Buy, Sell or Rent the Farm: An Agent Based Simulation of Farm Succession and Land Valuation

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EXECUTIVE SUMMARY

Widespread farmland ownership by large external investors in Western Canada is perceived by many to have the potential to significantly affect farm structure. While mostly speculation to date, the potential effects of farmland ownership changes on Prairie agriculture are not well understood. In fact, there are sound financial reasons for institutional investors to want to purchase farmland as an investment, including diversification benefits available for investment portfolios. Previous studies have found that the correlation between farmland prices and those of major financial assets such as stocks, bonds and real estate are consistently negative.

In contrast, the long-standing objective of many farm family businesses is "to maintain control and pass on a secure and sound business to the next generation" (Hay and Morris 1984; Errington 2002). In Western Canada, farmland has been typically retained within a family by the process of succession, a situation in turn driven by strong personal and economic linkages. These linkages often create a situation where it can be difficult for retiring farmers to make objective decisions about the future of their land assets. While a very important issue with respect to future farm structure, in fact very little prior research has examined the long-term consequences of a more open sales or succession option for farmland in the region.

Due to the complexity and heterogeneity of these individual land decisions, I offer that an agent based simulation model (ABSM) framework is the best modeling approach to help shed light on this issue. The ABSM developed in this study builds directly upon Anderson's (2012) prior simulation of farm activity within Canadian Agricultural Region (CAR) 1A in the province of Saskatchewan. In effect, two detailed computational modules applied to that simulation framework were developed for this thesis. These modules capture both farm succession as well as the presence of institutional investors who are able to purchase Prarie farmland as a financial asset.

In the thesis, thirty years of future farming and investment performance are simulated for hundreds of farmers across four different scenarios. The simulation results help me estimate the potential effects of various levels of institutional investor participation on regional farm structure.

In sum, I find that institutional investors elevate farmland prices in the region from between approximately 15% to 40% across the scenarios. As a response to this, farmers will tend to lease more land over time to support their farming land base. I also find that the total number of farms in the region falls over time, while simultaneously larger individual farms form through the duration of the simulation. The latter occurs either with or without the presence of institutional investors. Based on my simulation findings, I conclude that the potential overall impact of institutional investors on future farm structure in the region could be significant, but will manifest in very subtle ways. Most critically, farming success with institutional investors operating in this land market is contingent on future farmers being willing to rely on land rental rather than ownership for the process of farm expansion.

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CHAPTER I: INTRODUCTION

1.0 Introduction and Background

Historically, one of the key objectives of a farm family business has been “to maintain control and pass on a secure and sound business to the next generation” (Hay and Morris 1984, Errington 2002). In this context, farm succession is an important part of any agricultural policy for future farming (Fennell, 1981). When farmers age, a gradual decline of the physical labor and management capacity pushes senior farmers to exit farming (Kimhia and Bollman 1999), but the transition to a younger generation is not as easy.

According to the *Farmland Value Report* (2012), farmland value in Saskatchewan doubled from 2008 to 2012. In the pursuit of greater efficiency and higher management returns, increasing farm size has led to higher level of farm debt, leading to higher financial leverage and potentially greater vulnerability to business adversity.

This problem is further exacerbated by the ubiquitous goal of farm expansion by farmland purchase instead of leasing, leading to further increased farm debt. Hence, the question of who finances farm expansion is critical. An alternative solution is to encourage expanding farmers to rent more land instead of purchasing. Moreover, the retired farmers might also hold their farmland for more capital to fund their retirement plans.

Bringing in capital outside of agriculture, buying farmland and renting it back to farmers may seem to be an obvious solution. Back in 1971, the Saskatchewan government purchased approximately 1.2 million acres from retiring farmers and leased it back to beginning farmers. This purchase was known as land banking (Evans, 2004). Another alternative is to allow ownership by outside investors. There are various motivations for investors to buy and hold farmland, for example, 1) higher food prices caused by population growth, 2) farmland scarcity (Byerlee and Deininger 2014) and 3) the low correlation between farmland and other assets (Painter and Eves 2008).

There has been a tradition of strict regulation about which and how much land non-farmers can own in Saskatchewan (Ferguson, Furtan and Carlberg, 2006). For example, the current legislation forbids pension plans and investment trust and limits foreign farmland ownership. However, the merits of farmland investment have driven off-farm investors to own Saskatchewan farmland. For example, as of 2013, three major farmland investing entities: Agcapita, Assiniboia and Bonnefield own 175,000 acres of land worth $452 million in Saskatchewan (Bell 2014). According to Desmarais et al (2016), 1.44% of Saskatchewan farmland was owned by non-farming entities, but this ratio was merely 0.09% in the year 2002.

The impact of widespread farm ownership by external investors is uncertain. It is likely that in a free market, there increased demand for farmland could drive prices up. Retired farmers receive greater revenue from increased farmland prices. Expanding farmers, however, will purchase less land and rely more on rental land than before. However, leased land is not perceived to be as financially secure as owned land. In addition, farmers will forgo any capital gains from farmland price appreciation by renting farmland. As a result, the effects on farmer wealth are somewhat ambiguous. The efficiency of rental markets may also have unintended knock-on or cascading effects on farm structure, farm succession, and agricultural commodity prices. To start this thesis, we need to review farmland ownership regulations carefully.

1.1 Problem Statement

If large institutional farmland ownership is allowed, three problems arise regarding its effects on, 1) farmland purchase prices and rent, 2) farm succession and 3) long-run farm structure.
These are crucial problems that policy makers must address before considering changes to farm ownership laws.

1.2 Objectives

The primary aims of this study are, 1) to identify the dynamic processes associated with farm succession and farmland investment by institutional investors and 2) to assess the long-run impact of farmland succession behavior and off-farm ownership on the long-run structure of Saskatchewan farms under alternative investor purchasing scenarios. Additional objectives include the evaluation of the impact of institutional investor behavior on the farmland rental market, farm investment strategies and farm succession.

1.3 Expected Results

Key expected outcomes of this simulation analysis are as follows.

1) We expect more frequent farmland transactions and increased farmland prices,
2) Relative farmland rents (rent/price ratio) may drop due to a more abundant supply,
3) Farm structure may change due to the increase in leased land and
4) Farm succession can successfully retain the majority of farmland ownership despite the intervention of off-farm investors.

1.4 Problem Characteristics

The objectives of the non-farm investors are critical. In this simulation, we assume institutional investors are optimistic about the future value of Saskatchewan farmland, and they want to hold the optimal amount of farmland in a well-diversified, long-run investment portfolio.

Another key to this study is the role of farm demographics on farm succession and the successful transition from one generation to next. Farm demographics include farm type, size and gender of heirs, offspring education levels and the opportunity costs of running farms.

The intention for institutional investors in bidding for farmland is to increase their portfolio efficiency as measured by their return-risk ratio. Contrary to the objectives of most farmers, we assume investors consider farmland as a financial asset that yields dividends and capital gains. With lesser concerns about budget constraints, investors will likely compete against local farmers in the farmland purchasing market. Non-active farmers, such as retired farmers, might be more likely to sell their farmland to institutional investors to search for a better price. However, farm succession effectively retains farmland within farm control. Thus, we generate complex interactions between institutional bidders and the process of farm succession. Moreover, it is also uncertain whether the introduction of outside investors will change farm structure. In the following chapters, we develop an agent-based simulation model to test these outcome hypotheses.

1.5 Outline of Thesis

There are six chapters in this thesis. The basic background to the issues raised in this research is in Chapter 1. Chapter Two is an overview of the relevant literature on agent-based simulation models (ABSM), farm succession decisions and investment in farmland. Chapter Three presents analytic details of succession models and investment strategies, describing agent behavior in the simulation. In Chapter Four, we report the data for scenario initialization and the various time paths used in the simulation analysis. We also conduct model verification in comparison with the relevant data sources to confirm that the model is a reliable representation of the farming region. In Chapter Five, we initially conduct the model validation based on the data from Canadian Agricultural Census. Then, we report and discuss the model simulation results. Finally, the last chapter is a summary and concludes the thesis.

1.6 The Author's Contributions

The model in this study is inherited from Anderson (2012). In Anderson(2012)'s model, the behavior patterns of farmers, including crop planning, harvesting, product transporting, machinery adopting and bidding mechanisms in the farmland purchasing and leasing market are comprehensively established. In this study, the following contributions are made:

1) Upgrade the farm succession module. In Anderson (2012)'s model, the farm succession is based on a fixed probability. In this study, the probability of farm succession is determined by the heterogeneous situations of the farm and the heirs, and every heir of each retired farmer will be given a unique willingness score to take over the farm,

2) Add the institutional investor module. In Anderson (2012)'s model, the off-farm investor is the "bottom feeders," randomly buying 10% of the unsold farmland from the farmland purchasing auction with sellers' reserved prices. In this study, we add three heterogeneous portfolio investors competing against farmers in the farmland auction, and their bidding prices are based on the financial value of farmland,

3) Update the bootstrapping method. In Anderson (2012)'s model, the model inputs, such as the future grain prices and yields, are simulated by resampling techniques. In this study, a GARCH process is used to simulate the variance and covariance among different series better.

4) Update the reporting structure. In this study, the reported results cover each type of farmers, and the upper and lower 5 runs for each of the four scenarios and

5) Update the non-dynamic model inputs. The model inputs are updated to the values of 2014 as the starting year of model simulation.

CHAPTER II: LITERATURE REVIEW

2.0 Introduction

This chapter contains an overview of the main concepts associated with farm succession and institutional investments in real estate and farmland. The chapter also includes an introduction to agent-based simulation modeling (ABSM), describing some of its advantages over standard economic methods used in agricultural research.

2.1 Farm Succession

2.1.1 Introduction

The economic literature has some insight into reasons for farm entry and exit. For example, Jovanovic (1982) maintains firms exit because their efficiency is comparatively lower than their competitors. Family farms can be independent companies. As a family operation, old farmers typically exit farming when they are no longer as efficient as they were when younger. However, contrary to many other types of firms in an economy, intergenerational farm transfer is the premise for the sustainability of the agricultural business (Uchiyama, Lobley, Errington and Yanagimura 2005)

More recent studies concentrate on the following aspects of farm transfer: 1) successors' motivation to take over the "reins of business", 2) measures to encourage early identification of successors, including the development of plans for "handing over the business", and 3) measures to reduce the apparent barriers to retirement (Lobley, Baker, Whitehead 2010). In the following sections, we review the studies the incentives, motivations and the likelihood of successful farm succession.

2.1.2 Farm Succession Incentives

2.1.2.1 Risk Sharing

We consider family farms as a form of intergenerational risk sharing process. Lotlikoff and Spivak (1981) point out that interfamily transfer enables the extended family to enjoy the benefits of intergenerational risk-sharing when the annuity market is imperfect. Wealth transfer from parents to children shares risks within families. Rosenzweig and Wolpin (1985) utilize a three-year panel data of 2900 Indian rural farms (1968 to 1971), finding that farmland-related experience could make for optimal interfamily succession. They also valued intergenerational farm transfers and joint production in implicit intergenerational contracts.

2.1.2.2 Transaction Costs Reduction

Farm succession can also contribute to reductions in overall transaction costs. Labard and Lentz (1983) assume that individuals have "soil-specific human capital" in their thorough understanding. Individuals discover the intimate knowledge of farmland, such as how the land responds to different weather and agricultural conditions, and this information can transfer to the next generation with minimum costs. Due to the existence of transaction costs, revealing true land value and transferring specific knowledge to an outsider is costly. Thus, they conclude that farm succession is motivated primarily by the transfer of farm-specific human capital from fathers to heirs and other children inside the farm.

Pesquin, Kimhi and Kislev (1998) also report a similar conclusion based on farm simulations. They discover that compared with hiring labor outside the family, family members are more efficient because they grow up on the farm and know their farms better than outsiders. The effect of "smoothing" the transaction, along with tax shields, are still major motivations for farm succession.

2.1.2.3 Cultural and Ethical Effects

Farm culture is a factor in succession planning. Barclay, Foskey and Reeve (2007) study the case of Australia. They claim that traditional Anglo-Saxon approaches to asset succession and inheritance that prefer a male successor to continue the family farm business have a strong impact on farm ideology and attitude. Nominating a male successor is the custom. Moreover, Kimhi (2004) analyzes the data from Israel and concludes that children from Asia or Africa are more likely to have off-farm employment. Moreover, various cultural backgrounds might have different influences on the attitudes on education, and a high level of education of the heirs decreases the probability of succession.

2.1.3 Determinants of Farm Succession

Studies found that female heirs are often viewed less favorably than male heirs (Stiglbauer and Weiss, 1999, Kazakopoulos, Arachoviti and Papadopoulos, 2000). In addition, other factors may also impact on farm succession decisions: 1) farm size, 2) farm type, 3) farmer age, 4) education of operators and heirs.

2.1.3.1 Farm Size

It is likely that a larger farm size increases the probability of successful family succession. Blanc and Perrier-Cornet (1993) utilize a dataset from 12 European countries from 1988 to 1989. They find that when the farm size is larger than a critical level, it is more common for the farm to have a successor. Barclay, Foskey and Reeve (2007) reach the same result with data from Australia. They argue that farms with smaller size cannot support two generations. Thus, children from small farms have to find off-farm employment and have less land-specific experiences than those who come from large farms. As a result, they will be less likely to take over the family farms. Potter and Lobley (2007), Mishra, Johnson and Morehart (2003), Mishra (2003), Glauben, Tietje, Weiss (2006) and Uchiyama, Lobley, Errington, Yanagimura (2005) also draw the same conclusions.

2.1.3.2 Farm type

Due to distinct managing, laboring and financial requirements for producing different products, farm type also plays a major role in succession (El-Osta and Johnson, 2004). Dairy, fruit and vegetable farms require higher levels of managing and operating skills. Thus, these farms are more likely to have successors. Potter and Lobley (2007), Glauben, Tietje, Weiss (2006), Kimhi and Nachlieli (2001) and Corsi (2006) also confirm this finding.

2.1.3.3 Farmer Age

Farmer age and possible successful transferring could share a non-linear, or U-shaped relationship. As a result, there might be an optimal age to consider farm succession. Laband and Lentz (1983) initially report a non-linear relationship when testing the data in 1962 from the U.S. Kimhi and Nachlieli (2001), Glauben, Tietje, Weiss (2006), Barclay, Foskey and Reeve (2007) and Ellinger, Barnard and Wilson (2007) support this finding. Kimhi (1994) explains this non-linear relationship. As the age of the farm operator increases, he/she will eventually become more aware of the need for succession. On the other hand, if a farmer delays to consider farm succession, his/her children could have to find off-farm occupations. As a result, the chance for succession will be smaller as the farmer get old.

2.1.3.4 Education Level of Operators and Heirs

Regarding farm operators, Lamband and Lentz (1983) argue there is no significant impact of educational level on farm succession. However, some other studies claim that a higher level of education for either farmers or successors will discourage farm succession. For example, Kimhi (1994) asserts that farm operators with a higher level of education will allow the children to have more time and flexibility to consider their future career options. Mishra, El-Osta and Shaik (2010) point out that once the potential successor has accomplished high school or college, the probability for him/her to take over the family farm will drop by about ten percent. They further claim that farmers with university degrees pay more attention to their children's education. As a result, any potential successors on these farms might prefer not to take over the family farms because of high opportunity costs. The findings of Glauben, Tietje and Weiss (2006) and Corsi (2007) also support this argument.

Several other studies, however, come to opposing conclusions on this issue. Stiglbauer and Weiss (1999), Hennessy and Rehman (2008) and Kimhi and Nachlieli (2001) claim that high education level increases the probability of succession. They believe that better-educated parents can prepare for succession more efficiently, thereby allowing themselves to make an earlier and better decision.

As for the education level of heirs, studies tend to agree that a higher educational attainment for potential successors increases the opportunity cost of taking over the family farms, thus decreasing the possibility of succession (for example, Kimhi (1994) and Hennessy and Rehman (2008)).

2.1.4 Summary

Transaction costs and risk sharing are critical determinants for farm succession. The relationship of tradition and culture is also important. To determine the probability of making successful succession plans, researchers should consider the gender, education, and age of the successor, as well as farm type and size. In conclusion, succession is more likely to take place when the farms are profitable and require more focused and specific managing and operating skills. Furthermore, the chance of successful farm successions increases when the successors have lower opportunity costs. Meanwhile, those who have lower education level or more experience in farming are more likely to take over the family farms.

2.2 Non-Farm Investors: Institutional Investors

2.2.1 Introduction

From a financial market and portfolio creation perspective, the work of Markowitz (1952) was the first that formulated the choice of optimal investment portfolios based on the concepts of expected returns (E) and returns variation (V). The efficient portfolio is the portfolio that has the property that "no portfolio can have either a smaller *V* (with the same or greater *E)* or higher *E* with the same or smaller *V*."

Many studies have noted that the addition of farmland could be helpful to improve the efficiency of a given portfolio (Speidell, 1990) because of its stable rate of return (Lins, Sherrick and Venigalla, 1992) as well as the benefits of risk diversification (Kaplan, 1985, Painter, 2005, Painter, 2008). The following sections contain the basic theory of "E-V" analysis and a review of investment in both real estate and farmland.

2.2.2 Theoretical Background on Institutional Investors: Asset Pricing Theories and Valuation

2.2.2.1 Markowitz's Portfolio Selection Theory

Markowitz (1952) introduced the concept of the efficient portfolio as a bundle of risky assets in his E-V analysis. Let:

$$\mathrm{R} = \sum_{i=1}^{N} R_i X_i \tag{2.1}$$

Where: R = the weighted average return of all securities,

R_i= the return of security i and

X_i = the relative amount invested in security i.

By assumption, $\sum X_i = 1$ and no short selling is allowed. Then we have the expected return E, written as,

$$\mathrm{E} = \sum_{i=1}^{N} X_i \mu_i \tag{2.2}$$

Moreover, its variance is:

$$\mathrm{V} = \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_{ij} X_i X_j \tag{2.3}$$

Thus, for any attainable portfolio, we always have a combination of (E, V). Following Markowitz (1952), portfolio X is efficient if and only if no other portfolios with the same V have a greater E, or conversely that no other portfolios with the same E have a greater V.

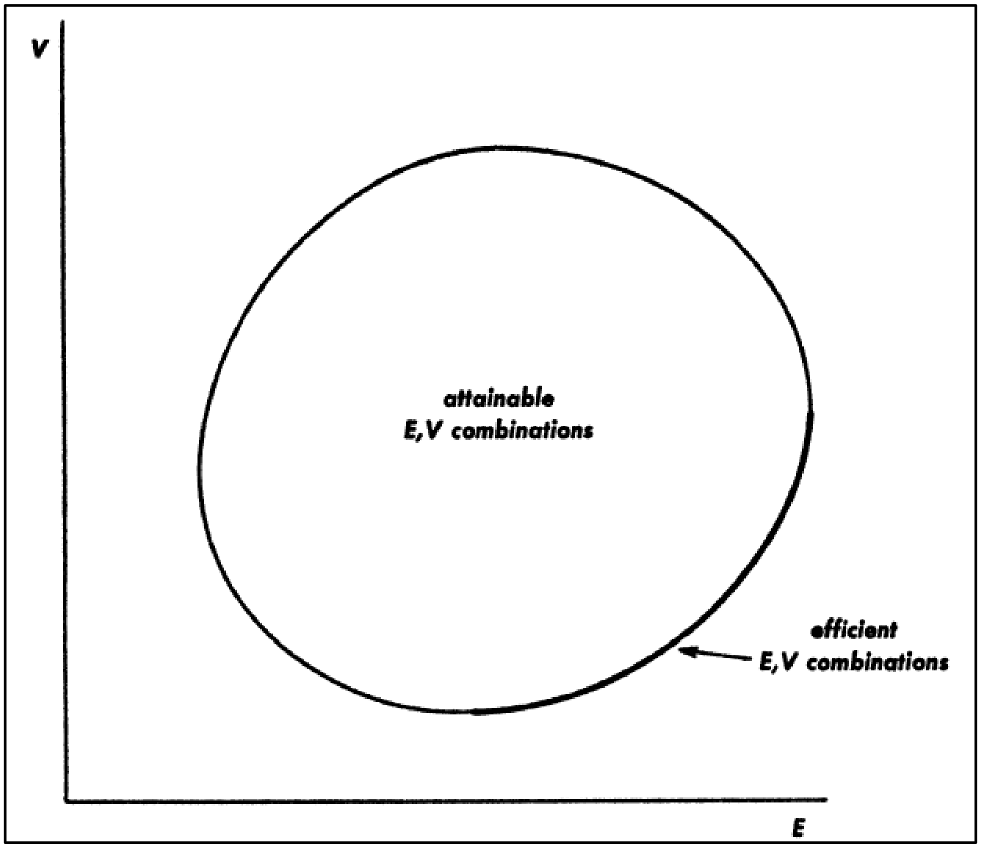

Figure 2.1: Efficient E-V combination, Markowitz (1952), p.82

To increase the efficiency of the portfolio with a targeted expected return, a rational investor needs to decrease the covariance of different securities in the portfolios.

2.2.2.2 Tobin's Two-Phase Portfolio Selection and Risk Preference Theory

Tobin (1958) adds risk preference and risk-free assets into Markowitz's model. He argued that regarding investment choices, there are two phases. The first phase is the selection of a combination of risky assets, while in the second phase, the investor adds a risk-free asset into that mix.

Tobin's other contribution is the application of preference theory from economics to help understand an investor's personal attitude toward risks. He pointed out that we can use the notion of utility and risk present in indifference analysis to distinguish investors by categories of either risk loving, risk-averting or risk neutral investors. Namely, to maximize utility, risk-averting investors have upward indifference curves in EV space, while risk-loving investors have negatively sloped indifference curves.

2.2.2.3 Sharpe's Capital Market Line and Capital Asset Pricing Model

Sharpe (1960) followed Tobin's work and derived the Capital Market Line (CML).

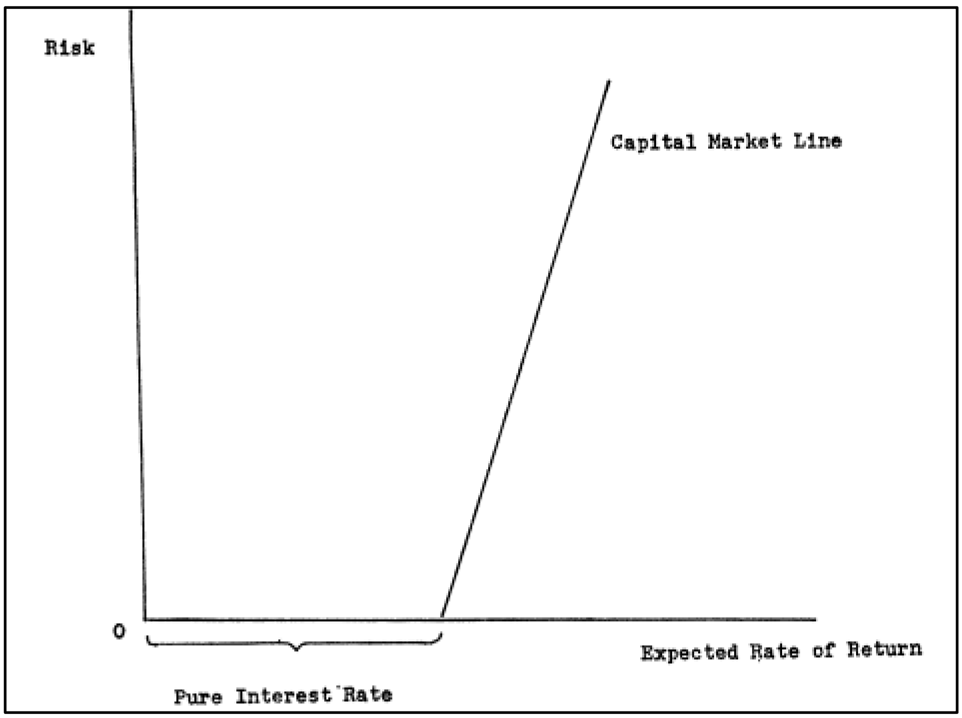

Figure 2.2: The EV Portfolio and the CML (Capital Market Line), Sharpe (1964), p. 426

From Figure 2.2, investors only hold risk-free assets to earn a risk-free rate. Each point on the CML and its extension is the optimal combination. Thus, there is no attainable portfolio with the same E and a lower V or with the same V and a higher E lying outside the CML. Figure 2.3 is employed to demonstrate the mapping of optimal investments.

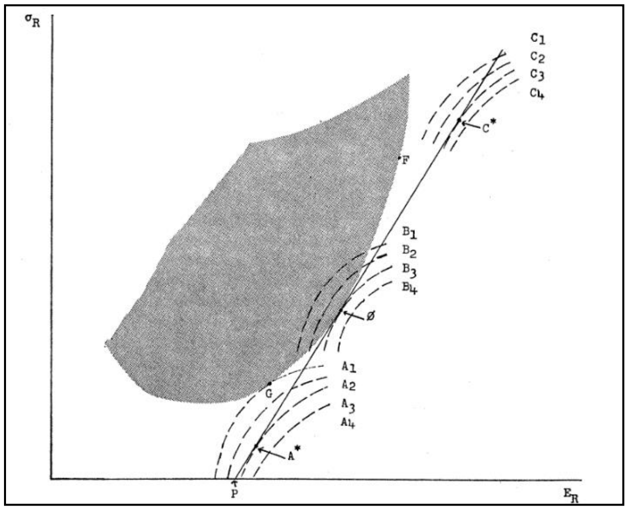

Figure 2.3: Portfolio Selection with Risk Preference, Sharpe (1964), p. 429

In Figure 2.3 the most efficient allocation of portfolio selection is always the tangent point between the CML and each set of indifference curves, namely A*, φ and C*.

Moreover, Sharpe (1964) argues that there are two types of risks to be considered, systematic risks and unsystematic risks. The correlation between expected return and systematic risks is straightforward, but unsystematic risk receives no compensation. Using this principle, Sharpe developed the so-called capital asset pricing model (CAPM):

$$E(R_i) = R_f + \beta_i(E(R_m - R_f) \tag{2.4}$$

$$\beta_i = \frac{Cov(R_i, R_m)}{Var\ (R_m)} \tag{2.5}$$

Where: $E(R_i)$ is the expected return of asset i,

R_f is the risk-free rate,

$R_m$is the expected return of the market and

β_i is the sensitivity between market return and return on individual asset i.

There are alternative asset pricing strategies such as arbitrage pricing theory (APT). Ross (1976) proposes APT and believes if there are no arbitrage opportunities in the equilibrium price, the expected return and the "factor loadings," i.e. the risks, share a linear relation. Huberman and Wang (2001) claim that the limited arbitraging capacity and dynamic portfolio investment leads to the failure of APT. In this study, the illiquidity nature of farmland restrains arbitrage, and the investor agents in the model manage dynamic portfolios. However, CAPM is the better and most parsimonious model relevant to the research question than APT.

In the following chapters, we will apply CAPM to farmland investment and pricing for our institutional farmland investors.

2.2.2.4 Application to portfolio construction

According to E-V analysis, Painter (2013) finds that to achieve minimum variance with a given expected return, we need to:

$$Minimize\ X'QX$$

Subject to:

$$R_p = C'X$$

$$W = e'X \tag{2.6}$$

Where X is the vector of the wealth share invested in each asset,

Q is the variance-covariance matrix of asset returns,

R_p is the weighted expected return on assets,

C is the matrix of returns on each individual return,

W is a singleton 1 and

E is a N×1 vector of 1.

2.2.2.5 Section Summary

This section introduced classical theories of investment portfolio selection, risk preferences and CAPM. In the following chapter describing the simulation parameters, we calculate the reserved bidding price for non-farm investors following this method. In the simulation model, CAPM comprises the decision rule for investors to help determine their bidding price for farmland.

2.2.3 Real Estate Investments

2.2.3.1 Introduction

DeLisle (2002) points out that real estate is a distinct asset class that has some implications for asset allocation, portfolio construction and portfolio management. Webb, Curcio and Rubens (1988) analyze the data from 1947 to 1983 over successive periods. They construct six portfolios with different assets and conclude that the optimal portfolio contains 2/3 real estate and 1/3 other financial assets. They further claim real estate is very effective in risk diversification.

Fisher and Sirmans (1994) argue that although investment in the land might not be attractive because of low historical returns, the low correlation between housing and debt or stock makes it become an excellent diversifying asset. Kaiser (1999) analyzes the data from 1951-97 from the U.S. and concludes that real property can reduce the standard deviation of both the bond/stock mix and the return/risk ratio. Thus, bond/property combinations seem to have superiority over a single asset approach. Lu and Mei (1999) and Corgel and DeRoots (1999) also reach the same conclusion.

Alternatively, the effect of inflation hedging of real estate is still ambiguous. Ibbotson and Siegel (1984) and Hoesli (1994) indicate that housing is an “excellent” inflation hedge with almost non-beta risks. On the other hand, some other studies hold the belief that real estate return and inflation share positive correlation, such as Gatzlaff (1994), Stevenson and

Murry (1999) and Onder (2000).

In some real estate studies, the Real Estate Investment Trust (REIT) is used as a benchmark. Following Giliberto (1993), REIT is a capitalization-weighted index that provides investors with the opportunity to own a share of real estate. Moreover, there are two types of REIT, mortgage REITs which lend mortgage to property owners, and equity REITs that collect rent from owned property (Titman and Waege, 1986).

Miles and McCue (1982) find low risk and low return features of REIT due to passive management. However, they also find real estate is a useful financial vehicle for risk diversification. Liang and McIntosh (1998) analyze data from 1984 to 1997 and point out that equity REIT outperforms the market over the last four sample years. Regard its use as an inflation hedge, Gyourko and Siegel (1994) conclude that REIT has a low correlation with inflation, thus providing effective protection against inflation.

2.2.3.2 Institutional Investment in Farmland

Farmland is a subcategory of real estate. Ibbotson and Fall (1979), Ibbotson and Siegel (1984), Painter (2000) and Painter (2008) argue that farmland can be used to diversify the risks of an investment portfolio and hedge inflation risks. They also find that farmland sometimes outperforms regular residential and commercial real estate.

To this end, Ibbotson and Fall (1979) divide properties into two groups, farmland and housing. With their data from 1974 to 1978, they find both houses and farmland performed extremely well, with almost zero betas. Moreover, farmland does a little better than housing based over this period. Ibbotson and Siegel (1984) investigate data from 1947 to 1982 from the U.S. They find farmland is better than residential housing. More recently, Hardin and Cheng (2005) apply a mean-semi variance approach[1] to calculate the lower partial moment

[1] Mean – semivariance is a “linearized” version of LP that uses simple, unsquared deviations from a mean a criterion.

as the minimum required return of the investors. When taking farmland into the simulated portfolio, they assert that farmland is as equally risk-efficient as real estate.

Following Farbairn (2014) and Gunnoe (2004), we define institutional investors to include pension funds, hedge funds, university endowments, private foundations, life insurance companies and sovereign wealth funds. Wheaton and Kiernan (2012) estimate that total institutional investments in farmland are between total $30 – 40 billion globally, or about 1% of the total volume of investment. Although farmland is now considered a good alternative in real estate investment Carter 2010)[2], historically, it was never considered as a financial asset candidate until about 1980 when Barry (1980) included U.S. farmland as a risky asset into a potential investment portfolio. National or regional farmland contribute little to systematic risk and its non-systematic risk can be readily derived based on the theory of Sharpe (1964) that non-systematic risk can be eliminated by asset diversification. It is critical because the purpose for institutional investors to buy and hold Saskatchewan farmland is to diversify their portfolio to reach CML.

Kaplan (1985) examined long-term correlations between farm real estate and stock, corporate bonds, government bonds and US Treasury bills. He found that farmland is positively correlated only with Treasury bills. Moss, Featherstone and Baker (1987) applied E-V analysis on a portfolio including US farm assets, and they report that the historical risk-return relationship of agricultural assets makes them attractive for nonfarm investors to hold. Irwin, Forster and Sherrick (1988), Lins, Sherrick and Venigalla (1992), Lins, Kowalski and Hoffman (1992) and Bjornson and Innes (1992) come to the same conclusion. Finally, Bjornson and Innes indicate that farmland is also a good hedge toward uncertain inflation.

[2] Carter maintains that farm real estate has gone through a “financialization” process (where profit is generated from financial rather than productive channel nowadays,

Shiha and Chavas (1995) and Webb (1995) identify ownership regulation as a potential barrier to external investment funds entering farmland markets. Hence, a more relaxed regulation system could encourage more non-farm investment in agricultural land. Moreover, both farmers and non-farmers should exploit both markets as Oltmans (2007) points out: both the agricultural and non-agricultural sectors should bilaterally hold assets on the other side. Following this reasoning, Harvey (1982) argues that farmland can become an important form of interest-bearing capital rather than an element of production.

Regarding farmland in Canada, Painter (2002) argued that farmland in Saskatchewan is an excellent hedge tool against inflation. Using E-V analysis, Painter (2002) also finds farmland has low risks, high dividends and lower returns. Moreover, being related to similar studies in the U.S., he also reports that the correlation between Saskatchewan farmland and other assets is negative. Painter (2008) regards Canadian farmland as a lower risk category than stocks with a lower investment yield. Moreover, seemingly overpriced farmland is not overpriced when prices for other farm assets are expected to increase. He concludes that land prices in Western Canada might eventually rise because of upcoming non-farm premia.

Painter (2010), in a subsequent study, discovered additional evidence, asserting that capital market gain and risks associated with farmland are lower than stocks. Contrary to the findings of Harding and Cheng (2005), he suggests that portfolios for median risk-median return performance would be better off after adding farmland.

Painter (2010) also recommends that international portfolio investors hold Canadian farmland. From this perspective, Painter (2011) compares Canadian farmland with gold and oil. He argues that farmland was almost as good as gold at improving the efficiency of portfolios at medium risk. Painter (2013) also finds that farmland investments offer protection against inflation and stable annual dividends.

2.2.3.3 Summary of the Effectiveness of Real Estate and Farmland in Investment Portfolios

Based on these prior studies, real estate provides at least two benefits to investment portfolios: 1) low or negative correlation with most other assets, 2) low risk and more stable returns. Moreover, the previous research not only shows that farmland shares the same merits for investment purposes, but also outperforms commercial and residential real estate in some aspects.

2.3 Non-Farm Ownership and Farmland Ownership Regulations in Saskatchewan

2.3.1 Ownership Regulation in Saskatchewan

The Saskatchewan Farm Security Act (FSA) was updated in 2002. It is the current active farmland ownership law in the province of Saskatchewan. It indicates that "only Canadian residents and 100 percent Canadian-owned entities are allowed to own more than 10 acres of Saskatchewan farmland". This is the so-called "10 acre" rule. Moreover "Canadian-owned entities" are defined explicitly, meaning that at present, investment trusts and pension plans are not allowed to purchase Saskatchewan farmland.

FSA was originated from The Saskatchewan Farm Ownership Act back to 1974. The purpose of that act was to give way to local agricultural industry and support the development of rural areas. Amendments to the original Act took place in 1980 and 1988. In 1988, the Saskatchewan Farm Security Act replaced the Saskatchewan Farm Ownership Act, combining home quarter protection provisions originated in the 1930s with other changes. An overview of these detailed rules are as follows:

Table 2.1: Current and Historical Farmland Ownership Regulations in Saskatchewan

Owner Identity		Year				
		1974	1977	1980	1988	2002
Individuals	Saskatchewan Residents	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
	Other Canadian Residents	$15,000	160 Acres	160 Acres	10 Acres	Unlimited
	Non-Canadian Residents	$15,000	160 Acres	160 Acres	10 Acres	10 Acres
Companies	Canadian Agricultural	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
	Saskatchewan Non-Agricultural	160 Acres	160 Acres	10 Acres	320 Acres	Unlimited
	Other Canadian Non-Agricultural	160 Acres	160 Acres	10 Acres	10 Acres	Unlimited
	Non-Canadian Companies	$15,000	160 Acres	10 Acres	10 Acres	10 Acres

(Source: Carlberg, Furtan and Moss (2003), p. 395)

The 2002 amendment removes the restrictions for both Canadian residents and 100% Canadian owned companies (not public traded). The current act seems to relax ownership restrictions on Canadian residents and Canadian commercial entities. However, there are more precautions built in based on perceived foreign threats on farmland security.

Table 2.2 shows a comparison of current farmland ownership limitation in all provinces. It is clear that except for acreage differences, most of the provinces share at least some restrictions on foreign ownership. That might imply land authorities prefer to smooth farmland values and otherwise protect against price disturbances potentially caused by large-scale (international) land purchases.

Table 2.2: Provincial Comparison in Farmland Ownership Restriction

International Investor Identity	Province						
	Saskatchewan	Alberta	B.C.	Manitoba	Ontario	Prince Edward Island	Quebec
Residents	10 acres	20 acres	No Restriction	40 acres	No Restriction	5 acres	10 acres
Cooperation	10 acres	20 acres		40 acres		5 acres	10 acres
Canadian Pension Plan	Not Allowed	Allowed	Allowed	Not Allowed	Allowed	Allowed	Allowed

(Source: Government of Saskatchewan, Saskatchewan Farmland Ownership)

2.3.2 Effect of Land Ownership Regulations

2.3.2.1 Effect of Land Ownership Regulation on Farmland Price

Farmland ownership in Saskatchewan faces certain restrictions, but the effect of the Saskatchewan Farm Ownership Act on farmland price is still ambiguous. For example, Halt (1979) and Harris and Raviv (1981) studied the pricing effects of the Act using a sealed bidding scenario and discovered that increased competitiveness raises the tender land price. Brannman, Klein and Weiss (1987) found that when bidding on a fixed asset with an uncertain value such as farmland, adding one more bidder will push the bid value of the winning bidder in proportion to (1/number of bidders), essentially to avoid a winner's curse[3]. Consequently, ownership barriers likely decreases farmland prices.

Moss and Schmitz (2008) using 1952 to 1999 data offer that there is no indication that the FSA led to Saskatchewan farmland price decreases. They believe this is a likely story because Saskatchewan residents "bid away all possible future land rents" without any credit constraints. Ferguson, Furtan and Carlberg (2006) reach a similar empirical result. Using a simple OLS model and 1951 to 2002 Saskatchewan farmland prices, they found that that a 1% increase in the stringency of the ownership regulation reduced Saskatchewan

[3] Following Thaler (1988), there are two descriptions about winner's curse. 1) the winning bid is higher than the true value of the tract and the winner loses money, and 2) the winner is disappointed because the winning bid is higher than the expert-estimated value of the track.

farmland values by 2.87%. However, as indicated in Table 2.2, off-farm investors are likely to bid a higher price in a farmland auction for a variety of reasons.

2.3.2.2 Effect of Land Ownership Regulation on Non-farm Ownership

Desmarais, Qualman, Magnan, and Wiebe (2015) gathered farmland ownership data for three small towns in Saskatchewan and identified a dramatic increase in external investor ownership of farmland in the regions. The average proportion of farmland holding by investors is more than ten percent of the total. In effect, the benefits of growing farmland values might be offset or reversed by these so-called “barbarians at the gate.” In the study of Desmarais et al. (2016), the dramatic increase of the amount of investor-owned farmland is revealed at the provincial level. They point out that the 2002 FSA removes the restrictions of Canadian individuals and cooperatives to own Saskatchewan farmland, and in the middle of 2014, 1.44% of the total farmland in Saskatchewan have been owned by non-farming entities, yet the proportion was 0.09% in 2002. Furthermore, Desmarais et al. (2016) observe a concentrating trend for non-farm land ownership. In 2014, the four largest private landowners had about 57% of the non-farm owned land. Finally, they also point out that the interviewed farmers concern about the rising farmland price will be a barrier for the young farmers, but the retired farmers might enjoy better retirement package for land sales.

2.3.3 Summary

The last 50 years has witnessed stricter ownership regulations of Saskatchewan farmland. While finally adopting farmland ownership restrictions similar to adjacent provinces as of 2002, Saskatchewan is still the most conservative province regarding foreign farmland ownership in terms of acreage allowed as well as the prohibition of pension plan ownership. However, with the introduction and growth of off-farm investors, the original purpose of the farmland ownership acts of controlling provincial farmland prices by banning or limiting farmland ownership, is starting to come apart. While a few studies provide evidence and support for increased external investor ownership of farmland, this research will look into simulating real changes to the FSA within subsequent chapters.

2.4 Models of Long-run Structural Change and Land Use

2.4.1 Agent-Based Models and Agents

Driven by the desire to better explore inherently complex economic systems, applications of agent based modeling (ABM) within the field of economics has become more and more popular for policy-based research (Parker and Filatova, 2008). Agent-based models are effective “the computational study of systems of interacting autonomous entities, each with dynamic behavior and heterogeneous characteristics” within an artificial world (Heckbert, Baynes and Reeson, 2010). The researchers, like those who conduct scientific experiments, are observers and must interpret the output created by the simulated agents. Every ABM ideally builds complex interactions between agents and their operating environment, as well as representing complex behavioral patterns, while providing valuable information about the working of real-world systems (Bonabeau, 2002).

Agents, as the basic building blocks or objects in an ABM, are defined by Verburg, Schot, Dijst and Veldkamp (2004) as real or abstract entities that can act on themselves and their environment, communicating with other agents and whose behavior is the result of observation. As a first step, modelers must construct agents first in the process of building a “bottom up” virtual system or economy. Agents can be participants in economic activities, such as farmers, speculators, and institutional investors, or alternatively represent various decision-making entities in other social and environmental phenomena, such as market auctioneers (Farber, 1999, Tesfatsion, 2002). Agents may nest their own individual behavioral paradigms in interacting with the operating environment and other agents. Overall, the behavior of the whole simulated system depends on the aggregated individual behavior of each agent. (Mattews, et.al , 2007)

As a whole, in contrast to traditional economic models that are macroscopic in perspective, ABM is a microscopic modeling technique that recreates real-world or macro level complexity from the interacting behavior of individual participants (Bonabeau, 2002).

2.4.2 Existing Problems with Conventional Models

"I should, I think, be prepared to argue that, in a world ruled by uncertainty with an uncertain future linked to an actual present, a final position of equilibrium, such as one deals with in static economics, does not properly exist."

- -John Keynes in a letter to H. D. Henderson

Tesfatsion (2006), Marks (2006) and Fagiolo, Moneta and Windrum (2007) point out that traditional mathematical economic general equilibrium models are constructed using the problematic assumption that an equilibrium always prevails in a market. In the real world, as Keynes speculates, economics markets are dynamic and adaptive and out of equilibrium with constant spikes and obstacles to stability (as cited in Arthur, 2006).

Kirman (1992) argues that it is a fatal flaw to impose order on the economy through the concept of an omniscient individual, designed to be the "representative" individual in the economy, completely ignoring heterogeneity of behavior and preferences. As a result, the demand curve of one agent is extrapolated to represent the demand for the particular good of the whole economy (Tesfatsion, 2006). But for agricultural research the set of activities conducted by farmers are strongly influenced by the cumulative effects of experiences and observations of neighbor experiences (Berger, 2001).

Meanwhile, Simon (1982) speculated that given the limitations of knowledge and computational power, people generally fail to judge whether a belief or behavior is right. And Williamson (1971) mused that the absence of unlimited computational capacity would prevent the market from achieving optimality. However, unbounded rationality is one basic assumption of “rational economic man” in the theories of neoclassical economics (Fagiolo, Moneta and Windrum, 2007). Berger (2001) also points out two more flaws in conventional agricultural economic policy models. Initially, they do not capture the interaction between economic agents, thereby assuming there is no transaction and information cost, and secondly, almost never is a spatial dimension and the physical immobility of land ever considered as part of the individual decision process.

2.4.3 Characteristics and Advantages of Agents and ABMs

As the basic component of ABM model, agents have the following characteristics (summarizing the work of Tesfatsion (2006), Fagiolo, Moneta and Windrum (2007), Matthews et.al (2007), Heckbert, Baynes and Reeson (2010), and Crooks and Heppenstall (2012)),

1. Autonomy. Agents are autonomous and free to interact with their environment in a dynamic fashion.
2. Heterogeneity. Agents are equipped with different decision-making abilities, using both rule-based and analytical functions to represent various behavioral rules, competencies, rationality, or computational skills.
3. Goal-directed. Agents are often endowed with different goals to achieve that ultimately guide their behavior.
4. Adaptive bounded rationality. Agents are assumed to behave as bounded rational entities, possessing adaptive type expectations over past choices made by other agents in the population.
5. Networked interaction. Agents are inter-dependent and follow loops of interaction with each other through markets, social networks and /or institutions through adaptive expectations.
6. Complexity. As agent behavior is computationally complex, these models are a more natural way of describing the system rather than the processes.

Being designed with these characteristics, ABMs are therefore endowed with the following advantages, according to Bonabeau (2001):

1. Capture emergent phenomena. When a new phenomenon emerges, the setup of theoretic frameworks is generally incapable of handling this. However, as a bottom-up method, ABMs are able to study emergent phenomena by creating a simulated economy with non-linear agent behaviors that can be characterized by thresholds, if-then rules and nonlinear coupling.
2. Increased flexibility. ABMs can be observed by multiple dimensions since every result is generated endogenously, and the models are also able to reflect any changes to agents' behavior descriptions and interaction rules.
3. Better natural description of a system. ABMs create the whole systems composed of behavioral entities. The observers can understand every step of the system elevation by watching the agents and their movements.

2.4.4 Application of ABMs in Agricultural Economics

Nolan et al. (2009) highlight advantages with the application of ABMs to agricultural economics research, including the ability to model urban-rural fringe land use and the evolution of agricultural chains, measuring structural changes in farming on farmland value and the learning processes of farmers. Since the agent population (although synthetic) is the fundamental building block of an ABM, a very low level of micro-activity and the building blocks of a society or economy may generate a much longer forecast of agricultural structural change.

It is not surprising that many agricultural ABMs incorporate land as a foundation (e.g., Verburg, Schot, Dijst and Veldkamp, 2004, Tesfatsion, 2006 and Parker et.al 2012). However, agent behavioral characteristics are influenced by demographics (age, marriage, out-migration) and their actions are constrained by technology and markets. For example, Bert et al. (2011) find that farmland ownership is concentrated by fewer farms owning more land in their 100-year simulation. They assert that small farms cannot generate sufficient working capital over time, losing their ability to expand and becoming non-competitive and shifting into rental markets.

There are currently two well-known agricultural simulation models, called MP-MAS and Agricultural Policy Simulator (AgriPoliS). MP-MAS has been updated to MP-LUCC by adding climate changes to evaluate climate-related policies (Berger and Troost, 2012). AgriPoliS was created by Balmann (1997) and Berger (2001). The model has been used to analyze agricultural issues in Chile, Ghana, Thailand, Vietnam, Uganda and Germany (Schreinemachers and Berger, 2011). This model includes dynamic farmer agent investment, crop and livestock production and consumption decisions subject to initial resource conditions, stochastic crop yields landscape and water resources and land and water market.

AgriPoliS is direct descendent of MP-MAS (Schreinemachers and Berger, 2011) expanded to allow broader economic outcomes than just production to be assessed in agricultural policy analysis. In their model, farm agents who populate real landscapes (using GIS), are independent agents who pursue goals such as income maximization and market agents and are responsible for determining the demand and supply of production input and outputs such as farmland or grain prices. They use their model to test the interrelationship of rents, technical change, product prices, and the efficiency of agricultural policies (Happe, Balmann and Kellermann, 2004 and Happe, Kellermann and Balmain, 2006)

Freeman (2005) extends these models to Saskatchewan to evaluate structural change (1969-2000), and also develops a land bidding market. Stolniuk (2008) improved this model by including livestock, economies of size and changes in land use. Anderson (2012) further enhanced the model by adding linear programming (LP) and mixed-integer programming (MIP) decision portions (similar to AgriPoliS) into these models, and also introduced energy crops as a future crop choice. However, none of these models incorporated farmland investors as possible economic agents in Saskatchewan farmland markets nor either had no farmland succession or rather simplistic farmland succession. Thus, we update these models by adding institutional investors and more realistic farm succession modules. Moreover, we also improve the data bootstrapping technique used for generating better simulation model input.

2.4.5 Repast© Symphony Platform

Repast© Symphony Platform is a widely used free and open-source agent-based modeling and simulation toolkit developed by the University of Chicago using the Java language. It is maintained and managed by a non-profit group called ROAD (Collier, 2005, North et al. 2006). It provides a library of objects for creating, running, displaying and collecting data from an agent-based simulation (Collier, 2005). Until December 2015, the latest available version of Repast© Symphony 2.3.1 was downloadable on 1 June 2015 (Repast© 2015). However, this research is derived from the work of Anderson (2012), which was written in Repast© Symphony 1.10. To avoid compatibility problems related to the new Windows 64-bit system and the updated versions of Java and Repast©, this model was coded using Repast© Symphony 1.10.

2.6 Summary

The introduction of external investors into existing farmland markets is expected to affect farmland prices and have carryover effects on Saskatchewan agriculture. There is little precedence for the widespread entry of outside investors into western Canadian agriculture, and therefore statistical analyses are infeasible. Moreover, farmland prices and farm structure are both complex and dynamic in their interrelationship. Farm succession is an event founded in both culture and economics and is surely heterogeneous among modern farms. Because of this heterogeneity, we offer that ABM simulation is the most appropriate methodology for analyzing emergent behaviors that may, in turn, lead to structural changes in this agricultural sector.

CHAPTER III: THE DUALINVESTMENT MODEL

3.0 Introduction of the *DualInvestment Model*

The *DualInvestment* model builds upon the prior work of Freeman (2005), Stolniuk (2008) and Anderson (2012). In Anderson's (2012) model, farm agents maximize profit from both croplands in producing grain and marginal land in producing second generation biofuel plants such as willow and hybrid poplars. The farm level decision process in this latter model involves both long-run strategic (i.e. farm size, forage rotations and herd size) and short-term decision phases (annual crops). Farm succession is based on a randomized likelihood of retirement. With respect to farmland markets, non-farm investors, in this case, are essential "bottom-feeders," and are permitted to purchase any unsold farmland where farmers were unable to meet the seller reservation price.

DualInvestment captures two distinct types of farmland purchasers, institutional investors, and farmers. In turn, we introduce a more realistic mechanism in determining farm succession. The next chapter gives an overview of the conceptual model, followed by detailed discussion of 1) assumptions on operating rules for farmers, 2) farm succession and transfer, 3) behavior of non-farm investors in farmland investment, 4) auction and bidding processes of both farmland rental and purchase markets, and 5) a chapter summary.

Accordingly, the interplay of these agents in land auctions and the subsequent winning or losing of bids determines land ownership and rental success. The generated ownership and rental patterns affect farm size, financing, survival and succession over several generations as well as a farm structure. Major variables we consider in the model include 1) the number of farmers and investors, 2) farm types, 3) farming heir education levels and opportunity costs of farm succession, 4) attributes of our investors, and 5) financial returns and prices of agricultural products.

3.1 Model Agents

The *DualInvestment* Model simulates a regional agricultural landscape composed of heterogeneous farmer agents and farmland. To start, we assume that each model agent behaves rationally[4]. In the model, we consider five classifications of agents as farmland market participants: 1) regular farming agents, 2) farmer landlords, 3) exiting aging farmers, 4) non-farming investors (also landlords), 5) the auctioneer agent acting as the "invisible hand" (Smith, 1776) to help clear farmland markets.

As in Anderson (2012), the "invisible hand" of the auctioneer agent helps set farmland pricing by overseeing farmland auctions. The auctioneer agent is a *deus ex machina* agent, and is responsible only for the land auction, matching farmland buyers to sellers through the auction process. However, land auctions are influenced by the behavior of operating farm agents and retired farm landlords. In turn, farm agents are composed of three types: pure grain farm, mixed farm and pure-beef cow farms. Finally, different asset choices determine the heterogeneity of our non-farm investors.

3.2 Model Overview and Assumptions

The following section provides an overview of the basic assumptions as well as the dynamic feedback mechanisms active in the *DualInvestment* model. The model builds upon the work of Anderson (2012), with the addition of institutional farmland investors and farm transfer modules. The basic organizational structure of the Anderson (2012) model is shown in Figure 3.1. More details of the Anderson (2012) model are listed in Appendix A.

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[4] The (heterogeneous) landscape is based on (Census Agricultural Region) CAR 1A, located in the southeast corner of Saskatchewan. The landscape and farm plot details of CAR 1A will be discussed in more detail in Chapter 4.

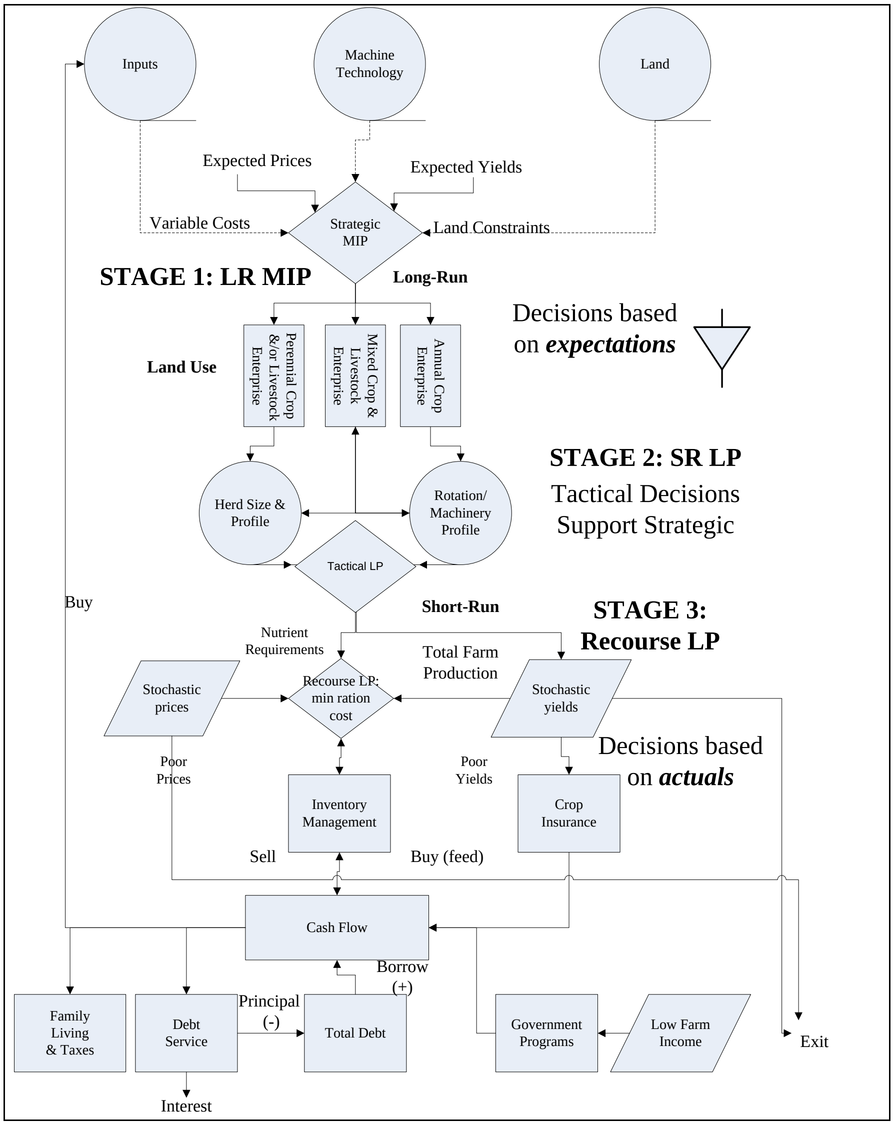

Figure 3.1: An Overview of the Farmer Agent Decision Making Process (Anderson, 2012, p.36

In the *DualInvestment* simulation model, we make following assumptions.

1. Farmland can be owned, leased or lay idle. Institutional investor landlords deliver the land to the rental market immediately after purchasing land.
2. For model simplification purposes, no technological improvements are allowed during the simulation period, i.e., the capacity of the machinery, the expected

productivities and prices of grains and livestock remain the same over 30 simulating years.

3. Both farmers and non-farm investors pursue profit maximization, subject to their own (risk) preferences. We assume that farmer agents are imbued with a desire to purchase land in striving towards maximum efficiency, but are subject to financial constraints, age and risk preferences. In sharp contrast, non-farm investor agents use farmland to build an efficient investment portfolio (sections 2.2 and 2.3).

4. Each farmer has unique circumstances, risk preferences and future price expectations. Farmers expected future yield and commodity prices are a weighted average of historical values and adjusted for personal risk preferences. Non-farmer investor expectations are based solely on historical returns of farmland and other financial assets.

5. Following Desmarais (2016), the four largest off-farm investors have owned 59% of all the non-farm owned farmland. As a result, three institutional investor agents representing broad classes of investors are included in the model because of the ownership concentration. Each investor group purchases and sells from a fixed number of global stock indices with no transaction fees.

6. Institutional investors only buy and hold farmland for subsequent cash rental. Once purchased, farmland is assumed to be held indefinitely since these are assumed to be global investors.

7. Farmers cannot invest outside the agricultural sector.

8. When a farmer fails to maintain sufficient business liquidity or asset solvency, that agent is forced to exit.

9. We set the willingness for possible successors to take over their family farms using data from a real-world survey.

10. CAPM determines the bidding value of farmland for non-farm investors (please refer to Section 2.2).

11. Actual farm commodity prices will follow one of a series of multiple time paths. Farm yields are derived from stochastic yield time paths and adjusted by individual land productivity.

12. Current tax policy continues throughout the simulated era.

13. In setting auction bids, investors pay their actual bids but farmers pay the average of bidding price and the minimum accepted price. The latter is done in order to prevent "winner's curse"[5] by farmers over land purchases.

Agent heterogeneity in this simulation is an important assumption. Agents are initially assigned a variety of personal and business attributes. Regarding farm agents, individual farm size is important in determining appropriate tillage technology, machinery application, corresponding returns to scale and potential farmland bid prices. Any failure in buying or leasing farmland at a reasonable rate tends to reduce future farm competitiveness. An important feedback mechanism at play here is the "balance sheet" effect, meaning that a higher farmland value enables farmers to borrow more by relaxing some financial constraints and *vice versa* (Anderson, 2012).

An important dynamic role in the land market is provided by our (three) non-farming investors. The introduction of non-farm investor landlords potentially creates higher demand in the land purchase market, but can also generate additional supply in the

[5] The definition of "winner's curse" can be found in the footnote in Section 2.3.2.

farmland rental market. Thus, a drop in expected rent could counteract an expected price increase in the purchasing market.

Farming continuity depends on the ability of the farm to find a qualified and willing successor, as well as the on-going profitability of the agricultural business. As discussed in Section 2.3, farm size, farm type and non-farm employment opportunities are all important determinants of the probability of successful farm succession.

3.3 Farmer Exit and Succession

3.3.1 Introduction

The farmland succession model is an important complementary modification to the Anderson (2012) model. Anderson (2012) assumed a fixed and exogenous probability of a willing farm successor being available, along with a minimum equity requirement of $500,000 necessary to meet projected retirement family living requirements (Anderson, 2012, p. 83). Here, it is assumed that succession only takes place on economically sustainable farms. In section 3.3.2, sustainability and the simulation of farming generations and the farm succession process are further discussed.

3.3.2 Farmer Exit and Farm Succession

The farm succession decision process flowcharts as listed in Anderson (2012) are suitably modified and displayed in Figure 3.2. Note that the census data used in the farm succession module can be found in Chapter IV.

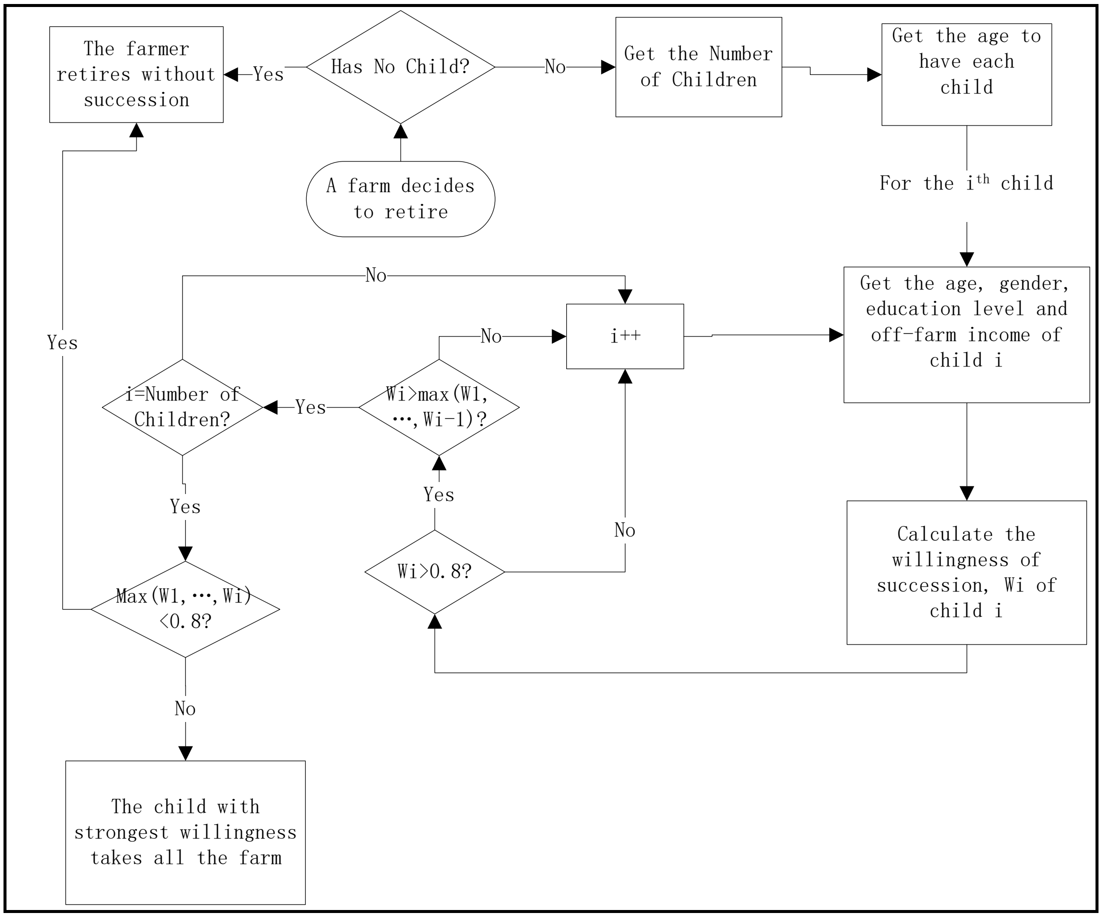

Figure 3.2: Farm Exiting and Succession Module Flowchart

In the simulation, we check whether individual farmers have heirs or not at the beginning of the process, and immediately after succession. We use census data of Statistics Canada to generate and calibrate the distribution of children within the simulation. Given this, each of the farmer agents in the simulation has an assigned probability of having zero children. Any given farmer will have zero children if:

$$No\ Child_{prob} > Pre_{prob} \tag{3.1}$$

Where: $No\ Child_{prob}$ is the probability of having zero children and

Pre_{prob} is a randomly generated probability.

If farmers are determined in this manner to bear at least one child, we assign each of them a total number of children on the farm, as well as the year the children are born. For example, farmers will only have one child if:

$$One\ Child_{prob} > Pre_{prob} \tag{3.2}$$

$$Two\ Children_{prob} < Pre_{prob} \tag{3.3}$$

Where: $One\ Child_{prob}$ and $Two\ Children_{prob}$ are the randomly generated probabilities and

Pre_{prob} is the assigned probability of having just one or two children.

If the farmers have three or more children, the total number of children is given by:

$$Number\ of\ Children = round(Normal(3.68,1),0) \tag{3.4}$$

(Source: Statistics Canada, http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil50i-eng.htm)

The assigned year for having children, based on Census of Statistics Canada in the year 2010, is as follows:

$$Year\ of\ Having\ Children = round(Normal(27.5,4),0) \tag{3.5}$$

(Source: CANSIM Table 102-4505)

Financially, we assume that farming families will not be responsible for any college tuition coming from their offspring.

Farm exits are created by retirement, or voluntary and involuntary farm financial conditions. Following Anderson (2012), at the beginning of each simulation period, each farm is checked for the net cash flows and solvency. Involuntary or forced exits are created by business insolvency and/or problematic cash flows:

$$TFL \geq TFA * 0.9 \tag{3.6}$$

Where: *TFL* is the total farm liabilities (debt) of the farmer and

TFA is the total farm assets of the farmer.

Chronic cash flow problems can result in involuntary exits. For modeling simplicity, farmer agents who experience cash flow deficits more than five years in a row have an increasing probability of voluntarily exiting the simulation:

$$Rand_{prob} < \mathrm{Pre}_{prob} \tag{3.7}$$

Where: $Rand_{Prob}$ is the randomly generated probability of exit and

Pre_{Prob} is the pre-determined probability of exit.

When reaching an age of 55 years, all farmers are assumed to be subject to probabilistic retirement. In the simulation, the probability of retirement increases in five-year increments. This is modeled as,

$$Age \geq LB_{age} \ and \ Age < UB_{age} \tag{3.8}$$

$$Retire_{prob} < Pre_{prob} \tag{3.9}$$

Where: *Age* is the current age of the farmer,

LB_{age} is the lower bound age in that increment,

UB_{age} is the upper bound age in that increment,

$Retire_{Prob}$ is the probability generated randomly and

Pre_{Prob} is the pre-determined probability for that age increment.

In setting actual farm succession, a probabilistic willingness indicator for each heir of senior farmers to take over the family farm is calculated by (3.10) and compared to a threshold of 0.8. If the willingness indicators for all heirs are less than the threshold, there would be no family succession. Otherwise, the heir with the strongest willingness takes over the entire farm and replaces the old farmer, taking over everything including reserved cash, machinery, farmland and debt.

3.3.3 Survey and Succession Equation

In order to quantify the effects of heterogeneity on succession probability, University of Saskatchewan (College of Agriculture) undergraduate students who are also the children of farmers were asked as to their opinion as to how their own farm peers would respond to a number of questions.[6] A total of 98 students participated with 64 usable results from March 20, 2015, to April 1, 2015. The questionnaire can be found in Appendix E. Survey questions included off-farm wage, farm size, farm type and gender of heirs as determinants for farm succession. The estimated equation of our succession model is shown in 3.10, and additional details are found in Appendix B.

$$\begin{aligned} Probablity_{succession} &= 0.68 + 0.02 * Onwer + 0.06 * Log(Land) - 0.15 * Gender - 0.05 \\ &* Income - 0.23 * Type \end{aligned} \tag{3.10}$$

Where: Owner is the percentage of land owned by the farmer,

LLand is the log value of acres of land,

Gender is the dummy variable for gender of the respondents, 1 is male,

Income is the projected off-farm wage and

[6] The University of Saskatchewan Committee for Ethics in Human Research (UCEHR) was contacted and ultimately determined that the succession questionnaire did not fall within their purview, and so did not require ethics approval. This decision was made because of the nature of the questions posed: students were asked about their opinions as to the likely response of their farm peers, which do not constitute responses about themselves.

Type is the dummy variable for farm type - 1 is pure grain and 0 is mixed farms or pure beef farms.

The variable "Income" in (3.10) is calculated based on (3.11).

$$Income = Uniform(0.7,1.3) * Expected\ Income\ on\ Given\ Education\ Level\ and\ Age \quad (3.11)$$

Where: $Expected\ Income\ on\ Given\ Education\ Level$ is the average wage of each education level, drawn from census data.

3.4 Farmland Auction

3.4.1 Introduction

The land auction is the only means in the model to change land ownership. Moreover, auctions take place only once per simulated period (one calendar year). Based on the Anderson (2012) model, there are two types of land, cropland and marginal land. The auction of cropland is conducted prior to the auction of marginal land because while farmers can participate in both auctions, investors are assumed to only participate in cropland actions. Figure 3.3 demonstrates the procedure of our farmland auctions.

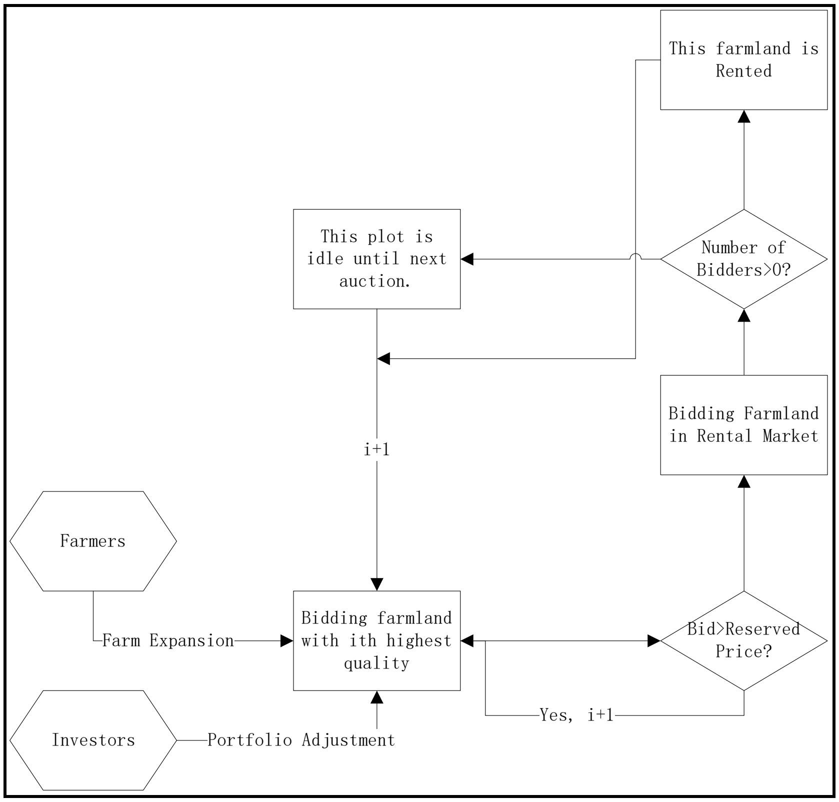

Figure 3.3: Farmland Bidding and Leasing Auction Flowchart

The supply of farmland at any given time comes from exiting farmers. In the auction market, due to land heterogeneity, each parcel is auctioned separately based on its attributes. In the purchase market, the auctioneer agent is responsible for managing the auction. The farmer or investor with highest bid price will acquire land if the price is greater than the reserve asking price of the seller.

3.4.2 Farmer Agent Land Bid Value Formulation

Following Anderson (2012) and Stolniuk (2008), since the incentive for farm expansion is to achieve a higher return on the scale, farmers who meet cash flow and financial criteria can submit bids in farmland purchase auctions. In the farmland rental auctions, only farmers participate. Their bidding price in the latter is solely based upon yield and product selling price expectations, computed as moving averages of the previous five years (Stolniuk, (2008).

All farm agents are screened prior to entering their farm level strategic optimization problems (a mixed integer program, or MIP) by age, debt load and minimum cash flow. All farmers who want to perform land expansion must pass the financial bid screen prior to entering the purchase market. If they cannot enter the purchase market, these farmers must proceed to the land rental market. Farmers who pass the financial bid screen will first enter the purchase market where they try to submit bids high enough to obtain the chosen parcel of land, with sufficient cash flows as projected are maintained. As a result, farmer agents' maximum bidding capacities are restrained by their financial bid. The financial bid equation is:

$$Bid_{Fin} = Min(Bid_{cash,} Bid_{d/a}) \tag{3.12}$$

Where: Bid_{Fin} is the financial bid

Bid_{Cash} is the bid based on available cash and

$Bid_{D/A}$ is the maximum bid to maintain sufficient debt to asset ratio.

Available cash represents the cash flow needed to maintain a positive cash balance for the farm expansion phase. The definition of total available cash is based on Stolniuk (2008) and includes the following - minimum cash per acre and per cow for all farm enterprises and down payments for new capital investments. The available cash formula is written as:

$$Cash_{Avail} = Cash - min_{cash} - min_{cow} - min_{fam} - \propto (Cap_{Value}) - Cash_{res} \tag{3.13}$$

Where: Min_{cash} is the minimum cash per acre for each farm enterprise,

Min_{cow} is the lowest cash amount per cow required,

Min_{fam} is the minimum family withdrawal expense,

α is the down payment percent required on new borrowing,

Cap_{Value} is new land asset value and

$Cash_{Res}$ is cash reserves required of the farm.

The maximum debt-to-asset ratio bid is calculated as follows:

$$Bid_{\frac{d}{a}} = \frac{\gamma * (Assets_{new} + Land_{Value}) - Debt_{new}}{\gamma * (\alpha + (1 - \alpha))} \qquad (3.14)$$

Where: γ is the maximum debt-to-asset ratio allowed,

α is the down-payment,

$Assets_{new}$ is the new assets required (plus old assets),

$Land_{Value}$ is the market value of the land and

$Debt_{new}$ is the new debt (plus old debt) of the new assets,

These purchase bids are income based and are the net present value of the certainty equivalent of future income earning ability (R_t^{XY}) and final land value (EV_n) using r, the risk-free rate,

$$Buy\ Bid_{income}^{xy} = \sum_{t=1}^{n} (\frac{E[CE(R_t^{XY})]}{(1+r)^t} + \frac{E[CE(EV)]}{(1+r)^n} \qquad (3.15)$$

Where: r is the assumed risk-free discount rate.

Expected income comes from the objective function for the MIP problem. We use annual contribution margins, less variable and fixed costs for machinery and labor variable costs as well as costs associated with additional land acquisitions, less expected income taxes and family living. If $Income_{bid}$ is larger than the $financial_{bid}$, the higher bid submitted to the land auction becomes the $financial_{bid}$.

3.4.3 Institutional Investor Agent Land Bid Value Formulation

3.4.3.1 Introduction

The introduction of institutional investor agents is a critical component to our simulation model. In order represent the complex and highly heterogeneous world of institutional investors. But to maintain tractability, we assume that just three institutional investor agents can represent such diverse institutions as pension funds and insurance companies. By assuming rationality in maximizing their risk-return, following Tobin (1958) that is discussed in Section 2.2.2, all investors share a common set of behavioral accounting equations and decision-making processes. Table 3 is employed to introduce the three institutional investor agents.

Table 3.1: The Definition of Three Institutional Investor Agents

Investor Agent Type	Characteristics
Full Investor	This investor agent can buy all of the ten international stock indices
Non Asian Investor	This investor agent cannot buy Nikkie (Japan) and Hang Seng (Hong Kong) Indices
North American Investor	This Investor agent can only buy NASDAQ and TSX (Canada) Stock Indices

The following flow diagram, Figure 3.4, is shown to give a flavor of the behavioral patterns of our institutional investors. There are two stages in the institutional agent bid formulation process. First, the investor agents generate their own optimal portfolio and the associated farmland bidding price, based on E-V analysis and CAPM. All optimal portfolio proportions are generated exogenously based on the exogenous asset prices as discussed in 3.4.3.2 and 3.4.3.3. In the second stage of this process, all investors participate in a sealed bid land auction.

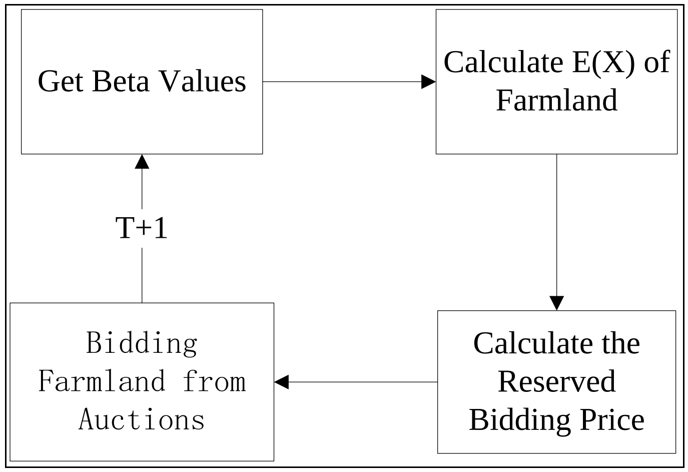

Figure 3.4: Investor Agent Flowchart

3.4.3.2 Theoretical Optimal Portfolio Construction

Following section 2.2, investors conduct an E-V analysis to determine the optimal portfolio bundle. This is computed as,

$Var(Portfolio)$ =X'QX

$$= (a_1 \quad a_2 \quad a_3 \quad \cdots \quad a_n)\begin{pmatrix} Var(A_1) & \cdots & Cov(A_1, A_n) \\ \vdots & \ddots & \vdots \\ Cov(A_n, A_1) & \cdots & Var(A_n) \end{pmatrix}\begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{pmatrix}$$

(3.16)

Expand this to get:

$$SD(Portfolio) = \sqrt{\sum_{i=2}^{n} a_i Var(A_i) + \sum_{i=2}^{n}\sum_{j=2}^{n} 2a_i a_j Cov(A_i, A_j)}$$

(3.17)

Where a_i is the Proportion of asset A_i in the portfolio,

A_i is the Asset i.

Moreover, the average return will be:

$$R(Portfolio) = \sum_{i=2}^{n} R_i a_i$$

(3.18)

Where: $R(Portfolio)$ is the optimal return for the portfolio,

R_i is the geometric mean of asset return[7] and

a_i is the optimal proporation of asset i.

Furthermore, the most efficient asset allocation (Chapter 2) maximizes the portfolio Sharpe Ratio or return-risk ratio:

$$Sharpe\ Ratio = \frac{R(Portfolio) - r}{SD(Portfoilo)}$$

$$= \frac{\sum_{i=1}^{n} R_i a_i}{\sqrt{\sum_{i=2}^{n} a_i Var(A_i) + \sum_{i=2}^{n} \sum_{j=2}^{n} 2 a_i a_j Cov\left(A_i, A_j\right)}}$$

(3.19)

From (3.19) and assuming concavity, we can find the proportion of each asset, a_1 to a_n by the following:

$$\begin{cases} \dfrac{\partial Shaprte\ Ratio}{\partial a_2} = 0 \\ \dfrac{\partial Shaprte\ Ratio}{\partial a_2} = 0 \\ \vdots \\ \dfrac{\partial Shaprte\ Ratio}{\partial a_n} = 0 \\ \displaystyle\sum_{i=2}^{n} a_i = 1 \end{cases}$$

(3.20)

[7] A geometric mean is applied here because it fits data with wide fluctuation and two digits compared with arithmetic mean.

(3.20) is used to find the optimal portfolio bundle.

3.4.3.3 Institutional Investor Agent Reserved Farmland Buying Price Determination

Following Chapter 2 we can write,

$$\beta_{farmland} = \frac{Cov(R_f, R_{portfolio})}{Var\ (R_{portfolio})} \tag{3.21}$$

Where: $\beta_{farmland}$ is the Beta value for the whole portfolio,

$R_{portforlio}$ is the return of portfolio on CML and

R_f is the risk-free rate.

To determine the beta value exogenously for model simplicity, we assume that 1) the $\beta_{protforlio}$ is equal to the optimal investment portfolio beta value excluding farmland, and 2) that the return on farmland in (3.21) is the 30-year historical farmland return to calculate the covariance of farmland and portfolio, and the return on portfolio is the optimal portfolio of all simulated stock indices excluding farmland. Accordingly, investor agents calculate the bidding value of farmland based on their expected return imputed from its investment portfolio:

$$E(R_{FL}) = R_f + \beta_{farmland} * (R_{portfolio} - R_f) \tag{3.22}$$

Where $E(R_{FL})$ = the expected return of farmland and

R_f = risk-free rate.

The bid value is then based on the NPV of future earning ability using $E(R_{FL})$ as the discount rate:

$$PV_{farmland} = \sum_{t=1}^{n} \frac{CG_t + R_t - P_t - C_t - TC_t}{(1 + E(R_{FL}))^t} + \frac{P_n^f - (P_n^f - PV_{farmland}) * 0.5 * t_n}{(1 + E(R_{FL}))^n} \tag{3.23}$$

Where: CG_t is the capital gain in period t,

R_t is the rent in period t,

P_t is the property tax in period t,

C_t = economic cost in period t,

TC_t = transaction cost in period t,

P_n^f = future selling price and

t_n = future income tax rate.

(3.23) is equal to capitalization formula:

$$PV_{farmland} = \min\left(\frac{CG_0 + R_0 - P_0 - T_0}{E(R_{FL})}, \frac{\sum_{t=1}^{30} \frac{CG_t + R_t - P_t - T_t}{\left(1 + E(R_{FL})\right)^t} + P_{30}^f - 0.5 * P_{30}^f * t_{30}}{\left(1 + E(R_{FL})\right)^{30} - 0.5 * t_{30}}\right) \quad (3.24)$$

Where: CG_0 is the expected capital gain,

R_0 is the expected rent determined endogenously,

P_0 is the expected property tax,

T_0 is the expected transaction cost,

P_{30}^f is the expected selling price in the 30th year and

t_{30} is the expected income tax rate in the 30th year.

.

To avoid “winner’s curse” in land bids or another irrational bidding, an upper limit for land bid price is imposed on institutional investors, and the tender price is shown in (3.25):

$$Bidding\ Farmland_{\ t} = Min\left(\frac{CG_0 + R_0 - P_0 - T_0}{E(R_{FL})}, \frac{\sum_{t=1}^{30} \frac{CG_t + R_t - P_t - T_t}{\left(1 + E(R_{FL})\right)^t} + P_{30}^f - 0.5 * P_{30}^f * t_{30}}{\left(1 + E(R_{FL})\right)^{30} - 0.5 * t_{30}}, Uni(1.5,2) * Bidding\ Farmland_{\ t-1}\right)$$

(3.25)

Where:

$Bidding\ Farmland_{\ t}$ is the bidding price of farmland in period t,

$Uni(1.5,2)$ is a uniform distribution from 1.5 to 2 and

$Bidding\ Farmland_{\ t-1}$ is the bidding price of farmland in period t-1.

Farmer agents have a much more elaborate model of expected price formulation that includes some “memory” of past prices. While investors have a similar price expectation structure in land rent expectations, these are not in place for non-land returns. In contrast, institutional investors have no financial constraints. This situation creates the potential for institutional investor-driven farmland price market exuberance. Accordingly, we set upper bounds on farmland bid price changes from year to year. Historically (1971 to 2014), real annual farmland price changes never exceeded 150% of the price in last year. So, in order to provide somewhat more flexible upper bounds, we assume that the upper bound on year-to-year bid value increases ranges from a ratio of 1.5 to 2.0. Thus, our upper bid bound is stochastically set as a random number drawn from a uniform distribution between 1.5 and 2[8] (i.e. Uni (1.5,2)).

Each investor determines their bid price independently and they also compete against each

[8] Since we look at the length of 30 future years, we allow a big sample size to include all the possible scenarios along with the time paths.

other. However, with a sealed bidding process as assumed here, other agent bidding prices are unknown for each bidder.

3.4.4 Farmland Selling Minimum Acceptable Bid Formulation

When sellers enter a farmland market, they hold a reserve price based on a capitalized expected lease rate for both farmers and investors. Following Anderson (2012), the capitalized lease rate is calculated using the last updated lease rate and the expected change in the rental rate for the coming year based on price expectations for all commodities. Further, we assume that there is no transaction cost for the farmers on land purchases and the rental market, but following Schnitkey, Taylor, and Barry (1989), "5% charge of brokerage fee" (p.145) is placed on the value of reserved price as transaction costs. This equation is as follows,

$$E(Cap_{Lease}) = L_{r_{t-1}} + \sum_{i=1}^{2} \frac{\left(E(P_{t,i}\right)- E(P_{t-1,i}))}{E(P_{t-1,i})} * L_{r_{t-1}} \tag{3.26}$$

Where: $E(Cap_{Lease})$ is the expected capitalized lease rate,

L_{rt-1} is the rental rate from last year,

$E(P_{t,\ i})$ is the expected price of commodity I,

$E(P_{t-1,\ i})$ is the expected price of commodity I last year.

The minimum accepted price for the farmers then becomes:

$$Min_{accept} = \frac{Risk_{Owner} * Cap_{Lease} * (1 - Adm_{Fee})}{r} \tag{3.27}$$

Where: $Risk_{Owner}$ is the risk level of the current owner based on probability,

Cap_{Lease} is the adjusted lease of the capitalized lease rate,

Adm_{Fee} is the management fee for the auction process and

r is the discount rate.

Again, following Anderson (2012), we assume that 25% of farmer-owned land entering the purchase market has an amplified urgency to sell due to various reasons, including death, divorce or other circumstances. Thus the minimum acceptable selling price in these cases is reduced by 65%.

3.4.5 Minimum Rental Acceptable Bid Formulation

The land rental market also results from the strategic farm level MIP model. Lease bid value is income based and is calculated from the expected after-tax income less family living, divided by the total crop acres and then multiplied by a risk parameter,

$$Rent\ Bid_{income} = \frac{AI}{TCA}\ \alpha \tag{3.28}$$

Where: *AI* is the After-tax expected Income,

TCA is the total crop acres and

α is the risk parameter of the farmer.

As for investor landlords, we impose a fixed proportion of transaction cost for institutional investors, to capture the fact that they are not likely to have adequate rural land and farming experience. So, their reserve price will be:

$$Min_{accept} = \frac{Cap_{Lease} * (1 - Adm_{Fee})}{E(R_{FL})} * (1 + tc\%) \tag{3.29}$$

Where: Cap_{Lease} is the adjusted lease of the capitalized lease rate,

Adm_{Fee} is the management fee for the auction process,

$E(R_{FL})$ is the expected return of farmland based on historical return and

tc% is the transaction cost rate.

3.4.6 Lease Renegotiation

At the beginning of every year, a random choice is generated for lease renegotiation for both farm-owned and investor-owned farmland. This is calculated as,

$$Renegotiation_{prob} > Pre_{prob} \tag{3.30}$$

Where: $Renegotiation_{prob}$ is a randomly generated probability and

Pre_{Prob} is a pre-determined probability for lease renegotiation.

If the random number generated is greater than the pre-set lease renewal probability, the leased will be renewed for next period. Otherwise, the lease will remain so for the next year. But lease values will be automatically re-adjusted to the prevailing market lease rate if they have either increased or decreased by 20% in any given time interval.

3.4.7 The Auctioneer Agent

Following Anderson (2012), all farmers and investors must submit their bids to the auctioneer agent. The bidding process is sealed and thus bidders are ignorant of others' bid prices. The auctioneer agent sorts all farmland for sale according to its inherent productivity rating, and either the cropland or marginal land market. Likewise, the land lease market follows the same process. However, unlike the purchase market, the land rental market has no reservation price. Moreover, if there is no bid to lease a plot of farmland in a given year, the auctioneer asserts that the plot of farmland remains idle until next year's auction.

3.5 Taxation Treatments for Farmland Transfer

According to the Section 85 of the Canadian Income Tax Act (ITA), "the capital cost to the transferee of the property is deemed to be the amount that was its capital cost to the transferor, and the excess is considered to have been deducted by the transfer". This is known as the "rollover": retired farmers can transfer farm assets to their children and enjoy tax deferral from generation to generation by selling, gifting or inheritance. Eventually, when a successor sells farmland (from April 20, 2015 onwards) the exemption limit for lifetime capital gains for farm assets including farmland is $1,000,000 dollars.

The exemption will likely exempt the income tax from capital gain from all farmland sales by farmers. However, under Canadian law investors still have to pay 50% of the capital gains from farmland sales to taxable income for the current year, and the tax rate is 11% for the first $44,601 dollars, 13% of next $82,829 dollars and 15% for the reminder. This will need to be considered in investor bidding prices for farmland. As a result, investors will subtract projected tax payments when calculating their expected capital gain.

Moreover, buyers of farmland, both farmers and investors, have no obligation for the goods and service tax (GST) (this tax rate in Saskatchewan is 5%) because the land remains in agricultural production.

CHAPTER IV: THE DATA

4.0 Introduction

In this chapter, we present the physical and financial characteristics of farms located in CAR 1 in Saskatchewan. This region has a relatively heterogeneous landscape that varies from relatively flat, highly productive cropland to unimproved pasture. The former allows pure crop farms while the latter is associated with beef or dairy herds (Anderson, 2012) and is a good test of my model.

There are four general types of data reviewed in this chapter: 1) those data associated with the landscape, 2) those data associated with the farmer agent characteristics, 3) non-stochastic data associated with the individual farm businesses and their associated decision making and 4) stochastic farm commodity yields and prices and the various stock market indices returns.

The first three data sets are mostly based on Anderson (2012) updated for price changes and inflation to 2015. However, estimates of potential heir off-farm opportunity costs are required by a much more developed model of farm business succession. In the model, the wage for off-farm employment, as the opportunity costs for farming, is based on real-world statistics in Table 4.5 and Table 4.6 in Section 4.2.2. The fourth data type, stochastic data are associated with the various possible future time paths. A new method used to generate a total of 100 different 30 -year future time paths crop yields, crop prices and financial indices is reviewed and verified against historical data.

4.1 The Regional Landscape

The landscape of the research area, CAR 1A, is a portion of the Assiniboine River Basin of Saskatchewan, located in the southeast corner of the province (Figure 4.1). According to the 2011 Census of Agriculture[9], there are 2,679,151 acres of arable land in CAR 1A. Detailed land use is represented in Table 4.1. In the CAR 1A area, about 60% is farmland used for crop production and about 20% of the land is used for pasture or hay production.

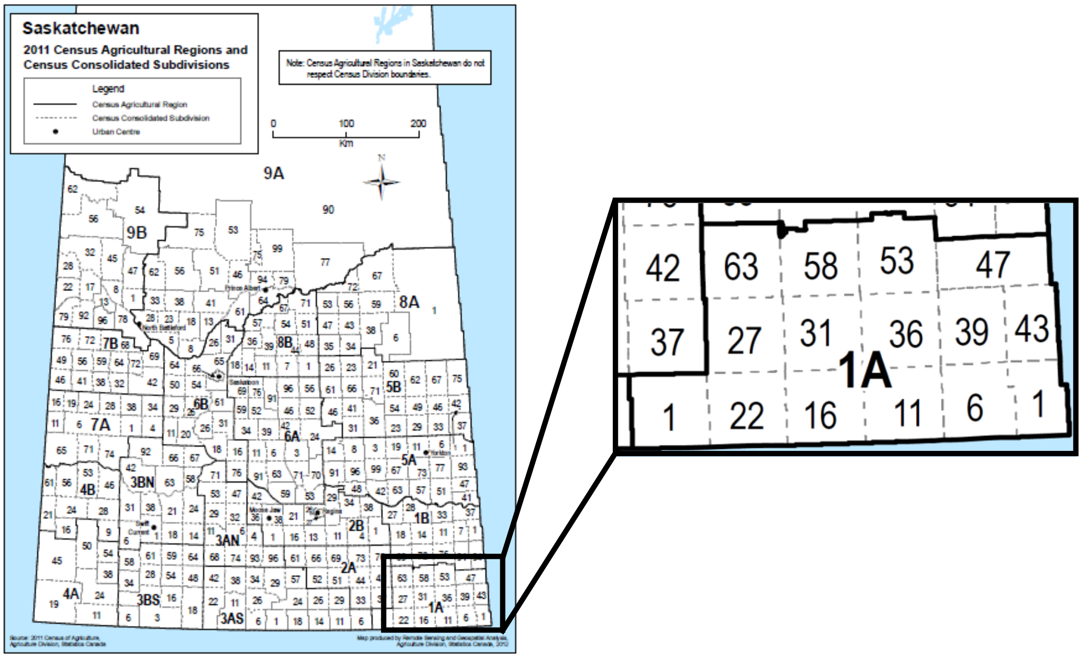

Figure 4.1 Census Agriculture Region (CAR) and CAR 1A

(Source: 2011 Census, Statistics Canada)

Table 4.1: Land Use in CAR 1A

Land Type	Area (1,000 Acres)	Proportion (%)
Cropland	1,447	54.0%
Summerfallow Land	157	5.85%
Tame or Seeded Pasture	245	9.15%
Nature Land of Pasture	350	13.1%
Wooldlands and Wetlands	133	4.97%
Other	347	13.0%

(Source: 2011 Agricultural Census, Statistics Canada)

[9] The 2011 National Agriculture Census result was the latest available data when conducting the study during 2014 to 2016.

4.1.1 Study Landscape

Following Anderson (2012), there is a total of 1099 plots of land in the simulation (1 plot = 640 acres) varying in potential land use, productivity and location.

4.2 Farm and Farm Operator Characteristics

4.2.1 An Overview of CAR 1A Farms

By the 2011 Census, there is a total of 1,501 farms with 2,040 operators in the region, 17.7% fewer than existed in 2006. The major types of grain grown are wheat, canola, flax, barley, durum, pea, lentils and hay. The main types of livestock are beef cows and calves (Table 4.3).

Table 4.2: Production in CAR 1A

Crop Type	Number of Farm	Areas (1,000 Acres)
Hay	885	23.4
Wheat	811	40.7
Canola	604	39.4
Flaxseed	311	9.17
Barley	269	7.00
Pea	115	4.70
Durum	107	8.66
Lentils	61	2.57
Others	559	7.95
Livestock Type	**Number of Farm**	**Heads (1,000 Head)**
Beef Cow	614	51.5
Calves	622	40.2
Sheep and Lamb	34	2.36
Pig	9	0.31
Horse	317	4.27
Others	52	1.21

* The number does not include broilers, dairy cattle or turkeys.

(Source: 2011 Census, Statistics Canada)

Farm characteristics and operator age distribution in the CAR are reported in Table 4.4 and 4.5, respectively.

Table 4.3: Characteristics of Farms in CAR 1A

Farm Size	Number of Farm		Total Farm Capital	Number of Farm		Total Farm Receipt	Number of Farm
<240 Acres	209		<$350,000	281		<$25,000	319
240-760 Acres	366		$350,000-$1,000,000	564		$25,000-$100,000	433
760-2280 Acres	669		$1,000,000-$2,000,000	355		$100,000-$500,000	525
>2280 Acres	257		>$2,000,000	301		>$500,000	224

(Source: 2011 Census, Statistics Canada)

Table 4.4: Characteristics of Farmers in CAR 1A

Farm Age	Number of Farm
<35	205
35-54	845
>55	990
Average Age	53.6
Farm Gender	Number of Farm
Male	1,595
Female	450

(Source: 2011 Census, Statistics Canada)

From Table 4.4 and 4.5, most of the farms in CAR 1A are mid-sized (240 – 2280 acres), and about 50% of the farmers are 55 or older.

4.2.2 Off-farm Income and Education

The education level of the relevant Saskatchewan population is shown in Table 4.6 for 2006.

Table 4.5: Education Level Distribution in Saskatchewan in 2006

Education Level	Percentage
<High School	30.2%
High School	26.8%
Trades Certificate	11.3%
College	14.6%
University Degree <Bachlor	4.20%
Bachelor	9.30%
>Bachlor	3.59%

(Source: CANSIM Table 109-0300)

The inflation-adjusted expected annual income based on their gender, age and education are presented in Table 4.7 for the entire Canadian population.

Table 4.6: Inflation Adjusted Real Annual Income in Canada (2006)

	Age	<Secondary	Secondary	Trades	College	<Bachlor	Bachelor	>Bachlor
Male	25-34	$36,280	$38,605	$45,744	$46,339	$47,409	$54,434	$56,478
	35-44	$39,340	$45,791	$52,383	$57,040	$56,376	$71,849	$79,040
	45-54	$39,665	$47,310	$54,136	$60,170	$63,530	$76,943	$89,498
	55-64	$30,488	$38,693	$45,517	$49,001	$52,922	$72,127	$88,750
Female	25-34	$21,685	$26,576	$27,871	$34,477	$38,992	$51,046	$56,033
	35-44	$25,413	$32,362	$32,850	$39,641	$52,877	$62,367	$69,599
	45-54	$28,401	$35,428	$34,750	$42,761	$52,179	$69,494	$73,985
	55-64	$26,486	$32,264	$30,742	$40,466	$46,029	$63,160	$74,311

(Source: Statistics Canada, http://www12.statcan.ca/census-recensement/2006/dp-pd/hlt/97-563/T803-eng.cfm?Lang=E&T=803&GH=4&SC=1&SO=99&O=A)

4.2.3 Synthetic Farm Population

The model landscape is fixed over the entire period of study but our (synthetic) farm population characteristics are fixed only upon model initialization. The simulated populations vary subsequently as it ages, as farmers exit or enter and as farms grow or disappear from farming. Farmer agents vary in farm size, age, and financial situation, risk preferences and in preference/aversion for/to cattle. Following Anderson (2012), our synthetic farmer population characteristics are based on CAR 1A using 2011 Census data (*Statistics Canada* 2011). Important farmer agent characteristics include farmer age, farm size, off-farm income, and debts and assets. The initial synthetic farm agent population is set at exactly 717 farmers.

As in Anderson (2012) and Stolniuk (2008), farm assets include cash, farmland, cropping and beef handling systems, as well as machinery and beef cow herd. Initial beef cow systems and cropping machinery levels are based on the farm size. The synthetic farm population is updated for changes in farm assets to the year 2015 and since the debt-asset ratio is assumed to be constant, farm debt must also be updated. The initial farm debt to asset ratio is randomly assigned as a per acre value of the various farms. A total of 159 (22%) farms has no debt at the beginning of the simulation, while the average debt per acre is set at $78.79[10].

Off-farm income is assigned randomly to farm agents based on farm size: smaller farms have higher off-farm income and *vice versa* following Anderson (2012) in Table 4.9. The initial ages of farmers, farm assets, farm debt and farming acreage are shown in Tables 4.13 to 4.16.

We assume that farmer heirs can obtain off-farm employment anywhere. Accordingly, a stochastic education level is used to generate potential off-farm income for farm heirs, according to Table 4.7. This subsequently sets their off-farm opportunity cost and affects their willingness to succeed, found in equations (3.10) and (3.11) in the previous chapter.

The plot assignments to individual farmer agents are also retained from the work of Anderson (2012). From Tables 4.14 and 4.16, larger farms possess higher asset values, and

[10] The original debt level and distribution is based on an individual farm survey following Anderson (2012). Since there is no farm-level data in CAR 1A region, in this study, the average debt per acre is adjusted by inflation, but the debt distribution and levels of Anderson (2012) are used in this study.

farmers with higher asset value and larger farming acreage tend to have higher debt. Finally, farm age allocation can be found in Table 4.7.

Table 4.7: Initial Age of Farmers by Farm Acreage

Farmed Acres (1,000 Acres)	Farmer Age							
	20-30	30-40	40-50	50-60	60-70	>70	Total	Percentage
<1	23	43	77	76	41	24	284	39.6%
1-2	14	38	76	82	38	27	275	38.4%
2-3	2	12	33	27	10	3	87	12.1%
3-5	0	10	17	15	10	4	56	7.81%
>5	1	4	4	4	2	0	15	2.09%
Total	40	107	207	204	101	58	717	100%
Percentage	5.58%	14.9%	28.9%	28.5%	14.1%	8.09%		

Table 4.8: Initial Farm Assets by Farm Acreage

Asset Value ($100,000)	Farmed Acres (1,000 Acres)						
Grade	>1	1-2	2-3	3-5	>5	Total	Percentage
0-5	97	1	0	0	0	98	13.7%
5-10	108	63	1	0	0	172	24.0%
10-20	76	101	21	1	0	199	27.8%
20-30	3	83	24	5	0	115	16.0%
30-40	0	10	14	23	0	47	6.56%
40-50	0	17	2	2	0	21	2.93%
50-100	0	0	25	19	3	47	6.56%
100-200	0	0	0	6	6	12	1.67%
200-300	0	0	0	0	3	3	0.42%
>300	0	0	0	0	3	3	0.42%
Total	284	275	87	56	15	717	100%
Persantage	39.6%	38.4%	12.1%	7.8%	2.1%		

Table 4.9: Initial Off-farm Income by Farm Acreage

Off-farm Income ($1,000)	Farmed Acres (1,000 Acres)						
	>1	1-2	2-3	3-5	>5	Total	Percentage
0	90	92	22	14	6	224	31.2%
0-5	18	25	5	10	3	61	8.51%
5-10	11	23	11	3	0	48	6.69%
10-20	23	19	8	3	0	53	7.39%
20-40	46	29	16	8	2	101	14.1%
40-60	51	42	12	6	0	111	15.5%
60-100	28	23	9	8	3	71	9.90%
>100	17	22	4	4	1	48	6.69%
Total	284	275	87	56	15	717	100%
Persantage	39.6%	38.4%	12.1%	7.81%	2.09%		

Table 4.10: Initial Farm Debt by Asset

Debt Value ($1,000)	Asset Value ($100,000)											
	0-5	5-10	10-20	20-30	30-40	40-50	50-100	100-200	200-300	>300	Total	Percentage
0	10	35	37	27	11	3	3	1	0	1	128	17.9%
0-5	33	18	2	0	0	0	0	0	0	0	53	7.39%
5-10	22	23	18	6	2	0	0	0	0	0	71	9.90%
10-15	11	25	9	1	3	0	0	0	0	0	49	6.83%
15-20	14	11	17	4	1	0	4	0	0	0	51	7.11%
20-25	2	18	10	3	2	1	2	0	0	0	38	5.30%
25-30	2	21	22	8	2	0	3	0	0	0	58	8.09%
30-50	4	14	33	16	1	2	1	1	0	0	72	10.0%
50-100	0	7	35	36	12	6	8	1	0	0	105	14.6%
100-300	0	0	16	14	12	8	20	3	1	1	75	10.5%
300-500	0	0	0	0	1	1	6	5	0	0	13	1.81%
>500	0	0	0	0	0	0	0	1	2	1	4	0.56%
Total	98	172	199	115	47	21	47	12	3	3	717	100%
Percentage	13.7%	24.0%	27.8%	16.0%	6.56%	2.93%	6.56%	1.67%	0.42%	0.42%		

4.3. Non-stochastic Farm Business Variables: Farm Enterprise Costs, and Resource Requirements

Farm enterprise costs and resource requirements are based on Anderson (2012), but updated for price changes, yet they are assumed to remain constant over the simulation period. Initial beef cow numbers are set according to the farmer agent and associated forage acres. The initial herd forage handling system and crop machinery package owned are based on farm size and are set in the initialization phase. However, these factors may change with changes in farm size. Here, we assume ten different farming machinery packages according to farm size, and that farmer agents select the least-cost machinery package as they change farm size.[11] The exact purchasing cost and variable costs for the machinery packages can be found in Appendix D.

4.4. Stochastic Variables: Future Time Paths

The *DualInvestment* model tracks farmer agents and investors for a total of 100 simulated time paths over 30 years. Each time path corresponds to one iteration of the simulation and these are held constant over all scenarios. The key to estimating the future variable time paths are 1) autocorrelation between years, and 2) correlations between stochastic variables. The following sections describe the procedure used to generate the time paths for 1) financial markets and 2) farm commodity prices and yields.

The historically low correlation between stock market yields and Saskatchewan farm commodity prices and yields (<20% in general) means that the time paths of stock market yields and farm commodity prices and yields are generated independently.

[11] Farm size is a long-run strategic decision and is an important management variable in the integer programming model. Each machinery package has an associated investment requirement, annual cost and a maximum acreage constraint. There are no lower bounds, however. Hence, a change in size may require an accompanying shift to a different least-cost machinery package.

The general procedure used to estimate time paths is described in the following sections. The simulated time paths are presented followed by a comparison of the simulated data to historical data. It is important to verify our various time paths. While there is no way to check all the possible future paths used here, simulated time paths can be compared to historical data in a very general way. This is an important part of model verification, a process that helps determine whether the simulation has been correctly programmed and that the data have been entered correctly (Xiang, Kennedy and Madey, 2005). Here, much of this basic ABSM has already been verified by Anderson (2012). However, the various time paths are unique to this thesis and should also be verified. Important considerations in time path verification include 1) comparisons of simulated to historical data based on means and correlations, and 2) degree of coverage of the variable sample space.

4.4.1 Simulated Future Financial Market Yields

Ten different stock indices from the U.S., Canada, Australia, Germany, France, UK, Spain, Japan and Hong Kong are considered in our financial portion of the simulation. These markets were chosen because all of them are informationally transparent, with limited political interference and they also contain sufficient historical data to generate reasonable asset returns and correlations. On that note, the relevant risk-free asset considered here is the 3-month bond issued by the Bank of Canada.

Table 4.11: Historical (1970-2014) Correlation and Variance

Country	US	Hong Kong	Japan	UK	Germany	France	Spain	Canada	Australia	3MBOBC
US	100%	39.2%	36.5%	59.1%	55.8%	57.6%	47.2%	74.1%	56.1%	10.5%
Hong Kong	39.2%	100%	33.7%	42.4%	36.6%	35.2%	33.9%	42.5%	43.0%	-1.43%
Japan	36.5%	33.7%	100%	41.4%	40.8%	43.7%	42.2%	37.4%	37.2%	4.54%
UK	59.1%	42.4%	41.4%	100%	54.3%	63.1%	48.0%	57.9%	55.0%	7.00%
Germany	55.8%	36.6%	40.8%	54.3%	100%	73.2%	58.5%	49.6%	45.6%	3.60%
France	57.6%	35.2%	43.7%	63.1%	73.2%	100%	59.4%	55.2%	49.7%	5.43%
Spain	47.2%	33.9%	42.2%	48.0%	58.5%	59.4%	100%	45.6%	46.6%	4.25%
Canada	74.1%	42.5%	37.4%	57.9%	49.6%	55.2%	45.6%	100%	65.4%	0.38%
Australia	56.1%	43.0%	37.2%	55.0%	45.6%	49.7%	46.6%	65.4%	100%	4.23%
3MBOBC	10.5%	-1.43%	4.54%	7.00%	3.60%	5.43%	4.25%	0.38%	4.23%	100.0%
S.D.	0.04	0.10	0.06	0.06	0.06	0.07	0.07	0.06	0.07	0.00

Note: 3MBOCB stands for three-month bond issued by Bank of Canada.

Asset correlations between different indices are presented in Table 4.11. The various indices are correlated between themselves with values that range between 35% and 75%, indicating potential for diversification. In addition, the various indices chosen have sufficiently low correlations with the risk-free rate that independence can be assumed.

In generating simulated historical relationships between the indices, the U.S. stock index is assumed to move freely and the remaining relationships are based on their correlation with the U.S. stock index. For example, Canadian stock indices have the highest correlation with the U.S. stock index and accordingly, this historical relationship is a simple linear function of the U.S. index, plus a random error. The UK stock index has the second largest correlation with U.S - its relationship is generated using a linear function of both U.S. and Canadian indices plus an error term, and so on. All parameters here are estimated using OLS regressions. In setting the various time paths for these variables, the real return of the U.S. stock index NASDAQ is calculated as:

$$NASDAQ_t = NASDAQ_{t-1} + Diff_{historicial\ i} \tag{4.1}$$

Where: $NASDAQ_t$ is the simulated real return in the future time t,

$NASDAQ_{t-1}$ is the simulated real return in the future time t-1 and

$Diff_{historicial\ i}$ is the difference of historical real returns in a randomly generated period.

But in applying this method, we found that the generated variance is excessive as compared with actual data. This problem is very typical for resampling processes (Breiman, 1996). Subsequently following Parmanto, Munro and Doyle (1996), we know that the average of a set of resampled data will decrease the variance without adding more bias. So, an average of five simulated paths was used to generate a similar variance pattern to the historical data. The following equations are used to generate our other indices:

$$Index_{i,t} = \alpha_i + \sum_{j=1}^{n} \beta_j * Index_{j,t} + \mu_{i,t} \tag{4.2}$$

$$\mu_{i,t} \sim Normal(0, \sigma_{i,t}) \tag{4.3}$$

$$\sigma_{i,t}^2 = GARCH(1,1) = \gamma_i + \theta_1 * \sigma_{i,t-1}^2 + \theta_2 * Index_{i,t}^2 \tag{4.4}$$

Where: $Index_{i,t}$ is the real return for index i in time t,

$Index_{j,t}$ is the real return for index j in time t,

$\mu_{i,t}$ is the simulated error,

$\sigma_{i,t}^2$ is the variance of the simulated error for index i in time t,

$\sigma_{i,t-1}^2$ is the variance of the simulated error for index i in time t-1,

α_i and β_j are the parameters from an OLS regression on other indices and

γ_i, θ_1 and θ_2 are the parameters from a GARCH (1,1) process for variance simulation.

Following Bauwens et al. (2006), GARCH model can be applied in the studies of "the relations between the volatilities and co-volatilities of several markets" (p.79). In this study, the GARCH (1,1) model is used to estimate the variance of the residues and take into account the correlation between the different stock markets.

4.4.1.1 Verification of the Simulated Stock Return Time Paths

Four of the 100 simulated time paths for four chosen stock indices are displayed in Figures 4.2-4.4 as examples of simulated stock returns. While individual variable movements are somewhat difficult to discern in these graphs, the overall patterns highlight the following: 1) variable ranges fall within expectations, based on historical ranges, and 2) the full range of values is in fact sampled over all simulated years. As the base index, we note that the time paths for NASDAQ are most stable with the least "vibration." Alternatively, following historical data, the Hang Seng Index generates the greatest oscillations with the highest variance (Figure 4.4)

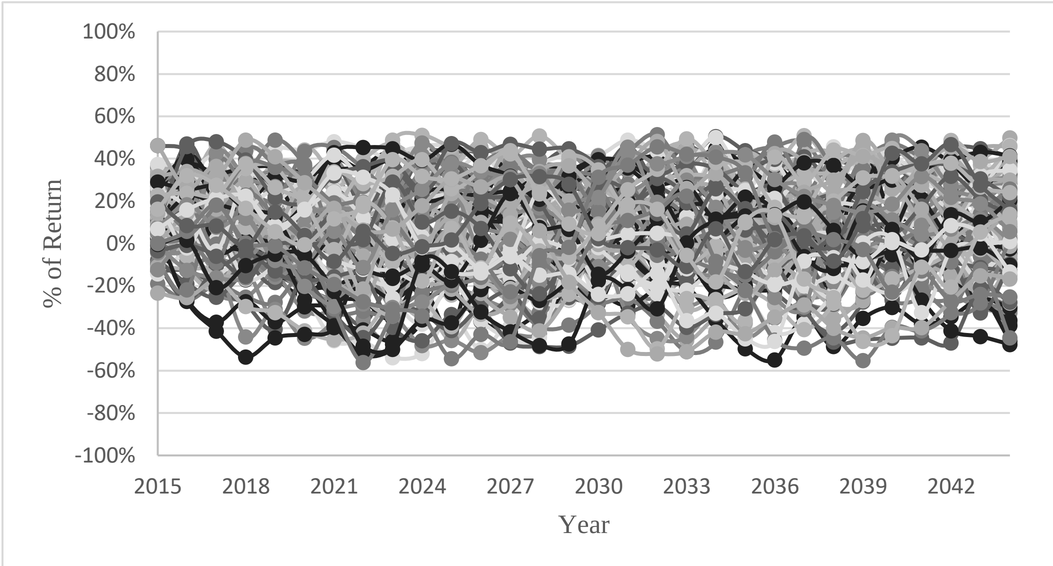

Figure 4.2: Simulated Time Paths of NASDAQ Stock Index Returns

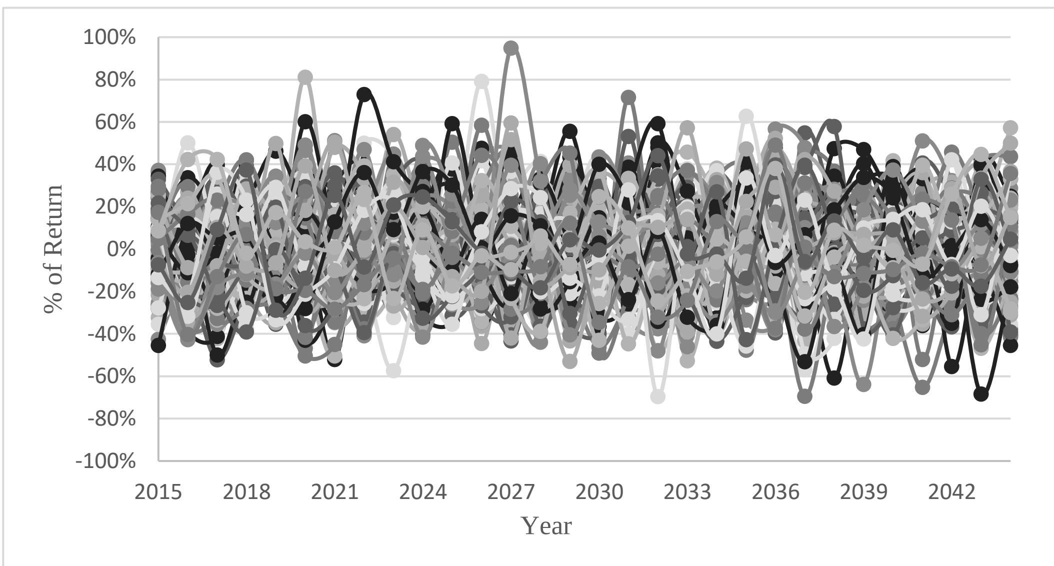

Figure 4.3 Simulated Time Paths, Spanish Stock Index Returns

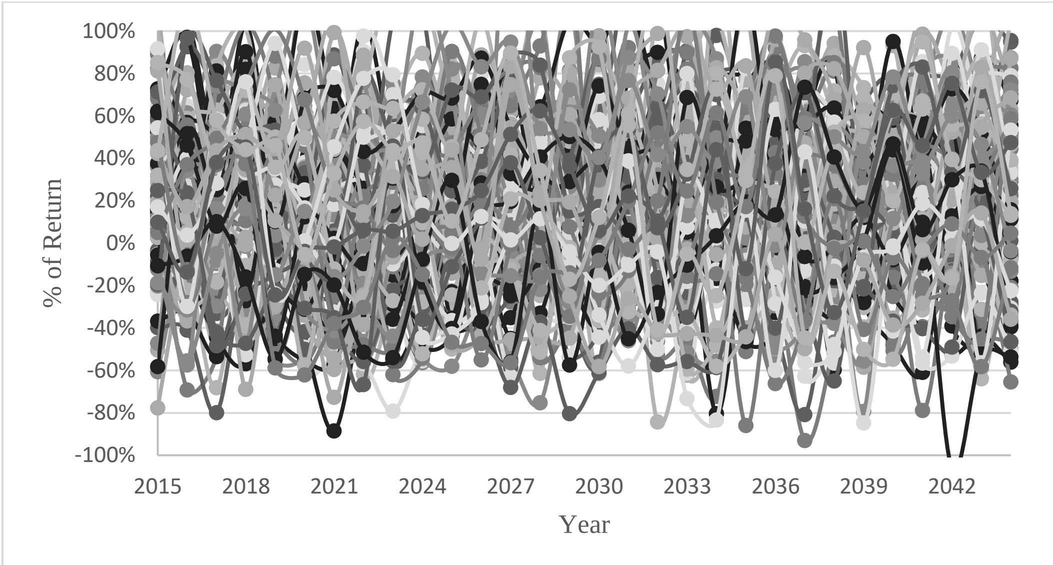

Figure 4.4: Simulated Time Paths, Hong Kong Stock Index Returns

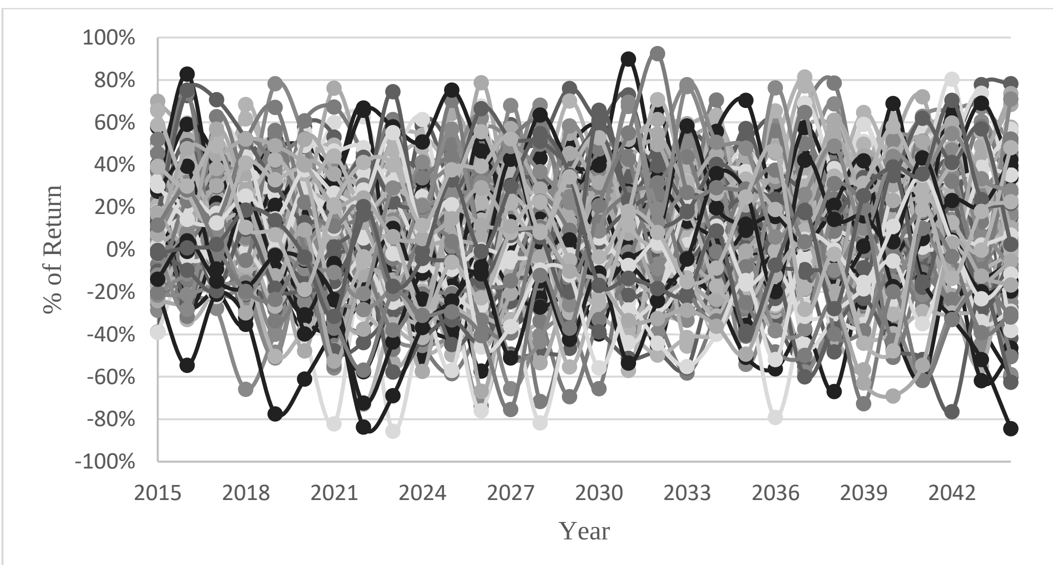

Figure 4.5: Simulated Time Paths, UK Stock Index Returns

The simulated and historical stock index yield means and the standard deviations (SD) are compared in Table 4.9, while their correlations are compared in Table 4.10. The stock return time paths reported in Table 4.9 is the average of our 100 simulated time paths.

Table 4.12: Comparison of Simulated and Historical (1970-2014) Stock Indices

	Country	US	Hong Kong	Japan	UK	Germany
Mean	Simulated	0.06	0.18	0.08	0.08	0.08
	Historical	0.06	0.18	0.08	0.08	0.08
	Difference	3.63%	1.52%	2.38%	0.60%	1.83%
S.D.	Simulated	0.20	0.43	0.31	0.26	0.29
	Historical	0.18	0.43	0.31	0.25	0.29
	Difference	-10.80%	-1.44%	-0.57%	-2.39%	-2.24%
	Country	France	Spain	Canada	Australia	3MBOCB
Mean	Simulated	0.08	0.08	0.07	0.07	0.03
	Historical	0.08	0.08	0.07	0.07	0.03
	Difference	1.99%	0.95%	-0.90%	-0.23%	-1.81%
S.D.	Simulated	0.28	0.31	0.21	0.26	0.03
	Historical	0.27	0.3	0.21	0.26	0.03
	Difference	-4.70%	-2.58%	-1.31%	-0.79%	-8.53%

Table 4.13: Comparison of Simulated and Historical (1970-2014) Stock Index Correlations

Country	US	Hong Kong	Japan	UK	Germany	France	Spain	Canada	Australia
US									
Hong Kong	1.46%								
Japan	5.72%	1.1%							
UK	2.77%	0.75%	3.18%						
Germany	-2.33%	-22.5%	-13.6%	-3.36%					
France	7.96%	39.5%	27.1%	11.2%	2.22%				
Spain	9.05%	7.82%	2.36%	10.4%	-15.9%	26.9%			
Canada	8.83%	-5.25%	-2.26%	-3.24%	-16.3%	20.0%	7.38%		
Australia	7.75%	-3.36%	-2.73%	-0.08%	-23.0%	39.2%	6.26%	-3.17%	

Following the assumptions laid out in Chapter 2, after retrieving a time path stock return, investors then calculate their optimal portfolio composition. In the simulation, a VBA program is used to solve the quadratic optimization problem, within Microsoft Excel© Solver©. After the optimal financial portfolio is identified by assuming that the covariance between farmland yields and their optimal portfolio remains fixed, investors then derive their Sharpe Ratio (eq. 3.19). The optimal portfolio bundles are calculated externally for model simplicity. Then, the beta value, expected returns of the optimal portfolios and farmland are calculated following eq. 3.22. The expected returns of farmland in the optimal portfolios are considered as model inputs. In the model simulation, these inputs are subsequently used in conjunction with the endogenously derived crop rents from the farmland rental markets to set their farmland bid prices following eq. 3.25. The bidding prices of the institutional investors are generated within the simulation.

Historically, the Hong Kong Stock index tends to have a significantly higher mean return and variation, while the market indices in the US and Australia have comparatively lower return and risk. In addition, stocks in North America and Europe tend to have a stronger correlation with each other than with Asian stocks. Moreover, the indices for stocks of geographically proximate countries, such as France, Germany or Spain, are typically also more closely related. Here, the average difference between the simulated and historical mean index is less than 5%, while the difference of the S.D. is within 10%. The relative differences between our simulated and historical stock return correlations are generally within 25%.

4.4.2 Simulated Future Commodity Prices and Yields

Following Anderson (2012), stochastic farm variables used here include de-trended prices and yields for eight outputs. These are canola, wheat, durum, barley, flax, pea, lentil and hay and the price of calves. Graphs of farm yields and prices are displayed in Figures 4.6 and 4.7 respectively.

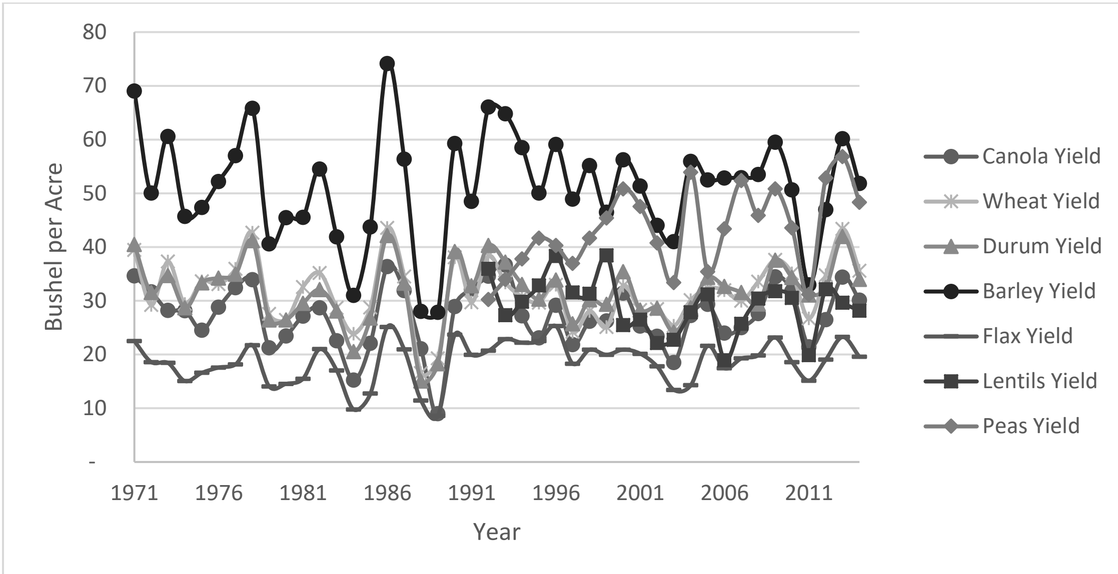

Figure 4.6: Detrended CAR 1 yields, 1971 to 2014 (Source: Statistics Canada)

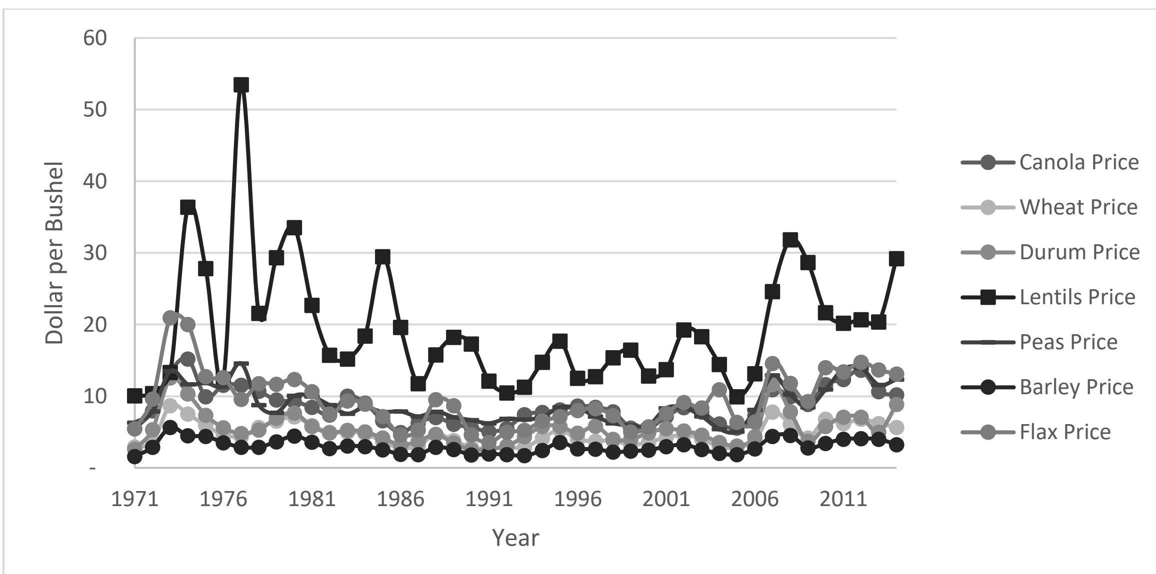

Figure 4.7 De-trended farm commodity prices, 1971 to 2014 (Source: Statistics Canada)

A similar process is used in estimating various future commodity yield and price time paths. Strong autocorrelation exists with canola prices. The adjusted R^2 for an AR (1) estimate of the canola price is 50%, and the lagged price is significant at the 1% level. Canola prices and yields have the highest correlations with other commodities, so canola was used as the base commodity for generating various output time paths, through repeated resampling.

$$Canola\ Price_t = \ Canola\ Price_{t-1} + Diff\ Price_i + Error_t \tag{4.5}$$

$$Canola\ Yield_t = \ Canola\ Yield_{t-1} + Diff\ Yield_i + Error_t \tag{4.6}$$

Where:

$Canola\ Price_t$ is the simulated canola price in the period t,

$Canola\ Price_{t-1}$ is the simulated canola price in the period t-1,

$Carnola\ Yield_t$ is the simulated canola yield in the period t,

$Canola\ Yield_{t-1}$ is the simulated canola yield in the period t-1,

$Diff\ Price_i$ is the historical price difference in historical period i,

$Diff\ Yield_i$ is the historical yield difference in historical period I and

$Error_t$ is a stochastic error term from period t.

Other yields and prices are generated based on eq. 4.7 and 4.8. Namely, the simulated price and yield of wheat that have the strongest correlation with canola are generated by a univariate equation of canola plus an error term, and the parameters are from the univariate OLS regression. Moreover, the simulated price and yield of the crop that have the second strongest correlation with canola are generated by a bivariate equation of canola and wheat plus an error term, and the parameters are from the bivariate OLS regression *et cetera*. The method is to keep the mean, variance and the correlation being similar to the historical values. In addition, there is no strong historical correlation between calf price and the other commodities, so it must be estimated separately.

Likewise, future prices and yields for other crops are generated through the use of GARCH (1,0) processes, since the lag of returns squared is not statically significant in all cases:

$$Price_{i,t} = \alpha_i + \sum_{j=1}^{n} \beta_j * Price_{j,t} + \mu_{i,t}$$

(4.7)

$$Yield_{i,t} = \rho_i + \sum_{j=1}^{n} \tau_j * Yield_{j,t} + \mu_{i,t}$$

(4.8)

Where:

$$\mu_{i,t} \sim N(0, \sigma_{i,t}^2)$$

(4.9)

$$\sigma_{i,t}^2 = GARCH(1,0) = \gamma_i + \theta_i * \sigma_{i,t-1}^2$$

(4.10)

Where:

$Price_{i,t}$ is the price for grain i in the period t,

$Price_{j,t}$ is the price for grain j in the period t,

$Yield_{i,t}$ is the yield for grain i in the period t,

$Yield_{i,t}$ is the yield for grain j in the period t,

$\mu_{i,t}$ is the error term for grain i in the period t,

$\sigma_{i,t}^2$ is the variance of error term for the grain i until the period t-1,

$\sigma_{i,t}^2$ is the variance of error term for the grain i until the period t-1 and

$\alpha_i, \beta_i, \rho_i, \tau_i, \gamma_i, \theta_i$ are the parameters estimated using OLS.

4.4.2.1 Verification of Commodity Price and Yield Time Paths

In lieu of cumbersome formal testing, by examining figures 4.8 to 4.11, it appears that the 100 iterations of the simulation span these parameter spaces sufficiently to mimic reality.

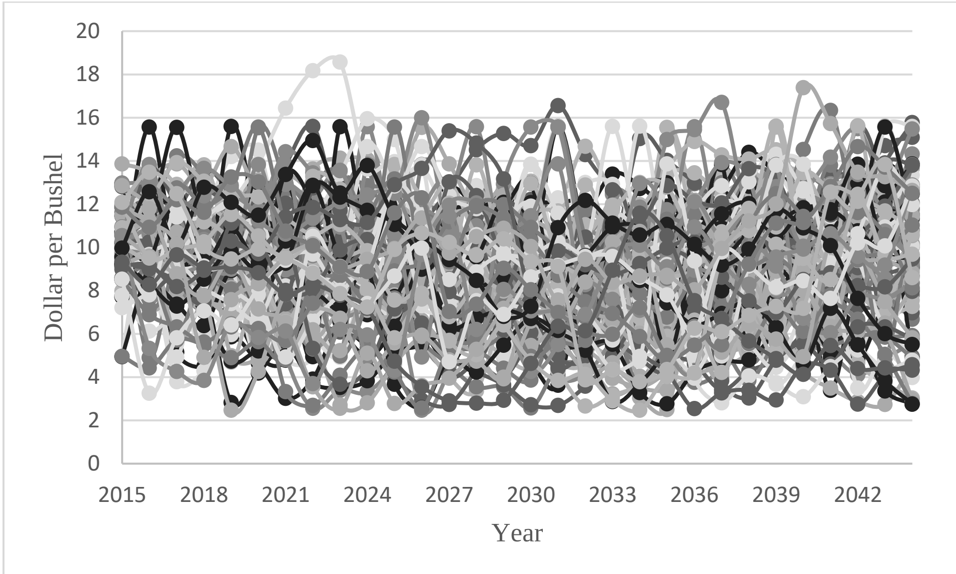

Figure 4.8: Simulated Canola Yield Time Paths

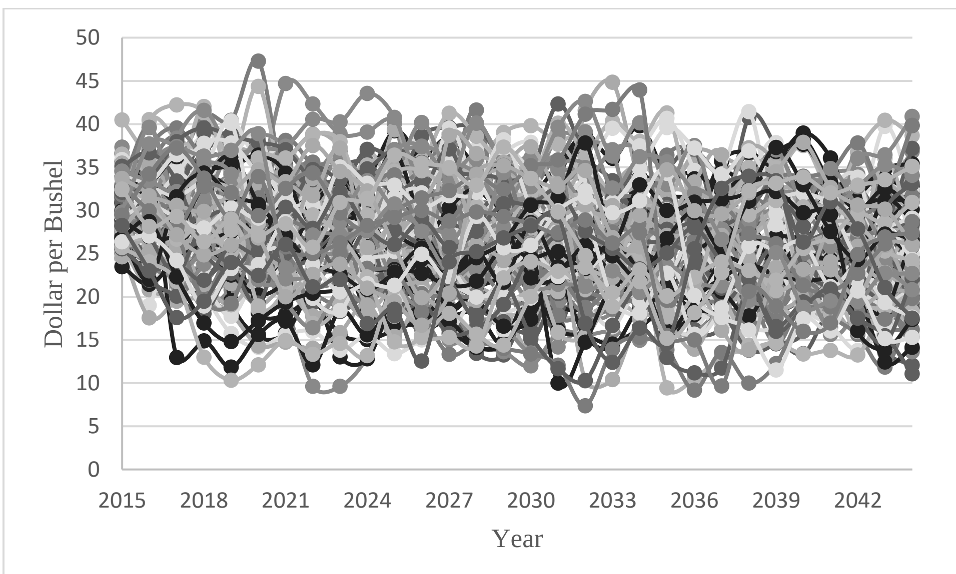

Figure 4.9: Simulated Canola Price Time Paths

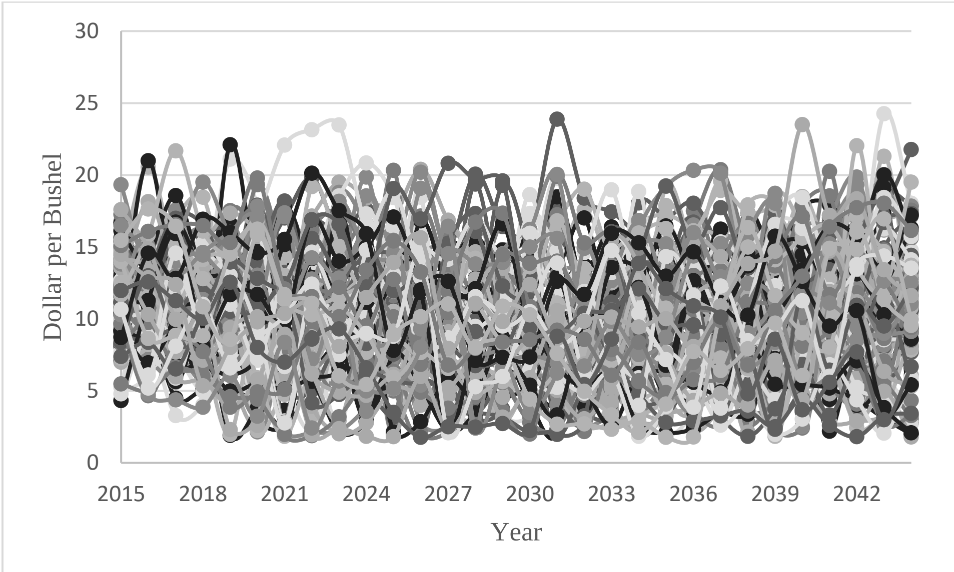

Figure 4.10: Simulated Flax Price Time Paths

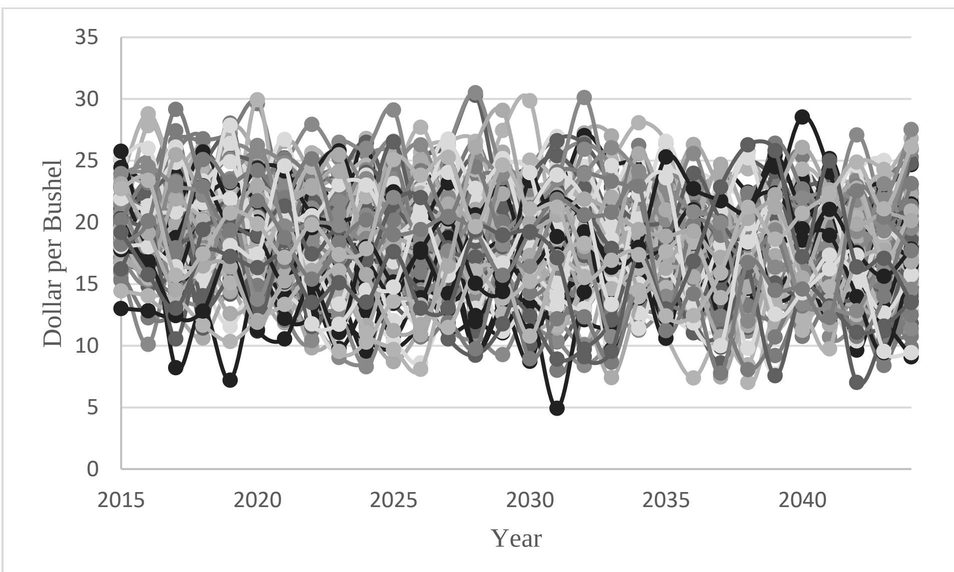

Figure 4.11: Simulated Flax Yield Time Paths

The simulated future farm data and the historical data are shown for comparison in Tables 4.14 and 4.15. We note that the simulated means and standard deviations generally fall with 10% or less of their corresponding historical values.

Table 4.14: Comparison of Simulated and Historical Yields

Yield		Canola	Wheat	Durum	Flaxseed	Lentils	Peas	Barley	Hay
Mean	Simulated	26.7	31.2	31.2	18.4	29.7	42.3	50.7	1.78
	Historical	27.2	31.6	31.7	18.6	29.1	43.2	51.2	1.77
	Difference	-1.86%	-1.41%	-1.47%	-1.42%	2.17%	-2.15%	-1.17%	0.63%
S.D.	Simulated	5.64	5.37	5.38	3.68	5.06	7.9	9.43	0.60
	Historical	5.71	5.77	5.83	3.93	5.15	7.67	10.2	0.64
	Difference	-1.19%	-6.87%	-8.16%	-6.38%	-1.68%	3.03%	-7.07%	-5.55%

Table 4.15: Comparison of Simulated and Historical Farm Commodity Prices

Price		Canola	Wheat	Durum	Flaxseed	Lentils	Peas	Barley	Hay	Calf
Mean	Simulated	9.14	4.71	5.52	21.1	19.6	8.75	10.3	67.7	1.53
	Historical	8.55	4.71	5.45	19.4	19.4	8.84	9.51	67.6	1.49
	Difference	6.84%	0.18%	1.33%	8.72%	1.08%	-1.04%	8.68%	0.23%	2.65%
S.D.	Simulated	2.45	1.54	2.14	9.38	8.56	2.53	3.79	14.5	0.38
	Historical	2.51	1.56	2.22	8.68	8.68	2.52	3.91	14.2	0.40
	Difference	-2.34%	-1.26%	-3.77%	8.05%	-1.45%	0.36%	2.14%	2.14%	-3.27%

CHAPTER V: SIMULATION RESULTS

5.0 Introduction

One of the primary objectives of this research is to assess the impact of institutional farmland purchases on the long-run structure of Saskatchewan farming. Currently, there are considerable limitations on non-Canadian farmland ownership (Table 2.1 and Table 2.2). Allowing the entrance of institutional investors into Saskatchewan farmland markets can potentially disrupt farmland purchase and rental markets through the shift of land ownership to those outside the farm community. It is widely believed (see for example, Desmarais et al., 2016) that the shift of farm ownership to non-farm owners has several potential knock-on effects through its impact on the accumulation of farm equity and farmland control potentially affecting the ability to transfer land from one generation to the next.

The study of farmland ownership is complicated by many factors including: 1) heterogeneous farmer demographics and expectations; 2) varying agricultural landscapes; and 3) uncertain yields, prices and government actions. The result is that the much of the underlying behavior and individual interactions in farming are too complex and recursive to be modeled using traditional static farm models. Accordingly, a farm level agent based simulation model (or ABSM) is extended to include individual farm and investor level decisions over agricultural production, farmland transactions and succession plans. As we shall see, the simulation generates results 30 years into the future. Four distinct scenarios are considered based on different levels of investor participation. In this manner, the long-term effects of institutional investors and the interactions between investors and local farmers on farmland markets as well as agricultural performance can be observed. The long-run consequences of allowing outside investors to bid on and own farmland will be assessed based on changes in the structure and financial well-being of a synthetic population of farmer agents. These virtual agents are located on an actual landscape known as CAR 1A, a Census region located in southeastern Saskatchewan.

Assessing the consequences when allowing large institutional investors to compete for farmland purchases is a key part of our (counterfactual) analysis. But to start, a benchmark or base scenario (hereafter base) simulates the current market situation with limited institutional investors in the land market. My counterfactual analysis consists of re-simulating the base model using the same time paths and length of model runs in order to generate three alternative policy scenarios. I then broadly compare the impact of each scenario on long-term agricultural structure as well as farm performance in comparison to the base scenario.

The four scenarios are described in Table 5.1. Once again, the base scenario models the current situation with no outside investors allowed in farmland markets.

Table 5.1: Definitions of Four Simulating Scenarios

Scenario Name	Meaning
Base	No Institutional Investor
II-BB	Institutional Investors Only Bid for Big Plots (>4 Plots).
II-BP	Institutional Investors Only Bid in Randomly 30% Auctions
II-BA	Institutional Investors Bid for All Auctions

The three scenarios called II-BB, II-BP and II-BA are grouped as “alternative scenarios” or “counterfactual scenarios” in this thesis. In Scenario II-BB, we assume that investors pursue high-efficiency purchases, meaning that small land parcels (less than four plots in size in the the simulation) are not worth purchasing and administering. In the second scenario, II-BP, we assume there are somewhat lowered barriers to land market entry by large investors, represented by certain regional farm community beliefs and customs. The latter might include exiting farmers who prefer to sell to neighbors, but the scenario also covers any limited informational resources on land for sale or even community peer pressure. Finally, Scenario II-BA allows unrestricted entry by institutional investors. While this is considered a somewhat unlikely future scenario, it is included to allow study of the extreme situation of fully open land markets in the province. Again, I run 100 simulations for each scenario using the same sets of time paths of stock returns, grain yields and prices. In the following sections, I report on; 1) simulated farm production; 2) agricultural sector structure; 3) farmland purchasing and bidding market performance characteristics; and 4) differences between the base and counterfactual scenarios. To this end, scenarios II-BB, II-BP and II-BA are compared using period means, long-trends and in a few cases extreme event analysis, where we test for relevant statistical differences using a paired T-test.

5.1 Model Validation

In Chapter 4, time path characteristics were compared to historical values in order to ensure that the set of time paths are a reasonable representation of potential future variable time paths. If the model performs to expectations in this sense, the next step in the simulation is model validation. The goal of model validation is to "guarantee that the results generated endogenously are correct and the model performs accurately" (Anderson, 2012). The first simulated year (2015) uses real values, so that the first year of the base scenario (i.e. no institutional investors) is compared to historical data to check whether the simulation generates results similar to those of reality.

Table 5.2: Model Validation for First Simulated Year

Average Farm Value	Historical Data in 2014	Simulated Data in 2015	Difference
	($1,000)	($1,000)	(%)
Assets	2,292	2,416	5.14%
Debt	368	440	16.3%
Net Worth	1,924	1,976	2.66%
Gross Income	371	407	9.05%
Net Operation Income	60.8	61.7	1.55%

Looking at Table 5.2, we see that differences between historical and simulated financial data are generally within 10% of each other. In fact, the higher value of simulated assets and net worth can be explained by higher prices for farmland in CAR 1. Following

Anderson (2012), we generate debt value from a farm financial survey (see Appendix A). Note that this will not be a very precise comparison because the historical data are provincial averages, whereas the specific data for CAR 1A for 2014 are not available.

Table 5.3: Simulated and Actual Crop Acreage Proportions in 2015

Statistic	Wheat	Canola	Peas	Flax	Barley	Lentils	Fallow
Actual	28.43%	19.50%	3.95%	2.20%	3.51%	1.26%	12.72%
Simulated	17.15%	21.59%	19.90%	19.32%	17.62%	4.42%	0.00%
Difference	-11.27%	2.08%	15.95%	17.12%	14.11%	3.16%	-12.72%

The simulation model includes only beef cow, mixed and grain farms. For tractability in setting up the number of farmer agent types, we excluded other potential types of farms, such as dairy farms. From Table 5.3, we see that the simulated proportions of canola and lentil production are similar to actual production, while simulated wheat production (including spring wheat, winter wheat and durum) is 11.27% lower. As Anderson (2012) notes, this outcome could be the result of the exclusion of small farmers, farmers who mainly produce wheat using older technologies.

5.2 Simulated Farms

5.2.1 Farm Numbers and Size

One of the major concerns voiced about the introduction of off-farm investors is the possible reduction in the total number of farms in the region. According to Desmarais et al. (2016), higher farmland prices will make it difficult for younger farmers to enter. However, based on the simulation these concerns may be overhyped. Table 5.4 shows simulated farm numbers over the 30-year simulation period.

Table 5.4 Simulated Farm Numbers

Scenario	Farm Type	Number of Farms					
		Beginning Farm Number	Ending				
			Average			Range	
			Farm Number	Survival Percentage (%)	Rate of Change (%)	Lower 5% (Number)	Upper 5% (Number)
Base	**All Farms**	717	367	51.2%	-2.21%	263	450
	Pure Grain	342	199	58.1%	-1.80%	114	257
	Pure Beef	144	83	57.5%	-1.83%	61.7	103
	Mix	231	86	37.2%	-3.25%	68.3	103
II-BB	**All Farms**	717	354	49.4%	-2.32%*	252	434
	Pure Grain	342	194	56.6%	-1.88%*	109	256
	Pure Beef	144	76	52.6%	-2.12%*	56.7	93.4
	Mix	231	85	36.7%	-3.29%*	71.3	102
II-BP	**All Farms**	717	351	49.0%	-2.35%*	252	426
	Pure Grain	342	191	55.7%	-1.93%*	108	254
	Pure Beef	144	77	53.6%	-2.06%*	59.2	94.4
	Mix	231	84	36.2%	-3.33%*	69.2	97.8
II-BA	**All Farms**	717	349	48.7%	-2.37%*	255	424
	Pure Grain	342	189	55.3%	-1.96%*	112	252
	Pure Beef	144	77	53.3%	-2.08%*	57.3	90.4
	Mix	231	83	36.0%	-3.35%*	67.0	97.2

Notes:

1. The rate of change is the compound rate of this chapter as follow:

$$\text{Compound Changing Rate } = 1 - \left(\frac{Value\ in\ 30^{th}\ Year}{Value\ in\ first\ Year}\right)^{\frac{1}{30}}$$

2. Upper 5% is the average of the five highest values out of 100 simulations and lower 5% is the average of the five lower values out of 100 simulations in the class.
3. * indicates 1% of statistical significance in paired T-tests.

On average, approximately 50% of all farms in the region are projected to survive by the final (30^{th}) year in the base scenario. In the three alternative scenarios, farm survival rates are similar but slightly lower. But I note that the estimated simulated decline in mean farm numbers in fact follows past long-run provincial averages. The average annual rate of change for farm numbers in the province was 2.20%, from 1980 to 2016. (CANSIM 004-0001 and 004-0237). However, the decline in farm numbers depends on yield/price time paths, and varies from 250 to 450 farms indicating the importance of low prices and yields in predicting farm survival rates. In terms of farm types, pure grain and pure beef (ranch) tended to have lower mean rates of decrease, dropping at about 1.8% per year. This resulted in about 58% of these farms surviving until the last period. Mixed farms displayed considerably higher exit rates than other farm types, averaging about 3.2% per year, resulting in only 37% of these farms surviving by the last year of the simulation.

Most farms in the simulation reduced farm debt over time. By the end of 30 years, approximately 50% of farms were successfully transferred or were still in business under the original owner. The approximately 50% of farms who did exit, did so for one of three reasons: 1) involuntary exit; 2) insufficient cash flow; and 3) farm succession failures (Table 5.5). These factors are examined in more detail in the next section.

Table 5.5: Simulated Farm Exits and Succession

Scenario	Lower 5%	Total Exits	Upper 5%	Proportion of Exits
Involuntary Exiting				
	(Number)	(Number)	(Number)	(%)
Base	28.0	56.2	97.4	16.1%
II-BB	45.2	65.3	93.2	18.0%
II-BP	47.3	66.9	92.2	18.3%
II-BA	46.5	68.9	106	18.7%

Scenario	Lower 5%	Total Exits	Upper 5%	Proportion of Exits
Insufficient Cash Flow				
	(Number)	(Number)	(Number)	(%)
Base	123	175.3	250.4	50.1%
II-BB	123	177.7	256.6	49.0%
II-BP	122	180.0	259.6	49.3%
II-BA	129	180.1	254	48.8%

Scenario	Lower 5%	Total Exits	Upper 5%	Proportion of Exits
Retire without Successor				
	(Number)	(Number)	(Number)	(%)
Base	97.8	118	140	33.8%
II-BB	100	120	145	33.0%
II-BP	99.5	119	141	32.4%
II-BA	97.2	120	143	32.5%

Scenario	Lower 5%	Total	Upper 5%	Proportion of First-generation Farmer
Successful Transfer				
	(Number)	(Number)	(Number)	(%)
Base	281	360	408	20.2%
II-BB	276	348	401	20.1%
II-BP	278	348	396	20.3%
II-BA	275	346	395	20.2%

Note: "Proportion of Exits" in Involuntary Exits is calculated as follow:

$$Proportion\ of\ Exits = \frac{Involuntary\ Exits}{Involuntary\ Exits + Insufficient\ Cash\ Flow + Retire\ without\ Sucessor}$$

The other two ""Proportion of Exits" follow the same pattern.

The number and percentage of exiting farms are presented in Table 5.5. Note that about 20% of the farms operate for the entire 30 years. Namely, they do not exit, retire or pass the farm to a successor over the 30-year simulation period. Conversely, about 1.5% of the survival farms have experienced two rounds of successions (Table 5.7). Thus the total number of exits and successions is less than the initial farm number used here (717).

In the base scenario, insufficient cash flow is the primary reason for 50% of farmers exiting, followed by retirement without a successor (33%) and involuntary exits (16%). Insufficient cash flows and involuntary exits together account for about 66% of all exits, reinforcing the importance of financing in long run farm survival. Insufficient cash flows are chronic cash flows that could be associated with too much farm debt service payments or a fundamental cost inefficiency due to the inability to reach a cost-efficient size (i.e. too much machinery with respect to farm size). Involuntary exits are due to technical bankruptcy likely caused by too much debt. In this model, farmer agent bid prices are based on a common set of bid rules but expectations, risk preferences and financial conditions are individual to each farmer agent. Hence, bid prices are heterogeneous and based on individual circumstances. Periods of increasing commodity prices can make farmers be optimistic about future prices. Likewise, periods of increasing farmland prices can also make farmers too aggressive through the so-called balance-sheet effect.[12] If the farmer agent is too aggressive in bidding and overbids, then this can also lead to too much debt, making the farm vulnerable to technical insolvency in an economic downturn characterized by decreasing farm asset values. Likewise, too much debt can lead to increased debt service,

[12] The balance-sheet effect is the higher capacity for the farmers to raise debts due to the increased value of the farmland as a composition of the assets.

in turn leading to chronic cash flow problems in a period of decreasing commodity prices or if increased interest rates are encountered.

Farm succession (Section 3.3.2) only takes place when the retiring farmer has at least one heir, and there is at least one heir whose indicator of succession willingness (eq. 3.10) is greater than the chosen threshold of 0.8. Moreover, I assume that the heir with the highest willingness indicator takes over the whole farm. Over the simulation, there are between 345 to 360 successful farm transfers across various scenarios, with 360 successful farm transfers on average in the base scenario over the whole simulation period.

Considering the alternative scenarios and farm exit, there are small differences between the base and the three alternative scenarios. On average, there are 2-3% more exits per year in the scenarios that include institutional investors. However, in terms of the reasons for farm exits, I find little differences between the scenarios. Farm acreage is held constant within CAR 1A, so that farms are typically associated with land being farmed by the existing farms while farm size gradually increases over time.

Table 5.6: Simulated Farm Size, by Scenario

Scenario	Farm Type	Average Farm Size				
			Ending			
		Beginning	Lower 5%	Mean	Upper 5%	Auunal Rate of Change
		(Number)	(Number)	(Number)	(Number)	(%)
Base	**All Farms**	1,533	2,432	2,946	4,116	2.20%
	Pure Grain	1,636	2,395	3,410	6,866	2.48%
	Pure Beef	1,928	1,812	3,046	4,002	1.54%
	Mix	1,133	1,356	1,712	2,372	1.38%
II-BB	**All Farms**	1,533	2,530	3,038	4,268	2.31%
	Pure Grain	1,636	2,503	3,582	7,400	2.65%
	Pure Beef	1,928	1,874	3,048	3,996	1.54%
	Mix	1,133	1,329	1,766	2,286	1.49%
II-BP	**All Farms**	1,533	2,560	3,072	4,386	2.34%
	Pure Grain	1,636	2,551	3,659	7,713	2.72%
	Pure Beef	1,928	1,826	3,027	4,255	1.52%
	Mix	1,133	1,279	1,740	2,347	1.44%
II-BA	**All Farms**	1,533	2,581	3,093	4,287	2.37%
	Pure Grain	1,636	2,577	3,685	7,543	2.74%
	Pure Beef	1,928	1,659	3,031	3,858	1.52%
	Mix	1,133	1,357	1,767	2,397	1.49%

Note: Upper 5% is the average of the five highest values out of 100 simulations, and lower 5% is the average of the five lower values out of 100 simulations in the particular class.

Average farmed, owned and leased acres per farm are presented in Table 5.6. Initially, with decreasing farm numbers, we eventually observe rapid farm size expansions. In the base scenario, we see there is 50% more owned farmland and 150% more rented land by the 30th year as compared to the beginning of the simulation. All three scenarios follow this basic trend.

By the end of the base scenario, pure grain farms are 100% larger, and both pure beef and mixed farms are 50% larger than their initial size. The differences between different scenarios on this factor is actually insignificant. By the final simulation year, pure grain farms are more than twice as large as mixed farms. Based on growth rates with dwindling farm numbers, mixed farming does not appear to be a particularly efficient future strategy under these conditions. This finding on mixed farms is likely due to initial smaller annual acreages, meaning fewer efficiencies can be gained with cow herd expansion beyond a certain size.

The distribution of farm sizes is represented in the histogram in Figure 5.1.

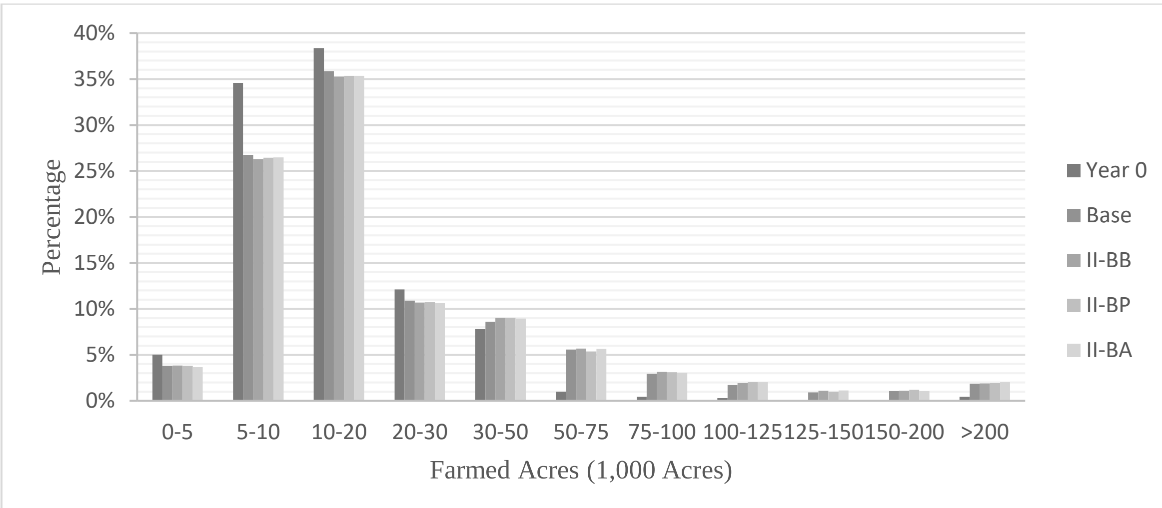

Figure 5.1: Histogram of Farmed Acres, Initial and Final Years

In Figure 5.1, at the beginning of the simulation, 99% of farms operate with less than 5,000 acres. Compared to the initial year (in the base scenario) the number of small farms (defined here as less than 2,000 acres) decreases over time, while about 10% of farms by the final year are very large farms, farming more than 5,000 acres. Once again, there are few significant differences among the various scenarios. For example, slightly more farms of more than 30,000 acres are generated in the alternative scenarios (especially in II-BA) while more farms of under 20,000 acres are generated in the base scenario. We conclude that institutional investor owned farmland does affect farm size through allowing more farmland to be available for rent, but the overall difference is rather small as compared to the base scenario.

5.2.2 Farm Age Profile

Farm expansion among each generation of farmers is critical for the farms to reach optimal size and efficiency. Table 5.7 presents the renewal situation for farmers in each scenario.

Table 5.7: Age Structure in the Last (30th) Year of Simulation

Scenario	Generation	Percentage
Base	First	20.0%
	Second	78.8%
	Third	1.24%
II-BB	First	20.1%
	Second	78.6%
	Third	1.25%
II-BP	First	20.3%
	Second	78.5%
	Third	1.23%
II-BA	First	20.2%
	Second	78.5%
	Third	1.31%

At the beginning of the simulation, all farmers are necessarily first generation. If a farmer transfers the farm to his/her heir (one succession), new farmers will then become a group of second generation farmers. Referring to Table 5.7, about 80% of the operating farms in the simulation experience at least one family transfer, whereby successful farm transfer means that most of the farmland remains under family control. The difference among scenarios with or without investors in this regard is very slight.

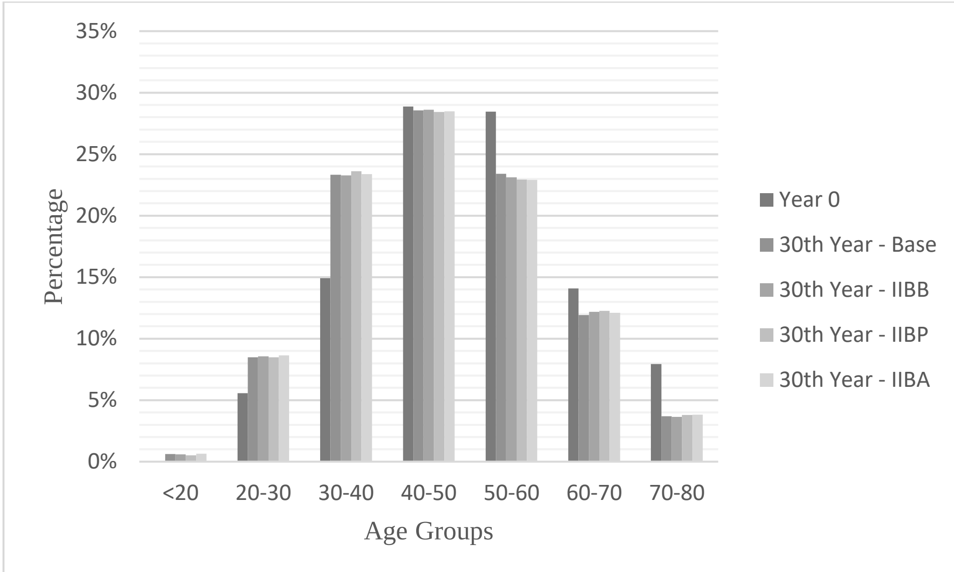

Figure 5.2: Histogram of Age Distribution in Year 0 and Year 30

By the 30th year, age of the average farmer decreases from 51.1 to 47.1 in all three alternative scenarios. Farmers are allowed to consider retirement after age 55, but face 80% or higher probability of retirement as they hit 70 years or older. In the initial year of the simulation, the density of senior farmers is higher than at the end. This is illustrated in Figure 5.2. As a result, farm age by the final simulation year is lower than at the beginning. From Figure 5.2., we see a larger proportion of young farmers in the 20-40 age group and a lesser proportion of farmer in the 50 or over group through the final simulated years across all four scenarios. As a result, farm succession smoothly decreases the age distribution of farmers.

5.2.3 Simulated Farm Tenure

The ownership pattern of farmland is presented in Table 5.8. Initially, there is no significant difference among the four scenarios. In the base scenario, the proportion of owned farmland starts at about 69 percent and by the end only half of the farmland is owned by operating farms. As expected, more rental farmland is present in the three alternative scenarios. In scenarios II-BB, II-BP and II-BA, farmers operate with about

100 more leased acres per farm on average, which explains increasing crop production. Overall in all four scenarios, compared to the start of the simulation, there is about 30% more owned farmland and 100% more rental land at the end of the simulation.

Leasing farmland is the primary business expansion mechanism for farmers with or without outside investors. The introduction of outside investors, however, pushes the farmers to rely slightly more on rented land due to rising farmland prices and a larger supply of rental land. When looking at 5% bounds of the land ownership distribution (Table 5.8), we find that the owned acreage ratio for all farm categories slides to the left (falls) by about 2% in all three alternative scenarios.

Table 5.8: Simulated Farmland Owned Acreage Proportion

Scenario	Farm Type	Owned Acreage Proportion			
		Beginning	Ending		
			Lower 5%	Mean	Upper 5%
		(%)	(%)	(%)	(%)
Base	**All Farms**	68.9%	40.2%	50.7%	61.3%
	Pure Grain	65.5%	33.5%	49.6%	62.3%
	Pure Beef Cow	73.4%	36.5%	46.5%	67.4%
	Mix	71.5%	48.4%	64.2%	80.3%
II-BB	**All Farms**	68.9%	40.4%	49.9%	59.3%
	Pure Grain	65.5%	34.0%	48.8%	59.4%
	Pure Beef Cow	73.4%	36.1%	45.5%	66.0%
	Mix	71.5%	49.6%	62.1%	80.6%
II-BP	**All Farms**	68.9%	39.2%	49.2%	58.4%
	Pure Grain	65.5%	32.0%	48.0%	61.6%
	Pure Beef Cow	73.4%	33.6%	44.6%	66.1%
	Mix	71.5%	46.1%	62.3%	79.5%
II-BA	**All Farms**	68.9%	38.8%	48.7%	58.6%
	Pure Grain	65.5%	31.1%	47.2%	60.9%
	Pure Beef Cow	73.4%	34.5%	44.5%	67.6%
	Mix	71.5%	45.0%	62.5%	79.1%

Note: Upper 5% is the average of the five highest values out of 100 simulations, and lower 5% is the average of the five lower values out of 100 simulations in the particular class.

5.2.4 Simulated Farm Financial Structure

In the base scenario, average assets per farm increase from $2.4 to $6.7 million while average net worth per farm increases from $1.9 to $6.4 million. This is shown in Table 5.9. Overall, I offer that these numbers indicate that farming remains a sustainable and healthy industry. Also, in scenarios II-BB, II-BP and II-BA, given higher farmland prices in these scenarios, I find that asset and equity values are also higher. Meanwhile, the value of land is a part of property and equity - a higher farmland price leads to increased value and net worth properly. For instance, in II-BB the asset values are $100,000 greater, while in II-BP an II-BA these values are $1 million higher on average. The increased asset values are due primarily to the rise in farmland price.

Meanwhile, we see that the distributional range for asset and equity range from $4 million to $10 million in the base scenario. The tails of the distribution indicate that farm performance continues to be very sensitive to prices and yields of farm products. Moreover, in the three alternative scenarios, the ranges of asset, equity and debt are even greater due to higher variations in farmland prices. In Figure 5.3, we see that more farms with greater than $5 million in assets are found in II-BB and II-BA because of increased farmland prices, as compared to more farms possessing less than $200,000 of assets in the base scenario.

Referring to Anderson (2012), in this simulation I fixed machinery technology and investment requirements at 2014 levels. In turn, machines are replaced at a continuous rate, and as long as machine size and composition do not change, machine debt can effectively be rolled over with replaced machines. However, farm resizing can result in changing machinery size and changes in farm debt, and thus the need for debt repayment. Nevertheless, simulated farms here tended to pay off most of their farm debt. In the base scenario, the amount of farm debt declines from $4.92 to $2.74 million (Table 5.9). In fact, this slightly surprising result may be an artifact of our assumption of fixed machinery real prices and technology in the simulation.

On average, farm debt declines 1.3% to 1.5% annually in the three counterfactual scenarios, and 2% in the base scenario over the 30-year simulation period. The annual rate of change of the debt/asset ratio is -1.98%, which is very close to the historical rate of change for debt/asset ratio from 2001 to 2011 at -1.96% (Source: CANSIM 002-0065). However in reality, farm debt actually increased 3% per year in 2001 to 2011.

This mismatch could be the result of the following. Initially, all farmers with a debt-asset ratio greater than 90% are immediately forced to exit, so survival bias might lead to the underestimation of the farm debt. Moreover, since I assumed no technology improvements over the simulation period, the capacity and price of machinery are fixed. As a result, more advanced machinery with higher prices is not a factor causing farmers to replace machinery and increase debt. Also, the increasing asset price can lead to debt to increase in the real world, but asset prices in the model are assumed to be fixed, except for farmland. The debt/asset ratio, however, is free of price volatility both in the simulation and in the real world. As a result, the validity of my simulation results are supported by a similar changing debt/asset ratio.

From Table 5.5, we see more farms involuntarily exiting in the three alternative scenarios/ We also observe higher farmland prices in the three alternative scenarios. The average debt per farm in the alternative scenarios is $50,000 higher than in the base scenario (Table 5.9), where farmland price is higher but seemingly still affordable to remaining farmers. From Table 5.11, we see that a number of farmland purchases in these scenarios (II-BB and II-BP) are similar to the base scenario, so farms necessarily have a higher level of debt. But since the farmland price in scenario II-BA is eventually no longer as affordable for the remaining farms, the average amount of debt is actually lower.

Increased debt levels could lead to potentially greater financial problems as high farmland prices are not associated with greater productivity. Paying increasing amounts for farmland adversely affects farm cash flows and does not confer additional real wealth until the land is sold. Nevertheless, this impact is still not significant here because; 1) a relatively large proportion of farmland rolls over from one generation to the next; and 2) the farmland purchased by institutional investors enters the land rental market, meaning farm expansion through rental is less risky and easier than expanding by land purchases.

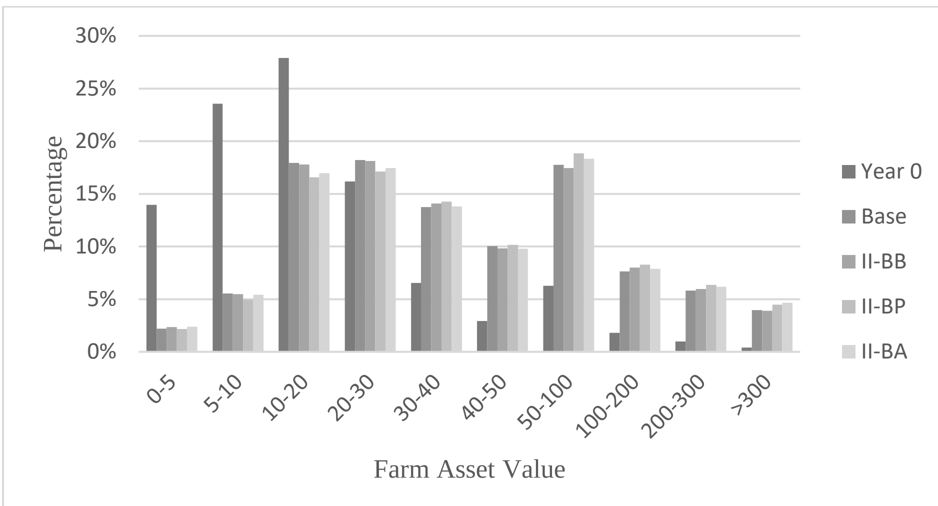

Figure 5.3: Farm Assets in Initial and Last Year, all scenarios

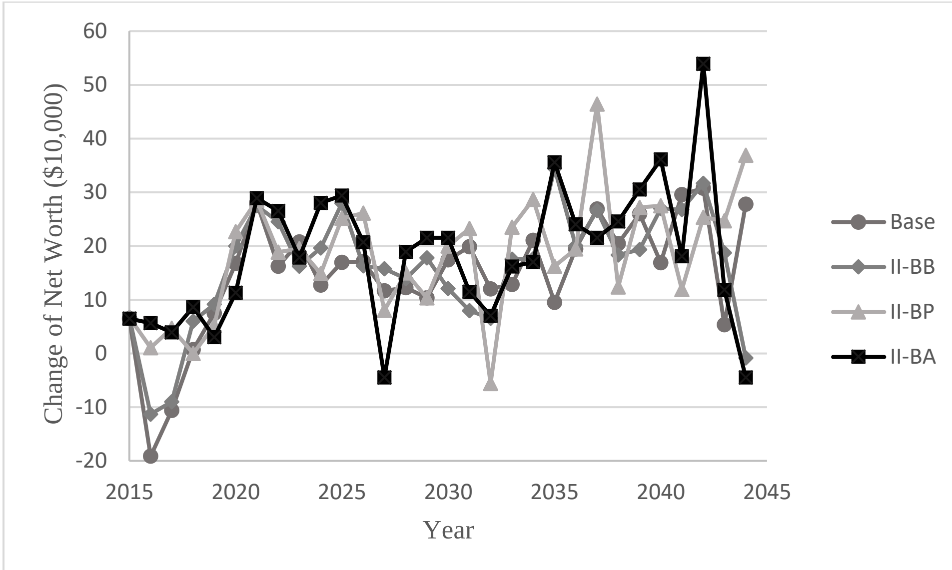

Figure 5.4: Average Annual Change of Net Worth, all Scenarios

Table 5.9: Simulated Farm Assets, Debt and Net Worth

Scenario	Farm Type	Average Farm Assets				Average Farm Debt				Average Farm Net Worth			
			Ending				Ending				Ending		
		Beginning	Lower 5%	Mean	Upper 5%	Beginning	Lower 5%	Mean	Upper 5%	Beginning	Lower 5%	Mean	Upper 5%
		($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Base	**All Farms**	2,416	4,933	6,684	10,713	492	210	274	829	1,924	4,593	6,411	10,184
	Pure Grain	3,606	6,216	8,798	17,530	628	381	363	1,445	2,979	5,630	8,434	16,608
	Pure Beef Cow	1,880	3,996	4,585	5,327	627	72	195	436	1,254	3,879	4,390	5,102
	Mix	985	3,386	3,679	4,269	209	65.4	127	271	776	3,292	3,553	4,130
II-BB	**All Farms**	2,416	4,993	7,103	12,851	492	297	330	1,061	1,924	4,662	6,773	12,182
	Pure Grain	3,606	6,350	9,432	21,836	628	402	450	1,876	2,979	5,833	8,982	20,626
	Pure Beef Cow	1,880	3,693	4,823	5,844	627	73.4	226	478	1,254	3,579	4,596	5,625
	Mix	985	3,315	3,806	4,610	209	61.2	142	322	776	3,194	3,664	4,463
II-BP	**All Farms**	2,416	5,387	7,689	11,796	492	290	322	1,087	1,924	5,078	7,367	11,400
	Pure Grain	3,606	6,993	10,509	19,219	628	416	441	1,497	2,979	6,534	10,068	18,622
	Pure Beef Cow	1,880	3,730	4,871	5,305	627	60.1	214	486	1,254	3,585	4,657	5,109
	Mix	985	3,241	3,861	4,402	209	70.1	144	329	776	3,136	3,717	4,231
II-BA	**All Farms**	4,939	4,939	7,755	13,638	492	274	318	886	1,924	4,650	7,437	13,049
	Pure Grain	6,277	6,277	10,778	21,307	628	483	434	1,633	2,979	5,835	10,344	20,351
	Pure Beef Cow	3,941	3,941	4,665	6,641	627	57	194	381	1,254	3,796	4,471	6,368
	Mix	3,150	3,150	3,738	4,861	209	63	147	302	776	3,043	3,591	4,650

Note: Upper 5% is the average of the five highest values out of 100 simulations, and lower 5% is the average of the five lower values out of 100 simulations in the particular class.

5.2.5 Farm Production

From Table 5.10, we see that average cropping and pasture acreages per farm increase by 100% for all four scenarios. On average, the size of existing farms doubled over the duration of the simulation. That is mostly due to the fact that 50% of the simulated farms at the start ultimately exited.

Compared with the base scenario, average cropping acreages in all three counterfactual scenarios increased between 70 to 110 acres, with more cropping acres per farm in II-BA than the other scenarios. Note that farmland price in II-BA is also higher than any of the other scenarios (Table 5.12), and the owned farmland proportion is the smallest for all four scenarios (Table 5.8). As a result, increased cropping acreage must come from additional rental farmland available through the institutional investor owners.

Overall, farmland that would be owned by institutional investors does not "plunder" farmland resources from farmers. Instead, the capacity for farm expansion will be greater than we find under the base scenario, and productivity will also be higher due to the continued exploitation of increasing returns to scale at the farm level. Farmers will ultimately rely more on rented land to expand their farms, while the marginal expenditure for rented farmland remains considerably lower than for purchased farmland. Moreover, since institutional investors in the simulation will always rent their owned farmland to farmers, rental farmland supply is comparatively stable.

In terms of sector average, there is more idle land in the three alternative scenarios than in the base scenario. As mentioned in Section 3.4.3.3, land bid prices for institutional investors are directly related to the performance of international stock indices. When the performance of these stock indices is poor, institutional investors buy very little farmland. But reservation land prices and renting by remaining land owners both increase due to growing land price levels. This eventually can lead to more idle farmland because of the occasionally large bid and ask spreads that can occur in the land market.

Table 5.10: Simulated Crop, Hay and Beef Cow Production

Scenario	Grain Production Acreage				
	Farm Average			Sector Average	
	Beginning (Acre)	Ending (Acre)	Rate of Change (%)	Beginning (1,000 Acres)	Ending (1,000 Acres)
Base	1,275	2,948	2.31%	846	839
II-BB	1,275	2,997	2.43%*	843	835
II-BP	1,275	3,049	2.46%*	843	837
II-BA	1,275	3,076	2.49%*	842	810
Scenario	**Hay Production Acreage**				
	Farm Average			**Sector Average**	
	Beginning (Acre)	Ending (Acre)	Rate of Change (%)	Beginning (1,000 Acres)	Ending (1,000 Acres)
Base	136	258	2.23%	97.4	185
II-BB	136	265	2.25%*	97.4	190
II-BP	136	269	2.31%*	97.4	193
II-BA	136	271	2.33%*	97.4	194
Scenario	**Beef Cow Head**				
	Farm Average			**Sector Average**	
	Beginning (Head)	Ending (Head)	Rate of Change (%)	Beginning (1,000 Heads)	Ending (1,000 Heads)
Base	78.3	54.9	-1.21%	29.3	9.26
II-BB	78.3	55.4	-1.15%	29.4	8.90
II-BP	78.1	55.2	-1.15%	29.3	8.87
II-BA	78.3	56.7	-1.07%*	29.4	8.43

Note:

1. * indicates 1% of statistical significance in paired T-test,
2. The average grain production acreage is the average of pure grain and mixed farms, and the average hay production and beef cow head is the average of pure beef and mixed farms.

5.3 Farmland Auction

5.3.1 Farmland Transactions

Apart from farm financial and operational well-being, the perception is that a healthy agricultural industry is also dependent on farmland purchase and rental prices. In effect, high farmland prices can impede farms from expanding and reaching overall efficiency. Desmarais et al. (2016) argue that one of the major concerns in allowing off-farm investors is that investors will tend to overbid versus local farmers, pushing up farmland price and eventually squeezing the farmers out of the land market. Comprehensive farmland market performance from the simulation can be found in Tables 5.11, 5.12, as well as Figures 5.5 and 5.6.

Table 5.11: Simulated Number of Plots Purchased by Farmers and Investors

Total Plot Purchases						
Scenario	Investors			Farmers		
	Lower 5%	Mean	Upper 5%	Lower 5%	Mean	Upper 5%
	(Number)	(Number)	(Number)	(Number)	(Number)	(Number)
Base	NA	NA	NA	54.0	125	248
II-BB	5.33	58.4	170	55.3	130	232
II-BP	62.7	124	284	61.8	124	221
II-BA	193	399	719	26.5	85.2	179
Total Purchased Plots/Total Plots						
Scenario	Investors			Farmers		
	Lower 5%	Mean	Upper 5%	Lower 5%	Mean	Upper 5%
	(%)	(%)	(%)	(%)	(%)	(%)
Base	NA	NA	NA	4.91%	11.3%	22.5%
II-BB	0.49%	5.31%	15.5%	5.03%	11.8%	21.1%
II-BP	5.70%	11.3%	25.8%	5.63%	11.3%	20.1%
II-BA	17.6%	36.3%	65.5%	2.41%	7.75%	16.3%
Total Purchased Plots/Total Sold Plots						
Scenario	Investors			Farmers		
	Lower 5%	Mean	Upper 5%	Lower 5%	Mean	Upper 5%
	(%)	(%)	(%)	(%)	(%)	(%)
Base	NA	NA	NA	100%	100%	100%
II-BB	7.76%	31.1%	61.1%	38.9%	68.9%	92.2%
II-BP	33.8%	50.1%	66.1%	33.9%	49.9%	66.2%
II-BA	67.7%	82.4%	93.9%	6.10%	17.6%	32.3%

Note: Upper 5% is the average of the five highest values out of 100 simulations, and lower 5% is the average of the five lower values out of 100 simulations in the particular class.

In II-BA, total farmland purchases by investors are greater than the other two counterfactual scenarios, while total plot purchases are also about 100% greater than found in II-BB and II-BP. In the base scenario, II-BB and II-BP, institutional investors have constrained accessibility to farmland auctions, and most farmland is initially unsold, being retained by exiting farmers and passing to the rental market where it is eventually sold. II-BA institutional investors bid in every farmland purchasing auction and are not constrained by capital, and as a consequence, there is little to no unsold farmland. As a result, much more successful farmland transactions are observed in II-BA.

The average amount of land bought by both investors and farmers over the 30–year simulation period is shown in Table 5.11. In the base scenario, about 125 plots of farmland are sold to farmers. Investors in II-BB and II-BP purchase 58 and 124 plots on average. Although the farmland price increases in II-BB and II-BP, farmers purchase as much farmland as compared to the Base scenario. On average, farmland price increases between $150-$300 in scenarios II-BB and II-BP (Figure 5.5). The same level of farmland is purchased by farmers in II-BB and II-BP. This indicates that farmland in these scenarios, especially low-quality farmland, is still affordable to farmers, but purchasing farmers will be burdened with more debt, as shown in Table 5.9. In II-BA, farmland is less affordable for farmers, so the amount of purchased farmland of farms drops by 40 simulated plots.

In II-BA, institutional investors buy 82% of farmland on the market on average, and farmers are effectively squeezed out from the market, pushing them to leasing for farm expansion. Moreover, the institutional investors take 36.3% of the total farmland in the CAR1A region, significantly affecting farmland ownership structure. Also in the upper 5% of the simulation runs the investors had already purchased about two-thirds of the whole area. However, I remind the reader that II-BA is considered as an extreme case that is very unlikely to happen even if all the farmland ownership regulations are removed.

Even though institutional investors purchase between 30% and 80% of farmland depending on the scenario, their ownership share of total farmland averages only between 5% and 11% of the total available acreage due to several factors, including: 1) scenario acreage limit restrictions; and 2) the amount of farmland transferred via succession from one farming generation to the next. Recall that annual acreage restrictions were relaxed in scenario II-BA, meaning that institutional investors purchase almost all the farmland, so that their land share reached an average of 36.3% by the end of the simulation period.

5.3.2 Farmland Prices and Rents

Simulated farmland prices and rents over the simulation are presented in Figures 5.5 and 5.6, and in Table 5.12. At the beginning of the simulation, both farmland price and rents decline. In the base scenario, farmland price drops to $1,100/acre within the first few years. The price represents the agricultural value of farmland with technology standards found in the year 2014. The farmland price then becomes stable since I assume there is no technology improvement and yield increases over the simulation period.

I observe greater price variability in II-BP, but by 2030 both price and rent stabilize. The main reason for farmland price declines is likely due to my initial condition assumptions: initial farmland prices were likely too high to be sustained by those initial commodity market conditions, and it was only as farm commodity prices regained historical levels that farmland prices eventually rebounded.

Since all scenarios use the same time path data, any land use differences between the scenarios must come from competition within the farm auctions. It is also clear from Figure 5.5 that increased investor auction participation drives up average farmland prices. For example, in the base scenario, average farmland price is found to be $1,184 per acre, about $100 less than that in II-BB and more than $200 than that in II-BP, while the average farmland price in II-BA is about $1,596 per acre.

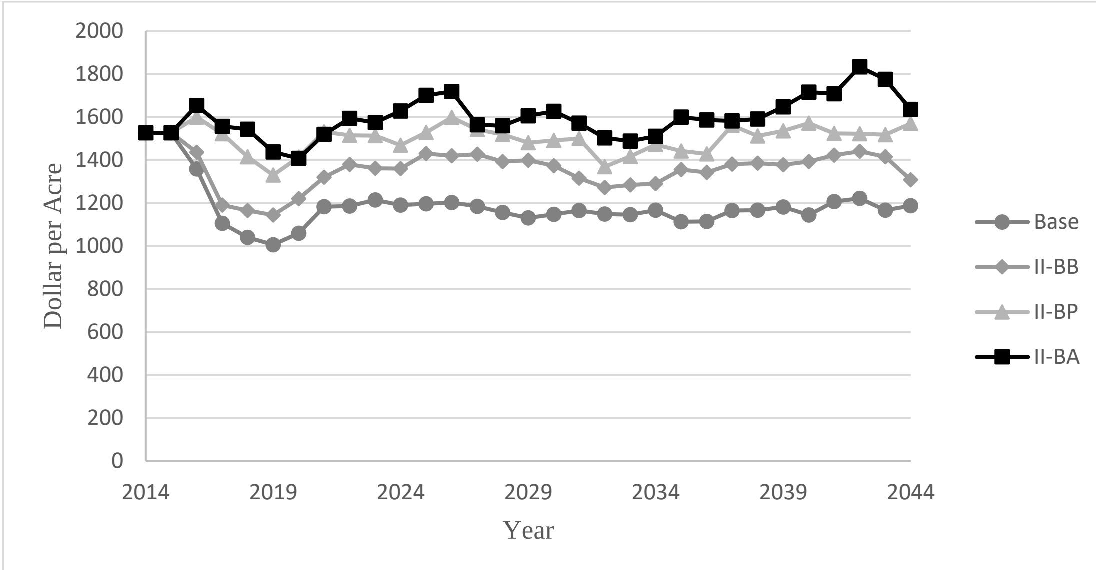

Figure 5.5: Simulated Mean Farmland Price

Note: Prices are detrended for inflation and embedded technology.

The average farmland price per acre within the simulation time frame is shown in Figure 5.5. Farmland rent among the four scenarios is very similar (Figure 5.6). Somewhat surprisingly, although farmland prices are significantly different across the scenarios, I find little difference among average farmland rents. This likely occurs for the following reasons. Initially, farmer rent bid values depend on their estimated future crop yields, and prices do not change between the various scenarios since the employed time paths are the same. Although the farmers bidding in the land auctions may change across scenarios and thus bids may change somewhat, the effects are not likely to be very dramatic. As more farmland is introduced into rental markets, there is more farmland available, and concurrently there are more renters bidding as unsuccessful farmers from purchase auctions will still want to grow their farms. The net result seems to be remarkably little differences generated in the farmland rental markets across all the scenarios.

Given this, what does change are land rent-price ratios. In all three of the alternative scenarios, land rent-price ratios are significantly lower than the base scenario because of the increase in farmland purchase prices.

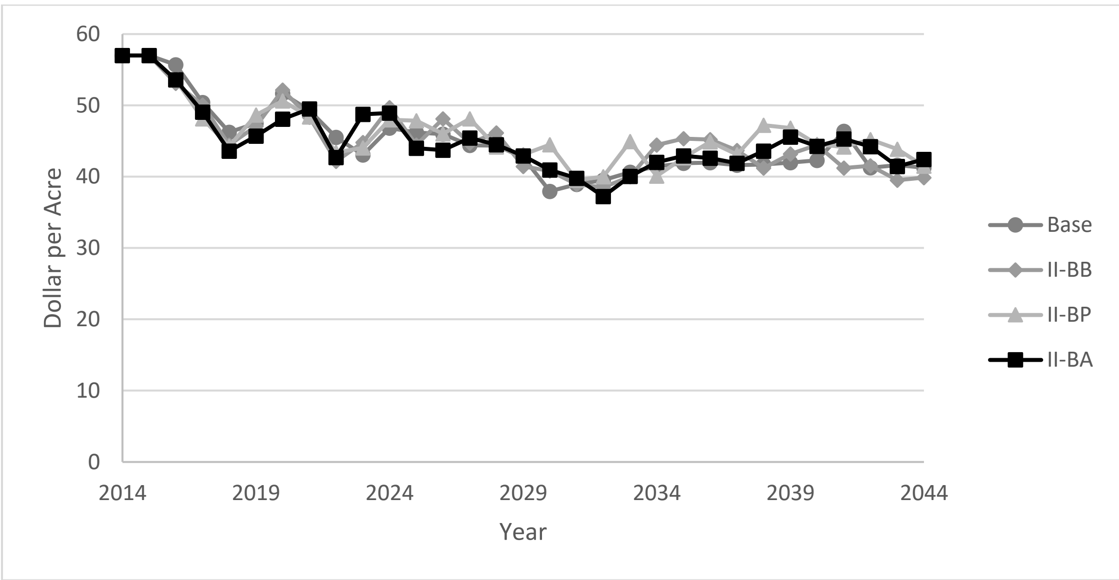

Figure 5.6: Simulated Mean Cropland Rent

Note: Prices are detrended for inflation and embedded technology.

Table 5.12: Simulated Farmland Price and Rent

Scenario	Farmland Price				
	Beginning	Period Mean	Ending		
			5% Lower	Mean	5% Upper
	(Dollar)	(Dollar)	(Dollar)	(Dollar)	(Dollar)
Base	1,526	1,184	924	1,187	1,661
II-BB	1,526	1,356	1,135	1,308	1,737
II-BP	1,526	1,498	1,255	1,570	1,991
II-BA	1,526	1,596	1,257	1,635	2,163
Scenario	**Farmland Rent**				
	Beginning	Period Mean	Ending		
			5% Lower	Mean	5% Upper
	(Dollar)	(Dollar)	(Dollar)	(Dollar)	(Dollar)
Base	57.0	45.0	33.2	41.3	61.8
II-BB	57.0	45.1	33.8	39.9	63.3
II-BP	57.0	46.0	34.7	41.5	64.6
II-BA	57.0	45.1	34.8	42.4	61.4
Scenario	**Farmland Rent**				
	Beginning	Period Mean	Ending		
			5% Lower	Mean	5% Upper
	(%)	(%)	(%)	(%)	(%)
Base	3.74%	3.80%	2.55%	3.48%	5.24%
II-BB	3.74%	3.33%	2.43%	3.05%	4.18%
II-BP	3.74%	3.07%	2.36%	2.64%	3.67%
II-BA	3.74%	2.83%	2.31%	2.59%	3.40%

Note:

1. Prices are detrended for inflation and embedded technology.
2. Upper 5% is the average of the five highest values out of 100 simulations, and lower 5% is the average of the five lower values out of 100 simulations in the particular class.

5.4 Institutional Investor Behavior

Apart from the farmers, the performance of off-farm investors is important to examine so as to understand the validity and motivation of the off-farm investors to hold farmland in their portfolios. The optimal portfolio performance for my three hypothetical investor agents is presented in Table 5.13. The impact of adding farmland to their investment portfolio is measured by changes in their Sharpe Ratio, i.e. the return/risk ratio (eq. 3.19 and 5.1).

$$Sharpe\ Ratio = \frac{R(Portfolio) - r}{SD(Portfoilo)} \tag{5.1}$$

Note that it is important to assess this ratio for the investors as it is critical from their perspective to understand both expected return and risk. Improvements in the Sharpe Ratio indicate an increase of the return-risk ratio in their portfolios. Investors prefer this, as it means their chosen portfolios are less risky but with the same level of expected return, or alternatively the portfolio has a higher return for a given level of risk.

The Sharpe Ratio Improvement is calculated as follow:

$$Sharpe\ Ratio\ Improvement = \frac{Sharpe\ Ratio\ with\ Farmland - Sharpe\ Ratio\ without\ Farmland}{Sharpe\ Ratio\ with\ Farmland} \times 100\% \tag{5.2}$$

Both median and mean changes in the Sharp Ratio are reported in Table 5.13. The median might be a more reliable indicator since it mitigates against the influence of extreme values. Especially when the Sharpe Ratio computed without farmland is negative or slightly positive with farmland, improvement in the Sharpe Ratio could be overestimated. For example, if the Sharpe Ratio without farmland is -5% and the Sharpe Ratio with farmland is 1%, the indicator of improvement would be 600% following eq. 5.2 as an extreme value.

As there are no institutional investors in the base scenario, this scenario is used to identify any additional benefits to the institutional investors if they purchased farmland. When it is beneficial for investors to hold farmland in our alternative scenarios, they will participate in the farmland auctions. In the alternative scenarios including institutional investors, Sharpe Ratios improved by 4% -5%. Moreover, 21% to 22% of agricultural land is part of the optimal portfolio for three institutional investor agents. We conclude that investors will likely be aggressive in participating in farmland auctions[13].

[13] Note that in the real world, these investors would face a much more expansive portfolio including non-farm real estate. We offer that in a more expansive portfolio farmland would likely comprise a smaller proportion of the total portfolio.

Table 5.13 Institutional Investors Median Performance Comparison in the Ending (30th) Year

Scenario	**Investor Agent Type**	Median		Mean	
		Sharpe Ratio Improvement	**Percentage of Farmland in Optimal Portforlio**	**Sharpe Ratio Improvement**	**Percentage of Farmland in Optimal Portforlio**
		(%)	(%)	(%)	(%)
II-BB	Full Investor	4.66%	20.7%	15.8%	27.4%
	Non Asian Investor	4.26%	19.8%	23.6%	28.4%
	North American Investor	5.34%	18.6%	45.6%	29.3%
II-BP	Full Investor	6.05%	22.3%	16.7%	28.6%
	Non Asian Investor	5.61%	21.8%	23.7%	29.7%
	North American Investor	7.71%	22.3%	40.8%	26.2%
II-BA	Full Investor	4.55%	20.0%	16.4%	26.1%
	Non Asian Investor	3.81%	19.7%	26.2%	27.1%
	North American Investor	5.63%	20.7%	44.4%	29.0%

Note:

The definitions of investor agent types can be found in Table 3.1. 1) Full Investor: This investor agent can buy all of the ten international stock indices, 2) Non-Asian Investor: This investor agent cannot buy Nikkei (Japan) and Hang Seng (Hong Kong) Indices and 3) This Investor agent can only buy NASDAQ and TSX (Canada) Stock Indices.

5.5 Chapter Summary

This chapter presented and discussed the simulation results. The base scenario is used as a control to help evaluate the consequences associated with the introduction of institutional land investors in the three alternative scenarios. The introduction of institutional investors raises farmland prices because they bring financial asset valuation to this land market. Increased farmland prices can, in turn, lead to higher farm debt, with slightly more involuntary exits of farmers. On the other hand, the introduction of institutional investors provides more capital for retired farms. I find that remaining farms will operate on more rented land to increase farm scale over the duration of the simulation with or without institutional investors. As a result, off-farm investors have minimal influence on farm expansion because farmland rents are very similar among four scenarios.

We find that farm succession keeps significant amounts of farmland within the control of extant farmers, at least for the period studied. In the simulation, 80% of the remaining farms experienced at least one round of successful farm succession. We also find that even if investors take unrealistically active roles in the Saskatchewan farmland market, their proportion of owned farmland is never more than 12%, save for the most aggressive or extreme investor scenario (II-BA), where the proportion was found to be as high as 36.3%.

CHAPTER VI: SUMMARY AND CONCLUSION

6.1 Summary

The basic structure of Anderson's (2012) agent-based simulation model is retained, but in this thesis I add two important model computational modules: 1) a module describing institutional investor agents as well as their participation in farmland markets, and 2) a detailed module of inter-generational farm succession. In the institutional investor module, heterogeneous institutional investors buy and hold farmland in order to improve the efficiency of their portfolios with different asset preferences. In this capacity, they bid against farmers and other institutional investors in auctions for farmland. After purchasing farmland, the institutional investors lease farmland back to the remaining farms. In the farm succession module, once a senior farmer decides to retire, he/she turns to his/her heirs whose gender, off-farm income and age are simulated based on actual current demographics. Subsequently, each simulated heir determines his/her willingness to take over the farm based on a formula (generated using a survey). In the end, one and only one heir with the highest willingness takes over the whole farm, and the new younger farmer replaces the senior farmer. Otherwise if there are no farm heirs, for example, the farm then exits the industry, and the retiring farmer's land passes into the farmland auction market.

Major stochastic variables in the model include seven crops (i.e. yields) and associated commodity prices. These include annual crop, hay and cattle prices as well as ten major world stock indices. In the bootstrap style process used to generate data for the simulation, farm crop yields are assumed to be correlated with each other but temporally independent of commodity prices and stock indices and autocorrelated with stock indices. World stock indices are also both autocorrelated and correlated with each other. A total of one hundred time paths, comprising 30 years of farm prices and yields are generated in this manner to be used in the simulation analysis.

Four different scenarios are developed using the simulation code and the data. These are, 1) no institutional investors (called the base); 2) institutional investor bidding on big land plots (II-BB); 3) institutional investors bidding on any farmland available, but limited to a 30% probability of entering the auction (II-BP); and 4) institutional investor bidding in every farmland auction (II-BA). As mentioned, each scenario is run 100 times over a 30 year simulation period using identical time paths of the generated data as input. A summary table of the 30 year simulation results can be found in Table 6.1.

Assuming transparent farmland auctions, compared to the base scenario, the participation of institutional investors drives up farmland prices. On average, farmland price per acre increases by $100 (to about $450) versus when investors are excluded from bidding. However, farmland rental values do not change significantly. As a result, increasing farmland prices motivate farms to gradually concentrate more on available rental land when considering production expansion. Due to falling rental costs as well as stable rental land supply with the presence of investors, we find that in all three alternative scenarios with institutional investors, higher farm assets and net worth are realized as well as slightly higher grain production. However, higher borrowing capacity caused by higher asset value leads to slightly more bankrupted farms in the alternative scenarios. Not surprisingly, we also find that holding farmland improves the portfolio structure of institutional investors through the simulation era.

Table 14: Summary of 30-year Simulation Results: 2014 and 2044

Year	Scenario	Farmer Age	Farm Number	Farm Exits and Transfer				Land Tenure	
				Involuntary Exits	Insufficient Cash	No Successor	Successful Transfer	Farm Size	% of Owned Acreage
		(Year)		(Number)	(Number)	(Number)	(Number)	(Acres)	(%)
2014		51.1	717	NA				1,533	68.90%
2044	Base	47.1	368	56.2	175	118	360	2,946	50.7%
	II-BB	47.1	355	65.3	178	120	348	3,038	49.9%
	II-BP	47.1	352	66.9	180	119	348	3,072	49.2%
	II-BA	47.1	349	68.9	180	120	346	3,093	48.7%

Year	Scenario	Farm Finance			Grain Acreage	Farmland Market		Proportion of Investor-purchased Land	
		Farm Asset	Farm Debt	Farm Equity		Farmland Price	Farmland Rent	CAR 1A	Land on Market
		($1 Million)	($1 Million)	($1 Million)	(Acres)	($)	($)	(%)	(%)
2014		2.42	0.49	1.94	1,275	1,526	57.0	NA	
2044	Base	6.68	0.27	6.41	2,948	1,184	45.0	NA	NA
	II-BB	7.10	0.33	6.78	2,997	1,356	39.9	5.31%	31.1%
	II-BP	7.69	0.32	7.37	3,049	1,498	41.5	11.3%	50.0%
	II-BA	7.76	0.32	7.44	3,076	1,596	42.4	36.3%	82.4%

Note:

1. The average grain production acreage is the average of pure grain and mixed farms.
2. The proportion of Investor-owned Land is the percentage of farmland being bought by the investors.
3. CAR 1A under "Proportion of Investor-owned Land" is the proportion of farmland in the simulating area (CAR 1A) held by the investors by the year 2044.
4. Land on Market under "Proportion of Investor-owned Land" is as follow:

$$Land\ on\ market = \frac{Farmland\ purchased\ by\ investors}{Total\ farmland\ for\ sale}$$

The major differences among the scenarios are farmland prices, land tenure and numbers of farms. In general, with higher farmland prices, we observe a greater proportion of rented land as well as reduced farm numbers overall, along with more intensive investor participation in the farmland purchase market. But overall, the introduction of outside investors does not seem to adversely affect the profitability of the farming sector.

The process of farm succession used here keeps much of the extant farmland under farm ownership. On average, more than 80% of the surviving farms in the simulation experience at least one round of family succession, while survivors tend to have larger and more efficient farms with the use of available rented land. Moreover, likely due to the initial data we used indicating that older farmers are more likely to operate smaller farms, we find the average simulated farmer age eventually drops from 51 to 47 years.

6.2 Conclusions

Under the most extreme model assumptions for investor behavior, I find that unconstrained institutional investing in farmland (counterfactual II-BA) will eventually dominate regional farmland ownership (controlling 36.3% of available farmland). However, this shift does not seem to affect overall farmer financial well-being or operations. Offsetting the presence of institutional investors is the fact that farm succession still keeps the majority of simulated farmland under farmer control, while the gradual shift from purchasing to renting farmland protects farms from being harmed by gradually rising farmland prices. Even in the II-BA scenario where institutional investors purchase considerable amounts of farmland, they appear to have limited impact on farming *per se*. A summary of the effects generated by institutional investors is presented in Table 6.2.

Table 15: Effects of Institutional Investors on Agriculture

Market Attendent	Effect
Institutional Investors	Better Portfolio Efficiency
Retired Farmers	More Retire Pension from Farmland Selling
Existing Farmers	Cheaper Access for Expansion
Farm Successors	No Significant Impact

I also find that institutional investors can generate better portfolio bundles (as shown in Table 5.14) and in general, their investment portfolio becomes about 5% better off, in terms of the Sharpe Ratio (return/risk ratio). Of course, retired or exiting farmers also gain by rising farmland prices. In the simulation, remaining farmers adjust to increasing farmland purchase prices by gradually shifting from land ownership to land rental for farm expansion, ultimately building up their final net worth.

The introduction of institutional investors into farmland purchase markets pushes up farmland prices but this possibility seems to have a minimal impact on farming in terms of sectoral production and overall farm financial health. However, it does eventually shift farm expansion towards reliance on land rentals.

In essence, increased farmland values increase the value of farmland already owned as well as the farmer's ability to borrow against their land, but through the simulation, it becomes gradually more difficult to purchase farmland, a situation that could potentially lead to increased farm debt and associated greater risk of bankruptcy. That this does not occur in the simulation appears to be due to two effects. These are: 1) the role of farmland succession from one generation to the next, providing wealth and stability to those who remain in farming; and 2) the (assumed) relative stability of farmland rental markets that are under investor control.

Given the latter situation, the overall impact of institutional investors on future farming will necessarily be subtle. Continued farm success will be contingent on farmers being willing to adapt and rely more on rented land for farm expansion. However, the assumption made here about open land rental access and the transparency of farmland rental auctions is significant. If a higher level of price discrimination or informational/transaction costs are somehow placed on the external investors in the land market, this can create an additional cost to renting farmland that could affect how easy I assumed farmers could rent investor purchased farmland. Thus the provision of a transparent farmland market, as opposed to one that prevents or blocks external investment appears to be another way to promote higher farmland valuation, greater farm wealth and positive agricultural sector development. On the other hand, once land price inflates due to the presence of investors, farm loan providers will need to be wary in evaluating farm borrowing capacity since increased farm asset value will no longer be associated with increased farm productivity. Furthermore, one last potential problem with investors is that because of their decision making processes, institutional investors will almost certainly generate noticeable variation in farmland prices.

Finally, we hope the reader agrees that agent based simulation modeling (ABSM) is a useful agricultural economic methodology that can help shed light on potential structural changes in agriculture. These include allowing the researcher to track simulated farm numbers, individual financial positions and farm productivity, as well as overall agricultural system stability. Heterogeneity in both landscape and agents, along with the inherent dynamics of farm agent behavior and the set of external random variables, the complex interactions among different agents and external inputs all combine to create a complex economic system. Given these factors, the use of ABSM is necessary in order to bettter understand and forecast future real world outcomes.

6.3 Limitations

There are several key limitations that constrained this research. To start, institutional investors are assumed to hold and never sell all owned farmland over the duration of the simulation. Although there is no publicly available data showing any farmland investors selling farmland in Saskatchewan, and chances are that another institutional investor instead of a farmer will buy the land, it is still possible that investors might sell their farmland to incorrect expectations. In addition, due to time constraints, farmland speculators are not allowed in the investor module. Their presence in reality is certainly possible because of the limited liquidity of farmland. In any case, as a result the simulation likely underestimates farmland price fluctuations that could arise after the introduction of institutional investors.

In reality, institutional investors are not likely to participate in all large plot sales or even limit their bidding on some fixed proportion (say 30%) of land auctions. As a result, the alternative scenarios likely overestimate the activities of institutional investors. Meanwhile, our choice of just three investor agents in the model might be insufficient to represent all potential global investors, while investor asset bundles could expand to broader investments such as futures and urban real estate. The next iteration of this model requires a more reasonable and defensible participation level of institutional investors, requiring at a minimum additional investor agents along with other assets in their portfolios.

A complete representation of farm succession should also include asset prices because higher farmland prices with investors might attract more heirs into taking over family farms. Moreover, retired farmers might wait for these farmland price increases. Future research should consider farmers' speculative expectations as part of the succession module.

Due to limits of computational capacity as well as data availability, the area researched was restricted to the CAR1A region in Saskatchewan. In fact, it is highly likely that farmland and farmland markets differ considerably across different regions even within Saskatchewan, much less across different Canadian provinces. As a result, the limited representativeness of CAR1A restricts the broader applicability of this study and my results, meaning that moving forward ideally the researched area should be expanded to include the whole province.

Technology improvements and climate change factors are explicitly not included in the simulation, and therefore the generated farmland prices across the four scenarios are relatively stable. However, technological improvements will increase long-run farmland prices because of increases in net income (Klinefelter, 1973) and it is also highly likely climate change consequences will also have an effect on farmland values through the modelled era (Darwin, 1999). Hence, if institutional investors are introduced into land markets, farmers will have to share land value appreciation with investors, but of course their originally owned land will also be more valuable. As a result, whether farmers can appropriate any land value appreciation is still difficult to know. In future research, different scenarios comprising technology improvements as well as climate change need to be introduced to help address their effects on farm structure.

Finally, the software (Repast©) used for the simulation had both positives and negatives for this researcher. While incredibly flexible for research applications, Repast is not nearly as user-friendly as some other more popular agent based software such as Netlogo© or AnyLogic©. To code in Repast, Java language knowledge is required, and this knowledge had to be gained as the research progressed. At times some assistance was needed with more detailed programming tasks. And due to limited time and resources, my coding in many instances is not particularly computationally efficient, meaning it takes a non-trivial amount of computational time to simply run through the simulation. In the future, I am sure that coding improvements would be helpful to save model run time.

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APPENDIX A: OVERVIEW OF THE ANDERSON MODEL (2012)

A.1 Introduction and Assumptions

This section is a summary of Anderson (2012)'s work on modeling farmer agents. Following 2.5, ABSM is the best methodology to depict the heterogenetic farmers with different age, type, size and utility. However, they share similar behavior and accounting for farm businesses and expectation for the future, which makes them being plausible to model. As stated in the previous section, we have three types of farmers, pure grain farmers, pure beef farmers and mixed farmers as they are major types in Saskatchewan.

In the model, we assume that the type for farms are rigid and it will not change over time or during succession. Theoretically, pure grain farms occupy large scale of farmland with a higher return of scale on producing a crop, while pure beef farms are interested in a marginal land with the better productivity of beef compared with mixed farms. In farmland and resource bidding stage, pure grain farms will have a competitive advantage on bidding farmland, so as to pure beef farms on hay and marginal land.

Before the optimization, all farmer agents are screened for their liquidity and pre-retirement conditions if they are less than fifty-five years of age. Those who fail the initial check or are 55 or older will enter the second stage, tactical optimization LP model. Otherwise, Stage two farmers will pursue the maximization of short-time profit from production subtracting cost and machinery. After farmers have known the yields and prices, all farmers with cattle proceed to the third stage of recourse decisions and minimize ration and feeding costs.

A.2 First Stage: The Strategic MIP

Following Anderson (2012), in the first stage of decision making, a Mixed Integer Programming (MIP) model is used to make long-run decisions to determine 1) sunk costs and 2) re-conversion costs. Long-run strategic decisions include 1) perennial crops, 2) machinery investment, 3) herd size and land acquisition.

Following Schoney (2010), the long-run strategic investment decision is the following:

$$\max_{I_0} NPV = -I_0 + B_0 + \sum_{t=1}^{n} \left[\frac{NOI_t - Taxes_t - P_t - FL_t - Rent_t - R_t}{(1+d)^t} \right] + \frac{V_n}{(1+d)^n}$$

(A.1)

Where: d_t is the real, after-tax, nominal opportunity cost of capital

n is the planning horizon,

I_o is the investment capital outlays,

(Land and machine are integer variables),

B_o is the amount externally financed (borrowed),

NOI_t is the net operating income from farming activities,

P_t is the principal payment on borrowed capital,

Fl_t is the annual family living expenses,

Ren_t is the total land rent of the farm,

R_t is the net machine replacement of existing machine, purchases fewer sales and

V_n is the ending value of all assets.

A.2.1 An Overview of the Strategic MIP Model

Anderson (2012) modified to maximize the annual equivalent by lying emphasis on actual cash flows. An example of a standardized matrix of MIP model without considering a variety of crops, land quality, technology and farm size.

Since the equipment is a capital-consuming asset for the farm, it is important for the farms to pick up the right machine to fit their farm size to achieve cost efficiency. Moreover, farmers must consider potential expansion of their farms. Thus, in this stage, the machinery sizing problem will be another critical issue for long-run crop land use decision.

According to Anderson (2012), Stage-one optimization, Z^1, occurs at the beginning of each period, namely spring. In Z^1, the farmers will maximize:

$$\max_{X,T,L,B,Fd,integer:Q,M,K} Z^1 = CX - RQ - VX_j^{Jm} - F^J M + C^L L + C^{\Delta L}\Delta L + DT - C^{Fd}Fd - F^L K - rB \tag{A.2}$$

Where: X is the acreage in annual, forage, crops and energy crops.

Q is the plot of land rented in or out,

X_j^{Jm} is the acres of machine operation,

M is the acres of ownership,

T is the forage feeds sold or purchased,

L is the numbers of herd,

ΔL is the change of herd size,

Fd is the amount of feed,

K is the herd facility capital requirement,

B is total borrowing,

C is the annualized cost,

R is the rent of land,

V is the variable cost of machine operation,

F^J is the machine ownership cost,

C^L is the herd gross margins apart from feed costs,

$C^{\Delta L}$ is the expansion/contraction cost,

D is the forage sales/ returns,

C^{Fd} is the feeding costs,

F^L is the real cost of capital and

r is the interest rate.

The MIP constraints are the following:

1) The total acres farmed (X) must be less than or equal to the total of all rented and owned land (Q^+).

$$X\text{-}Q^{+} \leq Owned$$

(A.3)

2) All annual crops require machinery system capacity. Total requirements X^J_j must be less or equal to the total operation of machines used, X^{Jm}_j. It is essentially a transfer row.

$$\sum_{j=1}^{n}(X_j^J - X_j^{Jm}) \leq 0$$

(A.4)

3) The next equation requires that the total machine capacity actually used less than the total available machinery package capacity: $\beta^m M_j^{Jm}$. Note that M_j^{Jm} is an integer variable indicating the number of packages. The constraint is

$$\sum_{j=1}^{n}(X_j^{Jm} - \beta^m M_j^{Jm}) \leq 0$$

(A.5)

Where: β^m is the package average machine system capacity.

4) The total feeding consumed cannot be greater than the amount of feeding both purchased and produced. Moreover, more mega calories must be provided to the livestock than the requirement to maintain the beef herds.

$$-T + Fd \leq 0 \tag{A.6}$$

Where: T is the total feeding providing to the herd.

$$-McalFd + Mcal(\Delta L + L) \leq 0 \tag{A.7}$$

Where: Mcal(L) is the minimum requirement to maintain the beef herds.

5) The change in livestock number, namely expansion of herd size related with acquisition cost and contraction caused by culling and selecting. It is assumed that the combination of contraction, expansion, and non-feed, herd operation costs of the beginning, herd size is less than or equal to the current herd size.

$$L - \Delta L^{+} + \Delta L^{-} \leq Cows \tag{A.8}$$

Where: L is the initial herd size,

ΔL^{+} is the increment herd,

ΔL^{-} is the subtracted herd and

Cows are the current herd size.

6) Similar to (3.2.2.5), the whole facility and labor capacity should be greater than or equal to the capacity needed for keeping the herd.

$$-\partial K^{L} + (\Delta L + L) \leq F \tag{A.9}$$

Where: ∂ is the amount of labor, machinery and handling system to keep 300 cows and

F is the initial facility endowment.

7) For each type of the farmers, the amount of cash outflow must be less than or equal to the total cash stock plus net borrowing.

$$CF - B \leq cash \tag{A.10}$$

8) The last constraint is a predetermined critical debt to asset ratio. By assuming rationality, farmers cannot overinvest to pass this red line. Namely,

$$\delta\left(I + R + \left(F_m^J M_m^J\right) + L + F^L K^L\right) + B \leq Equity \tag{A.11}$$

Where: δ is the critical debt to asset ratio,

I is the initial investment on energy crop,

R is the payment of farmland rent,

F^J $\mathbf{F_m^J}$ is the cost of machine,

M_m^J $\mathbf{M_m^J}$ is the number of machine units,

F^L is the fixed costs of the beef cow machinery, handling and labor,

K^L is the number of beef cow machinery, handling and labor and

Equity is the total equity a farm has.

A.$-\partial K^L + (\Delta L + L) \leq F$ 2.2 Second-Stage (Tactical LP)

The second-stage decision, Z^2 is a tactical decision process to make only short-term profit maximization without taking expansion into account. The Second-Stage Tactical LP is based on farmers' expectation of future yields and crop prices.

$$\max_{X} Z^2 = CX_j^{Jm} \tag{A.12}$$

Subject to:

$$X_j^{Jm} \leq total\ cropland \tag{A.13}$$

A.2.3 Third Stage (Recourse LP)

The third stage, Z^3, is about livestock feeding problem. Feeding cost is supposed to minimize the feeding cost subject to the herd nutrient requirement, which is determined by the trade-off between purchasing hay and feeds and produce them internally. However, extreme conditions such as adverse weather may both decrease the productivity of feeds and rocket the price, thus generate a negative impact on farm cash flow. The Stage Three LP problem is:

$$\max_{t,Fd} z^3 = DT - C^{Fd}Fd$$

(A.14)

Subject To:

$$-T + Fd \leq 0$$

(A.15)

$$-McalFd \leq Mcal(\Delta L + L)$$

(A.16)

The maximization problem is subject to the feeding transfer constraint as shown in the previous section.

A.2.4 Farmer Agent Business Accounts

Anderson (2012) generated some methodologies to calculate the financial situation, which will also be inherited and applied in this paper. At the end of the year, we achieve the actual production and each farmer agent calculates their total gross income and total expenses, including debt repayments for the year for all enterprises of the farm. This section presents the year-end structural accounting equations and other business related activities of the farmer agent. The following diagram (Figure 3.2) shows how the three stages and all the business related accounts interact in the model.

In the following section, subscripts are used to denote activity or enterprises use or affiliation.

A.2.4.1 Gross Farm Accounting Income

Total gross farm income includes gross income from sales of annual crops (GI_{AC}), calves and cull cows GI_{LS}, hay sales (GI_H), energy crops (GI_{EC}) and stabilization programs (GP_{IS}).

$$TGI = GI_{AC} + GI_{LS} + GI_H + GI_{EC} + GP_{IS} \tag{A.17}$$

Gross income generated from annual crop production is calculated using the stochastic yield (bu/acre), and stochastic prices ($/bu) for each annual crop sowed based on total harvested acres.

$$GI_{AC} = Y_{Cj} * P_{Cj} * Acres_{Cj} \tag{A.18}$$

Where: Y_{cj} is actual yield per acre of crop j.

P_{cj} is current price of crop j and

$Acres_{cj}$ is acres of crop *j*.

The gross income generated from beef cows comes from the annual sale of the calf crop and any cull cows sold off and replaced during the year. However, the gross income is based on an average weight per calf of 495 pounds[14]. This is then multiplied by the current market price per calf multiplied by the size of the herd. For pure annual crop farms that produce hay, their income from performing this activity is calculated here.

$$GI_{LS} = 495lbs * P_{calf} * Herd_{size} \tag{A.19}$$

$$GI_H = T_{hi} * P_{th} \tag{A.20}$$

Where: *495lbs* is weighted average of beef cows sold in pounds,

P_{calf} is average price of beef cows sold,

$Herd_{Size}$ is total herd size of the farmer,

T_{hi} is total tons of hay (improved baled or hayland baled) and

P_{th} is the current price per ton based on the local forage market.

[14] The Western Beef Development Center estimated average weaning weights of 523 and 565 pounds in 2003 and 2006 respectively for an average of 550 pounds per calf. Saskatchewan Agriculture and Food (1999) estimate a 10% death loss bringing the average calf weight to 495 pounds.

Not all energy crops produce the same yearly return as their return varies across their life-cycle. However, if it is a harvest year, gross income is calculated in the same manner as annual crop production.

$$GI_{EC} = Y_{ec_i} * P_{ec_i} * Acres_{eci}$$

$$GI_{EC} = Y_{ec_i} * P_{ec_i} * Acres_{eci}$$

(A.21)

Where: Y_{eci} is total yield of energy biomass crop i in oven-dried tones,

P_{eci} is price per oven-dried ton of biomass crop I and

$Acres_{eci}$ is the total acres of energy crop i harvested this year

A.2.4.2 Total Farm Accounting Expenses

Total farm expenses include all the farm operations including annual cropping, beef cows and energy crop enterprises as well as interest payments and hired custom work[15]. Fixed costs related to each farm enterprise include the debt payment portion of the fixed cost as well as the allowable depreciation expense.

$$TFE = AC_e + L_e + EC_e + Depr_{FA} + D_p + C_w$$

(A.22)

Where: *TFE* is total farm expenses,

AC_e is total annual cropping expenses,

L_e is total beef cow expenses,

EC_e is total energy crop expenses,

$Depr_{FA}$ is related depreciation expense on all depreciable farm assets,

D_p is interest on debt and

C_w is total expense of custom work hired out.

The total expenditures related to annual cropping include variable costs per acre, operating variable costs per acre of machinery, variable cost per ton to account for miscellaneous costs including transportation and freight charges of each crop as well as the lease rate per acre of any rented cropland. The annual cropping expenses become:

[15] The other component of debt service, principal payment is a cash outflow however.

$$AC_e = VC_{cj} * Acres_{cj} + VC_{mj} * Acres_{mj} + T_{cj} * VC_{t_{cj}} + Acres_l * r_l$$

(A.23)

Where: VC_{cj} is the variable cost per acre for annual crop j,

$Acres_j$ is the total acres sowed of annual crop j,

VC_{mj} is the variable cost per acre for machine option j,

$Acres_{mj}$ is the total annual crop acres used by machine option j,

T_{cj} is the total tons of annual crop j produced,

VC_{tcj} is the Variable Cost per ton of annual crop j,

$Acres_l$ is the total annual crop acres leased and

r_l is the rental rate of cropland rented in.

Beef cow expenses include all expenditures related to beef cow and forage production related activities. However, this excludes the cost of breaking land for forage production.

$$L_e = VC_{pi} * Ac_{Pi} + VC_{bi} * Ac_{hi} + n_c * VC_{cow} + n_{cl} * FC_l + Ac_l * r_l + T_{hi} * P_{th} + T_{hi} * VC_t + T_{hi} * VC_t$$

(A.24)

Where: VC_{pi} is the variable cost per acre associated with pasture type I,

Ac_{pi} is the total acres of pasture I,

VC_{bi} is the baling variable cost per acre of pasture type I,

Ac_{hi} is the total acres of hay production from pasture I,

n_c is the total herd size,

VC_{cow} is the variable cost per cow,

n_{cl} is the number of full-time cow laborers required,

FC_{cl} is the fixed cost per full-time cow laborer of $9,000,

Ac_l is the total annual crop acres leased,

r_l is the rental rate of cropland rented in,

T_{hi} is total tons of hay (improved baled or hayland baled),

P_{th} is the current price per ton based on the local forage market and

VC_t is the variable cost per ton of hay.

A.2.4.3 Government Programs

An essential component of analyzing the structural change in agriculture and the competitiveness of new farm enterprises with existing ones are the government programs available to farmers. Government programs or farm safety nets are triggered when farm agents suffer from low farm income and poor yields. The government programs used in this model follow the basic rules of *Crop insurance*, *AgriStability* and *AgriInvest*, and we simplify the procedure for ease of modeling. The *crop insurance, AgriStability and AgriInvest* sections of this thesis have been adopted from additions Stolniuk (2008) made to his NetLogo© model entitled "*Model Additions After Thesis*" (2008b). Government programs influence farmers' expectations and their ability to compete in the marketplace. This section outlines the various government programs used in the simulation.

A.2.4.4 Crop Insurance

Poor yields will trigger *crop insurance* payouts to farm agents with *crop insurance* coverage. A farmer's total *crop insurance* premium is a part of their variable expenses for each particular annual crop depending on coverage level. These premiums are based on reference values from each farmer agent's level of coverage and historical yields from previous years (Stolniuk 2008b). *Crop insurance* payouts are also based on each producer's level of coverage. The farmer agent's expected yield builds upon the weighted average of their previous five-year crop data. The standard of coverage for each farm is assigned randomly according to the following generated by Stolniuk (2008b) 1) 4.4% of farmers having no coverage, 2) 13.6% of farmers having 60%, 3) 34.1% of farmers having 70% and 4) the remaining 47.9% of farmers having 80% coverage. For modeling simplicity, this level of coverage is set at initialization and thus remains constant during the entire simulation period.

Each farm agent calculates their total premium paid according to the total liability encountered by *crop insurance* for each crop. Total liability is the expected insurance crop yield, historical yield index, insurance coverage level of the farmer and the current market price of the commodity. Total liability is on a per acre basis for each crop.

$$TL_j = IY_j * QI_j * P_j * IC$$ $$TL_j = IY_j * QI_j * P_j * IC$$

(A.25)

Where: TL_j is the total liability for crop j on the plot,

IY_j is the insurance expected yield for crop j,

QI_j is the yield index for crop j on the plot,

P_j is the current market price of crop j and

IC is the insurance coverage of the farmer currently farming the plot.

The total premium per acre is then the total liability multiplied by the premium calculated for that specific crop based on the level of coverage of the farmer. Following Stolniuk (2008b), we calculate the premium for each crop and coverage level using historical price and yield data to the CAR. The premiums will result in the long-run goal for *crop insurance* of breaking even, assuming that the producers pay 40% of the premiums, and the government pays the rest 60% (SCIC 2012).

$$\mathrm{T}P^{Plot} = \sum_{j=1}^{7} TL_j PR_j$$

(A.26)

Where: TP^{Plot} is the total premium of the plot and

PR_j is the premium for crop j based on the coverage level of the current farmer

The total premium paid by the farmer agent is then the sum of all crop acres in their control (Stolniuk 2008b). We calculate total *crop insurance* payout for each plot and then the farmer sums all the plots in their control. To calculate if a farmer agent is eligible for a crop insurance payout, the farmer agent determines the total insured production for the plot of each commodity.

$$IS_j = IY_j * IC * QI_j$$

(A.27)

Where: IS_j is the insured production of crop j for the plot.

Once the actual yield is known, we subtract actual yield from the insured yield, multiplied by the current market price as well as total crop acres of that crop. If the payout is negative, there will be no payment . However, if the calculation is positive, farmer will receive a payout from *crop insurance*.

$$CIP_{Cj} = \sum_{j=1}^{7} (IS_j - AP_j) * P_j * Acres_{Cj} \tag{A.28}$$

Where: CIP_{cj} is the total *crop insurance* payment for crop j on the plot and

AP_j is the actual production of the crop on the plot.

A.2.4.5 Net Cash Flows

Monitoring cash flows in farming are necessary because the industry is extremely capital intensive. Therefore it is essential that farmers maintain positive cash flows including enough to cover income taxes and the minimum family living withdrawal. Net cash flow is as follow:

$$CashFlow = Cash + NFI + OFI - Income_{taxes} - Family_{Living} \tag{A.29}$$

Where: *OFI* is off-farm employment income of the farm family,

$Income_{Taxes}$ is the amount of income taxes paid and

$Family_{Living}$ is the family living withdrawal.

A.2.4.6 Income Taxes

After we deduct the total farm expenses from the total gross income, we will achieve net farm income and add to farmer cash account. Also, the farmer will pay income taxes from the net farm income amount. For model simplicity, the income tax rate is constantly 20%.[16] Income taxes paid is deductible from each farmer's cash account. Thus, the income tax calculation is as follows:

$$Tax_{Income} = NFI * Tax_{rate}$$

[16] The income tax rate is based upon a weighted average of the small business tax corporate rate for Saskatchewan of 2 % and the regular rate of 12 % (CRA 2015) and the 2008 federal small business corporate tax rate of 11 % and regular rates of 15 % which stated to implement from January 2015 (CRA 2015) thus a simplified 18 % rate is used.

(A.30)

Where: Tax_{Income} is the amount of income tax paid by farmer I,

NFI is the net farm income of the farmer and

Tax_{Rate} is the total income tax rate.

After deducting the income tax, we add off-farm employment income to the cash account. Off-farm income does not have income tax deducted from it since we assume it is deductible. We generate off-farm income by a probability factor at model initialization. Smaller farms have a higher probability for off-farm income than larger farms. Finally, we subtract family living costs from the remaining cash flow.

A.2.4.7 Non-Land Asset Valuation

Capital farm assets including annual cropping machinery, beef cow machinery and beef cow handling systems depreciates following the same method used by Stolniuk (2008). This depreciation method allows the remaining capital value to depreciate at a constant rate except for 50% of the capital value following the first year rule. Based on Schoney (1980) the estimated parameter of 0.948 uses a larger depreciable amount in the first year assuming new machinery. According to the following formula, the current market value is:

$$V_n = V_0 * 0.948 * 0.901^n \tag{A.31}$$

Where: V_n is the capital asset value at n years,

V_0 is the new capital asset value and

n is the years of the capital asset value.

A.2.4.8 Family Living Withdrawals

There is a minimum family living expense that must be deducted from cash each year to cover basic family living requirements of the farm family. However, following Stolniuk (2008) farm families also have an increasing propensity to consume. The farmers increasing the propensity to consume a portion of the profits is built into the simulation as well. Therefore the living expense deducted is the larger value of either the minimum family withdrawal amount or the propensity to consume. However, propensity to consume farm profits eventually diminishes and an upper bound is placed on family living withdrawal. The remainder of farm profits is reinvested back into the farm. The family living expense is as follows:

$$Family_{Living} = Max(Fam_{min}, \delta NFI) \tag{A.32}$$

Where: Fam_{min} is the minimum family living withdrawal,

δ is the propensity to consume farm profits and

NFI is the net farm income or retained earnings before new investments.

A.2.4.9 Balance Sheet

As in any business entity, balance sheets must be updated and maintained to track changes in owners net worth and liabilities of the farm. The balance sheet in this model includes changes in asset values such as land value, inventory value of cows, capital, cash flows as well as the farmer's remaining debt. Total farmer's equity is:

$$Farm\ Net\ Worth = \sum_{t=1}^{n} Assets - \sum_{t=1}^{n} Debt \tag{A.33}$$

The land value of each farmer is calculated using the current market price of land times the average land quality divided by the average productivity rating multiplied by total acres owned. Capital value includes the annual crop machinery options and the beef cow equipment and handling system of each farmer. Capital values are updated yearly to reflect new purchases, sales of old capital as well as the loss in depreciation. Total beef cow value is calculated as the herd size times the price of a cow multiplied by an average cow weight of 1300 lbs. The calculation of total assets is:

$$\sum_{t=1}^{n} Assets = Land_{Value} + Capital_{eq} + Cash + Cow_{Value} \tag{A.34}$$

Where:

$Land_{Value} = \frac{P_L * Avg_{Land}}{Avg_{Prod} * Acres_{owned}}$

$Capital_{eq} = Machine_{ac} + Livestock_{eq_{Value}}$

$Cow_{Value} = n_{cows} * P_{cow} * 1300lbs$

Total debt of each farm agent is updated each period to reflect new debt taken on during the year as well as any old debt that has been reduced through principal payments. Updated debt is calculated as the following:

$$\sum_{t=1}^{n} Debt = Debt_{old} + Debt_{new} - Principal_{pay} \tag{A.35}$$

Where: $Debt_{Old}$ is any previously held debt,

$Debt_{New}$ is any newly obtained debt and

$Principal_{Pay}$ is the principal payment made on old debt.

APPENDIX B: FARM SUCCESSION QUESTIONNAIRE RESULTS

Table B.1 Regression Results, Farmland Succession Questionnaire

Variable	Coefficient	Std. Error	t-Statistic
Owned Acres/ Total Acres	0.02	0.03	-0.90
Log(Land)	0.06	0.07	0.80
Gender (0 = Male)**	-0.15	0.07	-2.25
Income	-0.05	0.11	-0.42
Type* (1 = Pure grain farm, 2 = Pure beef farm and 3 = Mixed farm**	-0.23	0.07	-3.26
Constant	0.68	0.30	2.23
Adjusted R-squared	0.23	**F-statistic*****	4.75

The result from the regression at least partially validates the previous literature. Initially, the signs appear as expected. Farms with more land owned, a male heir, higher off-farm income, and pure grain type possess a higher likelihood of succession, with a basic succession probability of 0.678. However, we note that 3 out of 6 coefficients are not statistically significant. Apart from possible sample bias and a limited number of respondents, the targeted respondents for the survey measures student intentions to operate their family farms rather the intentions of more senior farm operators, the latter of whom must have a greater influence on forming succession plans. In effect at the time of the survey, these students might not have made up their minds yet over future career goals, rendering the data potentially less reliable.

APPENDIX C: AN EXAMPLE OF PORTFOLIO CONSTRUCTION AND FARMLAND VALUATION

In the model, institutional investors can invest in risk-free bonds (three-month bond from the Bank of Canada), farmland and international stock indices. For a clearer exposition of this specification, we construct an example to show the detailed steps. In the example, the investor attempts to construct optimal portfolio bundles. The investor initially computes beta and uses the beta value along with CAPM to determine their bidding price for farmland, considering future capital gains and land rents.

Risk-free bonds and nine international stock indices such as the Dow Jones and TXS are available to the investor. Here, we construct hypothetical portfolios from 1978 to 2013 in Table 1.

Table C.1: Example of an Optimal Portfolio

Indices	US	Hongkong	Japan	UK	Germany	France	Spain	Canada	Australia	Risk-free
Proportion	23.22%	57.02%	0.00%	19.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Var-Cov Matrix	3.22%	3.93%	2.57%	2.96%	3.23%	2.79%	2.46%	2.67%	2.85%	0.03%
	3.93%	16.95%	6.27%	5.58%	3.56%	4.20%	4.59%	5.58%	6.52%	-0.01%
	2.57%	6.27%	6.79%	2.68%	3.40%	2.80%	3.30%	2.77%	2.83%	-0.12%
	2.96%	5.58%	2.68%	6.69%	4.29%	3.46%	2.87%	3.02%	4.76%	-0.04%
	3.23%	3.56%	3.40%	4.29%	8.80%	5.84%	4.53%	2.93%	3.89%	0.01%
	2.79%	4.20%	2.80%	3.46%	5.84%	5.84%	4.13%	3.20%	4.39%	0.06%
	2.46%	4.59%	3.30%	2.87%	4.53%	4.13%	7.27%	2.61%	3.63%	0.09%
	2.67%	5.58%	2.77%	3.02%	2.93%	3.20%	2.61%	4.43%	4.04%	-0.10%
	2.85%	6.52%	2.83%	4.76%	3.89%	4.39%	3.63%	4.04%	7.02%	-0.05%
	0.03%	-0.01%	-0.12%	-0.04%	0.01%	0.06%	0.09%	-0.10%	-0.05%	0.09%
Averag Excess Return	2.64%	8.61%	-0.58%	3.83%	0.06%	2.14%	2.76%	2.50%	1.91%	2.16%

The next step is to calculate the beta value and reserve bidding prices for farmland by using historical rents and capital gains of a CAR1 plot. The results and associated investment decisions are presented in Table 2.

Table C.2: Beta and Bidding Prices from 1986 to 2013

Year	Variance	Beta	Return	PV	Investor's Bid	Farmers' Bid	Decision
1987	0.13	-0.02	45.72	585.53	585.53	339.92	Buy
1988	0.12	-0.02	39.58	439.00	439.00	326.23	Buy
1989	0.12	-0.02	32.45	281.54	281.54	326.23	Don't Buy
1990	0.11	-0.02	26.00	211.29	211.29	323.95	Don't Buy
1991	0.11	-0.02	20.29	242.46	242.46	302.28	Don't Buy
1992	0.10	-0.03	8.24	133.37	133.37	290.87	Don't Buy
1993	0.11	-0.02	-0.05	-1.13	-1.13	288.59	Don't Buy
1994	0.11	-0.02	-4.68	-94.78	-94.78	309.12	Don't Buy
1995	0.11	-0.02	-3.18	-49.26	-49.26	341.06	Don't Buy
1996	0.10	-0.03	1.12	30.75	30.75	358.17	Don't Buy
1997	0.10	-0.03	9.26	339.88	339.88	375.28	Don't Buy
1998	0.10	-0.03	14.51	340.42	340.42	424.80	Don't Buy
1999	0.10	-0.03	21.17	461.56	461.56	392.64	Buy
2000	0.10	-0.03	27.90	554.66	554.66	378.21	Buy
2001	0.10	-0.03	25.70	731.55	729.68	418.31	Buy
2002	0.10	-0.03	26.22	1013.52	789.46	451.30	Buy
2003	0.10	-0.03	33.83	1138.67	752.21	451.31	Buy
2004	0.10	-0.03	37.96	1827.52	728.67	417.19	Buy
2005	0.09	-0.03	37.40	1407.52	674.61	410.03	Buy
2006	0.09	-0.03	31.08	817.39	712.65	428.80	Buy
2007	0.09	-0.03	26.70	740.07	687.39	552.46	Buy
2008	0.10	-0.03	29.15	1811.10	1028.65	565.42	Buy
2009	0.10	-0.03	41.84	58964.23	1123.75	661.61	Buy
2010	0.09	-0.03	40.49	18617.91	1062.40	783.07	Buy
2011	0.09	-0.03	55.38	12370.52	1494.15	1138.84	Buy
2012	0.09	-0.03	67.07	9244.35	1840.67	1502.62	Buy
2013	0.09	-0.03	100.67	13222.94	2597.02	1624.62	Buy

Looking at Table 3.4, the beta values for all 27 years are negative, implying the strong risk diversification function of farmland due to the negative covariance. Moreover, as the PV is based on farmer bidding value in the remaining few years, as mentioned the introduction of maximum bidding prices for land protects investors from bidding too high.

Interestingly, the negative beta value of farmland is a strong indication of the negative correlation between the returns of a market portfolio and farmland. As mentioned in Section 3.1, in the model simulation we only consider three different investors regarding their choices of assets. As a result, the only element that distinguishes their bidding price is the scope of asset selection.

APPENDIX D: UPDATED SYSTEMATIC MODEL INPUTS

Following Anderson (2012) and Stolniuk (2008), the real values of cost for machinery, variable cost for grain and beef production are fixed over the simulation period. In this model, these values were updated based on the rate of inflation. The updated values of these systematic parameters are shown in Tables 1 to 6. Values for other parameters in the model are the same as in Anderson (2012).

Table D.1: Systematic Parameters of Cropping Machinery

Item	Machinery Option	Value	Item	Machinery Option	Value
Machinery Value in Model Initiation Phase ($1,000)	Option 0	119	Annual Fixed Cost ($1,000)	Option 0	10.6
	Option 1	487		Option 1	52.7
	Option 2	944		Option 2	130
	Option 3	1,410		Option 3	204
	Option 4	1,827		Option 4	256
	Option 5	3,654		Option 5	481
	Option 6	4,938		Option 6	619
	Option 7	6,850		Option 7	875
	Option 8	8,929		Option 8	1,093
	Option 9	10,641		Option 9	1,328
Price for New Machinery ($1,000)	Option 0	512	Variable Cost ($)	Option 0	78.0
	Option 1	1,593		Option 1	21.5
	Option 2	2,002		Option 2	15.9
	Option 3	2,457		Option 3	14.5
	Option 4	2,675		Option 4	12.7
	Option 5	4,331		Option 5	14.1
	Option 6	5,673		Option 6	14.9
	Option 7	7,863		Option 7	13.7
	Option 8	10,089		Option 8	14.1
	Option 9	12,005		Option 9	13.7

Table 3: Systematic Parameters of Repairs of Cropping Machinery

Machinery Option	Value ($/Acre)
Option 0	8.54
Option 1	7.56
Option 2	5.91
Option 3	4.87
Option 4	4.19
Option 5	3.30
Option 6	3.53
Option 7	3.74
Option 8	4.11
Option 9	4.37

Table D.3: Systematic Parameters of Beef Cow Handling Machinery

Item	Value ($)
Fixed cost for cow handling	2,832
Fixed cost for cow machinery	14,910
Investment for cow machine	192,616
Investment for cow handling	36,829

Table D.4: Variable Cost of Grain Production

Item	Type of Product	Traditional	Non Till
Variable Cost per Acre ($/Acre)	Barley	81.6	84.8
	Canola	128	136
	Wheat	85.0	88.2
	Lentils	95.8	95.8
	Peas	85.4	89.6
	Flax	72.3	75.2
	Durum	85.0	88.2
Variable Cost per Tonne ($/Tonne)		0.26	0.26

Table D.5: Variable Cost of Fallow, Hay Production and Beef Cow Production

Category	Item	Type of Product	Value
Fallow	Variable Cost per Acre ($/Acre)	Wheat Fallow	71.1
		Summer Fallow	13.5
Hay Production	Variable Cost per Acre ($/Acre)	Bale IP1	13.4
		Bale IP2	20.1
		Hay IP1	23.4
		Hay IP2	30.1
		Natural Hayland	6.98
		IP	1.58
Beef Cow Production	Variable Cost per Tonne	Feed Grain	10.9
		Feed Hay	11.2
		Straw Bale	13.4
	Cow Labor ($/Year)		11750

Table D.6: Parameters of Farm Family Living, Wage Labor and Land Price Basis

Category	Item	Value
Family Living Withdraw ($/Year)	Maximum	141,070
	Minimum	29,600
Labor Wage ($)		93.0
Land Price Basis ($/Acre)	Farmland Price	1,526
	Pasture Land	1,049
	Farmland Rent	57.2
	Pasture Land Rent	39.3

APPENDIX E: WILLINGNESS TO FARM OPINION QUESTIONNAIRE/SURVEY[17,18]

"Willingness to Farm" Opinion Survey

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We are very interested in the future business health of Saskatchewan agriculture. I am currently working on an agent based model to project the structure of grain farms over the next 30 years under various scenarios. One of the most important factors affecting the health of our industry is the willingness of good young people to enter agriculture. I would like your opinions about your high school and college friends that grow up in a rural setting as to their willingness to start farming.

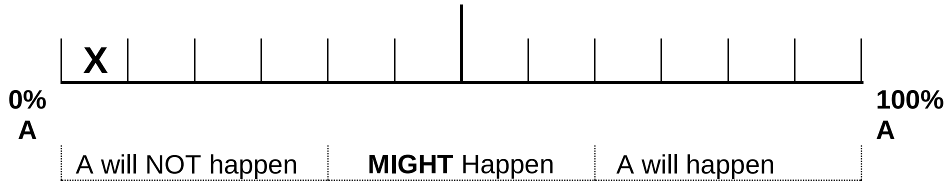
We have identified two major factors affecting the willingness of farm kids to return to their farm. 1) the relative income farming can provide in relation to off-farm income and 2) spousal willingness to adapt a farming lifestyle and 3) farm status.

Because we cannot be certain about values, we would like you to indicate the <u>most likely</u> value ("best guess) and then a range of values.

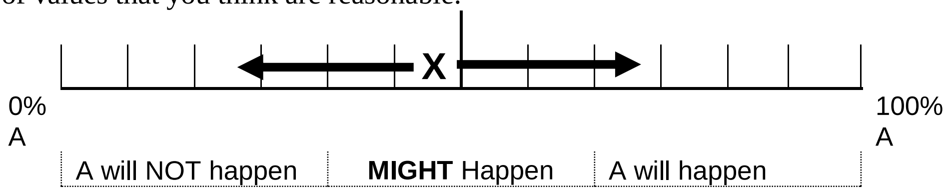
Filling out this Survey:
In filling out this survey, we would like you to indicate your **"best guess"** with an **"X."** Next, we would like for you to indicate the **range** of values that you feel that you would be 95% certain contain the true value. **As an example,** consider two options, ***Not A*** (will not be willing to farm) and ***A*** (willing to farm).

[17] The University Committee for Ethics in Human Research (UCEHR) was contacted and they determined that the survey did fall within their purview and hence, did not require their approval. This was because of the nature of the questions: the students were asked about their opinions as to the likely response of their farm peers, and do not constitute responses about themselves. Accordingly, they are exempt from the policies of UCEHR.
[18] This survey has been altered slightly from the original due to reformatting and the correction of a few typos.

(a) If you are **highly certain that A is unlikely to happen**, then you would put an X on the far left-hand side.



(b) If you think that **A might happen**, then you would put an X in the middle, with a line indicating **a range** of values that you think are reasonable.



- **Your responses are strictly confidential and will be used only for statistical purposes.**

Gender : ____ Male ____Female
You come from (check one): ____ Mixed Farm (Beef & Grain) _____ Straight Grain Farm
_____Other farm type _____ Not a Farm

1a. What % of farm kids do you think <u>will not</u> consider farming under <u>any</u> conditions?

0% 100%

1b. What % of farm kids do you think <u>will</u> consider farming under <u>any</u> conditions?

0% 100%

2. Of those that come from a <u>*mixed*</u> (Grain and Beef Cow) farm, what % will <u>not</u> consider <u>*mixed*</u> (Grain and Beef) farming under any conditions?

0% 100%

3. Of those that come from a <u>*mixed*</u> (Grain and Beef Cow) farm, what % will <u>not</u> consider <u>*straight grain*</u> farming under any condition?

0% 100%

4. Of those that come from a <u>*straight grain*</u> farm (i.e.,. with no livestock), what % will <u>not</u> consider <u>*mixed*</u> (Crop and Beef) farming under any condition?

0% 100%

5. Of those that come from a *straight grain* farm (i.e.,. with no livestock), what % will not consider *straight farming* under any condition?

0% 100%

Questions 6, 7 and 8 are for those kids who come from mixed (grain and beef) farms:

6. If they can make $35,000 from off-farm employment, what is the minimum % of that income would they need from the farm before they would farm?

0% 100%

7. If they can make $50,000 from off-farm employment, what is the minimum % of that income would they need from the farm before they would farm?

0% 100%

8. If they can make $65,000 from off-farm employment, what is the minimum % of that income would they need from the farm before they would farm?

0% 100%

Question 9, 10 and 11 are for those who come from straight grain farms:

9. If they can make $35,000 from off-farm employment, what is the minimum % of that income would they need from the farm before they would farm?

0% 100%

10. If they can make $50,000 from off-farm employment, what is the minimum % of that income would they need from the farm before they would farm?

0% 100%

11. If they can make $65,000 from off-farm employment, what is the minimum % of that income would they need from the farm before they would farm?

0% 100%

12. How important to your friends is find a potential spouse that is willing to adapt a farm lifestyle if they do decide farm?

0% 100%

13. How many acres of tillable acres does your family currently farm? _____
14 What is the proportion of land is owned by your family (instead of rented)? _____
15. If you have beef cows, how many heads does your family currently have? _____

Thank you for taking the time to complete this survey, if you have any additional comments please feel free to provide them on the rest of this page.