adapted Suits index for the total subsidy rate equals -6.9% and -7.6% in scenarios 1 and 4 respectively.[28] Index values which are less than one imply that the underlying subsidy rate structure is regressive. Larger firms, as measured by reference margin size, collect disproportionately greater subsidies than smaller firms. The degree of regressivity increases with risk. A regressive subsidy rate structure does not treat unequals fairly, hence it violates vertical equity.

In Canada, 100,284 farms, or roughly half of all Canadian enterprises, collected less than \$100,000 in gross revenues in 2006 (Sparling et al., 2008). If revenues are used as a proxy for reference margins, a simple example highlights the subsidy regressivity. Consider a farm in the second subsidy decile (refer to Figure 4.4) and assume that there is an exact correspondence between the sample the population. This operation has an expected annual AgriStability subsidy rate of 20.82% and has revenues of less than \$100,000. Next, a farm that earned \$500,000 in revenues would be in the eighth decile of Canadian operations (Sparling et al., 2008). This enterprise has an expected subsidy rate of 24.99% or 4.17% more than the smaller enterprise. Further, the larger enterprise has an expected dollar value subsidy equal to \$124,960 or more than total per farm revenues of all enterprises in the fifth decile or below. Subsidy regressivity means that according to the metric that the analyst selects, reference margins in this chapter, the larger or wealthier group receives a proportionally greater share than the smaller or less wealthy group. In this case, as few studies have examined the structure of subsidy rates, it is

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[28] For comparison: excise taxes, the most regressive tax structure in Canada, have a Suits index of -0.17 (-17%) (Livernois, 1986), while the joint Albertan-Canadian income tax rate structure has a Suits index of 0.21 (21%) (Schaufele, 2006).

difficult to determine whether the degree of regressivity is larger or small. These values supply a baseline for future investigations.

In general, the minimum requirement for a policy to be considered vertically equitable is that each firm receives an identical subsidy rate – i.e., even though a firm has a smaller reference margin, the percent of that margin which comes from government transfers is the same as a firm with a greater reference margin. One of the main justifications for providing transfers to farms relates to the value that society places on the family farm (Schmitz et al., 2002). According to this argument, people are willing to support the institutional framework of primary agriculture via subsidies to small farmers. However, this policy outcome would likely require a progressive subsidy rate structure where small farmers receive more support than large operations. Large farms are often negatively perceived by the public (e.g., Heyder and Theuvsen, 2008). The empirical results in section 4.7 demonstrate that AgriStability could be better designed if supporting small family farms were a desirable policy objective.

A small portion of AgriStability's regressivity can be explained by the program's fee structure. A producer pays a $4.50 per $1000 protected revenue *plus* an additional $55.00 administration. The fixed administration fee leads to a payout schedule that is mildly regressive. For example, a farm that has a reference margin of $50,000 will pay $5.79 for every $1000 dollars protected, while a firm with a reference margin of $500,000 will pay $4.63 for each $1000 dollars of protection. These differences are not large. However wealthier operations do obtain greater protection at a lower cost. This regressivity in the fee structure creates vertical inequity: wealthier firms receive the same benefits at a lower cost than do smaller farms.

Next, the violation of horizontal equity is discussed. The current fixed fee structure of AgriStability implies that two firms that have the same reference margin (i.e., the same long-run gross margin) may be treated differently. Grain, livestock and mixed operations have different risk profiles. The fact that firms, which are identical in terms of reference margin but differ in terms of risk profiles, are treated unequally violates the horizontal equity criterion. The relevant criteria for a risk management program should be the level of risk faced by a firm. Within AgriStability, a firm with greater variability around its reference margin receives more subsidies and greater income support than the firm with lower variance. This can be seen by examining **(4.22)**. Even though AgriStability is a risk management program, there is no risk in the actual enrolment cost calculation. To reiterate, the riskiness of a firm does not influence the amount that is paid for risk protection under AgriStability.

It is possible to identify how the enrolment fees structure of AgriStability affects producer incentives. Problems of distorted incentives emerge when one jointly examines that a firm's level of risk does not influence the price it pays for AgriStability along with the actuarially fair premiums that the firm would pay if the program were privately or quasi-publically provided. Premiums charged (actual costs) are significantly lower than the actuarially fair program costs. This generates two distorted incentives for producers. First, producers face a disincentive to diversify, as a direct result of disconnect of program enrolment costs and actual production risk. In general, enterprise diversification is encouraged to mitigate risk. Farmers are rewarded for taking risks under AgriStability's fee structure however. As a consequence, the first distorted incentive is with respect to risk reducing diversification. Next, larger firms are disproportionately rewarded by the program. For example, the median producer in the data sample, under the no catastrophic risk scenario (scenario 1 (see Table 4.1)), receives approximately $5.75/cwt (expected value) upon the sales of her calves. This value increases as firms get larger. The firm that is on the margin between the third and fourth quartile (75th percentile) collects a subsidy of $7.36/cwt. Firms perceive a distorted market signal – i.e., effective prices, the price used to make production decisions, is greater than the price offered by the market. Therefore, based on the combined information from the market and government programs, producers have an incentive to produce more output than is dictated by supply and demand fundamentals.

It should be noted that producers are not exploiting information asymmetries when behaviour is altered due to the enrolment fee structure. An information asymmetry is defined as a scenario where the producer exploits an information advantage which is unobservable (Varian, 1992). In terms of insurance, moral hazard may arise after the producer has entered into an insurance contract, as the producer is able to alter her behaviour as a consequence of owning the insurance contract. Risk does not enter into the actual premium calculation for the net revenue insurance contract. The only relevant piece of information is a firm’s reference margin. So, even if information was symmetric (i.e., the government had full *ex post* information on producer behaviour), identical incentive distortions develop under AgriStability. As a consequence, changes in producer behaviour due to the structure of the program should be considered moral hazard. Rather, producers are rationally responding to the incentives that they face and the insurer (government) should be cognizant of potential *ex post* changes in production decisions.

While the violation of vertical equity criterion in AgriStability's fee structure can be considered a minor flaw, the same cannot be said about the violation of the horizontal equity criterion. The divorce of the program fees from firm risk profiles is a serious shortcoming in the design of AgriStability. Moreover horizontal inequity arises due to a "one size fits all" approach to risk management. Fixing the program's fee structure would likely remove some of the regressivity in the programs subsidy rate structure.

The final feature of the AgriStability structure which can generate vertical inequity is the tier cut-offs (see Figure 4.1). Given the opportunity producers may be able exploit information asymmetries and generate moral hazard. Larger firms have a greater ability to exploit these asymmetries. As an example, assume that producers have some ability to control calf weight gain and that increased weight gain requires increased producer effort. If producers recognize that they are near a margin cut-off – e.g., say, 85 percent of their reference margin – and if effort is costly, they could reduce their effort and sell their animals at a lower weight ensuring that their revenues were below the cut-off. In this, they are exploiting an informational advantage to obtain AgriStability and insurance payments. In Figure 4.1, anytime that a given horizontal move (i.e., incurring a greater production margin loss) can be translated into a larger vertical move (i.e., trigger an AgriStability payment which is greater than the reduction in the production margin) the producer will be better off. This ability to exploit an informational advantage leads to moral hazard and can occur at the cut-offs between: i) tiers one and two and ii) tiers two and three. Larger firms control larger herds, thus have greater flexibility in managing their reference margin – particularly when it is near a tier cut-off. Because unequal firms have different abilities to exploit informational asymmetries, vertical inequity is possible.

4.6.3 Extensions to Analysis

Four extensions to the above analysis are suggested. The first focuses on normative implications. The latter three address analytical extensions to the research.

First, total subsidies are separated into inducement subsidies and pure wealth transfers. The pure wealth transfer is a direct transfer to agricultural producers from the government. As such, an extension to the above analysis would be to calculate the social cost of this transfer in terms of deadweight loss. If government revenues are primarily derived via income taxes, then the cost in foregone social welfare per dollar transferred is greater than one dollar – i.e., income taxes create disincentive effects which cause deadweight losses. Frameworks based on the Atkinson-Stern condition (Atkinson and Stern, 1978) and the marginal cost of public funds (Dahlby, 2008) can be applied. The combined value of the deadweight loss and subsidy can then be compared to society’s willingness to support the traditional agricultural institutional arrangement. This would be an empirical validation of the justifications for subsidies discussed in section 4.4.5.1.

Next, the Gini coefficient can be decomposed into separate components. It has already been posited that probability of catastrophic risk and herd size lead to greater inequality. Producers are heterogeneous. The factors which contribute most to overall inequality could be elicited via additional calculations. It may assist in policy design if the major factors which drive benefits inequality are known.

Third, this chapter effectively posits that it is possible to have a market with multiple, firm-specific equilibria – i.e., each revenue insurance contract is priced individually at the farm-level. Indifference and actuarial asset pricing techniques are employed to avoid equilibrium restrictions. However, in practice, this arrangement may be too costly in terms of information or administration. Moreover, governments are encouraged to produce a single priced program as a consequence of political pressures. A class of revenue insurance contracts, priced with actuarial and indifference methods, still can be framed in an equilibrium context. The construction presented in Rothschild and Stiglitz (1976) can be adapted to examine the implications of various insurance products – e.g., the degree of moral hazard that would be generated or the amount of inducement subsidy required to yield a “pooling” equilibrium can be calculated. This approach would be tantamount to specifying a social welfare function for agricultural insurance. It would also comprise a significant theoretically-consistent contribution to the literature on agricultural insurance. In fact, assuming firm heterogeneity within the familiar supply and demand framework permits substantial extensions to customary policy analysis.

Finally, Chambers and Quiggin (2000) introduced the state-contingent theoretical framework into agricultural economics. This framework is flexible in addressing topics that confound uncertainty and social arrangements. Little applied research has been completed with state-contingent models. However, this approach shows promise for the joint assessment of production economic under risk and social policy.

4.7 CONCLUSION

AgriStability is a new program which has yet to withstand detailed economic scrutiny. This paper analyzes the program under normal and catastrophic price risk for cow-calf producers. Two hypotheses were posited. First, it was hypothesized that net benefits from AgriStability were equally distributed across a heterogeneous sample of cow-calf farms. This hypothesis was rejected, both when program transfers are measured in dollars and in subsidy rates. The second hypothesis stated that catastrophic risk did not affect the distribution of AgriStability benefits. Evidence on this conjecture was mixed. In model (I), when transfers are measured in dollars, a positive probability of catastrophic risk did not have a noticeable effect on the distribution of benefits. However, when subsidy and transfer rates are calculated, as in model (II), increasing risk corresponds to increasing inequality. In fact, according to model (II) AgriStability's subsidy rate structure is regressive, with larger firms receiving higher subsidy rates, and that this regressivity increases with catastrophic risk.

Considerations of equity and heterogeneity have not played a major role in agricultural policy discussions. Likely this is due to the challenge of collecting and analyzing data on heterogeneous agents. Heterogeneity across firms' was viewed as a key component of responses to the BSE crisis. This paper combined statistical analysis with a simulation model to examine the equity implications of Canada's primary risk management program when there is a positive probability of similar BSE-type catastrophic event occurring.

Economic analysis should consider efficiency results, but must be cognizant that equity is often important to policy-makers, farmers and citizens. In fact, it is possible that considering the consequence of heterogeneity and equity can explain public reactions and policy responses better than efficiency analysis alone. Overlooking heterogeneity and equity is equivalent to neglecting a fundamental component of the economic landscape.

APPENDIX 4A: ADDITIONAL DATA AND TABLES

Tables 4A.1 and 4A.2 contain additional information about the cash flow simulation model. Table 4A.1 illustrates some basic model assumptions, while Table 4A.2 presents the input unit costs.

Table 4A.1: Some Basic Model Assumptions

Farm Description (acres)	
Cereal and Forage Area	840
Pasture Land	2560
Market Weight at Sale (lbs)	
Cull Bulls	1912
Cull Cows	1262
Open Heifers	1029
Weaned Steers	565
Weaned Heifers	520

Table 4A.2: Per Unit Fixed Input Costs for Cattle and Crop Capital Budgeting Model

General Livestock Costs per Cow Wintered	
Veterinary & Medicine	$ 21.99
Trucking and Marketing Charges	$ 9.72
Fuel	$ 13.47
Repairs – Machinery	$ 14.63
Repairs – Corrals & Buildings	$ 5.61
Utilities & Miscellaneous	$ 16.71
Custom Work & Specialized Labour	$ 9.34
Paid Labour & Benefits	$ 22.45
Pasture Costs per Acre	
Seed	$ 0.37
Fertilizer	$ 5.67
Chemicals	$ 0.05
Fuel	$ 1.52
Repairs – Machinery	$ 0.54
Repairs – Buildings	$ 1.06
Utilities & Miscellaneous	$ 0.58
Custom Work & Specialized Labour	$ 0.28
Paid Labour & Benefits	$ 0.71

Table 4A.2: cont.

Feed Barley per Acre		
Seeds	$	9.16
Fertilizer	$	28.02
Chemicals	$	21.90
Crop Insurance Premiums	$	2.32
Trucking and Marketing	$	1.56
Fuel	$	7.47
Repairs – Machinery	$	10.84
Repairs – Buildings	$	4.35
Utilities & Miscellaneous Expenses	$	5.00
Custom Work & Specialized Labour	$	2.35
Paid Labour & Benefits	$	6.79
Forages (Alfalfa/Grass Hay) per Acre		
Seeds	$	-
Fertilizer	$	2.97
Chemicals	$	-
Crop Insurance Premiums	$	-
Trucking and Marketing	$	0.20
Fuel	$	3.86
Repairs – Machinery	$	7.71
Repairs – Buildings	$	1.16
Utilities & Miscellaneous Expenses	$	9.67
Custom Work & Specialized Labour	$	0.34
Paid Labour & Benefits	$	1.65
Spring Wheat		
Seeds	$	40.19
Fertilizer	$	46.73
Chemicals	$	11.68
Crop Insurance Premiums	$	11.22
Trucking and Marketing	$	4.48
Fuel	$	9.16
Repairs – Machinery	$	14.42
Repairs – Buildings	$	0.72
Utilities and miscellaneous expenses	$	5.64
Custom Work and Specialized Labour	$	9.04
Paid Labour & Benefits	$	1.71

Table 4A.1 displays the error correlations for the cattle price models for steers, heifers, bred and cull cows, equations **(4.31)**.

Table 4A.3: Error Terms Correlations for Cattle Price Models

	υ_{Steer}	υ_{Heifer}	υ_{Bred}	υ_{Cull}
υ_{Steer}	1.000	0.976	-0.059	0.869
υ_{Heifer}	0.976	1.000	-0.020	0.861
υ_{Bred}	-0.059	-0.020	1.000	-0.006
υ_{Cull}	0.869	0.861	-0.006	1.000

Source: Miller (2002, pg. 101)

Table 4A.4 presents the ADF and KPSS tests for the wheat, barley and forage price series.

Table 4A.4: ADF and KPSS Tests for Crop Price Stationarity

	ADF Test		KPSS Test	
Crop	Without Trend	With Trend	Without Trend	With Trend
Wheat	-3.03	-2.97	0.104	0.089
Barley	-3.25	-3.33	0.558	0.092
Forages	-2.67	-2.70	0.578	0.122
Critical Value*	-2.57	-3.13	0.463	0.146

* - critical value at a 10% level of significance for ADF and 5% for KPSS

The determination of the appropriate number of lags is required for the crop price models. Two information criterions assess the appropriate structure: the Akaike Information Criterion (AIC) and the Schwartz Criterion (SC). These criterions are minimized, so a lower value indicates a better fit. The AIC tends to favour longer lags than does the SC. Table 4A.5 presents the AIC and SC values for these regressions. The AIC and SC disagree for both barley and forages. Shorter lags tend to generate more efficient estimates however; so, a shorter lag is used. Wheat provides a less ambiguous result, as the AIC and SC agree.

Table 4A.5: AIC and SC values for lagged Crop Price Models

	AIC			SC		
Lags	Wheat	Barley	Forages	Wheat	Barley	Forages
1	6.678	6.537	5.451	6.773	6.633	5.546
2	6.481	6.524	5.442	6.625	6.668	5.585
3	6.591	6.642	5.560	6.785	6.836	5.753

Note: The table presents the logged AIC and SC values

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CHAPTER 5: CONCLUSION

5.1 INTRODUCTION

This chapter has three parts in addition to these introductory comments. First, each of the research chapters is briefly reviewed. Next, four key extensions and limitations are presented. Finally, the main research objectives are reconsidered and several concluding statements are supplied.

5.2 SUMMARIES AND MAIN CONCLUSIONS OF THE THREE RESEARCH CHAPERS

Paper 1: Quantifying policy targets for crisis relief programs in agriculture

Chapter 1 introduced the first research paper as “dirty policy, done right”. It also described the Alberta Auditor General’s (AGO) criticism of the BSE crisis relief programs. The key message was that designing emergency aid programs is challenging. In crisis situations there is seldom sufficient time to wait and measure final impacts. Some short-run policy is required immediately – i.e., emergency relief policy may be called “dirty policy” in that, due to time constraints, it is likely imperfect. However, while designing crisis-relief programs is difficult, economic theory does not need to be ignored. Emergency relief policy can still be “done right” in the sense that the relief aid accounts for optimal producer behaviour.

This chapter introduced two tools that are useful in designing crisis relief programs in agriculture. First, a conceptual policy design framework was presented. This framework allows policy-makers to evaluate the impact of a crisis at the farm-level as technology shocks. Next, a flexible empirical framework was offered. This framework is based on generalized maximum entropy methods, a technique that permits consistent parameter estimation even when data are limited. These frameworks were applied to western Canadian cow-calf producers' experience with severe drought conditions in 2001 and 2002 and the bovine spongiform encephalopathy (BSE) induced farm financial crisis which began in May 2003. Profit and revenue functions were estimated. Two examples were supplied for predicting policy outcomes. These forecasts provided *quantitative* benchmarks for designing relief programs, addressing the AGO recommendation and supplying a framework for designing short-run emergency relief programs.

Paper 2: Does experience breed confidence? Production decisions with price uncertainty and BSE

This chapter's contribution was primarily empirical. It analyzed output price risk and risk aversion for a sample of Albertan cow-calf producers. Detailed farm-level data were used to estimate a series of models. Two demographic conditioning procedures were introduced to the production economics literature. These conditioning methods enabled the measurement of differential risk preferences across a sample of producers.

Four main results emerged from this Chapter. First, models which include risk variables fit the data better than risk neutral models. Next, an inverted parabolic relationship is demonstrated between a producer's number of years of farming experience and risk aversion – i.e., experience breeds confidence after the producer has been in business for several years. Third, the BSE crisis did not have a statistically significant effect on producers' risk premiums. In other words, producers' observed risk premiums did not exhibit a statistically significant change following the BSE crisis. Finally, producers who have higher levels of short- and long-run risk tolerance, generally, have lower risk premiums.

Paper 3: AgriStability in the aftermath of the BSE crisis: Equity implications for cow-calf producers

This paper examined the consequences of the AgriStability program for Albertan cow-calf producers when there is potential for catastrophic price risk. Two chief hypotheses were investigated. First, it is hypothesized that the AgriStability program produces an equitable distribution of benefits and costs for Albertan cow-calf producers. The second hypothesis is that increased catastrophic price risk does not influence the equality of the distribution of program benefits.

The normative economic notions of horizontal and vertical equity were used to evaluate program outcomes for cow-calf producers in the aftermath of the BSE crisis. The concepts of inducement subsidies and pure wealth transfers were introduced. A model that contained three elements was constructed. Actuarial techniques and indifference pricing methods were employed in combination with a simulation model to calculate: i) actuarially fair insurance premiums; ii) the upper bounds on premiums that Albertan cow-calf producers are willing to pay for the insurance contract; and, iii) several inequality measures such as Gini coefficients and Suits indices for the distribution of net AgriStability benefits.

The first hypothesis was rejected. According the principles of horizontal and vertical equity, AgriStability does not treat heterogeneous firms equitably. The inequality of the total subsidy distribution has a Gini coefficient of approximately 0.18 when benefit transfers are measured in dollars and -0.06 when measured in rates. The second hypothesis was demonstrated to be false in one instance but was not rejected in the second. The subsidy rate structure of AgriStability was found to be regressive, with wealthier firms receiving more AgriStability benefits than smaller producers. This regressivity increases with catastrophic risk. Finally, the design of the AgriStability program was shown to violate both the horizontal and vertical equity criteria when firms are heterogeneous.

5.3 EXTENSIONS AND LIMITATIONS

There are four key extensions to this research that should be highlighted. These are not exhaustive yet represent the most important questions and limitations of this study.

First, the three research chapters are completed in the aftermath of the BSE crisis. However, does *ex post* analysis of crises, in general, actually help governments and economic actors prepare for and manage future events? It is possible that a future crisis will be distinct from the BSE events and that this analysis is purely of historical interest. This issue is not directly addressed in this study. Adequately answering the question from an economic perspective would require an extensive discussion of expectations and perceptions, for both producers and governments, as well as an in-depth look at fundamental uncertainty. These are subjects that receive limited review in this research.

It is worth emphasizing that the state-contingent theoretical framework (e.g., Chambers and Quiggin, 2000; Gravelle and Rees, 2004) is well-suited to this type of analysis. Yet, empirical application of state-contingent analysis is not straightforward and has had minimal success in the applied literature.

Cow-calf producers must manage their herds dynamically. This is an important limitation and prospective extension to this research. One of the key features of the BSE crisis was its disproportionate impact on calves versus older animals. It would be a significant oversight to address only calves or only cull cows. Yet, within a given time period, both calves as well as cull cows are key outputs for cow-calf producers. Both may also be key inputs in the next period's decision problem. This study's analysis makes several steady state herd management assumptions. These maintained hypotheses limit what can be inferred from the data. Relaxing these restrictive conditions would be a significant extension to this analysis and a contribution to the literature. One approach to incorporate the dynamism of the producer's decision problem may be a variation of the macroeconomic stock-flow consistent model within a simulation framework (Tobin, 1982). Within this methodology, herd management is governed by balance sheet and biological identities in addition to behavioural equations. This modelling approach does not appear to have been embraced by the agricultural economic literature however.

Next, data limitations may prevent the generalizability of this study's results to other regions. All of the data used in this study are from Alberta. Other provinces may have had significantly different experiences with the BSE crisis than Alberta. If data from Saskatchewan, Manitoba or Ontario were available, interesting cross-provinces comparisons could be completed.

The final extension relates to a potential policy trade-off. Traditionally, the key trade-off for economic policy is one of efficiency versus equity, particularly for redistributive programs (Okun, 1975). However, the results of Chapter 2 and especially Chapter 4 highlight another potential trade-off: simplicity versus equity. As an example, look at the AgriStability and its predecessor the Canadian Agricultural Income Stabilization (CAIS) programs. Initially, CAIS was designed as a deposit-base stabilization program. However, this program structure was criticized as inaccessible and overly complex (AGC, 2007). The AgriStability program is substantially simplified and the cost of this simplification may be inequality of benefit distribution. The main task of economics is to facilitate policy-making by offering a framework for the trade-off between the various aspects of the decision making problem (Coupé, 2004). For this to occur, the appropriate trade-off must be understood. Many future research questions could be formulated by considering whether there is simplicity-efficiency or simplicity-equity trade-off in the policy design and implementation process.

5.4 CONCLUDING REMARKS

Crises in agriculture are multi-dimensional events, with economic, social and psychological consequences for affected groups. The main challenge of an agricultural crisis is derived from the fundamental uncertainty that accompanies a new state of the world. *Ex ante* prediction of producer behaviour and policy outcomes is challenging – particularly when no precedent exists. Nevertheless, detailed study of the consequences of crisis, from both a theoretical and an empirical perspective, could generate many economic insights. There is a rich collection of unexplored research topics in the agricultural economics literature.

The main objective of this research was to improve understanding of the economics of agriculture during periods of crisis with a focus on policy application. Complete understanding of a crisis is likely beyond the grasp of any project. Three chapters focused on combining economic theory and empirical methods to better understand cow-calf producer behaviour and government policy following the 2003 BSE farm financial crisis. In general, this research endeavours to illuminate a branch of economics that is under-investigated. The BSE crisis was a single event. Yet an improved appreciation of its consequences yields a contribution to understanding agriculture in crisis.

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