THE IMPACT OF CLIMATE CHANGE ON CANADIAN AGRICULTURE:

A RICARDIAN APPROACH

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By

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ABSTRACT

Climate change may change the frequency and intensity of weather events which will likely challenge human and natural systems more than normal change. Agriculture is considered one of the most vulnerable systems to climate change. The main goal of this study is to estimate the economic impact of climate change on agriculture in the Canadian prairies and to capture the impact of weather conditions on the viability of production systems along with the impact of market price effects by predicting the economic impact of climate change. A two way fixed effects panel model with time and provinces group fixed effects is calibrated to simulate a set of potential climate change and global change in prices on the economics of prairie agriculture.

The predicted impact of change in rainfall, increase in temperature and rise in future global market prices indicate that climate change will have complicated nonlinear effects on prairie agriculture. The results of this study also highlight the importance of precipitation for agriculture on the Canadian prairies. Marginal impacts of the evapo-transpiration proxy, rainfall, and July relative humidity indicate direct and positive relationship between agricultural land values and water related climate variables. It verifies that agriculture in the Prairies is very vulnerable to water scarcity and land use and land value strongly depends on the precipitation. The most important finding of this study is that climate change is beneficial for Canadian prairie agriculture except for some south east regions of Alberta. Comparing the results from direct impacts of climate and price changes on land value with the results from indirect impacts through area response estimation reveals that direct impacts of climate and price change increase farmland value by 31% while the indirect impacts from different scenarios increase simulated land value by up to 51%.

The results from base and three scenarios in this study reveal that climate change may not be a big threat for prairie agricultural economics if farmers employ appropriate adaptation strategies such as switching between crops and introducing new crops. As a matter of fact, climate change may provide an opportunity for agricultural producers in the prairies to gain from future price and environmental change. To achieve this goal, policies to address climate change concerns need to put a greater emphasis on dealing with water deficit and scarcity. Policies that facilitate access to irrigation and crop choices will help farmers to adapt to climate change.

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CHAPTER 1 INTRODUCTION

1.1 Background

Climate change is emerging as the most important environmental problem facing modern society. Increases in atmospheric stocks of greenhouse gases (GHG), including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), due to human activities have been linked to global climate change (Intergovernmental Panel on Climate Change (IPCC), 1990, 2007). The Fourth Assessment Report of the IPCC (2007) emphasizes that there will be changes in the frequency and intensity of some weather events and extreme climate events which will likely challenge human and natural systems much more than gradual changes in mean conditions. According to this report, it is virtually certain (more than 99% probability of occurrence) that most land areas will have warmer and fewer cold days and nights. It is also very likely that most areas (between 90 to 99 % probability of occurrence) will have warmer temperature, more frequent heat waves and heavy precipitation events. More drought, tropical cyclone, and incidence of extreme high sea level are also likely.

Agriculture may be particularly vulnerable to climate change due to its dependence on natural weather patterns and climate cycles for its productivity. There is a growing literature focused on predicting and quantifying the impact of climate change on agricultural systems in many areas around the world. A few degrees of warming will generally increase temperate crop yields while in the tropics, yields of crops near to their maximum temperature tolerance and dryland crops will decrease. A large decrease in rainfall would have even greater adverse effect on yields. In addition, degradation of soil and a decrease in water resources resulting from climate change are likely to have negative impacts on global agriculture (IPCC, 2001). However, with adaptation[1], crop yields will likely be less affected by climate change.

Quantifying the economic impact of climate change on agriculture is receiving increasing attention in the literature. It has been estimated that a temperature increase of 2.5 degrees (°C) or more would cause a decline in crop yields and prompt food prices to increase because growth in global food demand is faster than expansion of global food capacity (Parry et al., 1999,). Global income is expected to be impacted little with small or negative changes in developing regions and positive changes in developed regions (IPCC, 2001). Consequently, climate change not only will have an effect on the productivity of agricultural products but will also have economic consequences on farm profitability, agricultural supply and demand, trade, price, and so on (Kaiser and Drennen, 1993). Since there is great uncertainty in the understanding of the timing, magnitude and rate of climate change (CBO, 2003), it is important to quantify and monetize the economic impacts of change in climate on the agriculture sector.

From a policy standpoint, a response to the global threat of climate change required an international environmental agreement to foster efforts to reduce global GHG concentration in the atmosphere. The Kyoto Protocol was adopted by government negotiators in December 1997 at the Third Conference of Parties (COP 3) to the United Nations Framework Convention on Climate Change (UNFCCC). The purpose of the Kyoto Protocol is to limit GHG emissions to prevent or reduce the negative impacts of climate change. This protocol contains two objectives: policy and quantitative. The quantitative objectives require developed countries to reduce GHG emissions by, on average, 5 percent below 1990 levels during the period from 2008 to 2012 (first commitment period). Policy objectives include enhancement of energy usage and carbon

[1] Adaptation is defined as trials which society undertakes to diminish the damaging effects of climate change or take advantage of the beneficial opportunities which may arise from the change in climate (IPCC, 2001).

sinks as well as promoting sustainable forms of agriculture and forestry with respect to climate change.

In general, there are two categories of approaches to climate change recognized in the Kyoto protocol, mitigation and adaptation. Mitigation is an action that limits global climate change through the reduction of GHG emissions and enhancing the sink of GHGs. Alternatively, adaptation is focused on the ability to adjust economic systems to the effects of climate change or to respond to its impacts (IPCC, 1990). Adaptation is defined as activities which society undertakes to diminish the damaging effects of climate change or take advantage of the beneficial opportunities which may arise from the change in climate (Mendelsohn, 2001). If adaptation is one of the important ways to overcome the environmental damages associated with climate change, then improving the knowledge and understanding of these changes is necessary. In the last decade, many researchers have incorporated adaptation in their climate change impact models in an attempt to improve the conceptual and empirical approaches to explain the characteristics of environmental problem and measuring environmental effects on agriculture.

One of the extensively used models is the Ricardian approach introduced by Mendelsohn et al. (1994 and 1996). The land climate Ricardian model can be used to econometrically estimate the impact of climatic, socio-economic and geographical variables on the value of agricultural land which allows measurement of the marginal contribution of the attributes to the net farm income capitalized in land value. According to this theory, if a market is competitive then the agricultural land value will be equal to the present value of the future stream of annual net revenues derived from the most economically efficient management of the land. Therefore, this model not only considers the current farming practice but also allows land to be used for other future purposes as the land manager adapts to economic and environmental shocks and changes. Then, as climate changes, the best and most profitable use of land will also change. Because climate is used as an exogenous variable the model can be used to describe how changes in climate will change the value of land.

The study area for this study is the western Canadian prairies. The Prairies produce well over half of the total value of Canadian agri-food exports (McCrae and Smith, 2000). Also, crop and livestock production has historically been associated with prairie agriculture, while grain and oilseeds production continues to account for the majority of production. According to McCrae and Smith (2000), agriculture dominates the prairie landscape both in the percentage of land in agriculture (81%) and the share of Canadian agricultural GDP (46%). Agriculture is an industry that depends on seasonal weather patterns and the productivity of biophysical systems. Within the Canadian prairies, the significant historical change of weather has selected for production systems that minimize, or at least reduce, the risk associated with weather shocks. However, these systems may become vulnerable if the nature or intensity of the weather shocks changes. As such agricultural systems of the Canadian prairies may be particularly vulnerable to climate change. The capacity of Canadian prairie agricultural systems to adapt to the changing weather shocks associated with climate change is not well known. Developing a better understanding of this adaptation capacity provides the ground for wiser agricultural and environmental policies.

1.2 Problem Statement

The viability of western Canadian agriculture depends on the ability of producers to adapt their production systems to environmental and economic shocks and changes. This is particularly important as climate change alters the nature and intensity of these environmental shocks. Those systems that do not adapt will have increasing economic losses over time and ultimately will no longer be economically viable. In order to understand the economic viability of the agricultural systems of western Canada under increasing climate variability, as proposed in climate change forecasts, it is necessary to quantify the economic impact of this climate change on farms in western Canada.

1.3 Objectives

The primary objective of this study is to estimate the economic impact of climate normals on agriculture in the Canadian prairies, including a prediction of the economic impacts of climate change. The analysis will capture both the impact of historical weather conditions on the viability of production systems and the impact of market price effects from input and output markets. A Ricardian approach will be adopted to evaluate historical changes and a range of scenarios will be developed to consider the range of potential effects of climate change and global change in prices on the economics of prairie agriculture. The specific study objectives are as follows:

- to adapt a Ricardian model to evaluate the impact of climate change on the economic viability of agricultural systems
- to include the changes in global commodity prices on the Ricardian model and to reflect the importance of market price factor in Ricardian land climate model for prairies
- to determine the impact of global market prices on local prairie agriculture.

1.4 Methodology

The land climate Ricardian model was introduced by Mendelsohn et al. (1994), however, one limitation of this analysis was the assumption that the environmental change, which is global in scale, will leave market prices unchanged (although in the theoretical model prices are included). Consequently, the model developed by Mendelsohn et al. (1994) did not consider important global change effects in the analysis which means these significant factors were omitted from the model. Ignorance of the global market signals will exclude possible change in international markets and prices due to change in climate from the analysis. By inclusion of market prices, such as grain and oilseed prices, that represent changes in markets as influenced by global climate change, the present study can more fully capture the impact of climate change on prairie agriculture.

The empirical analysis for this study will be based on data from three time periods (1991, 1996, and 2001). The lack of data and change in the structure of data collections made it difficult to include 1981 and 1986 data. This analysis regresses farmland value per hectare on climate variables, non-climate (socioeconomic) variables, and market prices of grain which capture shifts in production function for crops as climate changes across space (adaptation strategy).

The estimation results of the model are used to project effects of climate change under different climate change assumptions. The comparison among scenarios enables estimates of the potential economic impacts of climate change. Also, the model can be used to examine the effects of expected future prices change on the market land value in the Prairies as an economic indicator of the potential future profit which might be derived from agricultural land use.

1.5 Organization of the Study

The remaining chapters of the dissertation are organized as follows. Chapter 2 contains a review of the literature and Chapter 3 describes the conceptual model and model adaptation. Chapter 4 describes methodology of the study. The empirical Ricardian model results, model analysis and panel models are described in Chapter 5. Climate Change Scenarios Simulation and Price Forecasting are described in Chapter 6. In the last chapter (chapter 7) conclusion and study limitations are presented.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

As outlined in chapter one the objective of the thesis is to quantify the potential impacts of climate change on the viability of Prairie agriculture. This chapter briefly reviews the literature which is related to assessing the economic impact of global and local climate change and also identifies the benefits and limitations of the Ricardian approach. Particularly, this literature review highlights the appropriateness of the Ricardian approach to assess the economic impact of climate change on the agricultural sector. This chapter begins by reviewing economic impact assessment studies in section 2.2 and describes three different approaches which evaluate the climate change impact on agriculture. In the section 2.3, the Ricardian studies, land price literature, and the role of prices on climate change impacts literature are presented. The final section (section 2.4) highlights the important issues and provides a link to Chapter three.

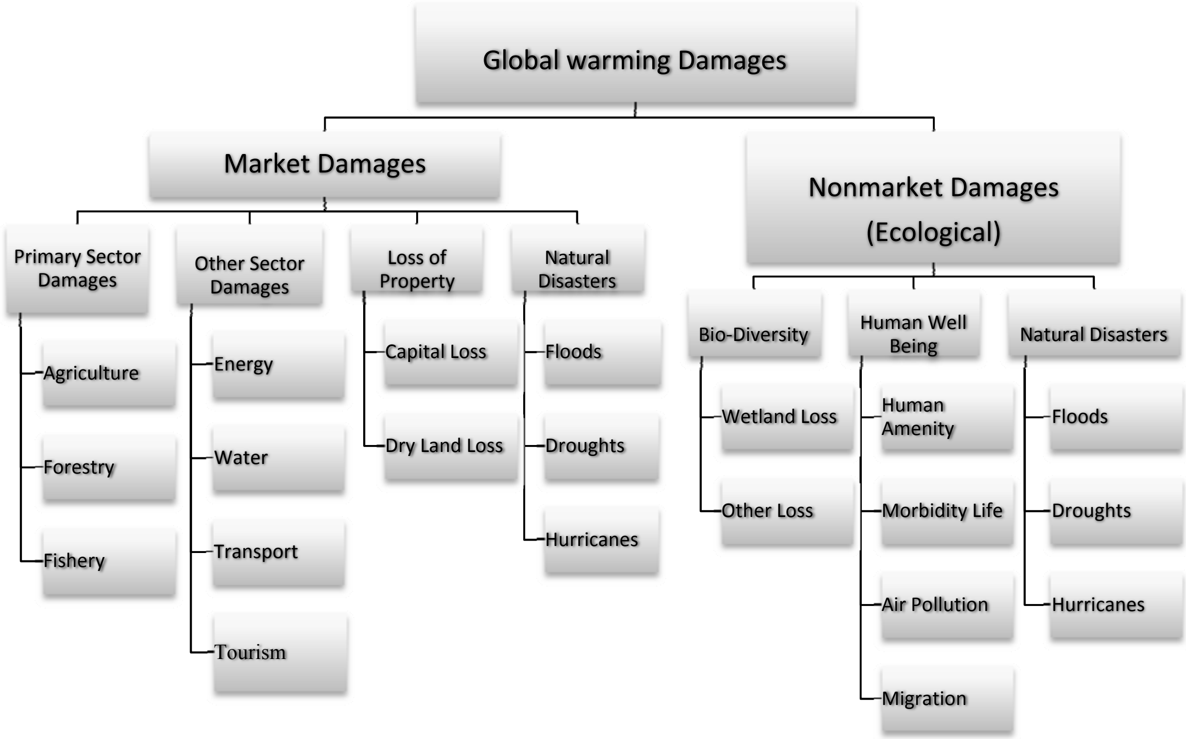
2.2 Assessing Previous Economic Impact Studies of Climate Change

Scientific debates on global climate change still exist after more than thirty years. Most recently, IPCC in fourth Assessment Report (AR4) states that:

> "Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases… [and that the] magnitudes of impact can now be estimated more systematically for a range of possible increases in global average temperature…" (IPCC, 2007; page 1 and page12)

In response to such affirmations, there have been a considerable number of studies examining the potential economic impacts of climate change on global and local economies. One large body of research focuses on the development of integrated assessment models (IAMs) and valuation of the impacts. A second active area of research is focused on developing quantitative local and regional indicators to assess the impact of climate change (Ringius, 2002).

As climate change has a multidimensional impact, impact studies could be differentiated based on sectors, themes, areas, etc (McCarthy et al., 2001). Manne et al (1995) have categorized climate change impacts into two categories: market and non-market damages (Figure 2.1). The knowledge of potential impact is investigated more extensively in the primary economic sectors such as agriculture, forestry and fishery. The reason for this focus is that the agricultural sector is highly sensitive to climate change due to its dependence on water availability, drought and growing season conditions. Among all areas in Figure 2.1, agriculture and sea level rise are the most studied sectors (Nordhaus and Boyer, 2000).



Source: Manne et al (1995)
Figure 2.1Overview of global warming impacts

Since the IPCC's first and second assessments, impact assessment studies have been receiving more attention and their impact estimate have been improved (Ringius, 2002). As IAMs modeling are diverse and cover many sectors (Tol and Fankhauser, 1998), here, the emphasis is only on some models which agriculture has the largest component of these assessment studies. In Table 2.1, a summary of some important studies with focus on the impact modeling and adaptation treatment has been presented.

Table 2.1: Representation of the climate change impact in some IAM models

Model	Damage categories Considered	Spatial detail	Impact measurement Treatment of adaptation
RICE-99 (Nordhaus and Boyer, 2000)	agriculture, sea-level rise, other market sectors, health, non-market amenity impacts, human settlements and ecosystems, catastrophes	13 regions (USA, Japan, other high income, OECD Europe, Eastern Europe, Russia, Middle income, High-income OPEC, Lower middle income, China, India, Africa, Low income)	separate functions for each category; monetized based on (Nordhaus and Boyer, 2000)
MERGE (Manne et al., 1995)	Farming, energy, coastal activities	five regions (USA, other OECD (Western Europe, Japan, Canada, Australia and New Zealand), former Soviet Union, China, rest of the world	two functions (market, nonmarket; monetized adjusted from Nordhaus (1991) not explicitly considered
CETA (revised) (Peck and Teisberg, 1992)	Wetland loss, ecosystem loss, heat and cold stress, air pollution, migration, tropical cyclones, coastal defense, dryland loss, agriculture, forestry, energy, water	six regions (USA, European Union, other OECD, former Soviet Union, China, rest of the world	two functions (market, nonmarket); monetized adjusted from Frankhauser (1995) not explicitly considered
FUND 1.5 (Tol, 1995; Tol, 1996)	Coastal defence, dryland loss, wetland loss, species loss, agriculture, heat stress, cold stress, migration, tropical cyclones, river floods, extratropical storms	nine regions (OECD America, OECD Europe, OECD Pacific, Eastern Europe and former Soviet Union, Middle East, Latin America, South and Southeast Asia, Centrally Planned Asia, Africa)	separate functions for each category; monetized based on Tol (1996)
MARIA (Fankhauser, 1993; Mori, 1996; Mori and Takahaashi, 1996; Mori and Takahaashi, 1997)	Coastal defence, dryland loss, wetland loss, species loss, agriculture, forestry, water, amenity, life/morbidity, air pollution, migration, tropical cyclones	four regions (Japan, other OECD, China, rest of the world)	one function; (Fankhauser, 1993)
FARM (Darwin et al., 1995; Darwin et al., 1996)	land and water resources, agriculture, forestry, other	8 regions (USA, Canada, European Union (12), Japan, Other East Asia, South East Asia, Australia and New Zealand, rest of the world)	separate models for each damage category; physical indicators; monetized based on Hertel (1993) production practices in agriculture and forestry, land, water, labour and capital allocation

GIM (Mendelsohn et al., 2000)	market impacts for agriculture, forestry, coastal resource, energy, water	178 countries based on 4° latitude x 5° longitude resolution of GCM, results are presented for 7 regions (Africa, Asia/Middle East, Latin America/Caribbean, West Europe, Former Soviet Union/Eastern Europe, North America, Oceania)	different response functions for each impact category; (Mendelsohn et al., 2000)

Source: Tol and Fankhauser (1998) supplemented by Ringius (2002)

These studies have focused on the agriculture sector because not only has agriculture been the most crucial sector for the climate change impact assessments but also the impact on this sector has been under more investigation than other economics sectors (Schlenker et al., 2006). Assessing the climate change impact on agriculture is the subject of abundant literature which has been divided into experimental-simulations and cross-sectional analyses by some researchers (Mendelsohn and Dinar, 2003; Mendelsohn, 2007). Also, Schlenker et al. (2006) put these approaches into three broad categories:

- Agronomic-Simulation models(agro-economic analysis)
- Computable General Equilibrium (CGE)models
- Ricardian cross-sectional Hedonic models

The following discussion will focus, in turn, on each of these categories of models.

2.2.1 Agronomic-Simulation models

The core idea of agronomic models is to use a controlled dynamic physiological process model of plant growth, like a complex production function to simulate yields given exogenous weather, nutrient and other input requirements. These models do not endogenize farmer behavior and economic considerations and sometimes the focus is on a single crop (Adams 1989, Rosenzweig and Parry 1994) while other studies (Kaiser et al., 1993, Adams, 1995) allow for crop substitution with a profit maximization analysis for different cropping patterns (Schlenker et al., 2006). In these experimental-simulation analyses, once models are calibrated with predetermined climate change then a series of assumed farmer behaviors and climate change scenarios can be extrapolated by simulation protocols.

There are some shortcomings with agronomic- simulation models: first uncertainty about functional forms and second ignoring the linkages with other sectors in the economy are some flaws that have been identified with this kind of analysis. Also including adaptation into the plant simulation models could ruin the controlled experiment (Mendelsohn, 2007) and can estimate a lower bound or an inaccurate estimate on the farm benefits of climate change (Reinsborough, 2003).

2.2.2 CGE Models

There is a rich literature that utilizes CGE models to relate agriculture to the other major sectors of the economy under global climate change (Bosello and Zhang, 2005) and allows resources to move among different sectors in response to economic incentives (Schlenker et al., 2006). A well known example was developed by Darwin et al. (1995) which examined an eight-region CGE model for the world agricultural economy. Rubin and Hilton (1996) examined the employment impacts of climate change on several sectors of the Pere Marquette Watershed region of Michigan of the U.S. Rosenberg (1993) examined the climate change impacts on Missouri, Iowa, Nebraska, and Kansas states (MINK). Inter-sectoral linkages and endogenous market prices are advantages of these models but they highly aggregate the sectors in an economy and there are only a few of them which are concentrated on the global warming (Bosello and Zhang, 2005). Moreover, these CGE approaches are elaborated simulation models where the climate change impacts are assumed to be simply exogenous. While a CGE model can make commodity prices endogenous and account for inter-sectoral linkage but spatially and economically diverse sectors are characterized by a representative (individual) farm or firm.

2.2.3 Ricardian Approach

As mentioned earlier, other models have limitations, agronomic models are weak to capture adaptation and mitigation strategies and CGE models are highly aggregated. In light of capturing adaptation and calculating the direct impact on farmers in a region, Mendelsohn, Nordhaus, and Shaw (1994) introduced an approach that attempts to capture the influence of economic, climatic, and environmental factors on the value of agricultural lands. It is called "Ricardian Method" after the 19th century classical economist David Ricardo (1772-1823) which observed that land values would reflect land profitability within a perfectly competitive market. The Ricardian approach [which will be more fully described in section(3.2)] is a hedonic model of farmland pricing that assumes the value of a tract of land equals the discounted value of the stream of future rents or profits that can be derived from the land (Schlenker et al., 2006).

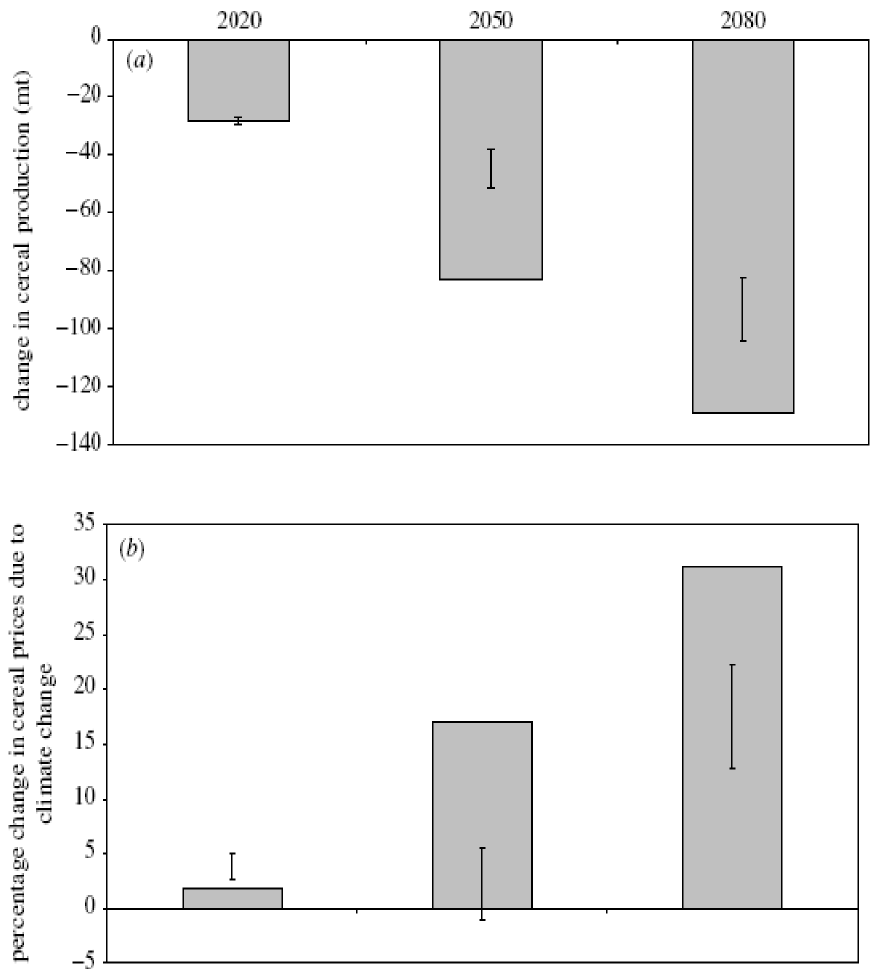
The basic concept of the Ricardian approach is that land values and agricultural practices are correlated with climate (environmental variable). If the production of an agricultural commodity that represents the optimal use of the land, then observed market rent on the land will be equal to the annual net profits from the production of this commodity. Now, land rent per hectare should be equal to net revenue per hectare (from a parcel of the land). As farm value is the value of the land in aggregate ($/ha multiplied by the number of hectare of available land), the present value of the stream of current and future revenues, under appropriate assumptions, should be equivalent the land value. The Ricardian model was developed based on this theoretical foundation. One can measure the impact of the environmental variable of interest on the present land value by examining the relationship between environmental variables and land value. The economic impact of the change in the environmental variables is captured by the change in land values across different conditions. Then, depending on the harmful or beneficial effects of environmental changes the long run accumulation of net profits determines the land value (Mendelsohn et al., 1999).

There are some land value studies debating that land values do not reflect net present value (NPV) of revenue. Clark et al (1993) discuss that using NPV is not appropriate to evaluate land prices and land values. Also, Just and Miranowski (1993) and Falk (1991) reject using NPV model to determine farm land value. However, Foutnouvelle and Lence (2002) found that land rents and prices behavior is consistent with a NPV model in the presence of the observed value of transaction costs. In the present study, following other Ricardian studies, land value will be represented by the discounted value of the stream of future rents or profits that can be derived from the land.

The Ricardian approach has been used to evaluate the impact of climate change on farm land value and to estimate the effects of possible climate change scenarios on agriculture (Mendelsohn, 2007). Moreover, as land value contains information on the value of climate attributed to land productivity, by regressing farmland value on environmental, socio-economic and other factors, one can determine the marginal contribution of each input to farm income as capitalized in land value. Finally, this approach accounts for the costs and benefits of adaptation because farmer adaptations are reflected in farmland value which is based on the fact that land values shift with climate and other control variables (Kurukulasuriya and Ajwad, 2007).

There are some limitations in the Ricardian approach. One issue with particular relevance to this study is the assumption that the environmental change, which is global in scale, will leave market prices for commodities and inputs unchanged. Consequently, the model has not considered important global change effects in the analysis which means that significant factors have been omitted from the model (Cline, 1996). Also, the Ricardian model underestimates damages and overestimates benefits by holding prices constant. Mendelsohn and Nordhaus (1999) explain that the assumption of constant prices remains a flaw of the technique and a global agricultural model needs to be built to find possible change in agricultural prices and supplies. The present study contributes to the literature by inclusion of commodity market prices to the model that represent changes in markets as influenced by global climate change. Response of prices to climate change will provide insight for farmers because price is one of the most important incentives driving their decision making process.

There is a body of literature that investigates change in agricultural production and prices due to change in global climate. Parry et al. (1999 and 2005), illustrate the climate change effects on agricultural commodities production and prices (Figure 2.2). Parry et al. (1999) projected output prices to rise between 3% and 32% for years 2020 to 2080 while cereal production fell between 25 and 125 million tons (mt) for the years 2020 to 2080. On the other hand, two other global scale economics studies (Darwin et al., 1995; Adams et al., 1998) project agricultural production prices to decrease even if precipitation increases moderately. There is agreement especially after the IPCC's second assessment, that a rise of more than 2.5°C in mean global temperature is likely to increase agricultural commodity prices. It is because temperature rise greater than 2.5°C will exceed the global food production system's capacity to adapt to this climate change without increasing in the price of agricultural outputs (Parry et al., 1999).



Source: Parry et al. 1999

Figure 2.2 Change in global cereal production and prices under projected climate change scenarios in years 2020, 2050 and 2080

Another limitation of Ricardian models is the assumption that farmers can observe all changes in climate. The Ricardian model optimistically assumes that farmers will adjust to climate change (adaptation) and it will be relatively inexpensive. However, research has shown that farmers are slow to adjust to climate change because farmers slowly update to their estimate of the true climate. Therefore, their adjustment would be expensive (Quiggin and Horowitz, 1999; Adams, 1999). Also, based on panel data representing county-level farm profits for Midwestern states in the U.S., Kelly et al. (2005) conclude that there is a significant source of costs associated with climate change (adjustment costs) because of the fact that farmers will not instantly observe the change in climate. Mendelsohn and Nordhaus (1999) state that as climate change is a long term phenomenon, it is more than likely that there will be several rounds of replacement of technologies, which will make the present value of adjustment costs over the long term very small.

As the Ricardian technique can be applied to different regions, researchers have widely used this method which will be described in the next section (2.3) as a review of Ricardian studies.

2.3 Ricardian Studies

The Ricardian technique for estimating the economic effects of climate change on agriculture has produced an unusual amount of attention and criticism (Polsky, 2004). This method has been applied in a variety of countries including United States, Canada, England and Wales, India and Brazil, Cameroon, China, and Sri Lanka. This section will now highlight some of the insights provided by this literature that is relevant to the present study.

In their influential paper on the use of the Ricardian technique to value climate impacts, Mendelsohn et al. (1994) introduce a cross-sectional approach which regresses value per acre for annual cropland, pasture and grazing for counties across the United States on a number of climate and other control variables. They discovered that a quadratic relationship exists between farm land value and climate variables (normal daily mean temperature and normal precipitation). Their estimates indicate that impacts in the United States range from a loss of $5.8 billion to a gain of $36.6 billion. These results are dependent on the type of model and climate scenario used in the analysis.

In a subsequent paper Mendelsohn et al, (1996) further expand the method and use aggregate farm value per acre in a county. The results indicate that climate change not only affects the value of the existing farms but the probability that land would be farmed. In 1999, Mendelsohn et al. included additional inter-annual temperature and precipitation and diurnal temperature variation in the Ricardian method. The results suggest that inter-annual temperature effects are more important than inter-annual precipitation effects.

Mendelsohn and Dinar (2003), revisited the U.S. case study examined earlier by Mendelsohn et al. (1994), to test whether surface water withdrawal can help explain the variation of farm values across the United States, and whether adding these variables to the standard Ricardian model changes the measured climate sensitivity of agriculture. The paper concludes that the value of irrigated cropland is not sensitive to precipitation, and increases in value with temperature. The authors find that sprinkler systems are used primarily in wet, cool sites, whereas gravity, and especially drip systems, helps compensate for higher temperatures. These results indicate that irrigation can help agriculture adapt to climate change.

Other authors have also used the Ricardian framework to evaluate irrigation value under climate change. Schlenker et al., (2005) included the role of irrigation to cover theoretical concerns about potential bias related to the inadequate treatment of irrigation in the previous Ricardian analysis which might bias the results. They discovered that using more accurate measures of climate variables will result in a more robust estimation. This research found an annual profit loss of about $5 to $5.3 billion for the U.S. counties. In a separate subsequent study, Schlenker et al., (2006) developed a spatially correlated error term Ricardian model for counties east of 100th meridian in the U.S. and explore very robust predictions and more than 75% of counties show statistically significant effects ranging from moderate gains to large losses. Most recently, Schlenker et al., (2007) employed individual farms data sets to examine whether climate and water had an influence on farm land value of California. They conclude that both water and heating-degree days were influential on California's agriculture.

Deschenes and Greenstone, (2007) estimated the effect of random year-to-year variation in temperature and precipitation on U.S. agricultural profits. Their estimates indicate that climate change will lead to a $1.3 billion in 2002 dollars or 4 percent increase in annual profit. These findings appear to contradict the popular view that climate change has substantial negative welfare results for U.S. agriculture.

Polsky (2004) discussed that Ricardian climate sensitivity analyses should employ spatial effects and temporal changes. In this case, the model used by Polsky reflects time specific contingencies as well as space characteristics. Also, this model provides the concept of spatial economics of a geographic variable like land value. The value of a land will be determined not only by the local conditions but also by the conditions of the geographical neighbors. Polsky (2004) employed six spatial econometric models to explore how human-environment relationships associated with climate sensitivities have varied over space and time in the U.S. Great Plains, during 1969 to 1992.

In Canada there are a few studies which employ the Ricardian model to address climate change issues. Reinsborough (2003) used a Ricardian land rent model (econometric approach) to analyze the potential impact of global warming for Canadian agriculture. This study found that Canada would benefit marginally as a result of climate change – some $1.5 million per year of increase in farm revenue. In contrast, Weber and Hauer (2003) found that Canadian agricultural landowners could gain substantially as a result of climate change. Their Ricardian rent model employed a much finer grid and greater intuition (national and regional scale) regarding agricultural operations than did Reinsborough. They projected average gains in land values of more than 50% by the year 2040 and increases of 75% or greater by 2060. They found that Canadian agriculture benefits from climate change by a $5.24 billion increase in annual GDP. The Ricardian land rent models of Reinsborough (2003) and Weber and Hauer (2003) also indicate that agricultural landowners in Canada can benefit from climate change. However, employing non-homogeneous national level data (different agricultural systems) and model misspecification (exclusion of relevant variables) were weaknesses in their approaches. In particular, there is an expectation that adaptation and the effects of climate change will differ for the arid Prairies versus, for example, corn and soybean regions of Southern Ontario.

Comparing two neighbor countries (Canada and USA), Mendelsohn and Reinsborough (2007) investigated whether a Ricardian study of a country is adequate to capture the effects elsewhere in the world. The results showed that climate sensitivity of each country (region) was different; therefore, the US temperate results cannot accurately predict what will happen in polar zone country (Canada) and vice versa. Also, it was argued that it is necessary to develop a cross-sections study for each region of the globe to have an adequate climate sensitivity analysis.

Maddison (2000) employed the Ricardian technique to estimate the marginal value of various farmland characteristics in England and Wales. His findings revealed that climate, soil quality, and elevation, in addition to the structural attributes of farmland, were significant determinants of farmland prices. Maddison also found that landowners were constrained by their inability to repackage their land (given that the size of the plot has a considerable influence on the price per acre).

Kumar and Parikh (2001) examined adaptation options while estimating the agricultural impacts in India. The relationship between farm level net revenue and climate variables is estimated using cross-sectional data in India. The authors demonstrated that even with farmer adaptation of their cropping patterns and inputs in response to climate change, losses would remain significant. The loss in farm-level net revenue given a temperature rise of 2°C–3.5°C was estimated to range between 9 percent and 25 percent. Kumar and Parikh (2001) projected a 30–35 percent reduction in rice yields for India given a similar temperature increase (or losses in the range of US$3–4 billion). Moreover, the authors concluded that government policy and prices have a major influence on variations in net revenues.

McKinsey and Evenson (1998) employed a model specification that is similar to the Ricardian model developed by Mendelsohn et al. (1994). In particular, they utilized a net revenue specification of the model, and using two-stage least squares, examine the processes of technological and infrastructure change that characterized India's green revolution. In contrast to earlier studies, McKinsey and Evenson (1998) examined the primary technological variables of the green revolution, that of adoption of high-yielding varieties, and expansion of multi-cropping and irrigation, within a framework that also incorporate detailed data on soils and climate, and public and private investment variables. Their results highlighted that climate affects technology development and diffusion. The authors also found that technology development affects the impacts of climate on productivity. Furthermore, the authors asserted that technology development and diffusion, and climate have a significant impact on net revenue in agriculture in India.

In a study of the southwestern region of Cameroon, Molua (2002) explored the impact of climate variability on agricultural production through an analysis at the farm household level. The results suggested that precipitation during the growing season, and adaptation methods through changes in soil tillage and crop rotation practices have significant effects on farm returns. Results from the Ricardian analysis confirmed that farm level adaptations including change in tillage and rotation practices and change in planting and harvesting dates positively correlate with higher farm returns. In addition, Molua found that irrigation in the growth period, especially during dry spells, is very important for productivity.

Using a county level cross-sectional data on agriculture, Liu et al., (2004) measured the economic impacts of climate change in China based on Ricardian model. They found that seasonal higher temperature and more precipitation would be beneficial for China's agriculture. Although five climate scenarios in year 2050 are beneficial in general but the Southwest, the Northwest and the southern part of the Northeast may be negatively affected.

Kurukulasuriya and Ajwad (2007) employed a micro level farm data (smallholder) to test climate sensitivity of the agriculture sector in Sri Lanka. They found that only 14% of the net revenues across farms are explained by climate variables. Also, non-climate variables explain about half the variation in net revenues. Overall, Sri Lanka will be hurt only slightly from warming. The key to Sri Lanka's future, however, lies in what climate change does to the monsoon rains.

2.4 Conclusion

This chapter presents a review the literature related to assessing the economic impact of global and local climate change and also identifies the benefits and limitations of the Ricardian approach. Mainly, this literature review highlights the appropriateness of Ricardian approach in evaluating the economic impact of climate change on agricultural sector. Also, Ricardian models can be employed to examine the impact of climate change on agriculture by quantifying the relationship between farmland value and other climate and non-climate factors and projecting climate change scenarios. Using this review, Chapter 3 will develop a conceptual and theoretical framework to evaluate the impact of historical climate means on prairie agriculture.

CHAPTER 3 CONCEPTUAL FRAMEWORK

3.1 Introduction

Chapter 2 provided a review of the relevant literature on Ricardian models and how these models use an empirical cross sectional approach to evaluate the impact of climate change on economic systems. This class of Ricardian model has been used to econometrically estimate the impact of climatic, socio-economic and geographical variables on the value of agricultural land which measures the marginal contribution of such attributes to net farm income capitalized in land value. In particular the literature review focused on the appropriateness of Ricardian models to evaluate the impact of climate change on agriculture by quantifying the relationship between farmland value and climate and non-climate factors.

This chapter develops a conceptual and theoretical framework used to evaluate the impact of historical climate means on the prairie agricultural economics. It begins by providing a detailed analysis of an appropriate Ricardian model. The model framework incorporates a structure that can capture farmer adaptation decisions to changing environmental conditions (sections 3.2). Section 3.3 will discuss the theoretical background of the Ricardian approach. Section 3.4 develops the Ricardian framework further to explicitly incorporate changes in market prices over time as influenced by climate change forces. The final section (section 3.5) concludes this chapter by highlighting the important issues and provides a link to Chapter 4 which presents the methodology of this study.

3.2 A Conceptual Perspective of Ricardian Model

The theoretical understanding of the Ricardian model here is directly obtained from Mendelsohn et al. (1994 and 1996). The basic concept of the Ricardian approach is that land values and agricultural practices are correlated with climate (environmental variable): the productivity of a crop is a function of an environmental variable like average temperature and precipitation. The ways in which the environment can act as a production input are varied. Environmental factors influence output by changing the productivity of inputs, by altering output that has been produced, or by reducing the effective supply of inputs.

The Ricardian model was extended to integrate changes in market prices in this study by relaxing the assumption that market prices do not change as a result of the changes in environmental variables. A basic production function with environmental (climate) factors is developed to link a climate variable to agricultural production.

In the present model it is assumed that there are a set of well-behaved (twice continuously differentiable, strictly quasi-concave with positive marginal products) production functions which link purchased inputs (e.g. seed and fertilizer) and environmental inputs into output of a farm at a certain location:

$$Q_i = Q_i(K_i, E), \qquad i = 1,...,n \tag{3.1}$$

$$K_i = (K_{i1},...,K_{ij},...,K_{iJ}), j = 1,...,J \tag{3.2}$$

$$E = (E_1,...,E_l,...,E_L) \quad l = 1,...,L \tag{3.3}$$

In this set of equations, *Qi* is the quantity produced of good *i*(wheat or canola), *Ki* is a vector of production inputs *j* used to produce *Qi* and *E* defines a vector of exogenous environmental factors *l,* such as temperature, precipitation, and soil that are biophysical characteristics of the specific location of production.

Now, consider a production function reflecting a non linear relationship between crop production (yield) and temperature (Figure 3.1). Holding other variables constant in this simple model, the yield of one crop (e.g. wheat) increases as temperature increases ($\frac{\partial Q}{\partial E} > 0$) up to some point (T1) where further increases in temperature are damaging to the crop such that the yield declines ($\frac{\partial Q}{\partial E} < 0$) as temperature rises. Finally, at a higher temperature beyond the coping range of the crop yield drops to zero.

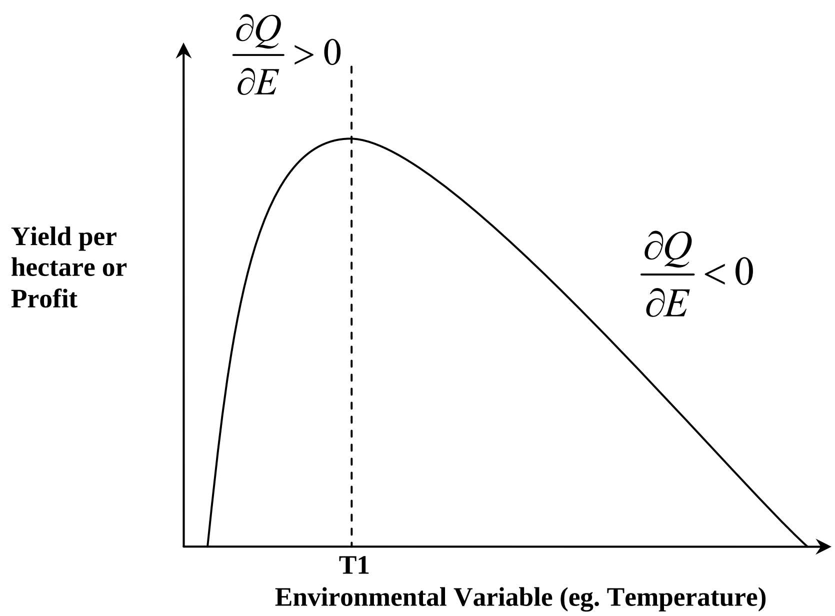


Figure 3.1: Impact of Environmental Variable on Production

It is assumed that the farmers' objective function is to maximize the profit function. A cost function needs to be introduced here to solve the profit maximization problem for farmers. Given a set of factor prices *wj, E* and *Qi*, cost minimization gives the cost function:

$$C_i = C_i(Q_i, \omega, E) \tag{3.4}$$

$$\omega = (w_1, \ldots, w_j, \ldots, w_J) \tag{3.5}$$

Where *Ci* is the cost of production of good *i* and ω is the vector of factor prices.

It is important to consider how the environmental factors influence production costs as well as farmers' profit. When $\frac{\partial C}{\partial E} < 0$, as the environmental factor increases, the cost of production will decrease, consequently, the profit will increase. As an example with more rainfall, the need for irrigation of the crops will decrease which can translate to a decrease in irrigation costs. In the case of $\frac{\partial C}{\partial E} > 0$, the costs increase as environmental input increase (e.g. as temperature increases) evaporation also increase and crops will need more irrigation which means more costs for farmer.

For illustration, from Figure 3.1, the value measured along the vertical axis is yield per hectare of land and as crop yield is a hill shaped function of temperature, then the profit is also a hill shaped function of temperature (Zilberman et al., 2004). Thus, the y axis can precisely show the value of output less the value of all inputs (net revenue). The net revenue for profit maximizing farmer is:

$$\pi = [P_i Q_i - C_i(Q_i, \omega, E)] \tag{3.6}$$

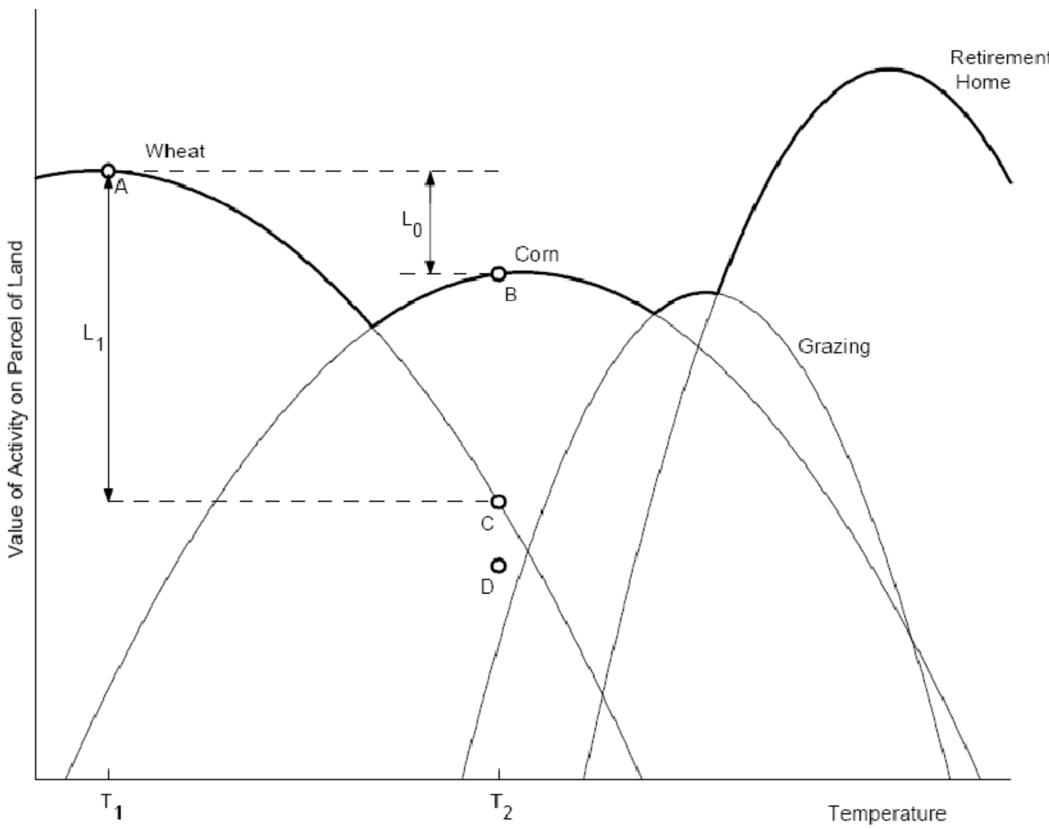
Where P_i is the price of good i and π is farmer's profit.

Thus far, this simple model links a climate variable to yield per hectare and/or profit of agricultural production. However, by adopting the Ricardian approach, instead of looking at the yields of specific crops, one can examine how climate in different places affects the net rent or value of farmland. This approach takes into account both the direct impacts of climate on yields of different crops as well as the indirect substitution (adjustment) to other activities by introduction of new land uses and other potential adaptations to different climates (Mendelsohn et al., 1994). Consequently, the analysis needs to be developed to capture more adaptation strategies which farmers can employ in response to climate change. The inclusion of adaptation into the conceptual model is described in the next section.

3.3 Adapting to Climate Change in Agriculture

In the previous section, a simple model was examined to represents the relationship between net revenue and climate variables. However, Ricardian land rents embody current producer adaptations as well as potential adaptations of alternative uses of the land (Darwin, 1999) which assume complete adaptation. Also, as mentioned in the literature review, considering land values as the discounted present value of the future stream of annual net revenues or rents, changes in agricultural land rents across space reflect the annual value of climate change to agriculture. In other words, it is assumed that spatial variation in climate can capture the influence of climate change over time in a single location. Figure 3.2, from Kelly et al. (2005), demonstrates the process of adaptation. This graph represents the economic returns that are possible from a series of alternative land uses as a function of temperature. The relationship is basically a production function for different crops and different land use. The heavier line represents a response curve to climate change that is maximum value of a parcel of land- i.e. the yield per hectare of land. A production function approach would estimate the value of each different crops/sectors production at different temperatures along its curve. For example, a production function for wheat would show how the revenue of the wheat varies with change in temperature which is consistent with the relationship represented in Figure 3.1.

Kelly et al., (2005) show that point A (Figure 3.2) is the value of the land before any change in climate (T_1). If average temperature rises to T_2 as a result of climate change, three alternatives are represented. First, point C indicates no adaptation such that the farmer continues to produce wheat using the same technology despite the decreased yields caused by the warmer climate, but the farmer can adjust other practices for instance increasing the allocation of land to corn production instead of wheat[1]. In this case, the land value decreases by the amount of L_1 while the farmers who invest in adaptation will lose just the amount of (L_0). Second, point D indicates no adjustment and no adaptation. In fact, at this temperature (T_2), the land cannot be optimally used for wheat and farmers may consider switching to corn. Finally, point B indicates complete adaptation (e.g., switching to the production of a new crop such as corn). In the case of complete adaptation the loss in the value of the land for two different temperatures is (L_0) where $L_0<L_1$ but the value of adaptation is (L_1-L_0) (Kelly et al. 2005).



Source: Kelly et al. 2005

Figure 3.2: Value of land as a function of temperature

[1] Farmers always face with risk and uncertainty which make them adjust to their new changing environment. Adaptation to climate change is one way that farmers employ to ensure their stable income and earnings. There are different adaptation strategies to choose: best management practices (BMPs), new technology and etc…

The basic hypothesis is that a crop production function shifts with changes in climate variables. Also, farmers at particular locations consider climate as given and adjust their production process (what, why, and how to grow?) to accommodate the change in environment.

Using these concepts, it is possible to measure the economic effects of climate on prairie agriculture. Returning to the profit function developed in the last section:

$$\pi = [P_i Q_i - C_i(Q_i, \omega, E)] \tag{3.6}$$

In this analysis, land as a production input is distinct from the environmental inputs (*E*) and it is assumed that land, *Li,* is heterogeneous with an annual cost or rent of P_L in a specific location. Using the cost function *Ci ()* at given market prices, profit maximization by farmers at a given location can be specified as:

$$\underset{Q_i}{Max}\, \pi = [P_i Q_i - C_i(Q_i, \omega, E) - P_L L_i] \tag{3.7}$$

Where P_i is the price of output *i*, such that under perfect competition at the optimum all profits in excess of normal returns to all factors (rents) are driven to zero:

$$\frac{\partial \pi}{\partial Q_i} = 0, \tag{3.8}$$

then we have

$$P_i = C_i^{'}(Q_i, \omega, E) \tag{3.9}$$

It is actually the known equality of price and marginal cost which after solving for *Qi* it will results in optimal output value. Now separating land rent P_L from other input prices and rearrange:

$$P_i - C_i^{'}(Q_i, \omega, E) - P_L = 0$$

then Q_i^* or outputs optimal value along with the inputs optimal value (including the optimal land use L_i^*) can obtain from equating prices and marginal costs. Now plugging Q_i^* back in (3.7) gives:

$$P_i Q_i^* - C_i^*(Q_i^*, \omega, E) - P_L L_i^* = 0 \tag{3.10}$$

If the production of good *i* is the optimum use of the land given *E*, the observed market rent on the land will be equal to the annual net profits from the production of the good *i*. Solving for value of the land rent per hectare P_L from the above equation gives:

$$P_L = [P_i Q_i^* - C_i^*(Q_i^*, \omega, E)] / L_i^* \tag{3.11}$$

From (3.11) land rent per hectare should be equal to net revenue per hectare (from a parcel of the land). As farm value is the value of the land in aggregate ($/ha multiplied by the number of hectares of available land), therefore, the present value of the stream of current and future revenues give the land value V_L:

$$V_L = \int_0^\infty P_L e^{-rt} dt = \int_0^\infty \left[P_i Q_i - C_i \left(Q_i, \omega, E \right) / L_i \right] e^{-rt} dt \tag{3.12}$$

In this equation *r* is discount rate and *t* is time. This is the essence of the Ricardian model. One can measure the impact of the environmental variable of interest on the present value of land by examining the relationship between this environmental variable and land value. The Ricardian model takes the form of equation (3.12). The economic impact of the change in the environmental variables is captured by the change in land values across different climatic conditions. An environmental factor affects production as well as costs, which changes the behavior of the farmer and influences net revenue (this can be seen from figures 3.1 and 3.2). Then, depending on the harmful or beneficial effects of environmental changes the long run accumulation of net profits determines the land value (Mendelsohn et al., 1999).

Based on production theory, the marginal cost of the agricultural production represents the supply curve for agricultural commodities. Also, as price takers, farmers face a horizontal market price line. The area between agricultural supply function and market price line (P_0AD in Figure 3.3) shows return to land as a fixed asset. In the present analysis, this area corresponds to the return to farmland value which can be used as a measure of economic welfare. This figure (3.3) illustrates the concept of the economic welfare and can be used to demonstrate the impact of exogenous changes in environmental variables on net economic welfare (ΔW). This captures change in the present net revenue per hectare (farmland value).

Initially consider an environmental change from the environmental state *A* to *B*, for example an increase in temperature which makes the annual crop more productive resulting in production increasing from *EA* to *EB*. From figure 3.3, we can see that in state *A,* producer welfare is the area P_0AD then after environmental change to state *B,* the new welfare increases to P_0BD. For instance, the productivity of certain crops that thrive in warmer climates will increase resulting from a warming scenario (state *B*), then the marginal cost for this crop (or supply curve) shifts outside. In this case, the net economic welfare is the change in welfare induced or caused by the changing environment from a given state to the other ($\Delta W=P_0BD-P_0AD$). It can be seen from figure 3.3, having unchanged price at P_0 the consumer welfare is not affected but producer welfare (or the net revenue per hectare) has increased by the area DAB. Therefore, the economic welfare change here is measured in terms of change in the capitalized value of the land.

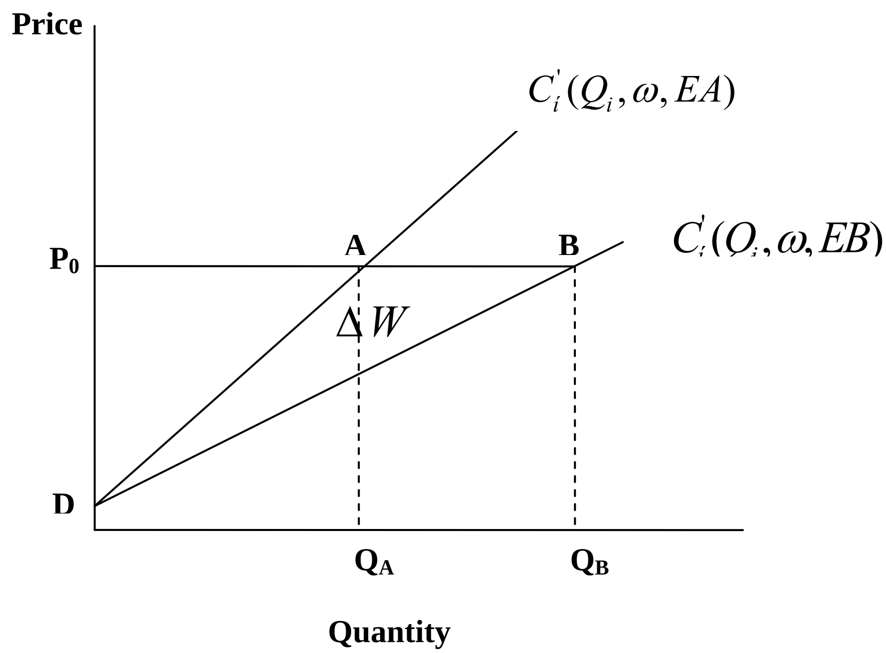


Figure 3.3: the welfare impact of a change in climate variable

The change in annual welfare can be written as:

$$\Delta W = W(E_B) - W(E_A) = P_0BD - P_0AD \tag{3.13}$$

$$\Delta W = \int_0^{Q_B} \left[P_i Q_i - C_i\left(Q_i, \omega, E_B\right) / L_i \right] e^{-rt} dQ$$

$$- \int_0^{Q_A} \left[P_i Q_i - C_i\left(Q_i, \omega, E_A\right) / L_i \right] e^{-rt} dQ \tag{3.14}$$

In their analysis of the impact of climate change, Mendelsohn et al., (1994) assumed that market prices do not change as a result of the change in environmental variables; therefore, considering a constant vector price $P = [P_1, ..., P_i, ..., P_n]$, the above equation reduces to:

$$\Delta W = W(E_B) - W(E_A) = [PQ_B - \sum_{i=1}^{n} C_i(Q_i, \omega, E_B)] -$$

$$[PQ_A - \sum_{i=1}^{n} C_i(Q_i, \omega, E_A)] \tag{3.15}$$

Substituting (3.10) into (3.15) gives:

$$\Delta W = W(E_B) - W(E_A) = \sum_{i=1}^{n} (P_{LB}L_B - P_{LA}L_A) \tag{3.16}$$

Where P_{LA} denotes the value per hectare of land area L_A in state A and P_{LB} denotes the value per hectare of land area L_B in state B.

Thus, the present value of the welfare change is:

$$\int_0^Q \Delta W e^{-rt} dt = \sum_{i=1}^{n} (V_B - V_A) \tag{3.17}$$

This is "the Ricardian estimate of the value of environmental change" by the definition of Ricardian model. Empirically, after estimating the base model with current climate condition, one can examine the value of change in the future climate by plugging any climate change scenario[2] into the base model (e.g. cooling or warming weather, change in precipitation patterns).

3.4 Relaxing Constant Market Prices Assumption

In the previous section, a traditional theoretical Ricardian analysis has been discussed in detail. One contribution of the present study to the literature is to include global commodity market prices into the Ricardian model and to address likely problems raised when the model has no prices and finally to exhibit a solution for it. In this section, an explicit discussion will be provided to add Market price analysis to the previous Ricardian studies.

[2] Described in Chapter 4 section 4.3.3

There are two potential problems with assuming fixed market prices: 1) a potential misspecification in the empirical estimation of the model and 2) a bias in welfare measurements. The first problem is when some important variables are excluded from a model[3] and it creates biased estimation[4]. The second problem needs to be described theoretically because one important objective of this study is to include change in market prices in the Ricardian model and to explore the potential importance of price factor in this analysis.

According to the relevant literature described in Chapter 2, the IPCC projects average warming for next century (IPCC, 2007), but researchers disagree about whether agricultural production prices are likely to decrease (Darwin et al.,1995) or increase (Parry et al., 1999). Therefore, it is important to illustrate the possible consequences of the decrease and increase in prices in a theoretical context.

Starting with a three panel "small open economy" trade model, the impacts of climate and price changes[5] can be evaluated. In this model, the Canadian Prairies is represented as a small open economy which has no impact on world agricultural market prices. Parameters used in this model are defined as follows:

D_i= Demand for Canadian prairies (D_P), Rest of the world (D_R), World total (D_T)

S_i=Supply for Canadian prairies (S_P), Rest of the world (S_R), World total (S_T)

S_T= World total supply

P_0= Current market price

S_{PCC} = Canadian prairies supply after climate change (CC)

S_{RCC} = ROW supply after climate change

[3] Omitted variable error
[4] Less trustable standard error and confidence intervals
[5] As Prairies has small share in world agricultural production.

S_{TCC} = World total supply after climate change

P_1= Market price after climate change

Figure 3.4 shows world supply and prices for agricultural market and illustrates the relationship between the Canadian prairies, the rest of the world (ROW) and world total (S_T=S_P+S_R). World total supply and demand (S_T, D_T) determine current market price (P_0) while each of the other two markets have their own market clearing conditions (supply and demand for ROW (S_R, D_R) and Prairies (S_P, D_P) are in equilibrium conditions.

As discussed earlier when climate changes the production of the agricultural commodities will change as well. If climate change results in greater water stress to crops by decreasing rainfall and increasing temperature and therefore increased evapo-transpiration, agricultural production will decrease[6]. This supply reduction is represented in Figure 3.4 as a leftward shift in the world total supply function (S_{TCC}). Consequently, Agricultural market price will rise to (P_1) and also the supply curve for the ROW and the prairies will shift to the left. In this case agricultural production in total world will be reduced. In the present study, it is assumed that there would be no other adjustment to a different and higher yielding crops. Relaxing this assumption may yield different results. If other conditions (adjustments) take place then supply expansion may finally result in a decrease in prices. In both cases, changes in market prices seems inevitable which in turn; more clearly support the idea of inclusion of global market prices in the Ricardian approach.

[6] Ceteris Paribus

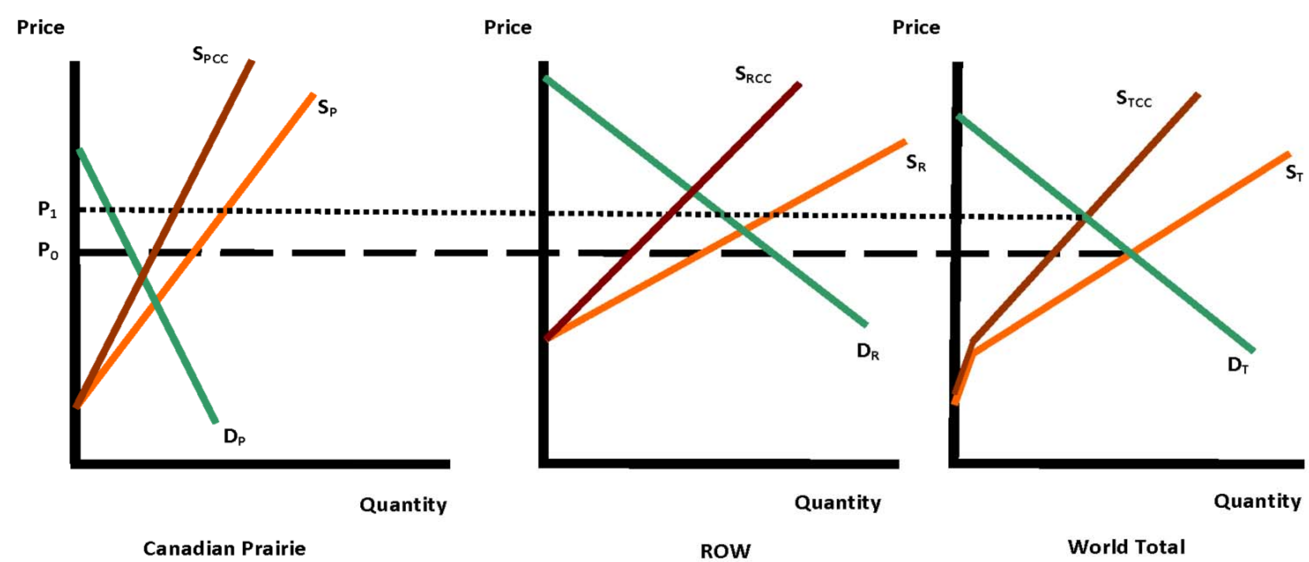


Figure 3.4: Climate change impacts on agricultural supply and price

To illustrate how the traditional Ricardian model conceptually could suffer from exclusion of prices; the current study employs a simple profit maximization concept. Since farmers in the Canadian prairies are assumed to be profit maximizing the starting point here is the following maximization:

$$\max_{A_i, Y_i} \pi = \sum P_i(E) A_i(P_i, E) Y_i(P_i, E) - C_i(Y_i, A_i, E, \omega) \tag{3.18}$$

where P_i is output prices and Y_i is yield of outputs and finally A_i is planted area of outputs[1]. The other elements were introduced previously in this chapter. It is assumed that all the above variables are influenced by climate, although the exact mathematical expression is unknown. Taking the first derivative (F.O.C) of the profit function with respect to area and yield respectively:

$$\partial\pi / \partial A_i = P_i(E) Y_i - C_i' = 0 \tag{3.19}$$

$$\partial\pi / \partial Y_i = P_i(E) A_i - C_i' = 0 \tag{3.20}$$

give the following optimal area usage A_i^* and produced yield Y_i^*.

$$A_i^* = f(E, P_i, \omega) \tag{3.21}$$

$$Y_i^* = f(E, P_i, \omega) \tag{3.22}$$

Now plugging A_i^* and Y_i^* back into equation (3.18) yields the following indirect profit function:

$$\pi^* = \sum_i P_i(E) A_i^*(E) Y_i^*(E) - C_i(E) \tag{3.23}$$

As in the current study the production yield ($\overline{Y}_i$) is not explicitly in the model therefore, the reduced form will be shown by:

$$\pi^* = \pi^*[P_i(E), A_i^*(E), E] \tag{3.24}$$

[1] Agricultural products like: wheat and canola.

therefore, the profit in this case is a function of external market prices (P_i), planted area (area response) to climate change (A_i), and climate change included in production function (E). As market prices and area response are all function of climate change, equation (3.24) can be reduced to $\pi^* = f(E)$ which show that profit and then profit per hectare (land value) are directly function of climate change.

Equation (3.24) shows that farmers profit is not only affected directly by climate change (E) but also indirectly through input and output prices, and planted area. Figure 3.5 shows that an environmental change (climate change) affects area of land allocated to the production of agricultural products (1) and prices (3) along with direct effect on profit (4). Also, climate change indirectly affects profit via all other variables (relationships 5 and 7 in Figure 3.5). In fact there are other influential variables such as output yields, production technology, and policies (δ) which are shown by relationships 2 and 6 that might affect profit. As all variables are a function of climate we can take total derivatives[2] of equation (3.24) to find the indirect influence of climate change on farmers profit and hence land value[3].

$$\frac{\partial \pi^*}{\partial E} = (\frac{\partial P_i}{\partial E})A_i + P_i(\frac{\partial A_i^*}{\partial E}) \qquad (3.25)^4$$

Based on this analysis, it is clear that the traditional Ricardian model with no prices ignores both the indirect effect of climate change via line 3 and 7 in Figure 3.5 and direct effects of price via line 7. In fact, considering Canadian prairies as a "small closed country" (autarky)[5]

[2] Chiang (1984)
[3] The process of retrieving Ricardian land value from profit described through equation (3.6) to (3.12) in this section.
[4] Taking total differentiation from (3.24) gives:

$$d\pi^* = A_i dP_i + P_i dA_i^*$$

then dividing both side of above equation by dE will result in change in profit with respect to environmental change [equation (3.25)].

[5] Economic independence and self-sufficiency in which the country is isolated from the rest of the world

with no import and export, the Ricardian model estimates accurate climate change impact on agricultural economics. But in this study, the prairie has an open economy with international interactions specifically in agricultural trade; therefore, market prices need to be included to obtain a more accurate estimate of climate change impacts.

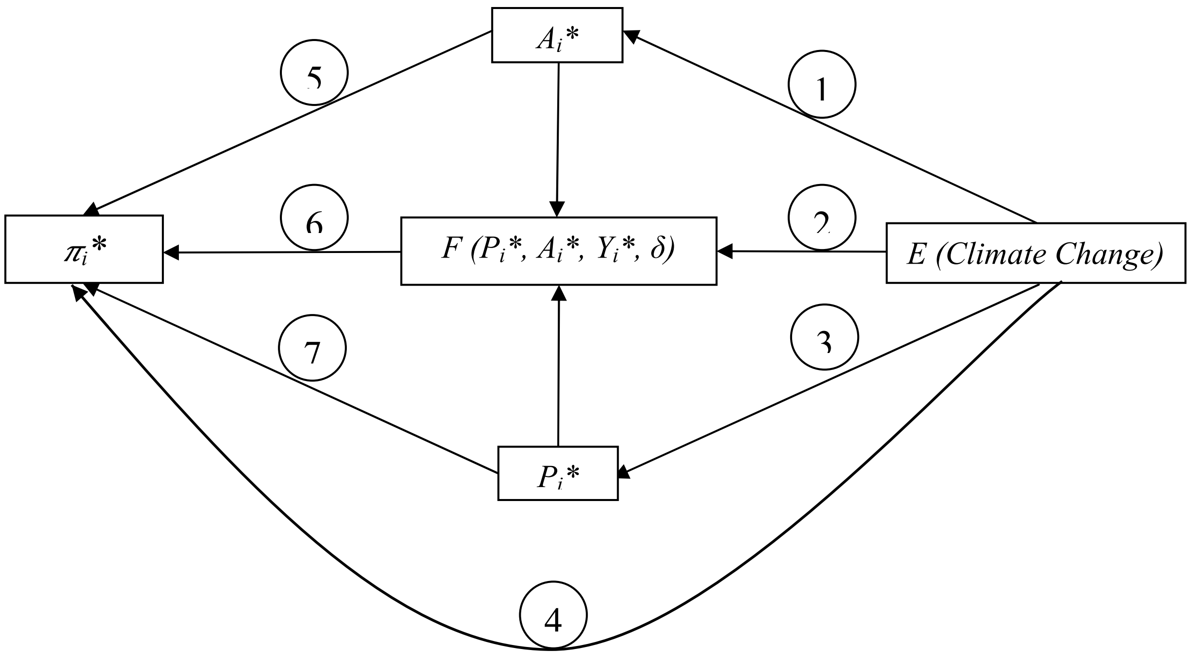


Figure 3.5 Direct and indirect influence of climate change on profit

In this analysis, an area response to climate change may provide a mechanism to analyze adaptation strategy, which will be undertaken by farmers. In other words, equation (3.25) shows that change in profit in response to climate change has two major components: market price change and planted area change (area response). In fact, the current study will contribute to the Ricardian analysis by adding price and area response change to the previous literature. Area response takes into account a value of adaptation as an influential factor in profit and hence in land value. A more technical explanation of this analysis will be discussed in section 3.5.

Using the concept presented in the three panel trade model (Figure 3.4), it can be shown that market prices are a function of world total planted area (A_i^D) which in turns are integration of prairies and ROW planted areas (A_i^{ROW} and A_i^{World}). In this case, we have:

$$P_i = H(A_i^D, A_i^{ROW}, A_i^{World}) \tag{3.26}$$

Now, taking total derivatives of (3.26) I can find the small influence of Prairies planted area on the global market price ($\frac{\partial H}{\partial A_i^D}$) from equation (3.27).

$$\frac{\partial P_i}{\partial A_i^D} = \left(\frac{\partial H}{\partial A_i^D}\right) + \left(\frac{\partial H}{\partial A_i^{ROW}}\right)\frac{\partial A_i^{ROW}}{\partial A_i^D} + \left(\frac{\partial H}{\partial A_i^{World}}\right)\frac{\partial A_i^{World}}{\partial A_i^D} \tag{3.27}$$

Comparing equations (3.24) and (3.26), the mutual interactions between market prices and farmers profit along with other factors can be inferred. The above relationships among factors in the international trade of agricultural products are another reason for the inclusion of global market prices in the Ricardian approach.

Now using new market price (P_1), the welfare impacts, as reflected in prairie agriculture as a change in land value, of climate change can be illustrated. As can be realized from the three panel trade model, the price of agricultural products will rise (from P_0 to P_1 in Figure 3.4 and 3.6) and the supply curve shifts to the left (from S_0 to S_{CC} in Figure 3.6). In this case, holding prices constant, the model reveals that the equilibrium condition in the Canadian prairies moves from A to B in Figure (3.6), therefore, the new farmland value is the area P_0BD (as demonstrated in Figure 3.3). However, relaxing constant prices assumption results in the new equilibrium point (point E) which changes the new land value to area P_1ED. Consequently, the Ricardian analysis with no prices will understate the damage of climate change with the size of

P_1 EBP_0. This bias (overstate) amount can be illuminated if one includes the market prices to this analysis.

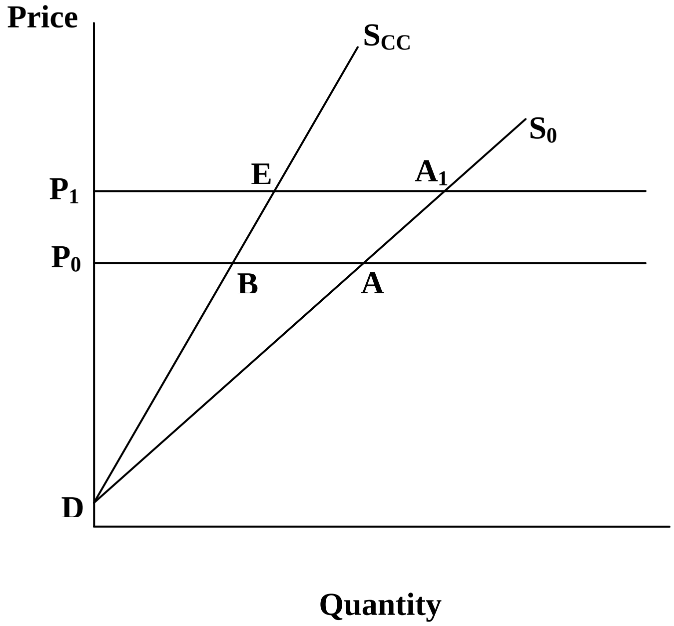


Figure 3.6: Welfare loss from supply reduction due to climate change

In a warming scenario, the productivity of certain crops that thrive in warmer climates will shift the supply curve for this crop to the right (from S_0 to S_{CC} in Figure 3.7). This supply shift could result in a decrease in output prices, therefore the Ricardian model where prices are held constant, estimates a benefit of *P_0 BD*. This is an overestimate of the benefits if the changes in global supply result in a decrease in output prices from P_0 to P_2. In fact the new land value in this case needs to be calculated based on movement from point A to E (instead of B by the Ricardian model). The new welfare is area P_2ED and area P_0BEP_2 is the size of this overestimation. Since the Ricardian model without price analysis is biased in welfare estimation, integrating the market prices in this analysis will give a better and more accurate estimation results.

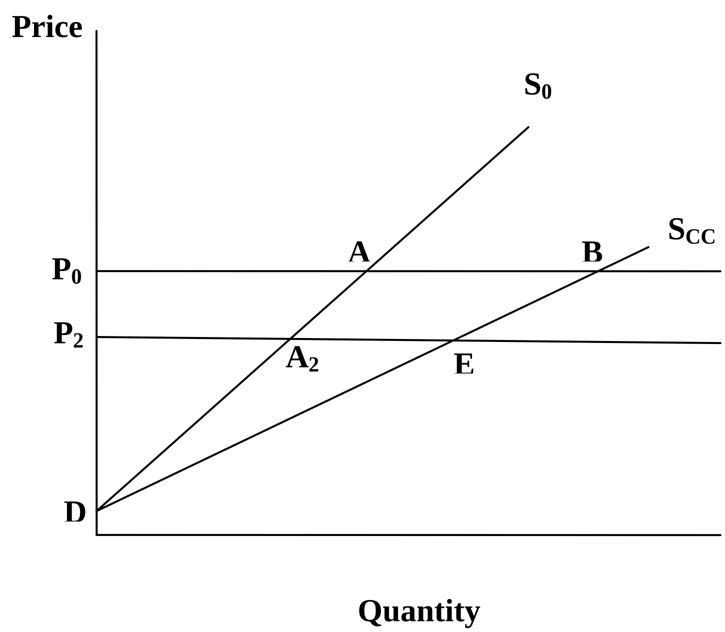


Figure 3.7: Welfare gain from supply expansion due to climate change

In this study market prices are included to alleviate biased estimation and to more accurately measure the welfare effects[6]. Utilizing this modified Ricardian model, one can investigate a variety of climate change and price forecasting scenarios in order to predict a cost or benefit for Canadian prairies agriculture. However, land use decisions by farmers might change due to adaptation to climate and price changes; therefore, a mechanism will be needed to endogenize land use decision in the current study. In the next section an area response analysis is introduced to address this issue.

[6] Also, in Chapter 5, model with included prices shows more robust and efficient estimation which clarifies the improvement in the traditional Ricardian analysis.

3.5 Area Response to Climate Change

Farmers in the Canadian prairies respond to climate change by making decisions on allocating their land to different types of production. Consequently, a mechanism is required to include (endogenize) land use or area response in the prediction of the consequences of climate and price changes on the pattern and economic performance of agricultural production. This analysis will begin with a profit maximization model which has two crops: wheat and canola.

$$\max_{A_W, A_C} \pi = P_W Y_W (E_i) A_W + P_C Y_C (E_i) A_C - C_i (Y_i, \omega, E) \qquad (3.28)$$

where P_W and P_C are wheat and canola output prices and Y_W and Y_C are wheat and canola yields and finally A_W and A_C represent the area allocated to wheat and canola respectively. The other parameters were introduced previously in this chapter. Taking the first order condition of the profit function with respect to wheat and canola area:

$$\partial\pi \big/ A_W = P_W Y_W (E_i) - C_i^{'} = 0 \qquad (3.29)$$

$$\partial\pi \big/ A_C = P_C Y_C (E_i) - C_i^{'} = 0 \qquad (3.30)$$

will give us optimal allocation of land to wheat and canola: A_W^* and A_C^*. Now plugging optimal land allocation back into equation (3.28) yields the following indirect profit function:

$$\pi^* = \pi^* [P_W, Y_W (E_i), P_C, Y_C (E_i), \omega] \qquad (3.31)$$

Now, taking the derivative of the indirect profit functions with respect to the revenues (R_W=$P_W Y_W$, R_W=$P_W Y_W$) will give area response function for wheat and canola as follow:

$$\partial\pi^* \big/ \partial R_W = A_W (P_W, P_C, E) \qquad (3.32)$$

$$\partial\pi^* \big/ \partial R_C = A_C (P_C, P_W, E) \qquad (3.33)$$

Notice that now, area response function for wheat and canola are function of prices and environmental (climate) variables (E).

In this analysis, one can estimate the above area response functions for canola and wheat. Conceptually, this estimation is an alternative analysis for adaptation strategy which will be undertaken by farmers. In other words, one can quantify the crop diversification decision by farmers in response to climate change. Then any climate and price change scenarios will be predicted by using estimated parameters. Finding fitted land use (different allocation of planted area to wheat and canola) in this case will lead to simulate both direct and indirect impacts of climate change and price forecast on the land value utilizing estimated Ricardian model.

3.6 Conclusion

This chapter presented a conceptual and theoretical framework to evaluate the impact of climate change on prairie agriculture. Also, with a three panel “small open economy” trade model, the effects of change in agricultural market prices are illustrated to show the welfare impacts of climate change. Then, the bias of the Ricardian approach on over/under estimation of the benefits and damages are demonstrated. Finally, an area response function is introduced to capture the indirect effects of alternative land use on the developed Ricardian model. Chapter 4 will develop the methodology of the present study.

CHAPTER 4 METHODOLOGY

4.1 Introduction

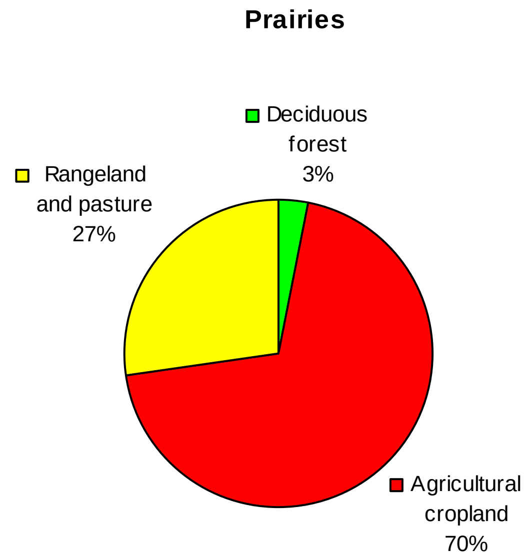
This chapter describes the econometric model that will be used to simulate climate change scenarios as well as agricultural market price forecasting of this study. First, the study area is described and the general types of variables and the various data sources for the dependent and independent variables used in the model are outlined. Also, a discussion of the specific variables and how and what each variable is being used to measure is developed. Next, a brief outline of the basic and panel model is presented to give readers a general overview of the econometric model and finally a review of how the base model is used to project future climate and price changes on land value. Chapter 4 concludes with a section highlighting the important issues and provides a link to Chapter 5.

4.2 Study Area and Data

The special biophysical and socioeconomic characteristics of the prairies are the main reason for choosing the Canadian prairies as the focus for this study. In this study, the study area is the Prairies Ecozone and some part of the Boreal Plains Ecozone(Ecological Stratification Working Group, 1995) (Figure 4.1). The Prairies Eco-zone is composed mostly of agricultural cropland (75%) and grasslands (Figure 4.2). Table 4.1 illustrates the number of farms and farmland area for Canada and the Prairies. More than half of the Canadian farms are located in the Prairies and with more than 54 millions hectare of farmland it has more than 80% of Canadian farmland (Sauchyn and Kulshreshtha, 2008).

Source: Environment Canada available at: http://www.statcan.gc.ca/pub/16-201-x/2007000/5212634-eng.htm

Figure 4.1 Canadian Climate regions



Source: Sauchyn and Kulshreshtha (2008) available at: http://www.ec.gc.ca/soer-ree/English/SOER/1996report/Doc/1-6-4-3-1.cfm#f4-1(f)

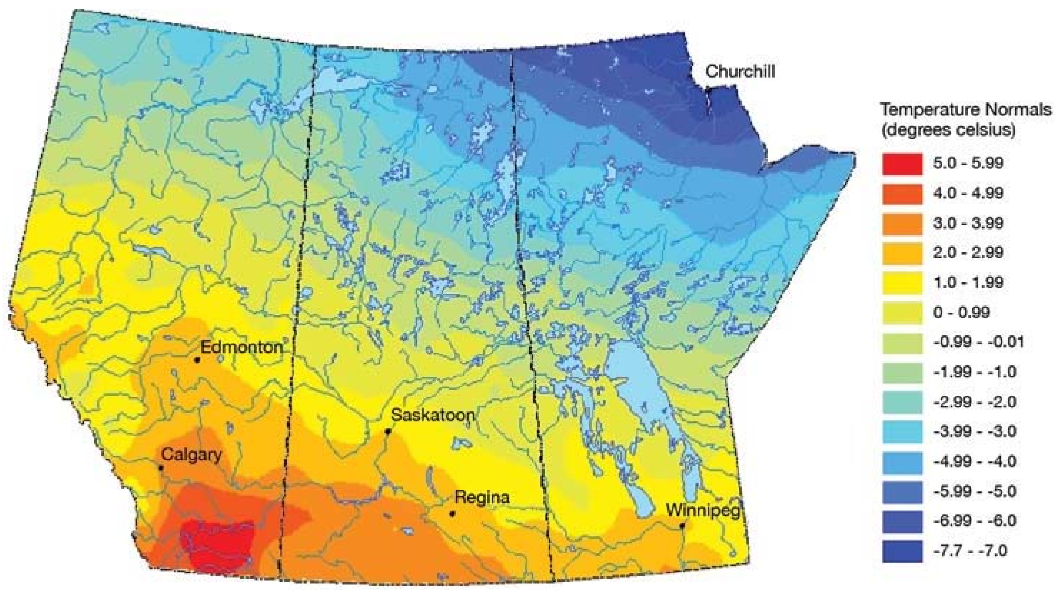
Figure 4.2 Land cover Distribution of Prairies

Table 4.1 Number of farms and farmland area in Prairies and Canada, 2001

	Alberta	**Saskatchewan**	**Manitoba**	**Prairies**	**Canada**
Number of farms	54×10^3	51×10^3	21×10^3	125×10^3	247×10^3
Area of farmland (ha)	21×10^6	26×10^6	8×10^6	55×10^6	68×10^6

Source: Statistics Canada (2001) available at: http://www.statcan.ca/english/agcensus2001/index.htm

The Western Interior Basin that comprises the northern portion of cultivable land in North America (Great Plains eco-zone) is where Prairie agriculture takes place (Millennium Ecosystem Assessment, 2005).The classification of the climatic regimes of the Prairie is cold and sub-Arctic. Hot summers, very cold winters, and low annual precipitation characterize the prairie climate[1] (Weber and Hauer, 2003). Average yearly temperatures are highest in southern Alberta and temperatures decrease in the direction of northern Saskatchewan and Manitoba (Figure 4.2).



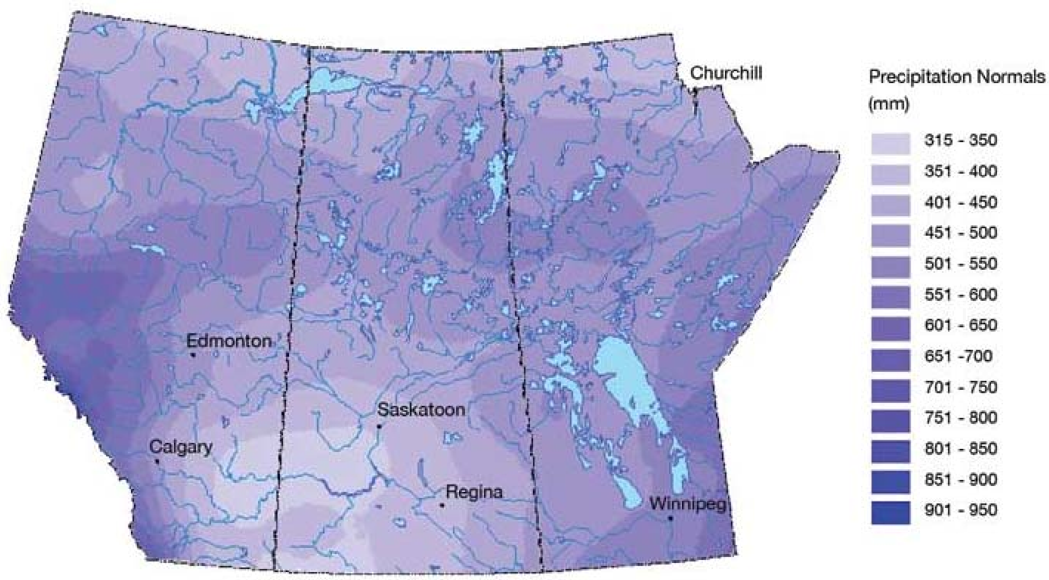
Source: Sauchyn and Kulshreshtha (2008) available at:
http://adaptation.nrcan.gc.ca/assess/2007/ch7/images/fig4_a_e.jpg

Figure 4.3 Prairies Climate Normal (1961-1990) Temperature

Annual precipitation ranges from 400 mm to 700 mm for Manitoba, Saskatchewan (300 mm–500 mm) and Alberta (300 mm–500 mm) tend to receive relatively less precipitation (Figure 4.3). Continuous snow cover in this region varies from year to year and from south to north but northern and eastern regions can expect about 4 to 5 months of snow cover (Herrington et al., 1997). Snow also is good source for soil moisture recharge and water storage. Across the Prairies the precipitation is relatively equal but the amount of available moisture is dramatically less in south western Saskatchewan and southeastern Alberta. Increasing temperature and wind are two important causes of evaporation and evapo-transpiration on the prairies. Burn and Hesch (2007) estimate an increasing evaporation trend using 40 years data for prairies. This trend

[1] Sub humid

shows an increase in northern regions than southern regions of Prairies. Availability of water for agricultural production is one of the most important impacts of climate change on agriculture.



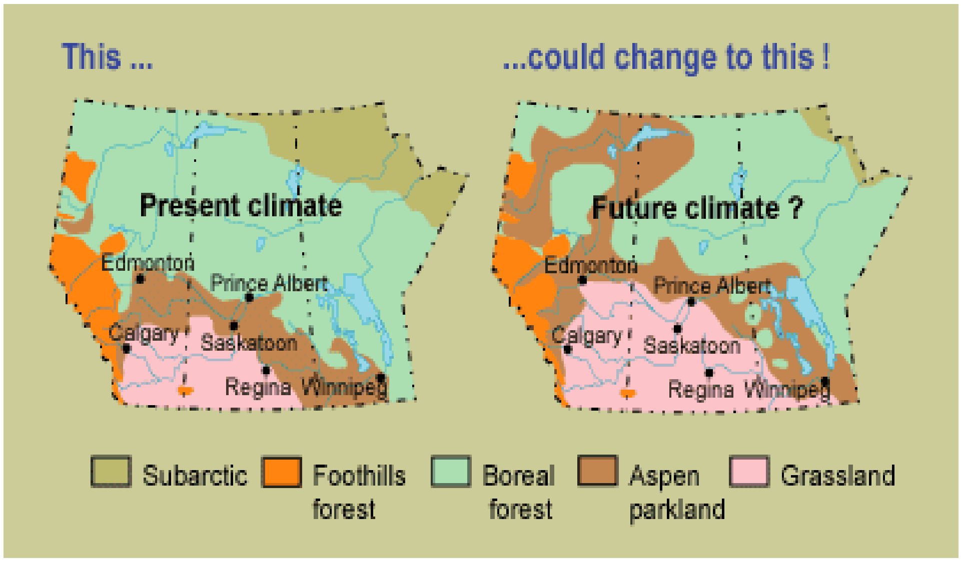
Source: Sauchyn and Kulshreshtha (2008) available at:
http://adaptation.nrcan.gc.ca/assess/2007/ch7/images/fig4_b_e.jpg

Figure 4.4 Prairies Climate Normals (1961-1990) Precipitation

Agricultural land use of this region is mostly specified for grain and oilseeds. Export of grains, oilseeds and animal products has played an important role in Canadian foreign exchange. Canadian Prairie agricultural makes a significant contribution to the nation's wealth. The prairies produce well over half of the total value of Canadian agri-food exports. Although grain production has historically been associated with prairie agriculture and continues to account for the majority of production, recently, farmers begun diversify into specialty crops (Tyrchniewicz and Chiotti 1997). Also, McCrae and Smith (2000) show that Prairie agriculture dominates in the share of Canadian agricultural GDP, grain and oilseeds represent approximately 52% of the

Prairies agricultural GDP while red meat contribute 33.5% of GDP. Also, the Prairies have lower productivity per hectare relative to Ontario and Quebec (Weber and Hauer, 2003).

According to Environment Canada (Hengeveld, 2000), yearly average temperature in the Prairie provinces have warmed about 1.2°C over the last 50 years, with average winter temperatures warming about 3.0°C, and summer temperatures increasing about 0.2°C. Since 1948, seven of the ten warmest years in the Prairies have occurred since 1981. Most of the climate change scenarios that have been projected for the Prairie Provinces suggest that the southern Prairies can expect an increase in the frequency and length of droughts. This region could experience deficiencies in soil moisture by the end of the century which is due to both changes in precipitation patterns and also due to increased potential evapo-transpiration. However, not all parts of the Prairie Provinces will experience the same effects (Hengeveld, 2000). Hogg and Hurdle (1995) anticipate the regional context of prairies may change from the left corner of the map (Lethbridge) to the right corner (north east of Winnipeg) due to change in the climate (Figure 4.5).



Source: Hogg and Hurdle, 1995

Figure 4.5 Anticipated changes in the regional context of Prairies

In brief, the large and diverse agricultural economy, favorable soils, and climatic regime have given a unique biophysical and socioeconomic characteristic to the Canadian prairies. Also, high probability of severe flooding, change in precipitation and temperature patterns and more frequent drought makes the prairies more vulnerable to climate change. These characteristics make the prairies an excellent region to examine the economic impacts of climate change.

The data for the empirical analysis of this study is based on three time periods (1991, 1996, and 2001) for the Canadian Prairies. The data sources are Agricultural Census 1991, 1996 and 2001, Census of population 1991, 1996 and 2001, Statistics Canada, Environment Canada, and C-RERL[2] (Canada Rural Economy Research Lab). In the next section all variables will be introduced and interpreted to make them relevant to represent Prairie condition.

[2] Most of the data previously has been refined by C-RERL

4.3 Variable Definitions

The unit of spatial analysis for this study is the Census Sub Division (CSD)[3]. The fundamental agent in the land use is the farmer or farm household. Unfortunately, the finest census unit which most of the required variables are available is CSD. In this analysis, I assumed that CSDs are internally homogeneous in terms of the behaviors of the individual farmers. Therefore, the results can be assumed to reflect the farmer's behavior.

The dependent and independent variables in this study are defined in Table 4.2. The independent variables are categorized into two groups: Climate and Non-Climate. Control variables, Dummies and Market prices are non-climate variables. Table 4.2 presents the definitions, source of each variable, and unit of measurement for this study. The following sections elaborate on these variables.

[3] I assumed CSD (1991) and Census Consolidate sub-division (CCS) 1996 are equal.

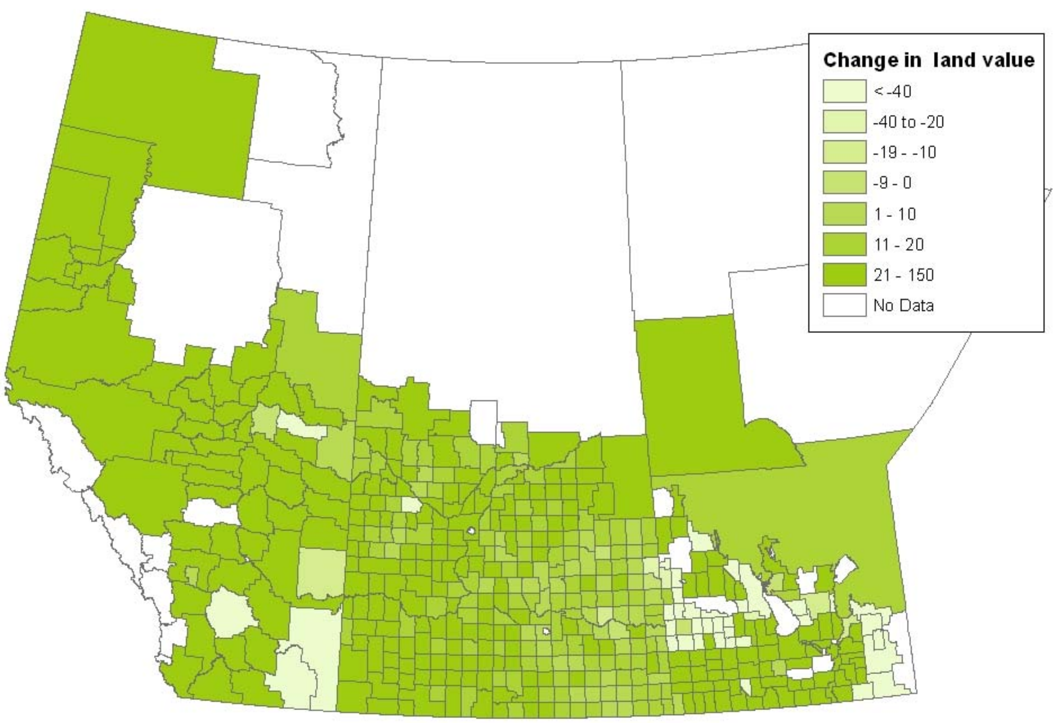
Table 4.2 Variables Description

Variable			**Definition**	**Source***
Dependent Variable	*LVAL*		Market value of land and buildings($CAD/Ha)	AG Census
Independent Variables	*Control*	INCCAP	Per capita income (×1000 $CAD)	CoP
		POPDEN	Population density (people per km^2)	CoP
		NETMIG	Net migration	CoP
		HIDIST	Distance to nearest Highway(km)	C-RERL
		GOVPAY	Government transfer payment($CAD/Ha)	StatsCan
		X_COORD	Longitude	C-RERL
	Dummy	BLACK_SZ	Black Soil Zone	C-RERL
		DGRAY_SZ	Dark Gray Soil Zone	C-RERL
		GRAY_SZ	Gray Soil Zone	C-RERL
		DBROWN_SZ	Dark Brown Soil Zone	C-RERL
		BROWN_SZ	Brown Soil Zone	C-RERL
		AL, SK, MB	Provincial dummies for Alberta, Saskatchewan and Manitoba	Auth
	Market prices	PW	Market price of Wheat($CAD/t)	FRM©,Auth
		PC	Market price of Canola($CAD/ t)	
	Climate	JAN, APR, JUL, SEP	Climate-normal annual mean temperature for 20 years preceding each Census year for January, April, July, October(˚C)	EnvCan, Auth
		GDD(month)	Climate-normal annual mean Growing Degree Days(GDD) for 20 years preceding each Census year for different months	EnvCan, Auth
		TEMPAV	Climate-normal annual mean temperature for 20 years preceding each Census year	EnvCan, Auth
		TPERC	Climate-normal annual mean precipitation for 20 years preceding each Census year(mm/year)	EnvCan, Auth
		RHJUL	The relative humidity for July (20 years average)	EnvCan, Auth
		TPTEMP	Proxy for Evapotranspiration(TPERC/TEMPAV)	Auth
		FFD	Frost free days	EnvCan, Auth
		SNOWAV	Annual average snowfall (20 years average)	EnvCan, Auth
		RAINAV	Annual average rainfall(20 years average)	EnvCan, Auth

* AG Census: Agricultural Census 1991, 1996 and 2001, CoP: Census of population 1991, 1996 and 2001, Auth: the author of this thesis, C-RERL: the Canada Rural Economy Research Lab, StatsCan: Statistics Canada, EnvCan: Environment Canada, FRM©: Freight Rate Manager (versions 1.0, 2.0 and 2.1) software has been used to calculate freight costs for each CSD. This software was developed by the agricultural Economics department at the University of Saskatchewan and Agriculture Institute of Management in Saskatchewan.

4.3.1 Dependent Variable

Consistent with most Ricardian models that have been developed in the literature, the dependent variable in the present model is per hectare agricultural land values ($CDN/ha) as reported by the market value of land in the Census of Agriculture (LVAL). In general, agricultural land values are higher in Alberta and increase from 1991 to 2001, while the agricultural land values for Saskatchewan and Manitoba are lower and increase steadily during the study period. Figure 4.6 reflects change in land values in each CSD over the previous decade (1991-2001). Land value in most CSDs has increased by between 10 and 150% between 1991 and 2001.



Source: Canada Rural Economy Research Lab (C-RERL)

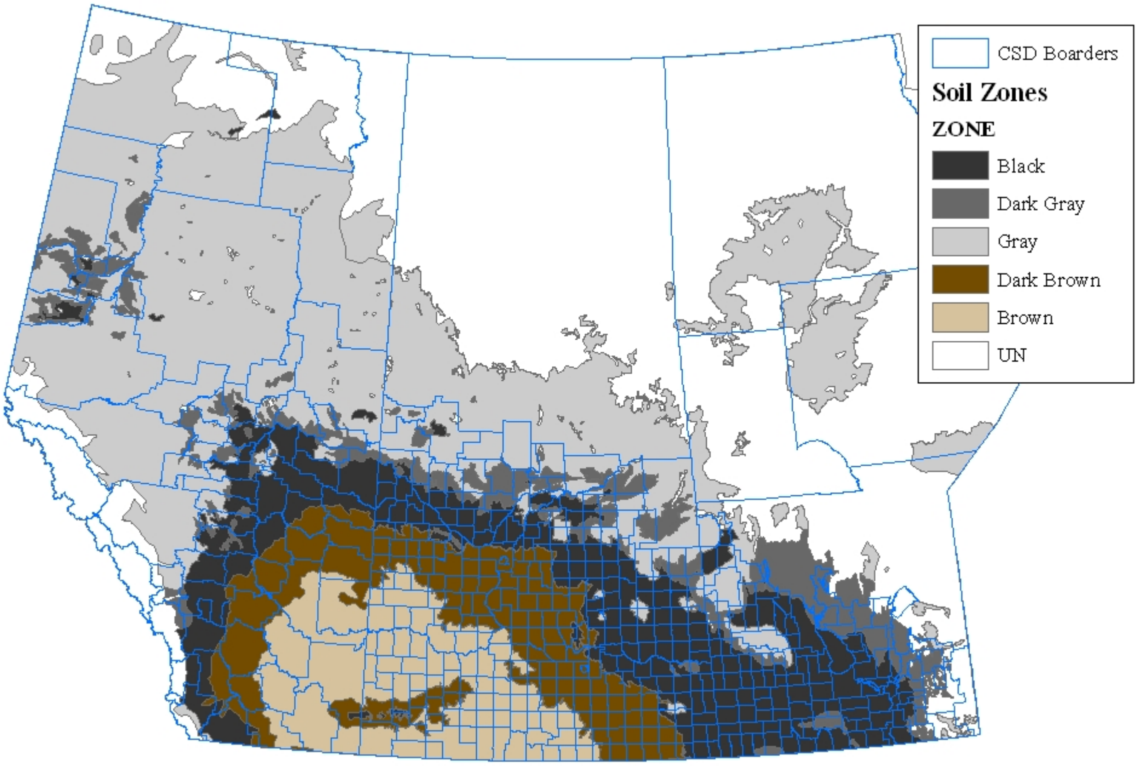
Figure 4.6 Percentage change in land value, 1991-2001

4.3.2 Independent Variables: Non-climate (control)

In the Ricardian model developed for the present research the independent variables are divided into four sets: non-climate (control), climate, agricultural market prices, and dummy variables. For non-climate factors, a variety of social, cultural, political, and economic factors are included in the model. Population density (people per km^2) (POP) and per capita income (INCCAP, average income in each CSD) are specified to control the competition for non-agricultural land uses. For change in population, (NETMIG) is defined as the subtraction of out migration from in migration in the prairies CSDs. The other policy variable is government transfer payment (GOVPAY) or alternatively any farm program which has transferred money to farmers by government.

4.3.3 Independent Variables: Dummy Variables

Soil type is a variable to control for the quality of the agricultural land. Figure 4.7 reflects the classification of soil types in the Prairies. There are five soil zones in this area (Black, Dark Brown, Brown, Gray and Dark Gray) and each zone is represented by a dummy variable (BLACK_SZ, DGRAY_SZ, GRAY_SZ, DBROWN_SZ and BROWN_SZ). Provincial effects (AL, SK and MB) are considered to account for province specific effects.



Source: Canada Rural Economy Research Lab (C-RERL)

Figure 4.7 Soil types for each census sub-division in Prairies

4.3.4 Independent Variables: Market Price Variables

Price variables are crucial components of this study as these variables can not only capture the effect of the market on the Prairies agricultural economics (by estimation of the base model) but also can be used to project the market fluctuations on the current Ricardian model (by simulating future expected prices in the base model). Consequently, it is crucial to define and determine appropriate variables which are important both locally and globally. The market prices received for major agricultural products in the prairies are chosen based on their share of total farm cash receipts. Wheat (PW) and Canola (PC) represent the largest cash receipts in western Canadian farm production. In fact, in terms of acreage, wheat and canola are the first and second most important crops grown in the Canadian prairie.

In this study, market price of wheat and canola in each CSD are different because each different delivery point in the prairies has different freight costs. In other words, as the freight rates from each delivery point (farms in each CSD) to each port (Thunder Bay or Vancouver) are different the proximity of delivery points to export ports causes a spatial variation in market prices. The market price for canola and wheat can be calculated based on subtraction of freight costs from the Canadian Wheat Board (CWB) price for each CSD. Freight Rate Manager (FRM©, versions 1.0, 2.0 and 2.1) software has been used to calculate freight costs for each CSD. This software was developed by the agricultural Economics department at the University of Saskatchewan and Agriculture Institute of Management in Saskatchewan. It is important to note that the area allocated to wheat and canola production are not the same in each CSD, therefore market prices are weighted by the hectare cultivated share of each crop. In this case, if one crop has not been cultivated in a CSD or if the hectare share of this crop is not significant it will not enter into market price calculation. Hectare cultivated share is calculated based on dividing the planted area of wheat (A_W) or canola(A_C) by the total planted area for wheat and canola (A_W + A_C). Therefore, wheat weighted market price is calculated by multiplying delivery point price of wheat by the cultivated share of wheat ($P_W \times \frac{A_W}{A_W + A_C}$) and canola weighted market price is ($P_C \times \frac{A_C}{A_W + A_C}$).

4.3.5 Independent Variables: Climate

Climate variables in this study include climate-normal annual means for the 20 years preceding each of the Census years (1991, 1996, and 2001). For example, climate variable for 1991 precipitation (TPERC) represents the years 1972-1991. The Climate variables for 2001 temperature represents the years 1982-2001, and so on. In the same fashion, JAN, APR, JUL and SEP is the 20 year climate normal mean daily temperature for the months of January, April, July and September respectively. An alternative variable that represents the solar energy input in the system is growing degree days (GDD). The number of growing degree days for a given day is defined in relation to the minimum and maximum temperatures at which a given plant is expected to exhibit significant growth. Relative humidity for the month of July (RHJUL) is another important climate variable. SNOWAV is climate-normal annual average snowfall and frost free days (FFD) as the days with more than zero temperature is the other climate variable in this study. As Prairies are dryland of Canada, the precipitation variables are important part of the model. SNOWAV, RHJUL and RAIN are water related variables which need to be in the model to capture the precipitation effects. FFD captures the growing season effects on the model. Table 4.3 shows descriptive statistics for all dependent and independent variables.

Next section outlines a brief and general overview of the econometric models employed in this study.

Table 4.3 Descriptive Statistics

Variable	Mean	Standard Deviation	Min	Max	Observations
Land Value	993.4	746.8	83.7	8272.8	1407
Income per Capita	15.0	3.5	4.6	32.8	1407
Population Density	10.3	89.8	3.91×10^{-2}	1317.8	1407
Net Migration	393.3	4325.7	-1535.0	108350	1407
Distance to nearest Highway	45.9	42.4	5.67×10^{-2}	388.2	1407
Government transfer payment	1407.9	1491.7	7.6	11143.1	1407
Price of Wheat	134.8	39.8	1.55×10^{-2}	230.8	1407
Price of Canola	63.5	46.0	3.57×10^{-10}	259.5	1407
Longitude	-105.2	4.9	-119.3	-95.8	1407
Black Soil Zone*	0.4	0.5	0.0	1.0	1407
Dark Gray Soil Zone*	0.2	0.4	0.0	1.0	1407
Gray Soil Zone*	0.2	0.4	0.0	1.0	1407
Dark Brown Soil Zone*	8.60×10^{-2}	0.3	0.0	1.0	1407
Brown Soil Zone*	9.52×10^{-2}	0.3	0.0	1.0	1407
Evapo-transpiration Proxy	-225.9	748.3	-1063.7	768.3	1407
January Temperature	-14.1	4.1	-23.6	18.2	1407
April Temperature	4.2	1.4	-4.7	17.1	1407
July Temperature	17.3	1.3	5.5	20.2	1407
September Temperature	10.7	1.2	5.1	15.0	1407
Rainfall	320.6	54.7	189.3	518.2	1407
Snow fall	105.8	23.4	42.8	262.5	1407
Frost Free Days	13.9	5.0	0.0	21.1	1407
July Relative Humidity	52.3	5.1	36.3	64.9	1407
Growing Degree Days for April	52.4	14.9	0.0	102.5	1407
Growing Degree Days for May	183.9	40.3	0.0	260.2	1407
Growing Degree Days for June	290.2	60.4	0.0	386.2	1407
Growing Degree Days for July	361.1	75.0	0.0	480.8	1407
Growing Degree Days for August	337.7	70.8	0.0	445.0	1407

* **Dummy Variables**

4.4 The Basic and Panel model

This section describes the econometric framework that I use to assess the effects of climate variations on Canadian agriculture. The econometric model specification involves regressing per hectare farmland value against climate variables while controlling for other environmental and socio-economic variables affecting agricultural farmland value for the years 1991, 1996 and2001. The data is pooled over the 3 census years and CSD level farmland value are regressed on climate , non-climate (control), agricultural market prices, and dummy variables to estimate the best use value function (also called best climate response function) across the Canadian Prairies. The econometric strategy is defined as a hedonic approach and panel fixed effects approach.

4.4.1 A Cross Sectional Approach

I initially consider the following cross sectional approach that has been predominant in the previous studies which is based on the following equation:

$$Y = \alpha N + \beta N^2 + \delta Z + \gamma P + \varphi D + \varepsilon_i \qquad (4.1)$$

where Y is agricultural land value, N represent the climate variables (N^2 is climate variables in quadratic form), Z are the socioeconomic variables, P are agricultural market price variables, D are the dummy variables and ε_i is a stochastic error term. The coefficient vectors (α , β , δ , φ and γ) will be estimated by OLS and Panel econometrics methods and the results reflect the effects of climate, non-climate, price and dummy factors on agricultural land value. Empirically, the basic hedonic model has been set up as follow:

$$\begin{aligned} LVAL &= \beta_1 + \beta_2(CLIMATE) + \beta_3(CLIMATE^2) + \\ &\beta_3(CONTROL) + \beta_4(PRICE) + \beta_5(DUMMIES) \end{aligned} \qquad (4.2)$$

Equation (4.2) shows that the functional form for climate variables is quadratic form which is consistent with literature[4]. Quadratic forms are designed to take into account any possibilities of nonlinearities in the climate sensitivities. If land values expressed as a quadratic function of climate variables then the partial derivative with respect to climate of the general equation would be:

$$\frac{\partial LVAL}{\partial CLIMATE} = \beta_2 + 2\beta_3 CLIMATE \tag{4.3}$$

These are simply means of the estimated slopes of the climate variables from the model ($\beta_2 + 2\beta_3 CLIMATE$) (Polsky, 2004). The linear terms represent the marginal value of climate at the Canadian mean, while the squared terms are representing the shape of the relationship between climate and land value. A positive coefficient indicates a U shape and the negative coefficient reflects the hill shape relationships (Mendelsohn, 2001). A hill shape relationship between a climate variable and land value indicates that as the climate variable increases the land value increase to the certain point (maximum) then increasing climate variable beyond this point reduces the land value. On the other hand, a U shape relationship shows that land value will decrease as climate variables rise to reach a certain point (Minimum) then both land value and climate variables will increase. The empirical examples will be presented in the next Chapter.

4.4.2 A Panel Fixed Effects Approach

As this study considers three points of time and as the Canadian Prairies spread across different provinces, the analysis must include a mechanism to represent regional and temporal scale variation in this study. Econometrically, these time and spatial effects can be tested by

[4] Described in section 3.2

running the model as a two way fixed effects method. The model can be estimated as a panel considering time and place fixed effects on the Ricardian analysis as follow:

$$Y_t = \eta_{province} + \lambda_t + \alpha N_t + \beta N_t^2 + \delta Z_t + \gamma P_t + \varphi D_t + \mu + \varepsilon_{it} \tag{4.4}$$

where Y_t is agricultural land value in 1991, 1996, and 2001, λ_t is year fixed effects and now the equation includes $\eta_{province}$ as a province indicator. There are two reasons to include this time-place fixed effects: first, the province fixed effects can absorb unobserved time invariant determinants of the dependent variable. Second, the year indicator λ_t control for time differences in the dependent variable which are common across CSD.

To show two way fixed effects regressors, assume N_t, N^2_t, Z_t, P_t, and D_t are all included in the X_{it} matrix:

$$Y_{it} = \eta_{province} + \lambda_t + \beta X_{it} + \mu + \varepsilon_{it} \tag{4.5}$$

then, the fixed effect two-way estimator for α, β, δ, γ, and φ in (4.4) is **b** as follows(Greene, 2003):

$$\mathrm{b}=[\sum_{i=1}^{3}\ \sum_{t=1}^{3}(\mathrm{x}_{it}\text{-}\overline{\mathrm{x}}_{i.}\text{-}\overline{\mathrm{x}}_{.i}+\overline{\overline{\mathrm{x}}})(\mathrm{x}_{it}\text{-}\overline{\mathrm{x}}_{i.}\text{-}\overline{\mathrm{x}}_{.i}+\overline{\overline{\mathrm{x}}})']^{-1}\times$$

$$[\sum_{i=1}^{3}\ \sum_{t=1}^{3}(\mathrm{x}_{it}\text{-}\overline{\mathrm{x}}_{i.}\text{-}\overline{\mathrm{x}}_{.i}+\overline{\overline{\mathrm{x}}})(\mathrm{y}_{it}\text{-}\overline{\mathrm{y}}_{i.}\text{-}\overline{\mathrm{y}}_{.i}+\overline{\overline{\mathrm{y}}})']^{-1} \tag{4.6}$$

now, the regression constant term is:

$$\hat{\mu} = \overline{\overline{\mathrm{y}}} - \overline{\overline{\mathrm{x}}}'\mathrm{b}$$

and fixed effect two-way estimator for other coefficients are:

for provinces fixed effects: $\hat{\eta}_{province} = (\overline{\mathrm{y}}_{i.}\text{-}\overline{\overline{\mathrm{y}}}) - (\overline{\mathrm{x}}_{i.} + \overline{\overline{\mathrm{x}}})'\mathrm{b}$ (4.7) and for time fixed effects: $\hat{\lambda}_t = (\bar{y}_{.t} - \bar{\bar{y}}) - (\bar{x}_{.t} - \bar{\bar{x}})'b$ (4.8)

where the bar symbol represents the average in the above formulas. For instance, $\bar{X}_{i\cdot}$ is average of X for three provinces in a fixed year and $\bar{\bar{X}}$ is average of X in all three years and three provinces (Baltagi, 2005 p. 34).

4.4.3 Area Response Function

In this analysis, to quantify the crop diversification decision by farmers in response to climate change, I developed a simplified area response function from Salassi (1995) represented by:

$$A_i = f\ (P_i, SS_i) \tag{4.9}$$

where A_i is the planted area of the crop i, P_i is the price of the crop i, and SS_i is a vector of variables representing supply shifters. According to Mythili (2001), Mahmood *et al.* (2007), and Salassi (1995) supply shifters include variables such as government support, lagged planted acreage of the commodity, lagged yield of crop, and lagged price of crop. Since yield is a function of climate, one can conclude that climate variables are indirectly a determinant of the area response function.

Area response function for wheat and canola in this study are a function of prices, government payment and environmental (climate) variables. This relationship can be written as:

$$A_i = \alpha N_i + \delta G_i + \gamma P_i + \varepsilon_i \tag{4.10}$$

where,

A_i = Planted area of wheat or canola

N_i = Climate variables

G_i = Government payment

P_i = Agricultural market prices of wheat or canola

and ε_i is a stochastic error term.

Now, equation (4.10) can be estimated to capture the impact of current climate change and prices on planted area. Then it will be used to simulate future climate and price changes directly on planted area and indirectly on future (simulated) land value.

4.5 Econometric estimation

An econometric model is an important tool available to researchers to separate and determine the influence of several explanatory variables on a dependent variable. The common problem with any econometric model needs to be considered in this study as well. Potential problems regarding the linear regression model are outlined. A reasonable expectation regarding whether these problems actually exist are formed, and how to mitigate these issues are assessed. Common econometric problems that can cause a violation of the fundamental assumptions of regression modeling include multicollinearity, heteroskedasticity, and measurement error.

For multicollinearity problem, it is important to not include any two independent variables in the model with a pair-wise correlation greater than 0.8. The important issue here is that climate variables and squared terms of them inherently have potential multicolliniarity. Kaufman (1998) emphasizes that running models with un-demeaned (when data are not subtracted from their mean) climate variables leads to frequent switching of the parameter estimates and may cause large marginal effects. Therefore all climate variables have been demeaned (subtracting all data from their mean) to prevent strong multicollinearity in the estimated model.

To avoid any unknown heteroskedasticity in the model, White's heteroskedasticity consistent covariance matrix estimator is utilized, which provides correct estimates of the coefficient covariances.

In the results chapter, different regressions considering a number of different specifications will be estimated to determine the most robust model, and to lessen econometric and theoretical issues. To address model robustness, it is necessary to establish the set of variables that provide the most robust specification, while minimizing potential theoretical and econometric concerns. Robustness has a variety of definitions, in the current study; the following factors are used to determine robustness:

1. The fit of the overall model as represented by the F-Statistic and R-squared values.

2. The level of significance of the individual explanatory variables as revealed by the coefficient t-statistics.

3. Whether or not the individual variables exhibit the direction of influence on the dependent variable are consistence with the literature and the theoretical model.

4.6 Simulation Method

After estimating the impact of climate means by using above panel model regression, in current years (1991 to 2001), one needs to evaluate the impact of future change in climate and prices (or revised climate and price variables) on land value. These new variables have been adjusted to meet new climate and price conditions in the future. The current analysis employs climate change scenarios to create new adjusted variables for temperature, precipitation and market prices. The current variables in the primary data set will be added by some °C to calculate the new temperature variable in case of future temperature, the precipitation variables will be multiplied by percentage change in future precipitation and price variables will be multiplied by percentage change expected in prices. Now by plugging the change between the old and new (modified) variables in the regression result, change in the farmland value will be simulated.

To illustrate the technical mechanism of this simulation, recall equation (4.4):

$$Y_t = \eta_{province} + \lambda_t + \alpha N_t + \beta N_t^2 + \delta Z_t + \gamma P_t + \varphi D_t + \mu + \varepsilon_{it} \qquad (4.4)$$

After estimating equation (4.4) all coefficients will be determined as well as fitted land value as follow:

$$\hat{Y}_t = \hat{\eta}_{province} + \hat{\lambda}_t + \hat{\alpha} N_t + \hat{\beta} N_t^{\,2} + \hat{\delta} Z_t + \hat{\gamma} P_t + \hat{\varphi} D_t + \hat{\mu} \qquad (4.11)$$

the above estimation is based on the 1991-2001 base model data set, now to simulate future climate and price changes in time t+1 following equation (4.12) needs to be subtracted from equation (4.11):

$$\hat{Y}_{t+1} = \hat{\eta}_{province} + \hat{\lambda}_t + \hat{\alpha} N_{t+1} + \hat{\beta} N_{t+1}^{\,2} + \hat{\delta} Z_t + \hat{\gamma} P_{t+1} + \hat{\varphi} D_t + \hat{\mu} \qquad (4.12)$$

notice that only climate and price variables (N_t, N^2_t, and P_t) will be changed therefore we will not see the other unchanged variables and constant terms in the new calculation:

$$\Delta Y = Y_{t+1} - Y_t = \hat{\alpha}(N_{t+1} - N_t) + \hat{\beta}(N_{t+1} - N_t)^2 + \hat{\gamma}(P_{t+1} - P_t) \qquad (4.13)$$

Changing climate and price variables in simulation will result in change for land value variable (ΔY). Now we can compare the results of simulated models with the base model and examine the impacts of climate change on the land value.

4.7 Conclusion

This Chapter highlighted the study area and discussed the econometric and simulation procedure to capture climate change in the developed Ricardian model. Also, chapter 4 developed the technical explanation for two way fixed effects estimation as well as a simple area response function. Chapter 5 illustrates and analyzes the estimation results for all developed models.

CHAPTER 5 BASE MODEL RESULTS

5.1 Introduction

The last chapter introduced a methodology for the current study. Based on the methodology, in this chapter a set of Ricardian models are estimated to investigate the impact of climate normals on the economics of agricultural systems in the Canadian prairies during three time periods (1991, 1996, and 2001). The econometric approach used to assess the climate impacts was a two way fixed effects panel model specification with time and provinces fixed effects. First this chapter will discuss the estimated parameters. Then a simple area response function application is presented in the next section. Finally concluding remarks will be provided to connect this chapter to Chapter 6.

5.2 Parameter Estimates

Parameter estimates from basic and panel fixed effects approaches are discussed in this section. Table 5.1[1] represents final base (only climate variables) and panel model estimations[2].As this study considers three points of time and as the Canadian Prairies spread across wide geographical area, the analysis must include a mechanism to represent regional and temporal scale variation. Econometrically, the time and spatial effects can be tested by running

[1] The quadratic forms for variables will be presented while number 2 appears right after each variable (e.g. TPERC2, JAN2, and so on). The quadratic forms are designed to take into account for any possibilities of nonlinearities in the climate sensitivities.(section 4.4.2)
[2] Full set of LIMDEP print outs are included in Appendix A.

the model as a two way fixed effects method[3]. The advantages of using a panel fixed effects model over cross section least square are the ability of using time and provinces effects simultaneously to capture more effects and also to acquire more accurate estimation (Baltagi, 2005).

As discussed in Chapters 3 and 4, price variables are necessary to avoid misspecification error (omission of relevant variable biased) in the Ricardian model. Before unfolding more of the results, and according to one of the objectives of this study which is to include and to explore the potential importance of price factor, it is important to discuss one potential problem with assuming unchanged market prices in the Ricardian model[4]. In the fifth column of Table 5.1, the classical Ricardian model has been presented. This model has no prices included and it is like all other Ricardian models which consider prices as constant. Therefore this model estimated to compare with the fourth column of Table 5.1 which is the basic panel model 1 of this study with prices being included. Note that the year variables are not significant when price variables are omitted. Although the R-squared statistic shows very small difference (in the third digit) whether prices are included or not, price variables do make a difference to the significance of April temperature, April temperature squared, July relative humidity, constant and time period variables.

There are some important results. First, including prices in the model takes the effect of year fixed effects out of constant term and makes year fixed effects significant[5]. It also supports the inclusion of prices in the model is necessary to capture the fixed effect nature of our data. Second, the model with prices can also take the impact of year fixed effects out of error term,

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[3] Described in section 4.4.2 of Chapter 4

[4] Misspecification error

[5] Practically, constant term includes all fixed effects of a model, by running the model with market prices some fixed effects can be excluded from constant term (year fixed effects in this context).

enabling the model to capture more information for variables such as April temperature, April temperature squared, and July relative humidity and consequently enable these variables to show their own effects in the model. In other words, the covariance between neglected price changes, which appears in the error term, and explanatory variables may offset the effect of those explanatory variables and make them insignificant. To end with, the above empirical results confirm the necessity of including commodity market prices in Ricardian model.

Two OLS (with only climate variables) and two panel models (with all variables) has been chosen from other models that were empirically estimated for the current available data set (Table 5.2). Since two sets of temperature and growing degree day (GDD) variables are employed in this study two panel models are presented. Panel model 1 includes temperature variables and growing degree day (GDD) variables are included in model 2 .The criteria to choose the better model were based on R-squared statistics which reflect the explanatory power of the independent variables of the model and partially from having more significant number of variables (Panel model 1 has 4 more significant parameters than panel model 2).

In the second Column of Table 5.2, the OLS model with only climate variables includes temperature variables. In this model, January and July temperature are significant; positive expected sign for the linear term and a negative sign for squared term guarantee a hill shaped relationship between land value and environmental factors[6]. The squared (quadratic) term shows the non linear shape of a climate variable (U or hill shaped). It is expected that temperature and land value will have hill shaped relation based on production function hill shaped relationship[7].

[6] The relation between climate variables and land value are based on the sign of the related coefficients. Here four relations have been identified: positive (positive linear and positive squared term; ex: rainfall and April temperature), negative (negative linear and negative squared term; ex: July temperature), U shaped (negative linear and positive squared term; ex: snowfall), and hill shaped (positive linear and negative squared term; ex: July relative humidity) relations. The main application of these concepts will be presented in section 5.2.1.1when Marginal Climate Impacts (MCI) will be introduced.

[7] See Chapter 3 section 3.2

A hill shape relationship between a climate variable and land value indicates that as the climate variable increases the land value increase to a certain point then increasing the climate variable beyond this point reduces the land value. In contrast, a U shape relationship shows that land value will decrease as climate variables rise to reach a certain point then both land value and climate variables will increase. The main application of these concepts will be presented in section 5.2.1.1when Marginal Climate Impacts (MCI) will be introduced.

Furthermore, April and September temperature and squared terms are not significant in the OLS climate model 1 and also annual average snow fall, relative humidity in July and Frost free days are not significant, even at the 10% level, although they have plausible signs. The other climate variables such as annual average rainfall (RAIN) and the evapo-transpiration proxy (TPTEMP) are significant reflecting that precipitation and potential available water play key roles in prairie agricultural production.

The OLS only climate model with growing degree day (GDD) variables is presented in the third column of Table 5.1. This model result indicates that growing degree days are not significant (except April's GDD) although they have expected signs (except GDD signs for June and July). In fact, there are not enough variations in GDD variables to significantly describe land value in this model. All other variables have the same descriptions as the first climate variable model (OLS climate 1). The OLS only climate 1 and climate 2 models have low R-squared values at less than 0.21. In other words, in these models climate variables only explain about 21% of the variation in prairies farm land values. The regressions consist of only climate variables and as such are not complete and suffering from lack of other relevant variables. In order to improve the estimation results, more appropriate variables and methods have been applied and followed. Adding more related variables along with different estimation method are shown to increase R-squared to 59%[8].

[8]In fact, the alternative model increases the R squared value from 0.2 to 0.58

Table 5.1 Basic and Panel Estimation Results

Variable	OLS Only Climate1	OLS Only Climate2	Panel Model 1	Panel Model 1 No Prices	Panel Model 2
Control					
Income per Capita	-	-	37.85***	38.30***	37.50***
Population Density	-	-	14.62***	14.78***	14.76***
Population Density Squared	-	-	-0.01***	-0.01***	-0.01***
Net Migration	-	-	0.03***	0.025***	0.03***
Distance to nearest Highway	-	-	-1.71***	-1.73***	-1.80***
Government transfer payment	-	-	0.04***	0.04***	0.04***
Longitude	-	-	14.76*	16.70**	9.72
Dummy					
Black Soil Zone	-	-	71.33	57.35	139.88
Brown Soil Zone	-	-	-217.33	-228.61*	-118.61
Dark Brown Soil Zone	-	-	-52.71	-68.24	34.93
Gray Soil Zone	-	-	31.52	22.19	87.38
Dark Gray Soil Zone	-	-	70.37	62.79	116.01
Market prices					
Price of Wheat	-	-	6.67*	-	7.92**
Price of Canola	-	-	4.08*	-	4.62**
Climate					
Evapo-transpiration Proxy	0.04***	0.04***	0.04***	0.04***	0.04***
Evapo-transpiration Squared	$0.38\times10^{-6***}$	$0.37\times10^{-6***}$	$0.37\times10^{-6***}$	$0.37\times10^{-6***}$	$0.38\times10^{-6***}$
January Temperature	9.84***	-	15.25*	16.85*	-
January Temperature Squared	-2.3***	-	-0.46	-0.50	-
April Temperature	13.84	-	22.04*	21.44	-
April Temperature Squared	3.16	-	3.05*	3.02	-
July Temperature	312.84*	-	-31.70*	-30.51*	-
July Temperature Squared	-11.12*	-	-5.40	-5.39	-
September Temperature	41.32	-	15.50	17.15	-
September Temperature Squared	-0.56	-	5.77	6.18	-
Growing Degree Days for April	-	22.47*	-	-	-2.86
Growing Degree Days for April Squared	-	-0.08	-	-	0.06
Growing Degree Days for May	-	2.04	-	-	0.77
Growing Degree Days for May Squared	-	-0.02	-	-	-0.05**
Growing Degree Days for June	-	-9.76	-	-	1.91
Growing Degree Days for June Squared	-	0.2	-	-	0.03**
Growing Degree Days for July	-	-4.20	-	-	-1.48
Growing Degree Days for July Squared	-	0.001	-	-	0.002
Growing Degree Days for August	-	7.77	-	-	-0.08
Growing Degree Days for August Squared	-	-0.01	-	-	-0.008
Rainfall	-6.73*	-8.57*	0.57	0.71	0.81
Rainfall Squared	0.02***	0.02***	0.03***	0.03***	0.03***
Snow fall	1.09	-4.02	-1.79**	-1.89**	-1.79**
Snowfall Squared	-0.01	0.01	0.01	0.01	0.01
Frost Free Days	12.01	-18.01	3.95	4.08	4.71
July Relative Humidity	58.57	62.15	9.15*	8.40	4.30
July Relative Humidity Squared	-0.38	-0.60	-0.35	-0.40	-0.21
Constant	-2797.67	450.11	617.98	1987.99**	-212.69

*** denotes significant at 1% level, ** denotes significant at 5% level and * denotes significant at 10% level.

Table 5.1 Continued

Variable	OLS Only Climate1	OLS Only Climate2	Panel Model 1	Panel Model 1 No Prices	Panel Model 2
Province Fixed Effects					
Manitoba	-	-	26.72	34.13	6.67
Saskatchewan	-	-	-90.59***	-95.39***	-91.95***
Alberta	-	-	385.40***	394.56***	429.62***
Year Fixed Effects					
1991	-	-	314.46**	-3.46	338.40**
1996	-	-	-323.89**	2.12	-373.04**
2001	-	-	1.21	1.40	25.18
R^2	0.21	0.15	0.59	0.59	0.59
Adjusted R^2	0.20	0.14	0.58	0.58	0.58

*** denotes significant at 1% level, ** denotes significant at 5% level and * denotes significant at 10% level.

The signs of the parameter estimates are the same in both set of models, the magnitudes are similar and the set of significant variables is almost identical between the two set of estimates. This similarity validates the decision to use Panel Fixed Effects model against OLS. It is noteworthy that OLS results also show similar signs and magnitudes; however, the number of significant variables are less than other models and also the R-squared for OLS with all variables are less than other panel models[9] which was expected as panel fixed effects model use time and provinces effects simultaneously to capture more effects.

It is important to recognize the fact that there are a number of missing factors such as irrigation, livestock, and urban development effects that are not included in the model. Particularly, Alberta with higher land value with respect to Manitoba and Saskatchewan needs to be examined for the above effects more carefully. A sensitivity analysis of removing Alberta's data from the base model has been executed to examine the difference between the complete model and a sub-sample of data set[10]. Table C.1 shows the results of the sensitivity analysis of the removing Alberta from data set. This sensitivity analysis result reveal that the signs and

[9] OLS with all variables presented in Appendix A.
[10] See Appendix C

magnitudes of the parameters estimated for complete and sub-sample models are similar except for January Temperature, January Temperature Squared, and July Relative Humidity. However, the R squared for model without Alberta is less that the model with Alberta showing the model without Alberta has the lower explanatory power that the other one.

An important point here is that the constant term and Alberta fixed effects in the both models are making the model with Alberta more representative than the model without Alberta. In fact, Alberta fixed effect captures at least some part of missing factors in the total sample model. On the other hand, when Alberta data is removed from the model the constant term captures this effect and not the other parameters on the model. As the inclusion of provinces fixed effects are to capture each province effect on the land value and as fixed effects inherently can be captivated from constant term (Baltagi, 2005), the model with Alberta can be justified to be used in the current analysis and model without Alberta has no advantage to the other model.

5.2.1 Climate Variables

The panel model 1 regression results from Table 5.1 demonstrate that most of the climate variables have a significant impact on land values (except September temperature and Rainfall). The estimated coefficients of most of the linear and quadratic terms are statistically significant. As expected, the climate parameters across the prairies change over the seasons. Since the squared terms for temperature of different seasons have different signs, a mixture of hill shaped and U shaped responses has been implied. Also, the parameter estimates for precipitation variables such as TPTEMP, SNOW, RHJUL and RAIN all have positive squared term implying U shaped response function.

The panel model 2 regression results reveal that climate variables based on growing degree days for different seasons are not significant and does not show any significance even at the 10% level except for May growing degree days squared and June growing degree days squared. Also, frost free days (FFD) is significant in none of the models. Rainfall (RAIN) and the evapo-transpiration proxy (TPTEMP) climate variables in this model are at the same significance level and similar in value with respect to the panel model 1. Therefore, the two model results are consistent with the understanding of the importance of precipitation in agricultural production within the prairie landscape.

5.2.1.1 Marginal Climate Impacts

Since it is difficult to interpret the linear (constant slopes) and squared coefficients (nonlinear slopes which are a function of CLIMATE variables) in raw form, Marginal Climate Impact (MCI)[11] for each climate variables has been calculated. Recalling equation 4.2 from section 4.3.1, if land values are expressed as a quadratic function of climate variables then the partial derivative of land value (LVAL) with respect to climate would be:

$$\frac{\partial LVAL}{\partial CLIMATE} = \beta_2 + 2\beta_3 CLIMATE \tag{4.3}$$

next, taking the mean from both sides:

$$E\left(\frac{\partial LVAL}{\partial CLIMATE}\right) = \beta_2 + 2\beta_3 * E(CLIMATE) \tag{5.1}$$

which is the MCI for any climate variable. Evaluating the marginal effects of all climate variables at their mean provides the MCI for each climate variable (Table 5.2). In fact, MCI is the amount of change in land value when one unit change occurs in any climate variable. In this case, MCIs represent the change in CAD/ha of farmland value per ˚C or mm/year, evaluated at the mean annual climate for farmland in Canadian Prairies. Equation (5.1) can be calculated based on the numbers from the estimation results. Therefore, it can be tested as a restriction for

[11] It is also called marginal influence, marginal value, marginal effects of climate (Mendelsohn and Reinsborough, 2007) or Ricardian climate sensitivities (Polsky, 2004).

panel model 1[12]. Now, to investigate the significant level of estimated MCIs, it is necessary to run an F-test[13] (Gujarati, 2006). All the F- statistics of the climate variables in the model are highly significant at the 1 percent level (Table 5.2).

5.2 Marginal Climate Impacts

Variable	β_2	β_3	**SD**	**MCI**	**F-statistic**
January Temperature	15.26	-0.46	-3.80	28.14***	54.91
April Temperature	22.04	3.05	8.43	47.38***	31.59
July Temperature	-31.70	-5.40	-14.20	-218.96***	237.65
September Temperature	15.50	5.77	14.23	139.42***	96.03
Rainfall	0.57	0.03	3.14	18.98***	36.47
Snow fall	-1.80	0.01	0.38	-0.10	0.07
July Relative Humidity	9.15	-0.35	-3.55	9.15***	6.66
Evapo-transpiration Proxy	0.04	3.69×10^{-7}	0.00	0.04***	5341.92

*** denotes significant at 1% level.

The estimated MCIs for the climatic variables are consistent with expectations and have intuitive signs as well. All variables, except Snowfall, are highly significant. The marginal effects of January and September temperature on land value are significant indicating that a marginal increase in temperature for these months is beneficial for prairie agriculture. In contrast, the MCI for July temperature is negative and significant; indicating that higher July temperatures will tend to decrease agricultural land value. The reason for this relationship is that the greater than the normal warming condition along with more water evaporation (due to higher

[12] The restriction to test is $\beta_2 + 2\beta_3 \mathrm{A} = \mathrm{B}$ where A, and B are numerical amount.

[13] The F-test to test the numerical amount of restriction (5.1) in the model can be estimated by the following way. Taking Standard Deviation (SD) from equation 5.1gives:

$$SD\left(\frac{\partial LVAL}{\partial CLIMATE}\right) = 2\beta_3 SD(CLIMATE)$$

which is presented as SD in column 4 of Table 5.4. Now, F-statistics of the joint significance is:

$$F = \{MCI / 2\beta_3 \times SD(CLIMATE)\}^2$$

which is presented in the last Column of Table 5.4.

air temperature, which takes available water out of reach of plants) can cause heat stress on crops and reduces the crop productivity. This discussion about change in productivity and yields of different crop needs to be used with caution since there are different perspectives on the effects of climate change on crop yield. Tubiello et al (2007) show that among some agronomical studies on the yield effects of climate change, high temperature during the critical flowering period of a crop may lower positive CO_2 effects on yield by reducing grain number, size, and quality. Also, increased temperatures during the growing period may also reduce CO_2 effects indirectly, by increasing water demand. This is justifying the negative MCI for July on the prairies.

It is also important to identify that the results cannot be interpreted explicitly as land value reflecting change in yield and crop productivity. There are other regional differences that might affect agricultural land values, especially for non- agricultural based CSDs. Irrigation, livestock, and urban development are some of those regional factors that directly and indirectly might affect land value. In fact, depending on dominant activity within each CSDs (agricultural or non-agricultural base), regional factors may have significant impact on the land value. For example, agricultural land values will be affected by the metropolitan spillovers such as competition over land for a range of non-agricultural uses.

The MCI results indicate that with a temperature increase of 1˚C in April, farmland value will increase, on average, by 47 CAD per hectare, while the same increase in temperature in July will decrease land value, on average, by 219 CAD per hectare. Amongst all temperature variables, September’s temperature has the most influence on Canadian prairie agriculture (with 139 MCI) and January’s temperature has the least effect (with 25 MCI). There are no crops on the land in January, and September is harvesting time for most of the crops on the prairies.

Moreover, warmer Septembers provide longer growing season which in turn can results in greater productivity.

Since the Prairies are Canada's main dry land, it is expected that water deficits will have significant harmful effects on agricultural production. As increasing water scarcity is a serious problem, it is also expected that there will be a positive relationship between precipitation and farmland value in CSDs where agriculture is primary driver of land values. According to the findings of this study, the Ricardian climate sensitivities (i.e. MCI) for precipitation variables are highly significant and positive in sign. Keeping all other variables constant, a 1 mm per month increase in Rain on average results in 19 CAD per hectare increase in farmland value. Moreover, RHJUL (relative humidity in July), another water related variable, is strongly significant but appears to have less strong of an impact on agriculture. Finally, TPTEMP which is a proxy for evapo-transpiration has the least influence on the land value. In fact, the results show that 1 mm/month decrease in TPTEMP (keeping temperature constant) will cause only 4 cents per hectare decrease in farmland value. Also, based on the definition of TPTEMP[14], if temperature increases (holding precipitation constant), TPTMP decreases causing land value to decrease. If precipitation increases (no change in temperature) then TPTMP will rise and thereby causing agricultural land value to increase.

Several interesting results appear from the regression analysis; first, the evapo-transpiration proxy (TPTEMP), rainfall (RAIN) and July relative humidity (RHJUL) are highly significant with positive signs which are consistent with the expectation of having a direct and positive relationship between agricultural land values and water related climate variables. Furthermore, July temperature negatively impacts land value which can be interpreted as an increase in water deficits for plants (more evaporation than normal). Again, it is consistent with

[14] TPTEP= (TPERC/TEMPAV) which is total annual mean precipitation divided by total annual mean temperature.

the claim that agriculture in the Prairies is very vulnerable to the water scarcity. In summary, as agriculture production on the Canadian prairies is highly constrained by precipitation, land use and land value strongly depend on the precipitation, at least for agricultural based CSDs.

5.2.2 Market Prices Effects

The most significant contribution of this study to the related Ricardian literature is to determine the impact of including market prices in the model. Price variables are a crucial component of this study as these variables can not only capture the effects of the market but also can be used to simulate the impact of future market fluctuations on the Ricardian model. Consequently, it is crucial to define and employ appropriate market price variables which are important both locally and globally. The commodities chosen to include market prices in this model are based on the share of total farm cash receipts. Wheat (PW) and Canola (PC) represent the largest cash receipts in western Canadian farm production. Wheat and canola on average comprised 43.18 and 19.53 percent of total planted area for 1991 to 2008 years that makes them the most common crops in the Canadian Prairies[15]. In fact, in terms of land allocation, wheat and canola are the first and second most important crops grown in the Canadian prairies. As a result, canola and wheat prices are important and significant determinants of the agricultural economics of the western Canada.

The proposition of including market prices in the Ricardian model can be tested by employing Incremental F-test[16] (Gujarati, 2006). It will be assumed that the panel model 1 with prices and panel model 1 with no prices are unrestricted and restricted forms, respectively. In fact, running the panel model 1 with restriction that the price coefficients are zero is used to test

[15] CANSIM II, last accessed at December 2009:http://www.statcan.gc.ca/cgi-bin/af-fdr.cgi?l=eng&keng=8&kfra=8&loc=http://estat.statcan.gc.ca/Results/OMNFF03.CSV
[16] Test for including market prices.

whether market prices for canola and wheat are jointly significant and have an impact on land value or not. The test is as follow:

$$F_{J,N-K-1} = \frac{(R_u^2 - R_r^2) \times (N-K-1)}{(1-R_u^2) \times J} \tag{5.2}$$

where J = number of restrictions imposed (in this case, 1),

K = number of variables in the unrestricted model (36),

N = number of observations (1407),

R^2_u= R squared for unrestricted model (panel model 1), and

R^2_r= R squared for restricted model (panel model 1 No Prices).

The null hypothesis here is that both price coefficients for canola and wheat are equal to zero. It can be written as:

$$\mathrm{H}_0 = \beta_{\mathrm{Pw}} = \beta_{\mathrm{Pc}} = 0 \tag{5.3}$$

Now, as panel model 1 No Prices is a restricted version of panel model 1 then the Incremental F-statistic for this hypothesis is:

$$F_{J,N-K-1} = \frac{(R_u^2 - R_r^2) \times (N-K-1)}{(1-R_u^2) \times J} = \frac{(0.59414 - 0.59312) \times (1407 - 36 - 1)}{(1-0.95414) \times 1} = 3.45$$

Comparing the calculated F-statistic with table F ($F_{j,n-k-1}$=3.45>F_{table}=3 for 95%) rejects the null hypothesis[17] in favor of alternative hypothesis which is that market prices for canola and wheat are jointly significant and have an impact on land value. This result helps to meet the second important objective of this study, namely to include and reveal the importance of market price factor in the Ricardian land climate model for prairies.

The estimated coefficients on the market prices variables are consistent with economic theory. Canola and wheat prices are important and significant determinants of the agricultural

[17] Wheat and canola prices have no effects on farmland value.

economy of western Canada. In the current analysis, both of these variables are positive and significant which indicates that an increase in wheat and canola price will increase agricultural land value. According to the findings of this study, if wheat price increase by \$10/t the land value in the Canadian prairies will increase by \$66.7/ha based on panel model 1 (or \$79.2/ha for the panel model2). Similarly, a \$10/t increase in canola price results in approximately \$40.7 (or \$44.6 for the panel model2) per hectare increase in farmland value. These results indicate that Canadian farmers, as price takers, will tend to follow changes in wheat and canola prices as vital components of land use and farming plan decision making.

5.2.3 Control Variables

It is important to clarify the reason for including the control variables. The control independent variables represent some of the non-climate features that influence the land use decision making and land value. The pattern of using control variables is consistent with all Ricardian models but there are some different variables included in the present model. All of the control variables reflect the human dimensions of the land use process. In addition, they have been used to avoid any bias from misspecification error (omitted variable bias).

Consistent with expectations, the population density parameter is positive and strongly significant which indicates that as population pressure increases, agricultural land value increases. As land is a limited production input (fixed factor of production), increase in the demand for land will cause its value to increase. However, the negative sign for population density squared (hill shaped relationship) indicates that this increase will be limited when the population growth pass its optimum level. Per capita income reflects the wealth of the residents of an area. Per capita income has a positive and significant relation with land value. In high income areas non-agricultural land uses, like industrial and commercial compete with farmers on the same land which generates upward pressure on land values. Net migration[18] indicates growing or declining population can directly affect the land value. In this study, net migration has a positive and significant coefficient meaning that as in-migration to prairies increases the land value will increase. This result is consistent with the result that more population will lead to higher land value as described earlier in this paragraph.

The other significant and positive parameter in the present Ricardian model is government payments (GOVPAY). The basic effect of government financial support is to lessen the farmers financial risk associated with instability in economic and environmental conditions. Theoretically, income stabilization is the main motivation for government programs but empirically the relationship between government payments and land value is very complex. In August 1990, two support programs were introduced to stabilize grain farmers' incomes (King and Narayanan, 1992). First, the Gross Revenue Insurance Plan (GRIP) was introduced to insure farmers' gross revenues in the short run. It was designed to protect farmers from natural hazards or from market risks beyond the control of producers. The second program called the Net Income Stabilization Account (NISA) was a farmer contributed fund to help farmers stabilize their income. The positive parameter estimate indicates that as government payments stabilize farmers' income the land value should be higher for farmers receiving payments (or at least not decrease).

As prairie farmers need to transport their grain to the nearest port or nearest grain elevator when transportation distances decrease and transportation costs become smaller, farmer income will increase. This will be capitalized in higher land values. The other theoretical expectation in the control variables is that distance to the nearest highway (HIDIST) should be

[18] Net migration for a given geographic area is the difference between in-migration and out-migration during a specified time frame.

negative. Indeed, better access to transportation and therefore decreased transportation costs, increases land value. Also, as a regional parameter, distance to nearest highway was employed to capture the effects of land use competition. For example, where farmland areas are near to the cities, there is more competition for land use which causes land value to increase. In the two panel models, this effect is captured by the fact that the coefficients estimated for distance to nearest highway were significant and negative in sign.

Finally, longitude parameter (X_COORD) is positive and significant at the 10% level. According to the land value data as we move from Manitoba to Saskatchewan and Alberta, land value increases, therefore, positive longitude parameter here indicates that increase in longitude corresponds to increase in land value.

5.2.4 Dummy Variables

As described in Chapter 4, soil zone dummy variables are included in this study to capture the productivity differences among the prairie soil zones. Unfortunately, according to the estimated results none of soil zone dummies are significant. Among all soil zones the BLACK, DGRAY and GRAY soil zones have positive signs but the coefficients are not statistically significant. Empirically, being in a more fertile soil zone, like the black soil zone, positively explains the higher land values in this zone. Apparently, as Census Subdivision (CSD) is not a proper gross scale to capture soil effects, more investigation with better soil characteristic data set needs to be done. The provinces dummy variables will be described in province fixed effects section.

5.2.5 Province and Year Fixed Effects

In Chapter 4[19], the concept of including time-place fixed effects was presented. The province fixed effects can absorb unobserved time invariant determinants of the land value while year fixed effects control for time differences in land value which are common across CSD. In the panel model results, the significant and negative coefficient on the Saskatchewan fixed effect indicates that land value in Saskatchewan are lower compared to Alberta. This effect may be due to Saskatchewan being more distant from the east and west coasts in comparison with other two provinces (farthest province to coasts). In general, the data shows that Alberta has higher land values compared to the two other provinces and it is confirmed by the panel model 1 and 2 presented in Table 5.1. Alberta has positive and highly significant estimated coefficient (also the largest magnitude) while the Manitoba parameter is not significant (positive sign). In fact, the province fixed effects results support the other control variables results presented earlier in this section. For example, increase in population and migration positively influenced land value in Alberta.

An interesting result for year fixed effects is the significant and negative coefficient for the year of 1996. In 1995, Canada repealed the Western Grain Transportation Act (WGTA), which was a rail transportation subsidy paid to prairie farmers. The end of the WGTA eliminated government support that had lowered producers' cost of transporting grain to export ports from the Prairie Provinces. Elimination of freight subsidies reduced returns for traditional grains such as wheat and canola (Vercammen, 1999). This negative relationship within the Ricardian model, between agricultural land value and 1996 year variable has captured the removal of the WGTA. The other two years fixed effects have positive effects on land value but

[19] Chapter 4 Section 4.4.2

only 1991 year fixed effect is significant. Further investigations need to be done by using more quantitative data rather than dummy variables.

5.3 Comparison with other Ricardian Assessments

The analysis so far has focused on the base Ricardian model for the Canadian Prairies at the CSD level. Unfortunately, the national assessments only report aggregate CD (Census Division) level for all of Canada, which makes it difficult to compare the results with the current study. In addition, based on the present analysis, previous Canadian-based Ricardian analyses are subject to misspecification error. Weber and Hauer (2003) assume climate variables are a linear function of the land value, and they do not include a squared form in their estimation. It means land value and climate variables have linear relationships and an optimum level of climate factors cannot be found. Therefore, not only does their model suffer from the omitted variable bias but from functional issues as well. On the other hand, the Reinsborough (2003) and Weber and Hauer (2003) studies are based on one year cross sectional data (1995 and 1996, respectively) and could not capture temporal effects. And last, but not least, none of the studies include the market price factor in their examinations.

Weber and Hauer (2003) show that increasing temperature for April and July are beneficial while January and October are harmful for Canadian agriculture. Meanwhile, Reinsborough (2003) reveals that rising temperature for January and April increase farmland value, while July and October temperature decreases land value. The current analysis is in agreement with Reinsborough (2003) on harmful effects of July and beneficial effects of January temperatures. However, this study disagrees with the harmful effects of January and beneficial effects of July results from Weber and Hauer (2003). In the case of precipitation, all water related variables are beneficial for agriculture production on the Prairies which is consistent with the Weber and Hauer (2003) results (except October negative effects) and consistent with the Reinsborough (2003) results (except April negative effects). All other control variables seem to have the same effects with this study where there is a similar variable. More comparison on the climate scenarios will be presented in Chapter 6.

As the current analysis is based on the Mendelsohn et al. (1994) study, it is important to compare the results of two studies specifically on the base model[20]. Mendelsohn et al. (1994) suggest that higher winter and summer temperatures are harmful for agricultural production while fall and winter rainfall are beneficial and summer and spring rainfall are harmful. The estimation results in this study show that higher temperature in winter is beneficial for Canadian prairie land values, but higher summer temperature is harmful, which is consistent with the results from Mendehlson's study. In addition, snowfall, as the closest variable to winter rainfall in the Canadian prairies, is harmful which is in agreement with Mendehlson's results. The total rainfall and relative humidity are two other beneficial variables in this study which are not comparable as there is no similar variable on the Mendehlson's American study.

5.4 Area Response results

In order to evaluate the indirect effects of climate change on land value[21] through planted area, an area response function for wheat and canola has been developed and estimated. The link between land value and area response function is through market prices in the model. As described in section 4.3.4, market prices are weighted by the cultivated share of wheat and canola. Therefore, instead of using the planted area for each crop, cultivated shares

[20] Chapter 6 will illustrate more comparison between two studies on the climate scenarios.
[21] Figure 3.5 in the section 3.5 of Chapter 3 illustrates direct and indirect influence of Climate change

($\frac{A_W}{A_W + A_C}$, $\frac{A_C}{A_W + A_C}$) are utilized to make the connection between predicted planted area and simulated land values in the projected panel models.

The area response results for wheat are presented in this section. The regression has a 73% goodness of fit meaning independent variables can describe more than 70% of the variations (Table 5.3). All variables are significant except frost free days (FFD). As each year planted area is directly correlated to the last years planted area, a three year lag[22] for wheat cultivated (area) share has been recognized in this data set. Interestingly, all temperature variables have positive effects on the share of the planted area for wheat in prairies. On the other hand, all the water related variables have negative effects on the planted share of wheat. These results seem to indicate that, as expected, given the greater drought tolerance of wheat, relative to canola, farmers chose to plant more wheat in dryer and hotter locations. Consistent with production theory wheat price is positive indicating that higher prices for wheat increase the share of planted wheat in the Prairies. However, canola (substituting crop with wheat) price has a negative effects which indicates that an increase in canola price will results in reducing in the cultivated area of wheat in favor of canola (substitution effects). Any supportive payment from government will increase the cultivated wheat area but in very small amount.

[22] Three lags have been recognized based on Autocorrelation correlogram. Seasonal patterns can be examined via correlograms. The correlogram (autocorrelogram) displays graphically and numerically the autocorrelation function (*ACF*), which is serial correlation coefficients (and their standard errors) for consecutive lags (Gujarati, 2006).

Table 5.3 Area response of Wheat

Variable	Coefficient	t-student
Wheat area share [1st lag]	0.33***	12.6
Wheat area share [2nd lag]	0.15***	5.71
Wheat area share [3rd lag]	0.08***	3.24
Government transfer payment	$0.34\text{x}10^{-5}$**	2.1
Evapo-transpiration Proxy	$-0.7\text{x}10^{-6}$**	-2.32
January Temperature	0.002***	3.32
April Temperature	0.005***	2.54
July Temperature	0.006***	2.62
September Temperature	0.008***	3.21
Rainfall	-0.2×10^{-4}**	-2.42
Snow fall	-0.2×10^{-4}*	-1.73
Frost Free Days	-0.5×10^{-4}	-1.11
July Relative Humidity	-0.007***	-9.96
Price of Wheat [1st lag]	0.001*	1.69
Price of Canola [1st lag]	-0.001**	-2.4
Constant	0.49***	7.89
R^2	0.73	
Adjusted R^2	0.72	

*** denotes significant at 1% level, ** denotes significant at 5% level, and * denotes significant at 10% level.

The coefficients presented in Table 5.4 show the estimation results for the canola area response function. The parameter estimates are mostly significant. No lags was recognized for canola area share[1] showing that for agronomic reasons canola is not planted for two consecutive years. Independent variables can only describe 56% of the variations in the regression. More interestingly, in contrast with the wheat case, all the water related variables have positive effects on the share of the planted area for canola in Prairies. Now, all temperature variables have negative effects on the planted share of canola. This likely reflects the fact that canola is less productive in warmer temperature and requires more water. Consistent with production theory

[1] Based on Autocorrelation correlogram (autocorrelogram)

canola price is positive indicating higher price for canola increases the share of planted canola in the Prairies.

Table 5.4 Area response of Canola

Variable	Coefficient	t-student
Government transfer payment	-7.11×10^{-6}***	-3.45
Evapo-transpiration Proxy	1.00×10^{-6}***	2.89
January Temperature	-0.004***	-4.77
April Temperature	-0.01***	-3.75
July Temperature	-0.009***	-2.93
September Temperature	-0.015***	-4.88
Rainfall	0.2×10^{-4}***	3.1
Snow fall	0.5×10^{-4}***	3.37
Frost Free Days	0.4×10^{-4}	0.75
July Relative Humidity	0.016***	16.68
Price of Wheat [1st lag]	-0.6×10^{-4}	-0.50
Price of Canola [1st lag]	0.4×10^{-4}	0.51
Constant	0.23***	3.06
R^2	0.56	
Adjusted R^2	0.55	

*** denotes significant at 1% level, ** denotes significant at 5% level, and * denotes significant at 10% level.

Using area response as a function of climate and prices, the effects of simulated planted area on future land value will be examined in the next chapter. The results found here will be utilized to simulate land values for future climate and price conditions. In fact, a third dimension of this study, as described in Chapter 3, is to evaluate the indirect impact of climate change by switching between crops as an adaptation strategy of farmers in the face of climate change. This third approach includes change in planted area to capture the farming system response to any climate and price changes. In Chapter 6, the results of direct impacts of climate and price changes on land value with the results from indirect impacts through area response estimation will be compared.

5.5 Conclusion

To summarize, in this empirical results chapter, first the regression results are presented. Several important results were revealed in this regression, first there was a direct and positive relationship among agricultural land values and water related climate variables. Then, July temperature were found to negatively affect land values as increasing the probability of potentially water deficits for plants. Again, it is consistent with the claim that agriculture in the prairies is very vulnerable to water scarcity, and land use and land value strongly depend on precipitation. Based on the estimated Ricardian results, climate change seems to have a complicated nonlinear effect on prairie agriculture.

The most significant contribution of this study is the inclusion of market prices in the Ricardian model; this proposition is tested and verified by the results. Also, I find that a combination of water and temperature is required to describe the impact of climate means on agricultural land value. Two area response functions for wheat and canola were presented in this chapter to evaluate the indirect impacts of climate change by switching between crops as an adaptation strategy for farmers. The following Chapter will investigate the climate and price change impacts on the agricultural economics of the prairies.

CHAPTER 6 SIMULATION RESULTS

6.1 Introduction

In this chapter, a set of potential climate and price change scenarios has been simulated to investigate the impact of climate change on the economics of agricultural systems in Prairie. The base model results are compared with the predicted results. Three different climate change scenarios, from 1961-1990 to Modest (2020), Strong (2050) and Extreme (2080) scenarios, have been used to make the comparison. After comparing different projections, the final simulated results for two direct and indirect impacts are illustrated. The impacts of change in rainfall, increase in temperature, and rise in future global market prices are employed to predict the economic consequences of global climate change. A conclusion section closes the chapter and introduces the final chapter.

6.2 Future Climate Scenarios and Price forecasts

The primary objective of the current study is to examine the economic impacts of climate change on the Prairies agriculture. In this section a set of climate change scenarios are projected to evaluate climate change impacts. These projections are an attempt to describe what would happen, given certain hypotheses (climate and price change). When a projection is well structured, it can provide predictive capacity helping in the design and assessment of the impact studies. Thus far, historical climate means and price change have been evaluated by using the base models. The regression coefficients from the plausible and robust[1] model have been used to evaluate the range of potential effects of climate change and global change in prices on the economics of prairie agriculture.

To accomplish the simulations, each temperature variable in the base model has been increased make new temperature variables reflecting different future climate scenarios. In the same fashion, current precipitation variables multiplied by percentage change in future precipitation, then new precipitation variables reflecting climate change scenario have been made. Finally, percentage change expected in prices has been added to the price variables to represent new grain prices under climate scenarios. These new variables now have been adjusted to meet new climate and price conditions in the future. Next by plugging the change between the old and new (modified) variables in the regression result, change in the farmland value will be simulated[2]. Finally, by comparing the results of simulated models with the base model, the impacts of climate change on the land value are presented. In order to project climate change scenarios, first these scenarios need to be determined from environmental climate models.

The climate scenarios used in the simulation analysis presented in this chapter were derived from appropriate global climate models (GCMs). The second version of the Canadian Global Coupled Model (CGCM2), as described by Flato and Boer (2001), was selected to form the basis of the climate change scenarios constructed for this study. Climate change simulations generated for the period 1900 to 2100 was based on different concentrations of GHGs. Data from CGCM2 grid[3] was available for three 21-year time windows: 1975-1995 (present climate), 2040-2060 (approximately CO_2 doubling) and 2080-2100 (approximately CO_2 tripling). Based on

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[1] A robust regression is an efficiently estimated model which is corrected or checked for Heteroscedasticity (Davidson and Mackinnon, 1999).
[2] See section 4.6 of Chapter 4 for projection methodology
[3] Canadian Climate Change Scenarios Networks

these CGCM2 data a number of projections were generated to represent changes in future temperature and precipitation (Table 6.1). The scenarios represent projected climate change from 1961-1990 to Moderate (2020), Strong (2050) and Extreme (2080). Based on these projections, the annual average temperature was forecasted to increase by 1.046, 2.019 and 3.26 ˚C respectively, while average precipitation was forecasted to increase by 0.016, 0.116 and 0.186 mm/day. These numbers are calculated by subtracting the annual mean of each climate variable in 1961-1990 from the annual mean of each certain year (2020, 2050 and 2080).

Table 6.1 Climate Change Scenarios

	Change in Temperature (°C) *					Change in Precipitation(mm/day)*	Change in Crop Price(CAD)**
Scenarios	**Yearly**	**Winter**	**Spring**	**Summer**	**Autumn**		
Moderate	1.046	1.037	0.852	1.140	1.149	0.016	5%
Strong	2.19	4.61	1.60	1.62	1.91	0.116	15%
Extreme	3.26	4.95	3.21	3.26	1.95	0.186	25%

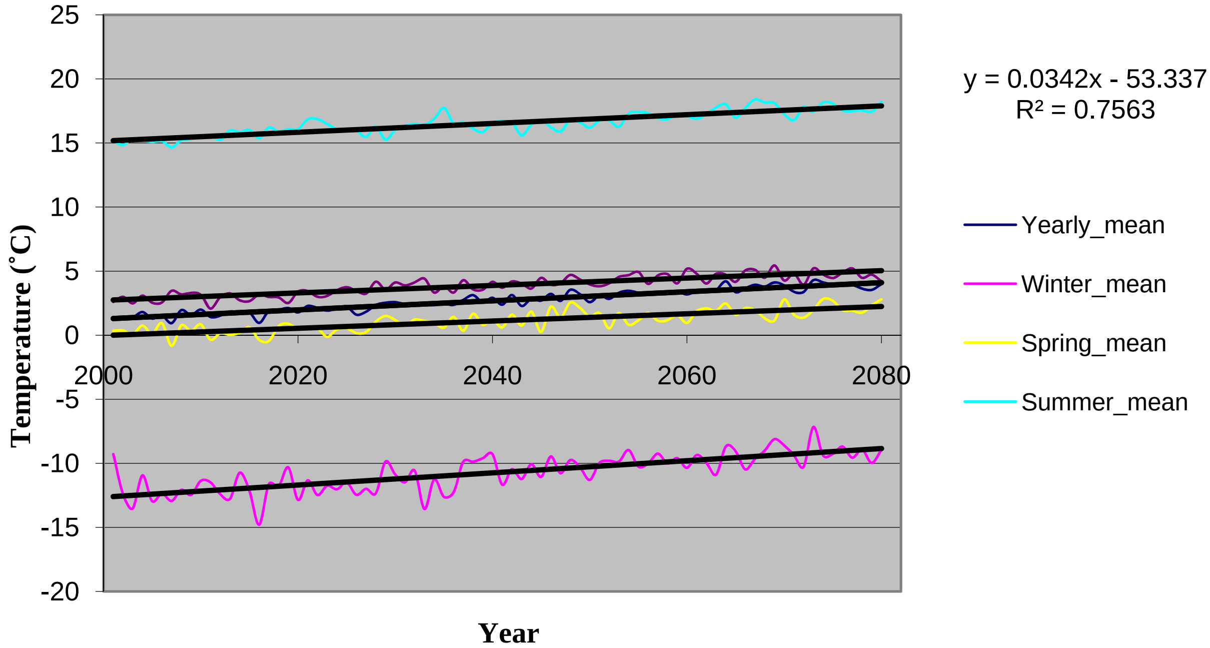
Source: *Environment Canada available at:
http://www.cccsn.ca/Download_Data/tools/CGCM1_canada.phtml?type=spatial and ** Parry et al. (1999)

The modeled projected mean annual and seasonal temperature for the prairies in the extreme scenario show that the temperature for different seasons and years are increasing, but much of the projected increase will occur in winter [4](Figure 6.1). The projected annual precipitation for the extreme scenario has been graphed using CGCM2 grid. This graph reveals that in this scenario precipitation increase slightly (about 0.016 mm/day) (Figure 6.2). It is worth

[4] Higher trend coefficient

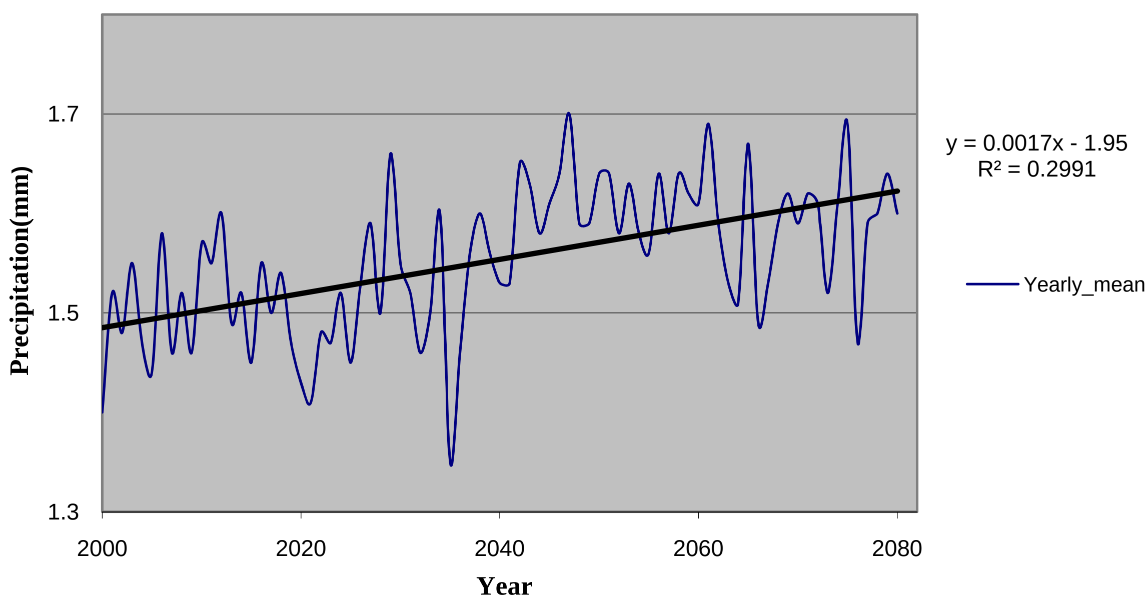
noting that for the three scenarios precipitation shows a very small increase (Table 6.1)[5]. In fact, this might be a more accurate and realistic prediction, as the prairie is one of the driest regions of Canada. For example, Sauchyn and Kulshreshtha (2008) showed that drying projections predicted moisture deficits for this region, specifically precipitation cannot offset water loss by evapo-transpiration as summertime drying in Prairies elevates aridity.

[5] Mean annual and seasonal temperature and annual temperature graphs for 2020s and 2050s are presented in Appendix B.



Source: Environmental Canada (CGCM2)

Figure 6.1 Mean Annual and seasonal Temperature to 2080s



Source: Environmental Canada (CGCM2)

Figure 6.2 Mean Annual Precipitations to 2080s

Each of the climate scenarios and each price forecast were used to predict future land value and these were compared with the base model (Table 6.1). These price scenarios were based on Parry et al. (1999)[6] which projected output prices to rise between 3% and 32% for years 2020 to 2080 and cereal production was predicted to fall by between 25 and 125 million tons for the years 2020 to 2080.The current analysis used a range of 5% to 25% change (increase) in the wheat and canola prices to evaluate the effects of price change on land value. The next section examines the future impacts of climate and price change on land value.

6.3 Economic Impacts on Land Value

The general impacts of the change in rainfall, increase in temperature and rise in future global market prices are projected. Using the climate and price parameter estimates from the base model, climate change impacts over a range of climate change parameters are estimated. For each climate scenario and each price forecast presented in Table 6.1, change in per hectare land value has been simulated for the moderate, strong and extreme scenarios. Then calculated change in land value has been compared with the base model to measure the economic impact of climate change on prairie agriculture.

In order to reveal the effects of climate change on prairie agriculture productivity and profitability, the change in average[7] value of land has been calculated by both including and excluding the influence of commodity prices (Table 6.2). It can be inferred from these results that under the three scenarios predicted land values increase under climate change in the range of \$16/ha to \$94/ha. Land values increase from 3.5% in the moderate climate change scenario to 9.5% in the strong climate change scenario. However, land value will increase by only 1.6% in the extreme climate change case, relative to the baseline model. This different prediction is due

[6] Discussed in Chapter 2, section 2.2.3
[7] This average is a simple average land value for whole CSDs within prairie and each CSD have different average from the average reported in this study.

to a negative and concave relationship between land value and July temperature[8]. In fact, July temperature has diminishing marginal effect on the land value which shows an increase in July temperature driving by climate change will results in a decrease in land value. As mentioned before, increases in July temperature have the effects of increasing potential water deficits for plants and therefore, decrease productivity of crops. The same as Chapter 5(section 5.2.1.1), change in temperature and precipitation may cause a reduction in yield and productivity, which within the agricultural CSDs can be capitalized in land value but the current study, assumes that this is the main reason for decreased land value. Once again, this interpretation needs to be used with caution. In the extreme scenario, July temperature was predicted to increase by more than 3 ˚C while a relatively small increase in precipitation was predicted. Therefore, this scenario leads to a smaller increase in land value over the base as a result of climate change.

The forecasted farmland values where prices change due to climate change demonstrate that increases in prices increase land values by 31% (Table 6.2). In fact, market prices play an important role in the model; ignoring prices can result in underestimating the impact of climate change by an estimated magnitude of $93/ha to $305/ha on average. In the extreme climate change scenario, the increase in land value due to increases in commodity prices is more than 29%, which is a significant increase in comparison to other scenarios. The results in this case show that even though the warmer and drier condition in extreme scenario will have slight increase (2%) in the productivity of prairie farm, which will result in a small increase in profitability, increase in commodity prices may cause more profitability. In general, based on the above analysis, it can be concluded that anticipated changes in market prices are at least as important to the economic viability of prairie agriculture under climate change as changes in the climate itself.

[8] See section 5.2.1 Chapter 5

Table 6.2 Predicted Impact of Climate Change on Farmland Values

	Average Land Value (CAD/ha)		
	No Price Change	**With Price Change**	**With Price and Area Change**
Base Model	993.38	993.38	993.38
Moderate	35.02	92.95	145.13
	(3.53)*	(9.36)	(14.62)
Strong	93.96	267.74	386.31
	(9.46)	(26.95)	(38.89)
Extreme	15.84	305.45	505.48
	(1.59)	(30.75)	(50.88)

* Numbers in parenthesis show percentage changes.

When wheat and canola prices increase, average land values in each of the three scenario will be greater. The results show that moderate climate change leads to increases in land value ranging from 4% to 9% (Figure 6.3). However, the economic impact on prairie agriculture is approximately 15 times greater when including price changes under extreme climate change (from 2% to 31%). In general, agricultural land values were predicted to increase regardless of the origin of the impacts which can be just climate change or climate combined with commodity price changes (Figure 6.3).

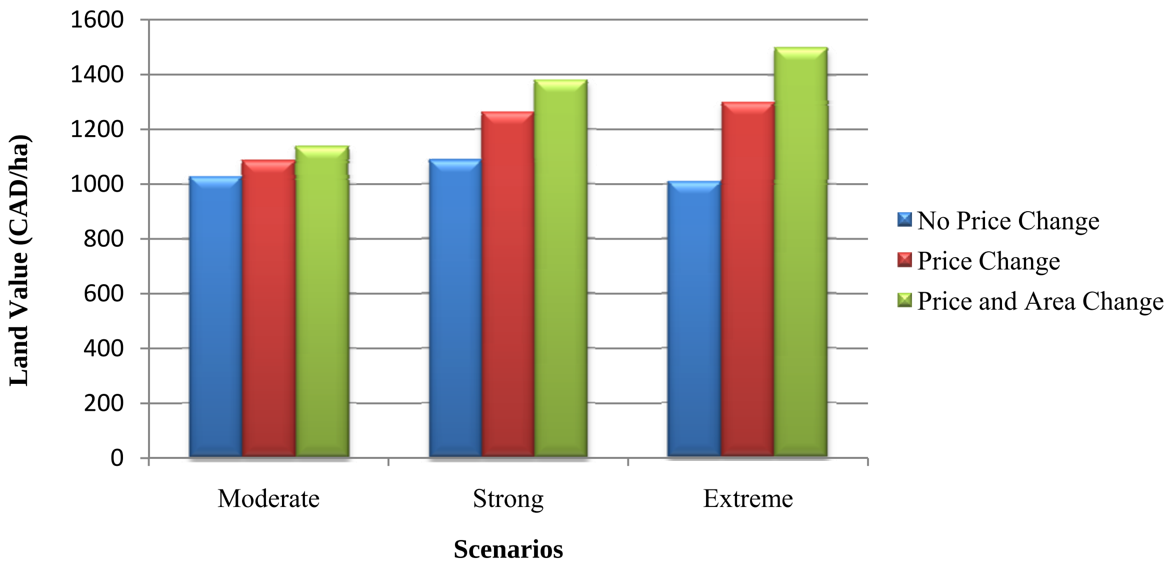


Figure 6.3 Change in Farmland Values for Different Scenarios

6.3.1 Economic Impacts including Area Response results

Thus far, the current analysis has been focused on two kinds of Ricardian approaches: a classical Ricardian model when no market prices are included and the Ricardian model that includes market prices for wheat and canola. Since the Ricardian analysis can partly incorporate adaptation possibilities for climate change scenarios, it is useful to examine how predicted planted area will affect the farmland value. In fact, farming systems in the prairies are apparently responsive to changes including climate and price changes. Switching between crops, therefore; might be a choice for farmers as a climate change adaptation strategy. In this section, using the area response estimated in Chapter 5, a third version of the Ricardian approach that includes not only the price changes but change in planted area will also be presented.

In Chapter 5 a simple area response function for wheat and canola was estimated. Those results have been used to simulate land values for future climate and price conditions. The fourth column of Table 6.2 reports the change in agricultural land value when farmers respond to climate change by changing their land allocation. When changes in the planted area occur, the forecasted farmland value increases up to 51%. In fact, area response to climate and price change itself plays a very vital role in the model. As climate change directly and indirectly affects profitability[9], including change in the planted area captures the farming system response to climate and price changes. Ignoring the indirect effect of climate change on land value will result in underestimating the benefit of climate change on prairie agriculture. The underestimating of the climate change benefits range from \$52/ha to \$200/ha on average[10].

In the extreme climate change scenario, the increase of land value due to change in planted area is the largest change relative to the other scenarios. The results in this case indicate that adaptation to the new climate and price conditions in the future might keep or increase the productivity of prairie farms which will result in profitability gain under forecast climate change. Comparing the results from direct impacts of climate and price changes on land value with the results from indirect impacts through area response estimation reveals that:

1. Direct impacts of climate and price change indicate an increase in farmland value up to 31% while the indirect impacts from different scenarios increase simulated land value up to 51%.
2. Both direct and indirect impacts have projected a similar pattern for moderate, strong and extreme climate change scenarios. However, the results from the indirect impacts

[9] See Figure 3.5 which shows direct and indirect influence of climate change on profit.

[10] These numbers are calculated by subtracting column 4 from column 3 in Table 6.2.

for strong and extreme climate change increase land value while a moderate increase in farmland value has been projected for the moderate scenario.

One possible explanation can be inferred from the way that price variables have been set up for the current regression estimation. As canola is not planted in some CSDs price variables are weighed by the planted share of each crop[11]. Also, the link between land value and area response function is through market prices included in the model[12]. Therefore, climate change combined with price changes may introduce an incentive for farmers to switch from one crop to other crops to maintain their income (for example, switching from wheat and canola to pasture or hay, which is out of scope of this study). These kinds of adaptation strategies seem to be a very important part of farmers' decision making process. As by the results of this study, there might be an opportunity for farmers to benefit from climate change if they respond to climate change by taking appropriate adaptation strategies.

6.3.2 Geographical Distribution of Impacts

A map representing the spatial distribution of impacts under the moderate climate change scenario without commodity prices and with commodity prices in combination with area response change can be employed to disclose some effects of climate and prices on farmland value. Figure 6.4 shows the impact of climate change when there is no change in commodity prices, while Figure 6.5 reflects the climate, price, and area response change combined. The predicted model with price and planted area change suggest that land value around big cities in the prairies gain as a direct impact of increases in market prices for wheat and canola. This rise in land value also can be seen for the southern part of Manitoba, some CSD's in Saskatchewan, and a few in Alberta. The maps clearly show that moderate climate change effects in

[11] Section 4.3.4 in Chapter 4
[12] Section 5.4 of Chapter 5

combination with a 5% increase in commodity prices can be beneficial for some regions within prairies. However, the regional change in land values is not uniform for the three provinces; the greatest increase in land values take place in Manitoba and Alberta. It is also shown that some CSDs in the south east of Alberta have decreased land value. As discussed in Section 5.2.1.1, there are other factors that might influence land value in CSDs that are not predominately an agricultural commodity based economy. The changes in land values in these areas are reflecting other regional effects. For example, clearly there is a stronger effect around cities, which is likely not due to agricultural productivity.

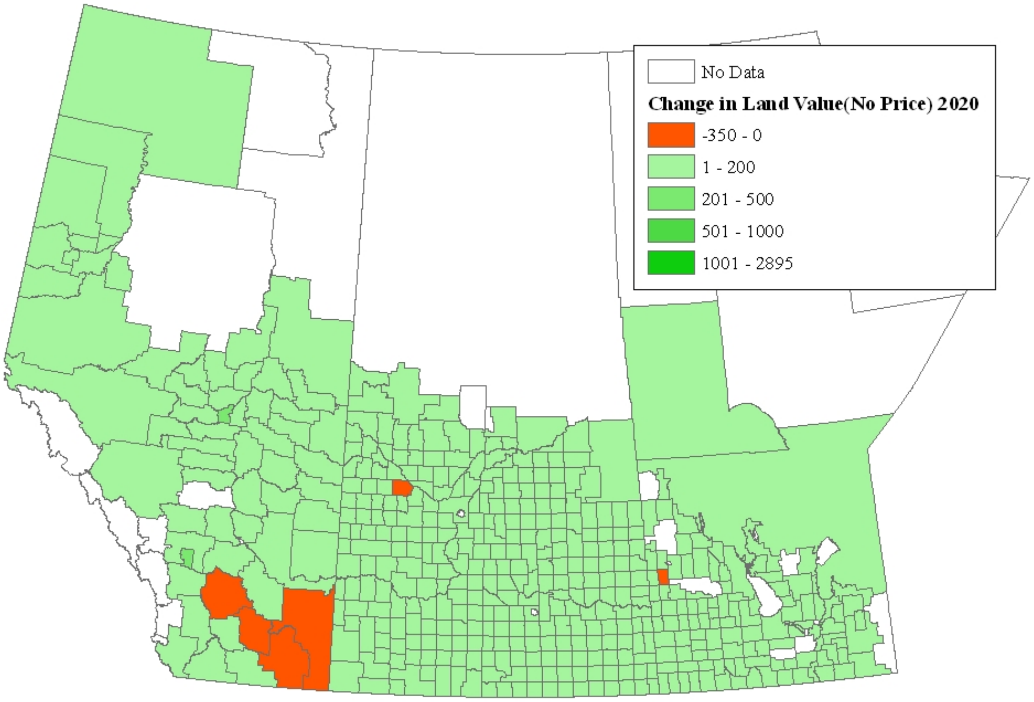


Figure 6.4 Change in Farmland Value ($/ha) under Moderate Climate Change and Constant Output Prices

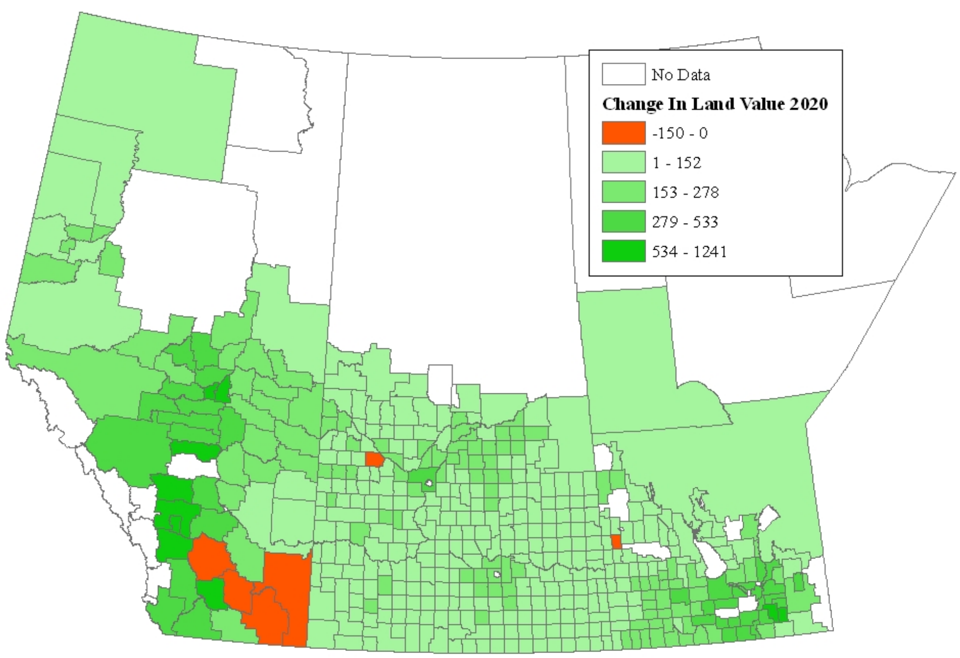


Figure 6.5 Change in Farmland Value ($/ha) under Moderate Climate, Output Price and Planted Area Change

To put the prediction results for strong climate change scenario in perspective, the simulated change in farmland value with and without commodity price change estimates along with area change are mapped in Figures 6.6 and 6.7. Climate change effects vary across the prairies in the strong climate change scenario, but the changes in land values show a similar pattern as the moderate climate change scenario. When price effects are included in the analysis, almost the same CSDs in the prairies will gain or lose from climate and price changes in comparison with the moderate climate change scenario. Saskatchewan and Manitoba gain more from the strong scenario than Alberta. The dark green areas indicate which areas benefit more than \$150/ha. The above results are the direct and indirect impacts of a15% rise in prices in combination with 2 ˚C temperature increase and 0.12 mm/day precipitation increment (Figure 6.7).

The moderate and strong climate change scenarios indicated that not only is a uniform change in land value across the region not predicted but commodity prices are also an important factor in the Ricardian analysis. The results suggest that farmland value around big cities in the prairies will increase more than other CSD’s in the first and second scenarios. The magnitude of these land value increase are from \$200/ha to more than \$3000/ha. This effect will tend to push up the land value if we consider the effects of switching between crops. In fact, adaptation to the new climate and price conditions makes farmers gain more from climate change.

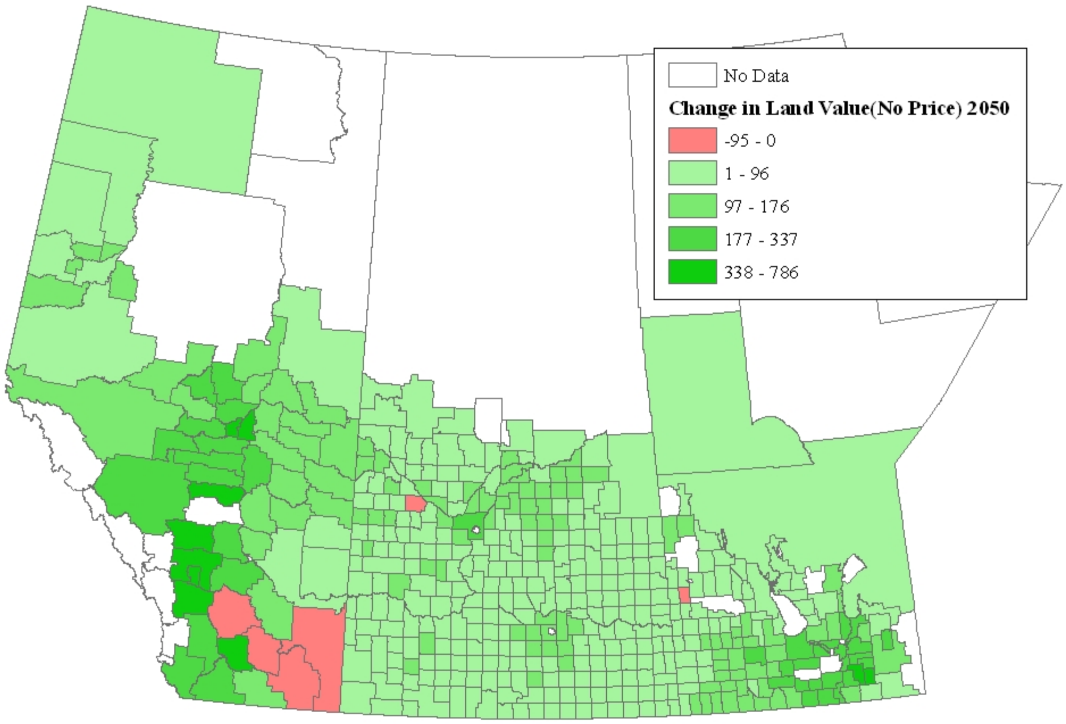


Figure 6.6 Change in Farmland Value ($/ha) under Strong Climate Change and Constant Output Prices

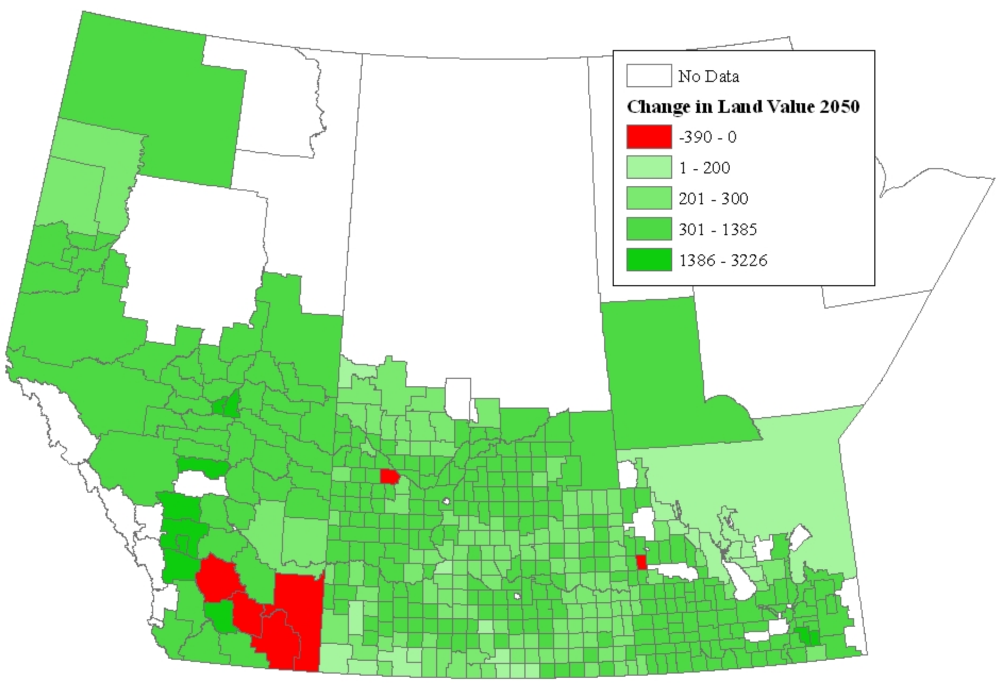


Figure 6.7 Change in Farmland Value ($/ha) under Strong Climate, Output Price and Planted Area Change

The regional distribution of climate, area and price impacts on land value in the extreme scenario indicate that most CSDs gain significantly from climate change on the Canadian prairies, while some lose value. Figures 6.9 and 6.10 show the extreme climate change effects on agricultural economy of Prairies. The positive effects of climate change on farmland value are predicted to be very limited when no price and area change are considered in the model. However, land value in the prairies increase under the extreme climate change scenario directly when an increase in market prices is included in the model. The indirect effects of including planted area change are predicted to make almost all CSDs gain more than \$200/ha in 2080, under the extreme climate change scenario. A few CSD's in southern Alberta have decreased land value in this scenario. In fact, farmland value in some CSD's predicted to benefit between \$250/ha to more than \$4000/ha from a 25% rise in market prices, more than 3 ˚C increases in temperature and 0.19 mm/day increment in precipitation. Consistent with the results under the moderate and strong climate change scenarios, the three provinces' regional change in land values is not uniform but the numbers of benefited CSDs in all three provinces are more than other scenarios.

The results from extreme climate change scenario should be used with caution as it is showing a 51% increase in land values. The results could be considered suspect due to the fact that the model is simulating very long term effects from past and present information. On the other hand, the pattern of increasing benefit of climate change remains the same with the two other scenarios. In short, as it is revealed by the above maps, the three scenarios support the fact that climate change makes an opportunity for agricultural producers in the prairies to gain from future price and environmental change.

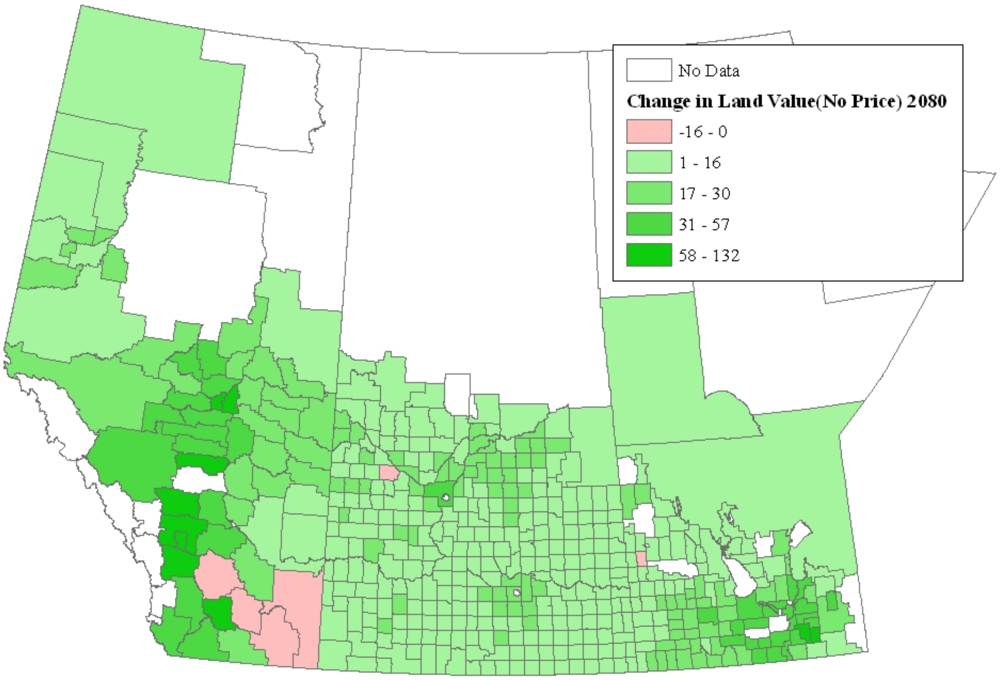


Figure 6.8 Change in Farmland Value ($/ha) under Extreme Climate Change and Constant Output Prices

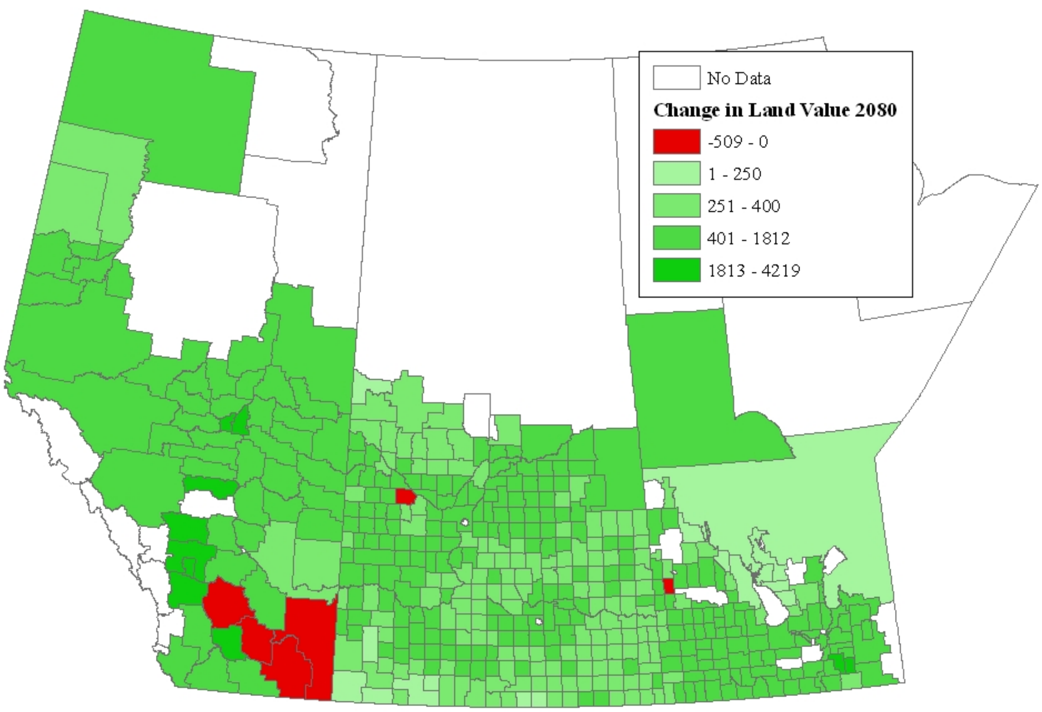


Figure 6.9 Change in Farmland Value ($/ha) under Extreme Climate, Output Price and Planted Area Change

When evaluating the impact of land values across the prairie region, the south east corner of Alberta is predicted to lose between $96/ha and $509/ha according to the different scenarios simulated in this analysis. As most of the CSDs in this part of Alberta are under irrigation, the climate response is very complex. Climate change affects not only irrigation demand but also the availability of water for irrigation. Under different climate change scenarios, with warmer and drier conditions, there may be less water available for irrigation while demand for irrigation might increase in southern Alberta. In this case, climate change will negatively affect farmland value in this region. This analysis did not include any improvement in irrigation technology and adoption of water conserving crops which makes this issue more complex. An examination of these effects remains out of the scope of the current analysis.

6.3.3 Comparison with other Ricardian Projections

In this section the results of Weber and Hauer (2003) and Reinsborough (2003) will be compared with the present analysis. Weber and Hauer (2003) conclude that the prairies will benefit from climate change but this benefit will be affected by increases in evapo-transpiration and soil moisture deficits. Meanwhile, Reinsborough (2003) concluded that the estimated impacts of climate change are neither catastrophic nor miraculous.

The current analysis is in agreement with Weber and Hauer (2003) in that the water scarcity has harmful effects and also imbalanced precipitation evaporation relationship involved with Prairie agriculture. However, the results in this study indicate increases in land values and possible diversification from cropland to pasture and livestock production. In this case, the present analysis is in disagreement with the results of Reinsborough (2003) study. As the unit of study in the two above studies are different (CSD in this study versus Census Division in the Reinsborough's study) from which was used here, a more detailed comparison is not possible.

In Chapter 5 comparisons were made between the base model results of the current study and the Mendelsohn et al. (1994) study. In this section climate change scenarios in both studies are compared. Mendelsohn et al. (1994) suggest that a 2.8˚C increase in temperature and an 8% rise in precipitation are harmful and, on average, decrease American farmland value. However, they conclude that the northern fringe of the U.S. might gain from climate change. Indeed, as the northern border of some state of U.S is the southern border of the Canadian prairies, their results are consistent with the beneficial impact of climate change, found in the results of current study. One key difference between the two studies is that the current study utilizes output prices as a critical and influential variable which can reflect the benefit of climate change on prairie agriculture while Mendehlson's study has emphasized just the impacts from climate change.

6.4 Marginal Climate Impacts

As climate change alters the impact of seasonal weather events, it is important to assess the impacts of seasonal effects of climate change on the profitability of prairie agriculture. In this section the marginal impacts of climate variables and their related elasticities have been calculated to show how the productivity of farming becomes more sensitive to local weather under climate change conditions. Marginal Climate Impacts (MCIs) and their elasticities for the three climate change scenarios are presented in Tables 6.3[13]. Recalling equation (5.1), the MCI for each climate variable can be calculated by:

$$E\left(\frac{\partial LVAL}{\partial CLIMATE}\right) = \beta_2 + 2\beta_3 * E(CLIMATE) \tag{5.1}$$

as climate variables have been adjusted to show the new climate condition, the new MCIs can be calculated by plugging the mean of each new climate variable into equation (5.1).

[13] Projected data for July's relative humidity and snow fall was not available for the period of 2020 to 2080.

The marginal effects of temperature on land values in January, April and September in the three climate change scenarios suggest that increases in the temperature in these months increase land value in the prairies. The marginal impact of temperature in July is negative which, as discussed earlier, suggests the harmful effect of high July temperatures on plants. Again, for CSDs where agriculture is not the dominant land use these values might not reflect productivity impacts. As mentioned in Chapter 5, increases in July temperature will also have the effects of decreasing the available water for plants.

Table 6.3 Comparison between MCI and Elasticities for different Scenarios

	Moderate		**Strong**		**Extreme**	
Variable	MCI	Elasticity	MCI	Elasticity	MCI	Elasticity
January Temperature	27.19	-0.36	23.923	-0.23	23.61	-0.22
April Temperature	52.57	0.26	57.138	0.33	66.96	0.50
July Temperature	-231.27	-4.30	-236.45	-4.51	-254.16	-5.27
September Temperature	152.68	1.83	161.46	2.06	161.93	2.07
Rainfall	19.22	6.29	21.39	7.81	21.64	8.00
Evapo-transpiration Proxy	0.04	0.01	0.04	0.004	0.04	0.003

Among all the temperature variables in the moderate climate change scenario, September and January, with 153 and 27 MCIs, have the largest and smallest positive effect on land value, respectively. As explained earlier (chapter 5) there are no crops on the farm lands in January. Almost the same results can be inferred for the two other scenarios. The positive effect of rain on land value seems plausible. Having all other variables constant, a 1 mm increase in rainfall on average results in more than a $19/ha increase in the value of farmland in all scenarios.

MCI of temperature in April suggests that in April the marginal impact of temperature on land value increases to 53 in 2020, to 57 in 2020, and to 67 in 2080 as severe climate change occurs (warmer conditions). The same situation happens for temperatures in July and September, while higher temperature in July has a negative effect on land value. The impacts of April and September temperatures are positive and significant which implies that when warmer conditions prevail the growing season on Prairie will be extended. The current growing season is very short and crops are subject to frost damage but as climate changes, expected longer growing season will result in increase in productivity and therefore more benefits for prairie agriculture. However, given the hill shaped relationship between land value and some temperatures, if increase in the temperature in warmer conditions gets closer to the top of the hill and pass this point then the value of Prairie farmland will fall (diminishing marginal effects). The negative MCI for July supports these results.

Increase in January temperature will gradually lessen the impacts of climate and price changes on the Prairie agricultural economy (Figure 6.10). However, projected impacts for April and September increase, indicates that estimated benefits rise over time. Consistent with the base model, future warming scenarios for July temperature has significant negative impacts on prairie agriculture.

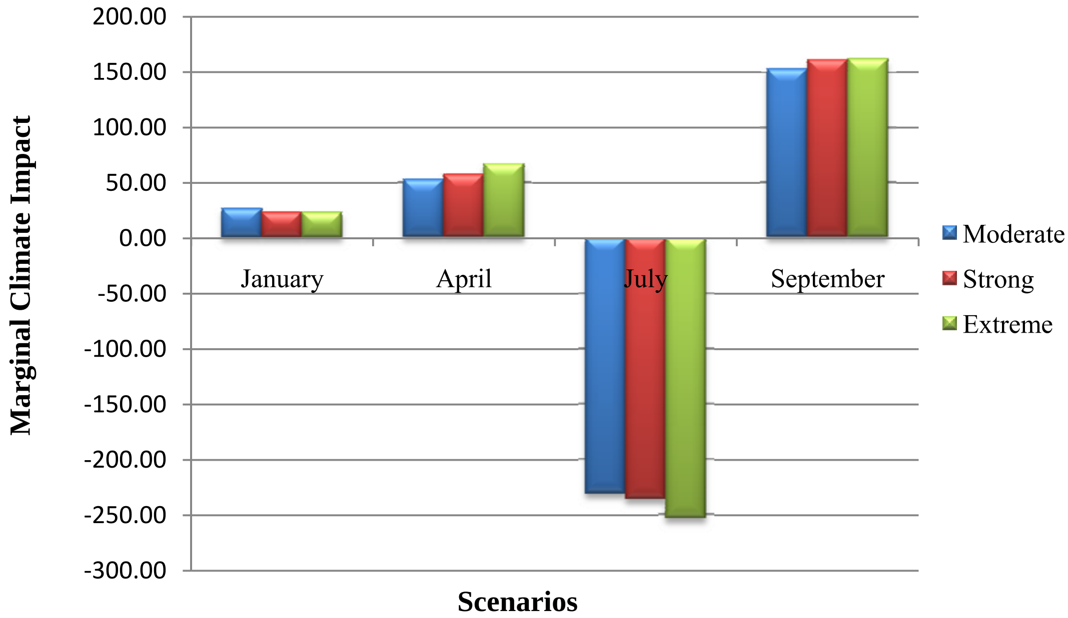


Figure 6.10 Seasonal Marginal Climate Impacts for all scenarios

Increase in future precipitation will result in higher land values under each climate and price changes scenarios. However, the benefits are not expected to be extensive under projected increased rainfall in the three scenarios in comparison to base model results (Figure 6.11). Basically, it shows that drier condition will likely occur in the prairies, which is consistent with Boehm et al. (2006) study. Boehm et al. (2006) state that decreasing potential evapo-transpiration from southwest to the northwest will influence the potential productivity and in turn reduces the value of the farmland.

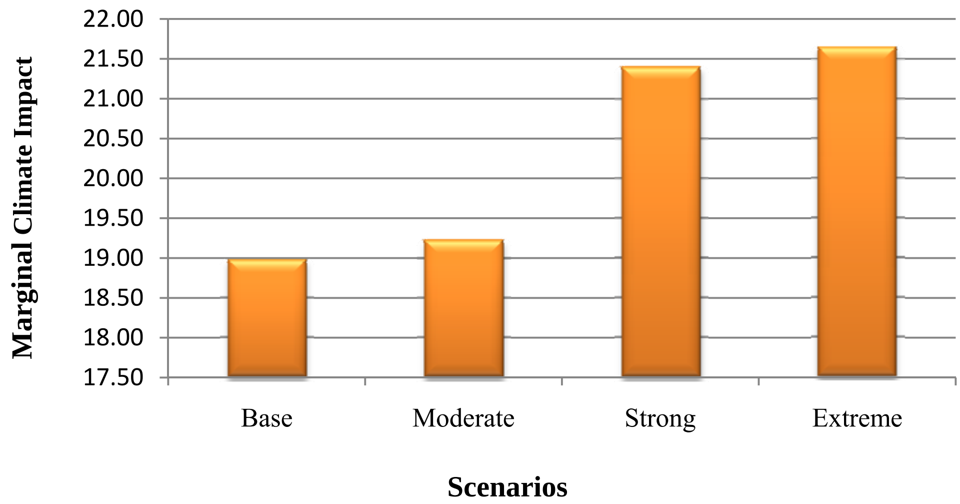


Figure 6.11 Marginal Climate Impacts of Rain for Base and all Scenarios

In addition to marginal climate impacts, elasticities[14] are measured to evaluate the sensitivity and vulnerability of land value to changes in each season's climate (Table 6.3). Since elasticities are designed to measure the percent change of a dependent variable (farmland value) in response to the percentage change in an independent variables (climate variables), they can be useful for analyzing the effects of climate change on land value. Rainfall is the most elastic climate variable influencing land value positively in the three climate change scenarios. It reveals that a 1% increase in rainfall would cause land value to increase, on average, by more than 6% in the three scenarios. July temperature negatively affects land value and it is elastic in the all scenarios. Land value appears to be less sensitive to the evapo-transpiration proxy than to the other climate variables. The evapo-transpiration proxy, January and April temperatures are all inelastic. Based on these results it can be predicted, for example, that 1% change in the evapo-transpiration proxy, January temperature, or April temperature would result in, on average, less

[14] The signs of elasticities are consistent with those of MCIs except for January temperature. But this negative elasticity is due to negative mean for January temperature variable and does not contrast the positive MCI of January temperature.

than 0.5% change in land value. In contrast, a 1% changes in rainfall, September or July temperature would result in a greater than 1% change in land value. The elasticity of January temperature is smaller for the moderate climate change scenario than for the strong or the extreme scenarios, while elasticities of other variables are increasing with greater levels of climate change.

In short, elasticities seem to be very useful in terms of comparing the vulnerability of land value in response to change in seasonal climate. Also, the elasticities can be used to determine that land value is more elastic or vulnerable in response to change in each climate variables. In the current study, the value of farmland seems to be more sensitive to change in rainfall and July temperature which indicates that these two seasonal weather events have the major impacts on the profitability of the prairie agriculture.

6.5 Conclusion

This chapter developed a simulation of the impact of climate and price changes on the Canadian prairie agricultural economy. The results showed that climate change along with corresponding commodity price changes will positively affect land value in nearly all regions. It also indicates that increases in prices signify the effect of global warming on the agricultural economy of Prairies. Predicting the land value after including area responses to climate change suggests that land values increase even more than other approaches when crop patterns change, which is induced by climate change, is considered to capture the importance of climate change adaptation measures used by farmers. To analyze the sensitivity and vulnerability of land value with respect to change in each season's climate, marginal climate impacts were calculated and interpreted for three climate and price change scenarios. Chapter 7 will provide a comprehensive summery including importance of analyzing the impact of climate change on the economics of

Canadian Prairies agriculture, contribution of the present study to literature, conceptual framework, results, and policy implications.

CHAPTER 7 CONCLUSION

7.1 Summary

Climate change may alter the frequency and intensity of weather events which will likely challenge human and natural systems more than normal variability in weather and climate. Agriculture is considered one of the most vulnerable industries to climate change. Quantifying the economic impact of climate change on agriculture can help to reduce the environmental damages and maintain the profitability of agricultural systems. The main goal of this study is to estimate the economic impact of change in climate normals on agriculture in the Canadian prairies and to capture the impact of weather conditions on the viability of production systems along with the impact of market price effects by predicting the economic impact of climate change.

The main contribution of this study to the literature is the inclusion of the grain market prices in the Ricardian approach. Assuming fixed market prices within a Ricardian model raises two potential problems: misspecification in the empirical estimation of the model and bias in measuring climate change impacts. These problems were demonstrated and tested empirically. An Incremental F-test confirmed that market prices for canola and wheat are jointly significant and have an impact on land value. Also, empirical results show that the economic impact of long run climate change on prairie agriculture when including changes in commodity prices can result in significantly larger land values as compared to simulations without these changes in prices.

The empirical results of direct climate impacts with no market price effects also are consistent with the findings of research using a traditional Ricardian model.

The most important finding of this study is that climate change is beneficial for most regions of the Canadian prairies except for some southern regions of Alberta. Comparing the results from direct impacts of climate and price changes on land value with the results from indirect impacts through arae response estimation reveals that direct impacts of climate and price change increase in farmland value, on average, by 31% while the indirect impacts from different scenarios increase simulated land value up to 51%. Moreover, both direct and indirect impacts have projected a similar pattern for moderate, strong and extreme scenarios. However, the results from indirect impacts for strong and extreme drives up land value while for the moderate scenario a temperate increase in farmland value has been projected. The results should be used with caution due to the fact that the model is simulating outside the range of historical climate means and summarizing a very long term effect from past and present information.

The results from area response function for wheat and canola have been utilized to simulate land values for the future climate and price conditions. When changes in the planted area occur (as an adaptation strategy), the forecasted farmland values demonstrate a large increase (greater than 20%) in comparison with the situation that adaptation is not included in the analysis. In fact, area response to climate and price change itself plays a very vital role in the model. In the extreme case, the increase in land value due to change in the planted area is more than 51%, which is the largest increase in land value with respect to other scenarios. The results in this case signify that adaptation to the new climate and price conditions in the future might keep or increase the productivity of prairie farm, which will result in profitability gains.

The results of this study are consistent with the general understanding of the importance of precipitation for agriculture of prairies. Marginal impacts of the evapo-transpiration proxy, rainfall, and July relative humidity indicated direct and positive relationship among agricultural land values and water related climate variables. It represents that agriculture in the Prairies is very vulnerable to the water scarcity and land use and land value strongly depend on the precipitation. Also, rainfall is the most elastic climate variable influencing land value positively in three scenarios. It reveals that a 1% increase in rainfall would cause land value to increase, on average, by more than 6% in all three climate change scenarios. However, under different climate change scenarios, with warmer and drier conditions, there may be less water available for irrigation while demand for irrigation might be increased in the southern Alberta. In this case, climate change will negatively affect the farmland value in this region.

Marginal temperature value for July reveals that increased July temperature reduces land value. In fact, a 1˚C increase in July temperature decreases farmland value by 219 CAD per hectare on average. An explanation for this, at least in the agriculture dominated CSDs, is that more than normal warming condition along with more water evaporation which takes available water out of reach of plants can cause heat stress on crops and reduce the productivity of the production. In the current study, the value of farmland seems to be more sensitive to change in rainfall and July temperature which indicates that these two seasonal weather events have significant impacts on the profitability of prairie agriculture.

The results from base and three climate change scenarios in this study reveal that climate change may not impose a significant economic impact on prairie agriculture if farmers employ appropriate adaptation strategies. The results of this study indicate that, given the assumptions of the Ricardian approach, climate change may provide an opportunity for agricultural producers in the prairies to gain from future price and environmental change. To achieve this goal, policies to address climate change concerns need to put a greater emphasis on dealing with water deficit and scarcity. Policies that facilitate access to irrigation and crop choices will help farmers to adapt to climate change and take the climate change opportunity.

The results of the current analysis may lead to several policy implications. First of all, as within this study an important component of adaptation is a switch in crop production towards canola, this should be carefully monitored by policy makers to prevent any instability in economic and environmental conditions. Canada is currently an important exporter of wheat. A decrease in wheat area would misplace Canada's place in international wheat trade. This might have crucial political reflections. Therefore, policy makers should be aware that climate change may induce substantial changes in prairie agriculture. They should be ready for introducing and supporting any adaptation strategy required for adjusting the impacts, minimizing the social costs, and maximizing the social benefits of such changes. For example, if the policy makers are severe to keep Canada's place in international wheat markets for any price, then they should try to make it more profitable for farmers to cultivate wheat. To aim at this, one adaptation strategy could be introducing new wheat varieties. This discussion needs to be expanded by including the effects of relative price of wheat to canola and relative global demand of wheat and canola, which is out of the scope of this study.

Another important implication for policy development would be to support the development and introduction of new crop varieties by encouraging R&D efforts. Policy makers may introduce an incentive for breeding and genetic engineering practices to work on drought tolerant varieties of currently cultivated crops. Breeding and genetic engineering practices can introduce new varieties of wheat and canola, which are more drought tolerant than current varieties. Since a major part of crop research, especially in the case of wheat, which in Canada is still public, government may have a key role to a resources towards research and development of drought tolerant varieties. Even in the case of private crop research institutes, government may still be able to encourage them to put more effort on R&D of drought tolerant varieties. Policy makers also may introduce an incentive for farmers to switch from the current varieties to the new varieties or other crops to maintain their income.

According to the climate change forecasts the Canadian prairies are going to be warmer and drier. As such, irrigation may be considered increasingly important to maintain the profitability of prairie agriculture. To ensure adaptation policy may need to focus on encouraging and providing more efficient irrigation methods and equipments for farmers who are currently practicing water-fed cultivation. In addition, policy makers should be aware that in future decades, irrigation might be necessary for those farms that are currently under rain-fed cultivation. Confounding this is the fact that while additional water will be required by crops there may be less surface water available. Therefore, analyzing the benefits and costs of large scale irrigation development and improving the water use efficiency of irrigation technology should be considered by policy makers as well as researchers.

7.2 Study Limitations

Several limitations need to be identified to ensure the results are interpreted correctly. First, due to the lack of available data for irrigation, the influence of irrigation on land values was not included in this model. Farmland values in some parts of the prairies depend on irrigation and this production input needs to appear in the model to capture irrigation impact, which might change the negative impacts of climate change on the most arid areas such as southeast of Alberta. Second, the analysis did not consider agronomic carbon fertilization effect (the impact of increasing CO_2 in the soil and air) which is predicted to increase future crop productivity. This effect might influence the impacts measured here and may lead to more beneficial impacts from climate change.

Another limitation of the present analysis is the fact that the econometrics model estimates land value changes due to relatively small changes in climate normals. The simulation analysis then develops results for changes, which exceed the range that responses are based on. Although, care has been taken not to simulate out of the range of each variable Standard Deviation (SD) but in the extreme scenario this range has been exceeded based on the nature of the warming scenario.

The Ricardian model optimistically assumes that farmers will adjust to climate change (adaptation), and it will be relatively inexpensive to do so. The current study did not include adjustment costs, which may result in overestimation of the benefits of climate change. There may be significant adjustment costs associated with adaptation to climate change because farmers will not instantly observe the change in climate. By including adjustment cost, the cost of adaptation will be more realistically captured in a model and the results likely would be more robust than ignoring these costs.

The other limitation in the current study is the omission of future technological change. Based on the recent history of rapid technological change in Canadian agriculture, it is likely that during the next decades production technologies will see significant further change. The productivity and profitability of agricultural production will be directly affected by the available technology. As the climate response is very complex, the results of change in technology in the long run might lead to very different outcomes.

7.3 Future Research

The current model can be extended to better estimate the impacts of climate change on agriculture. This may be attained by employing more detailed data for soil and irrigation characteristics. In this case the impact study will capture the effects of irrigation and soil moisture as well as possible adaptation to new crops and production technology. More studies will be needed on the impacts of weather volatility on agriculture. Also the current model considered just the two crop prices but theoretically this can be extened to include more input and output data to capture the impact on land values of a wider range of commodity price fluctuations.

Moreover, more studies could be done on the role of new technologies, particularly tillage systems, genetic innovation, and irrigation technologies. And finally, as this analysis shows that adaptation to climate change can be beneficial to farmers, the Ricardian model developed here can be further extended for related studies that focus on the adaptation on the Canadian prairies.

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APPENDIX A LIMDEP printouts for OLS and Panel models

OLS Only Climate1

```
+----------------------------------------------------+
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 00:58:15PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         19     |
|              Degrees of freedom   =       1388     |
| Residuals    Sum of squares       =   .6188521E+09 |
|              Standard error of e  =   667.7267     |
| Fit          R-squared            =   .2107184     |
|              Adjusted R-squared   =   .2004828     |
| Model test   F[ 18,  1388] (prob) =  20.59 (.0000) |
| Diagnostic   Log likelihood       =  -11137.84     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 18]  (prob) = 332.94 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   13.02117     |
|              Akaike Info. Criter. =   13.02117     |
| Autocorrel   Durbin-Watson Stat.  =  1.1263435     |
|              Rho = cor[e,e(-1)]   =   .4368282     |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	-2797.67408	1930.32183	-1.449	.1472	
JAN	9.84361968	5.64732773	1.743	.0813	-14.0810194
JAN2	-2.30334799	.38120410	-6.042	.0000	215.480684
APR	13.8420101	27.5279988	.503	.6151	4.15286527
APR2	3.16679669	2.51652385	1.258	.2082	19.1534458
JUL	312.846789	178.273886	1.755	.0793	17.3455512
JUL2	-11.1173627	5.35753396	-2.075	.0380	302.597890
SEP	41.3153501	174.638177	.237	.8130	10.7351281
SEP2	-.56320210	8.11379652	-.069	.9447	116.760891
RAINAV	-6.73407229	3.53085886	-1.907	.0565	320.588412
RAINAV2	.01808127	.00517390	3.495	.0005	105771.477
SNOWAV	1.09476858	3.63288637	.301	.7631	105.791094
SNOWAV2	-.01258234	.01458971	-.862	.3885	11739.1831
FFD	12.0090271	15.4095194	.779	.4358	13.8752801
FFD2	-.27413841	.82695491	-.332	.7403	217.106877
RHJUL	58.5655796	51.5083127	1.137	.2555	52.3037438
RHJUL2	-.37518213	.49641555	-.756	.4498	2761.39700
TPTEMP	.04293864	.01470746	2.920	.0035	-225.907528
TPTEMP2	.380903D-06	.112249D-06	3.393	.0007	.560861D+08

OLS Only Climate2

```
+----------------------------------------------------+
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:04:31PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         21     |
|              Degrees of freedom   =       1386     |
| Residuals    Sum of squares       =   .6627044E+09 |
|              Standard error of e  =   691.4779     |
| Fit          R-squared            =   .1547894     |
|              Adjusted R-squared   =   .1425930     |
| Model test   F[ 20,  1386] (prob) =  12.69 (.0000) |
| Diagnostic   Log likelihood       =  -11186.00     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 20]  (prob) = 236.61 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   13.09248     |
|              Akaike Info. Criter. =   13.09248     |
| Autocorrel   Durbin-Watson Stat.  =  1.0061644     |
|              Rho = cor[e,e(-1)]   =   .4969178     |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	450.109297	1456.46857	.309	.7573	
GDDM4	22.4653430	11.5964980	1.937	.0527	52.4366483
GDDM42	-.07697262	.10040476	-.767	.4433	2970.04687
GDDM5	2.03993176	11.5614035	.176	.8599	183.921217
GDDM52	-.01512041	.03060839	-.494	.6213	35452.0237
GDDM6	-9.76443396	10.8728007	-.898	.3692	290.161684
GDDM62	.02260630	.01895078	1.193	.2329	87841.1595
GDDM7	-4.20408354	8.13537041	-.517	.6053	361.053764
GDDM72	.00058870	.01124721	.052	.9583	135973.912
GDDM8	7.76628432	9.19195537	.845	.3982	337.749094
GDDM82	-.01246498	.01331721	-.936	.3493	119090.581
RAINAV	-8.56756381	3.65016441	-2.347	.0189	320.588412
RAINAV2	.02110396	.00533485	3.956	.0001	105771.477
SNOWAV	-4.01837520	3.73866387	-1.075	.2825	105.791094
SNOWAV2	.01089846	.01502945	.725	.4684	11739.1831
FFD	-18.0066386	18.3333753	-.982	.3260	13.8752801
FFD2	1.69086712	1.07860642	1.568	.1170	217.106877
RHJUL	62.1495627	55.1693515	1.127	.2599	52.3037438
RHJUL2	-.60322952	.53142931	-1.135	.2563	2761.39700
TPTEMP	.04317468	.01543061	2.798	.0051	-225.907528
TPTEMP2	.369698D-06	.118146D-06	3.129	.0018	.560861D+08

Panel Model 1

```
+----------------------------------------------------+
| OLS Without Group Dummy Variables                  |
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:18:22PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         32     |
|              Degrees of freedom   =       1375     |
| Residuals    Sum of squares       =   .3299838E+09 |
|              Standard error of e  =   489.8859     |
| Fit          R-squared            =   .5791400     |
|              Adjusted R-squared   =   .5696515     |
| Model test   F[ 31,  1375] (prob) =  61.04 (.0000) |
| Diagnostic   Log likelihood       =  -10695.46     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 31]  (prob) =1217.70 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.41083     |
|              Akaike Info. Criter. =   12.41083     |
+----------------------------------------------------+
```

```
+----------------------------------------------------+
| Panel Data Analysis of LVAL       [ONE way]        |
|           Unconditional ANOVA (No regressors)      |
| Source      Variation   Deg. Free.     Mean Square |
| Between       .147345E+09       2.     .736727E+08 |
| Residual      .636725E+09    1404.     453508.     |
| Total         .784070E+09    1406.     557660.     |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	36.8221095	4.40678490	8.356	.0000	14.9706563
POPDEN	14.8934757	1.06944420	13.926	.0000	10.3281815
POPDEN2	-.01090272	.00085429	-12.762	.0000	8165.47251
NETMIG	.02689232	.00467551	5.752	.0000	393.283582
HIDIST	-1.95232976	.37617998	-5.190	.0000	45.8647532
GOVPAY	.05143206	.00956430	5.378	.0000	1407.84663
X_COORD	-11.4988346	5.38185350	-2.137	.0326	-105.177028
BLACK_SZ	-48.8115976	115.531792	-.422	.6727	.42643923
BROWN_SZ	-377.494688	135.515908	-2.786	.0053	.15138593
DBROWN_S	-212.729783	125.886779	-1.690	.0911	.22459133
GRAY_SZ	-98.4318965	119.586912	-.823	.4105	.08599858
DGRAY_SZ	-16.4748619	117.125385	-.141	.8881	.09523810
TPT	.04472446	.01086252	4.117	.0000	.190653D-11
TPT2	.401817D-06	.831316D-07	4.834	.0000	.560350D+08
J	23.6622992	9.00978362	2.626	.0086	-.378397D-13
J2	-.72132387	.32272368	-2.235	.0254	17.2055766
A	22.2829712	13.2602470	1.680	.0929	.420096D-14
A2	3.56652545	1.86425574	1.913	.0557	1.90715584
JU	-16.3777241	17.2968122	-.947	.3437	-.408549D-14
JU2	-4.03700565	4.04704201	-.998	.3185	1.72974345
SE	19.4024944	14.9591908	1.297	.1946	-.638595D-16
SE2	3.92566983	6.14960274	.638	.5232	1.51791524
R	2.70299898	.47946063	5.638	.0000	.492280D-13
R2	.02606918	.00408566	6.381	.0000	2994.54695
SN	-2.09718679	.81759279	-2.565	.0103	.612292D-13
SN2	.01295900	.01095952	1.182	.2370	547.427475
FFD	2.40084840	2.84742721	.843	.3991	13.8752801
RH	14.5936141	5.48316572	2.662	.0078	.479581D-12
RH2	.23161062	.39234457	.590	.5550	25.7153897
PW	-.20372150	.47379139	-.430	.6672	134.829397

PC	-.33468184	.52412841	-.639	.5231	63.5451314
Constant	-781.324950	583.997282	-1.338	.1809	

```
+----------------------------------------------------+
| Least Squares with Group Dummy Variables           |
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:18:22PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         34     |
|              Degrees of freedom   =       1373     |
| Residuals    Sum of squares       =   .3189913E+09 |
|              Standard error of e  =   482.0079     |
| Fit          R-squared            =   .5931598     |
|              Adjusted R-squared   =   .5833814     |
| Model test   F[ 33,  1373] (prob) =  60.66 (.0000) |
| Diagnostic   Log likelihood       =  -10671.63     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 33]  (prob) =1265.36 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.37980     |
|              Akaike Info. Criter. =   12.37979     |
| Estd. Autocorrelation of e(i,t)     .438427        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.4032711	4.34937309	8.830	.0000	14.9706563
POPDEN	14.7492489	1.05344391	14.001	.0000	10.3281815
POPDEN2	-.01077298	.00084145	-12.803	.0000	8165.47251
NETMIG	.02524147	.00460878	5.477	.0000	393.283582
HIDIST	-1.70539120	.37186755	-4.586	.0000	45.8647532
GOVPAY	.04135468	.00953444	4.337	.0000	1407.84663
X_COORD	16.3165165	8.40364281	1.942	.0522	-105.177028
BLACK_SZ	57.4793161	115.270230	.499	.6180	.42643923
BROWN_SZ	-241.253404	135.585771	-1.779	.0752	.15138593
DBROWN_S	-75.3780740	125.825308	-.599	.5491	.22459133
GRAY_SZ	24.8938228	119.192785	.209	.8346	.08599858
DGRAY_SZ	64.9375410	116.083005	.559	.5759	.09523810
TPT	.04093265	.01074546	3.809	.0001	.190653D-11
TPT2	.371529D-06	.822239D-07	4.519	.0000	.560350D+08
J	16.4638322	8.94515765	1.841	.0657	-.378397D-13
J2	-.49413632	.31931235	-1.548	.1217	17.2055766
A	21.4916711	13.0496057	1.647	.0996	.420096D-14
A2	3.01285710	1.83888350	1.638	.1013	1.90715584
JU	-30.5120885	17.1649170	-1.778	.0755	-.408549D-14
JU2	-5.37560126	3.98687075	-1.348	.1776	1.72974345
SE	16.5854213	14.7618039	1.124	.2612	-.638595D-16
SE2	6.17589460	6.06760779	1.018	.3088	1.51791524
R	.72622787	.55395476	1.311	.1899	.492280D-13
R2	.02836139	.00418614	6.775	.0000	2994.54695
SN	-1.89587491	.80589408	-2.353	.0186	.612292D-13
SN2	.00855340	.01080270	.792	.4285	547.427475
FFD	4.05737298	2.81233379	1.443	.1491	13.8752801
RH	7.94141529	5.54017761	1.433	.1517	.479581D-12
RH2	-.41824977	.39765907	-1.052	.2929	25.7153897
PW	.17964063	.46952642	.383	.7020	134.829397
PC	-.02579083	.51919288	-.050	.9604	63.5451314

Estimated Fixed Effects

Group	Coefficient	Standard Error	t-ratio
1	1959.22367	850.92372	2.30247
2	1829.56135	873.30177	2.09499
3	2319.78612	936.68669	2.47659

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10695.46252	.3299837846D+09	.5791400
(4)	X and group effects	-10671.62810	.3189912743D+09	.5931598

Hypothesis Tests

	Likelihood Ratio Test Chi-squared	d.f.	Prob.	F Tests F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1217.695	31	.00000	61.036	31	1375	.00000
(4) vs (1)	1265.364	33	.00000	60.660	33	1373	.00000
(4) vs (2)	972.481	31	.00000	44.116	31	1373	.00000
(4) vs (3)	47.669	2	.00000	23.657	2	1373	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i)
Estimates:  Var[e]              =   .232332D+06
            Var[u]              =   .765662D+04
            Corr[v(i,t),v(i,s)] =   .031904
Lagrange Multiplier Test vs. Model (3) =   22.14
( 1 df, prob value =  .000003)
(High values of LM favor FEM/REM over CR model.)
Baltagi-Li form of LM Statistic =          10.02
Fixed vs. Random Effects (Hausman)     =     .00
(31 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares            .351062D+09
            R-squared                 .563886D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.3282860	4.34742556	8.816	.0000	14.9706563
POPDEN	14.8312691	1.05288721	14.086	.0000	10.3281815
POPDEN2	-.01083907	.00084103	-12.888	.0000	8165.47251
NETMIG	.02545281	.00460776	5.524	.0000	393.283582
HIDIST	-1.76002301	.37148613	-4.738	.0000	45.8647532
GOVPAY	.04408848	.00949442	4.644	.0000	1407.84663
X_COORD	4.52427190	7.11986614	.635	.5251	-105.177028
BLACK_SZ	21.5144013	114.594510	.188	.8511	.42643923
BROWN_SZ	-287.517925	134.631849	-2.136	.0327	.15138593
DBROWN_S	-116.399101	125.094974	-.930	.3521	.22459133
GRAY_SZ	-9.52652776	118.675837	-.080	.9360	.08599858
DGRAY_SZ	38.7462820	115.741703	.335	.7378	.09523810
TPT	.04072062	.01073415	3.794	.0001	.190653D-11
TPT2	.370455D-06	.821437D-07	4.510	.0000	.560350D+08
J	18.6981155	8.91381007	2.098	.0359	-.378397D-13
J2	-.55175591	.31880138	-1.731	.0835	17.2055766
A	21.4119502	13.0490459	1.641	.1008	.420096D-14
A2	3.02423494	1.83815236	1.645	.0999	1.90715584
JU	-28.3316962	17.1459513	-1.652	.0985	-.408549D-14
JU2	-5.03889818	3.98547945	-1.264	.2061	1.72974345
SE	18.3623988	14.7420408	1.246	.2129	-.638595D-16

SE2	5.33311141	6.05997909	.880	.3788	1.51791524
R	1.21155287	.53296293	2.273	.0230	.492280D-13
R2	.02662687	.00411303	6.474	.0000	2994.54695
SN	-1.98271968	.80521448	-2.462	.0138	.612292D-13
SN2	.00963791	.01079742	.893	.3721	547.427475
FFD	3.63917745	2.80928501	1.295	.1952	13.8752801
RH	8.53787947	5.52201322	1.546	.1221	.479581D-12
RH2	-.28848190	.39558323	-.729	.4658	25.7153897
PW	.10056363	.46888462	.214	.8302	134.829397
PC	-.05077901	.51874117	-.098	.9220	63.5451314
Constant	822.691582	757.914880	1.085	.2777	

Least Squares with Group and Period Effects
Ordinary least squares regression
Model was estimated Nov 23, 2009 at 02:18:22PM

LHS=LVAL	Mean	= 993.3796
	Standard deviation	= 746.7664
WTS=none	Number of observs.	= 1407
Model size	Parameters	= 36
	Degrees of freedom	= 1371
Residuals	Sum of squares	= .3182244E+09
	Standard error of e	= 481.7792
Fit	R-squared	= .5941378
	Adjusted R-squared	= .5837766
Model test	F[35, 1371] (prob)	= 57.34 (.0000)
Diagnostic	Log likelihood	= -10669.93
	Restricted(b=0)	= -11304.31
	Chi-sq [35] (prob)	=1268.75 (.0000)
Info criter.	LogAmemiya Prd. Crt.	= 12.38024
	Akaike Info. Criter.	= 12.38023

Estd. Autocorrelation of e(i,t) .438465

Panel:Groups	Empty 0,	Valid data	3
	Smallest 183,	Largest	880
	Average group size		469.00
Panel: Prds:	Empty 0,	Valid data	3
	Smallest 0,	Largest	473
	Average group size		469.00

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	37.8492815	4.92625650	7.683	.0000	14.9706563
POPDEN	14.6187924	1.05918720	13.802	.0000	10.3281815
POPDEN2	-.01068206	.00084516	-12.639	.0000	8165.47251
NETMIG	.02619255	.00463747	5.648	.0000	393.283582
HIDIST	-1.71183392	.37281374	-4.592	.0000	45.8647532
GOVPAY	.04056448	.00993868	4.081	.0000	1407.84663
X_COORD	14.7555845	8.45815236	1.745	.0811	-105.177028
BLACK_SZ	71.3268425	115.650600	.617	.5374	.42643923
BROWN_SZ	-217.327791	136.308563	-1.594	.1109	.15138593
DBROWN_S	-52.7133543	126.586459	-.416	.6771	.22459133
GRAY_SZ	31.5234560	119.367677	.264	.7917	.08599858
DGRAY_SZ	70.3730119	116.189224	.606	.5447	.09523810
TPT	.04056614	.01074937	3.774	.0002	.190653D-11
TPT2	.369324D-06	.822527D-07	4.490	.0000	.560350D+08
J	15.2547322	9.01367727	1.692	.0906	-.378397D-13
J2	-.45763300	.32128299	-1.424	.1543	17.2055766
A	22.0382442	13.0469087	1.689	.0912	.420096D-14
A2	3.05061276	1.83831724	1.659	.0970	1.90715584
JU	-31.7008739	17.1986904	-1.843	.0653	-.408549D-14

```
JU2     |   -5.39799527      3.99934369    -1.350   .1771   1.72974345
SE      |    15.4988160      14.8184990     1.046   .2956 -.638595D-16
SE2     |    5.77163932      6.07255823      .950   .3419   1.51791524
R       |     .57344695       .56199461     1.020   .3075  .492280D-13
R2      |     .02870752       .00419202     6.848   .0000   2994.54695
SN      |   -1.79570035       .80908196    -2.219   .0265  .612292D-13
SN2     |     .00803533       .01081836      .743   .4576   547.427475
FFD     |    3.95053706      2.81182111     1.405   .1600   13.8752801
RH      |    9.15072492      5.57805037     1.640   .1009  .479581D-12
RH2     |    -.34954338       .39982782     -.874   .3820   25.7153897
PW      |    6.67084149      3.61324423     1.846   .0649   134.829397
PC      |    4.08038393      2.33342335     1.749   .0803   63.5451314
Constant|    617.982847      1141.15005      .542   .5881

      Estimated Fixed Effects - Full sets of effects, normalized to sum to 0
      Group        Coefficient       Standard Error       t-ratio
           1          26.72343             46.38810          .57608
           2         -90.59148             15.57533        -5.81634
           3         385.39695             81.69670         4.71741
      Estimated Fixed Effects - Full sets of effects, normalized to sum to 0
      Period       Coefficient       Standard Error       t-ratio
           1         314.46448            175.44129         1.79242
           2        -323.89276            178.96458        -1.80981
           3           1.21112             22.98274          .05270
+--------------------------------------------------------------------+
|             Test Statistics for the Classical Model                |
+--------------------------------------------------------------------+
|      Model              Log-Likelihood  Sum of Squares    R-squared |
|(1)  Constant term only   -11304.31008  .7840701399D+09    .0000000 |
|(2)  Group effects only   -11157.86875  .6367247026D+09    .1879238 |
|(3)  X - variables only   -10695.46252  .3299837846D+09    .5791400 |
|(4)  X and group effects  -10671.62810  .3189912743D+09    .5931598 |
|(5)  X ind.&time effects  -10669.93483  .3182244095D+09    .5941378 |
+--------------------------------------------------------------------+
|                        Hypothesis Tests                            |
|         Likelihood Ratio Test           F Tests                    |
|         Chi-squared   d.f.  Prob.        F    num. denom.   P value |
|(2) vs (1)   292.883     2  .00000  162.451     2    1404   .00000 |
|(3) vs (1)  1217.695    31  .00000   61.036    31    1375   .00000 |
|(4) vs (1)  1265.364    33  .00000   60.660    33    1373   .00000 |
|(4) vs (2)   972.481    31  .00000   44.116    31    1373   .00000 |
|(4) vs (3)    47.669     2  .00000   23.657     2    1373   .00000 |
|(5) vs (4)     3.387     2  .18392    1.652     2    1371   .19206 |
|(5) vs (3)    51.055     5  .00000   10.133     5    1371   .00000 |
+--------------------------------------------------------------------+

+----------------------------------------------------------+
| Random Effects Model: v(i,t) = e(i,t) + u(i) + w(t)      |
| Estimates:  Var[e]              =   .232111D+06          |
|             Var[u]              =   .409972D+05          |
|             Corr[v(i,t),v(i,s)] =   .150113              |
|             Var[w]              =   .679245D+05          |
|             Corr[v(i,t),v(j,t)] =   .226388              |
| Lagrange Multiplier Test vs. Model (3) =   23.11         |
| ( 2 df, prob value =  .000010)                           |
| (High values of LM favor FEM/REM over CR model.)         |
| Fixed vs. Random Effects (Hausman)     =     .00         |
| (31 df, prob value = 1.000000)                           |
| (High (low) values of H favor FEM (REM).)                |
|             Sum of Squares          .351062D+09          |
|             R-squared               .563886D+00          |
+----------------------------------------------------------+
+--------+-------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
```

INCCAP	38.2134620	4.91477720	7.775	.0000	14.9706563
POPDEN	14.7053993	1.05762782	13.904	.0000	10.3281815
POPDEN2	-.01074510	.00084418	-12.728	.0000	8165.47251
NETMIG	.02578483	.00462391	5.576	.0000	393.283582
HIDIST	-1.72432951	.37273012	-4.626	.0000	45.8647532
GOVPAY	.04194881	.00990735	4.234	.0000	1407.84663
X_COORD	11.6175847	8.03882383	1.445	.1484	-105.177028
BLACK_SZ	52.6413258	115.298824	.457	.6480	.42643923
BROWN_SZ	-244.251823	135.692698	-1.800	.0719	.15138593
DBROWN_S	-77.2287742	126.052351	-.613	.5401	.22459133
GRAY_SZ	17.0296753	119.153365	.143	.8864	.08599858
DGRAY_SZ	59.0332916	116.046145	.509	.6110	.09523810
TPT	.04062132	.01074445	3.781	.0002	.190653D-11
TPT2	.369630D-06	.822203D-07	4.496	.0000	.560350D+08
J	16.6047330	8.99049619	1.847	.0648	-.378397D-13
J2	-.49502343	.32079886	-1.543	.1228	17.2055766
A	21.7394805	13.0451251	1.666	.0956	.420096D-14
A2	3.03044386	1.83808542	1.649	.0992	1.90715584
JU	-30.5263878	17.1860068	-1.776	.0757	-.408549D-14
JU2	-5.29678696	3.99890693	-1.325	.1853	1.72974345
SE	16.6804645	14.8050591	1.127	.2599	-.638595D-16
SE2	5.70360833	6.06897420	.940	.3473	1.51791524
R	.80266498	.55216436	1.454	.1460	.492280D-13
R2	.02794648	.00416671	6.707	.0000	2994.54695
SN	-1.87547857	.80800896	-2.321	.0203	.612292D-13
SN2	.00865715	.01081441	.801	.4234	547.427475
FFD	3.86896393	2.81047122	1.377	.1686	13.8752801
RH	8.71117236	5.55616753	1.568	.1169	.479581D-12
RH2	-.34419351	.39856650	-.864	.3878	25.7153897
PW	3.50079112	2.62860486	1.332	.1829	134.829397
PC	2.08840105	1.72190316	1.213	.2252	63.5451314
Constant	963.967180	1016.46797	.948	.3430	

Panel Model 2

OLS Without Group Dummy Variables
Ordinary least squares regression
Model was estimated Nov 23, 2009 at 02:31:28PM

LHS=LVAL	Mean	= 993.3796
	Standard deviation	= 746.7664
WTS=none	Number of observs.	= 1407
Model size	Parameters	= 34
	Degrees of freedom	= 1373
Residuals	Sum of squares	= .3316896E+09
	Standard error of e	= 491.5081
Fit	R-squared	= .5769643
	Adjusted R-squared	= .5667967
Model test	F[33, 1373] (prob)	= 56.75 (.0000)
Diagnostic	Log likelihood	= -10699.09
	Restricted(b=0)	= -11304.31
	Chi-sq [33] (prob)	=1210.44 (.0000)
Info criter.	LogAmemiya Prd. Crt.	= 12.41883
	Akaike Info. Criter.	= 12.41883

Panel Data Analysis of LVAL [ONE way]
Unconditional ANOVA (No regressors)

Source	Variation	Deg. Free.	Mean Square
Between	.147345E+09	2.	.736727E+08
Residual	.636725E+09	1404.	453508.
Total	.784070E+09	1406.	557660.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	39.0501266	4.45883581	8.758	.0000	14.9706563
POPDEN	15.1220501	1.07577599	14.057	.0000	10.3281815
POPDEN2	-.01113782	.00085879	-12.969	.0000	8165.47251
NETMIG	.02879627	.00469626	6.132	.0000	393.283582
HIDIST	-2.06348674	.38121624	-5.413	.0000	45.8647532
GOVPAY	.05403489	.00960570	5.625	.0000	1407.84663
X_COORD	-18.9266635	4.32945269	-4.372	.0000	-105.177028
BLACK_SZ	15.0095126	115.481431	.130	.8966	.42643923
BROWN_SZ	-263.743531	134.068438	-1.967	.0492	.15138593
DBROWN_S	-118.349720	125.789469	-.941	.3468	.22459133
GRAY_SZ	-52.8704319	120.058307	-.440	.6597	.08599858
DGRAY_SZ	18.3821528	118.071121	.156	.8763	.09523810
TPT	.04632477	.01103725	4.197	.0000	.190653D-11
TPT2	.410239D-06	.848210D-07	4.837	.0000	.560350D+08
GDM4	-1.46382715	2.25154030	-.650	.5156	-.131986D-12
GDM42	.02844623	.07244075	.393	.6946	220.444785
GDM5	.25042791	1.88485123	.133	.8943	.359504D-13
GDM52	-.04377419	.02181381	-2.007	.0448	1625.00965
GDM6	2.18332528	1.65745409	1.317	.1877	-.942581D-12
GDM62	.02307724	.01354684	1.704	.0885	3647.35640
GDM7	-1.58398106	1.30908148	-1.210	.2263	-.340150D-12
GDM72	.00375354	.00800033	.469	.6389	5614.09200
GDM8	-.18556974	1.21255937	-.153	.8784	-.184494D-11
GDM82	-.00555779	.00949705	-.585	.5584	5016.13001
R	3.25031719	.46519869	6.987	.0000	.492280D-13
R2	.02731878	.00411069	6.646	.0000	2994.54695
SN	-2.24223145	.79983559	-2.803	.0051	.612292D-13
SN2	.01668694	.01103121	1.513	.1304	547.427475
FFD	3.62591595	3.13605016	1.156	.2476	13.8752801
RH	6.93951640	5.34513413	1.298	.1942	.479581D-12

RH2	.39341802	.40199728	.979	.3277	25.7153897
PW	.34677285	.47199769	.735	.4625	134.829397
PC	-.25917201	.52675468	-.492	.6227	63.5451314
Constant	-1794.11418	460.947356	-3.892	.0001	

```
+----------------------------------------------------+
| Least Squares with Group Dummy Variables           |
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:31:28PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         36     |
|              Degrees of freedom   =       1371     |
| Residuals    Sum of squares       =   .3194408E+09 |
|              Standard error of e  =   482.6991     |
| Fit          R-squared            =   .5925865     |
|              Adjusted R-squared   =   .5821857     |
| Model test   F[ 35,  1371] (prob) =  56.98 (.0000) |
| Diagnostic   Log likelihood       =  -10672.62     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 35]  (prob) =1263.38 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.38405     |
|              Akaike Info. Criter. =   12.38404     |
| Estd. Autocorrelation of e(i,t)     .433465        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	40.1115799	4.39445569	9.128	.0000	14.9706563
POPDEN	14.8502852	1.05810933	14.035	.0000	10.3281815
POPDEN2	-.01090555	.00084471	-12.910	.0000	8165.47251
NETMIG	.02697390	.00462053	5.838	.0000	393.283582
HIDIST	-1.77970204	.37646376	-4.727	.0000	45.8647532
GOVPAY	.04238641	.00957465	4.427	.0000	1407.84663
X_COORD	11.3198226	7.81604378	1.448	.1475	-105.177028
BLACK_SZ	118.478056	114.589848	1.034	.3012	.42643923
BROWN_SZ	-151.499214	133.089693	-1.138	.2550	.15138593
DBROWN_S	1.60226295	124.790298	.013	.9898	.22459133
GRAY_SZ	75.2640344	119.278729	.631	.5280	.08599858
DGRAY_SZ	105.113618	116.658352	.901	.3676	.09523810
TPT	.04211792	.01088706	3.869	.0001	.190653D-11
TPT2	.379292D-06	.836442D-07	4.535	.0000	.560350D+08
GDM4	-2.57547703	2.21742637	-1.161	.2455	-.131986D-12
GDM42	.05714745	.07139818	.800	.4235	220.444785
GDM5	.54129926	1.85316597	.292	.7702	.359504D-13
GDM52	-.05427047	.02148158	-2.526	.0115	1625.00965
GDM6	1.84291752	1.62874856	1.131	.2578	-.942581D-12
GDM62	.02962918	.01333772	2.221	.0263	3647.35640
GDM7	-1.91533866	1.28678200	-1.488	.1366	-.340150D-12
GDM72	.00050243	.00786992	.064	.9491	5614.09200
GDM8	.46083329	1.19424844	.386	.6996	-.184494D-11
GDM82	-.00491092	.00932735	-.527	.5985	5016.13001
R	1.04650461	.54958111	1.904	.0569	.492280D-13
R2	.02967756	.00419768	7.070	.0000	2994.54695
SN	-1.96122869	.78691561	-2.492	.0127	.612292D-13
SN2	.01189819	.01085505	1.096	.2730	547.427475
FFD	4.83974097	3.09226687	1.565	.1176	13.8752801

RH	2.36929202	5.38093145	.440	.6597	.479581D-12
RH2	-.33991826	.40807171	-.833	.4049	25.7153897
PW	.65605257	.46630880	1.407	.1595	134.829397
PC	.06337807	.52129187	.122	.9032	63.5451314

Estimated Fixed Effects

Group	Coefficient	Standard Error	t-ratio
1	1226.61539	782.34038	1.56788
2	1110.84773	808.34865	1.37422
3	1639.09041	875.87821	1.87137

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10699.08991	.3316896447D+09	.5769643
(4)	X and group effects	-10672.61874	.3194407822D+09	.5925865

Hypothesis Tests

	Likelihood Ratio Test Chi-squared	d.f.	Prob.	F Tests F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1210.440	33	.00000	56.745	33	1373	.00000
(4) vs (1)	1263.383	35	.00000	56.975	35	1371	.00000
(4) vs (2)	970.500	33	.00000	41.265	33	1371	.00000
(4) vs (3)	52.942	2	.00000	26.285	2	1371	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i)
Estimates:  Var[e]              =   .232998D+06
            Var[u]              =   .858184D+04
            Corr[v(i,t),v(i,s)] =   .035524
Lagrange Multiplier Test vs. Model (3) =   25.51
( 1 df, prob value =  .000000)
(High values of LM favor FEM/REM over CR model.)
Baltagi-Li form of LM Statistic =          11.54
Fixed vs. Random Effects (Hausman)     =     .00
(33 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares          .356473D+09
            R-squared               .558941D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	40.2606623	4.39137251	9.168	.0000	14.9706563
POPDEN	14.9601751	1.05740521	14.148	.0000	10.3281815
POPDEN2	-.01099508	.00084414	-13.025	.0000	8165.47251
NETMIG	.02723567	.00461954	5.896	.0000	393.283582
HIDIST	-1.83566217	.37609336	-4.881	.0000	45.8647532
GOVPAY	.04529319	.00953506	4.750	.0000	1407.84663
X_COORD	-.99317704	6.50394254	-.153	.8786	-105.177028
BLACK_SZ	86.7672682	114.145459	.760	.4472	.42643923
BROWN_SZ	-189.249422	132.509962	-1.428	.1532	.15138593
DBROWN_S	-31.5838254	124.372630	-.254	.7995	.22459133
GRAY_SZ	43.1462918	118.890124	.363	.7167	.08599858
DGRAY_SZ	81.0379265	116.422882	.696	.4864	.09523810
TPT	.04209817	.01088003	3.869	.0001	.190653D-11
TPT2	.379027D-06	.835929D-07	4.534	.0000	.560350D+08
GDM4	-2.25996186	2.21527024	-1.020	.3076	-.131986D-12
GDM42	.04573690	.07128695	.642	.5211	220.444785
GDM5	.38937303	1.85226064	.210	.8335	.359504D-13
GDM52	-.05270613	.02147446	-2.454	.0141	1625.00965

GDM6	1.95391688	1.62834891	1.200	.2302	-.942581D-12
GDM62	.02851500	.01333301	2.139	.0325	3647.35640
GDM7	-1.80903876	1.28632347	-1.406	.1596	-.340150D-12
GDM72	.00127565	.00786658	.162	.8712	5614.09200
GDM8	.30302098	1.19332224	.254	.7995	-.184494D-11
GDM82	-.00509715	.00932717	-.546	.5847	5016.13001
R	1.56307313	.52786205	2.961	.0031	.492280D-13
R2	.02791998	.00413344	6.755	.0000	2994.54695
SN	-2.05297459	.78634984	-2.611	.0090	.612292D-13
SN2	.01314473	.01084851	1.212	.2256	547.427475
FFD	4.32594628	3.08682850	1.401	.1611	13.8752801
RH	2.24317059	5.36037821	.418	.6756	.479581D-12
RH2	-.20283239	.40594864	-.500	.6173	25.7153897
PW	.61932921	.46600530	1.329	.1838	134.829397
PC	.04500579	.52081128	.086	.9311	63.5451314
Constant	42.2524836	687.211444	.061	.9510	

```
+----------------------------------------------------+
| Least Squares with Group and Period Effects        |
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:31:29PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         38     |
|              Degrees of freedom   =       1369     |
| Residuals    Sum of squares       =   .3182323E+09 |
|              Standard error of e  =   482.1370     |
| Fit          R-squared            =   .5941277     |
|              Adjusted R-squared   =   .5831582     |
| Model test   F[ 37,  1369] (prob) =  54.16 (.0000) |
| Diagnostic   Log likelihood       =  -10669.95     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 37]  (prob) =1268.72 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.38311     |
|              Akaike Info. Criter. =   12.38309     |
| Estd. Autocorrelation of e(i,t)     .435988        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
| Panel: Prds:   Empty       0,   Valid data       3 |
|                Smallest    0,   Largest        473 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	37.5073711	4.91591018	7.630	.0000	14.9706563
POPDEN	14.7649831	1.06294282	13.891	.0000	10.3281815
POPDEN2	-.01084401	.00084763	-12.793	.0000	8165.47251
NETMIG	.02805908	.00464117	6.046	.0000	393.283582
HIDIST	-1.80114054	.37628516	-4.787	.0000	45.8647532
GOVPAY	.03915588	.00995736	3.932	.0001	1407.84663
X_COORD	9.72373788	7.89223308	1.232	.2179	-105.177028
BLACK_SZ	139.876884	114.858345	1.218	.2233	.42643923
BROWN_SZ	-118.605660	133.723941	-.887	.3751	.15138593
DBROWN_S	34.9273118	125.509515	.278	.7808	.22459133
GRAY_SZ	87.3843701	119.296009	.733	.4639	.08599858
DGRAY_SZ	116.015298	116.634888	.995	.3199	.09523810
TPT	.04223499	.01088684	3.879	.0001	.190653D-11
TPT2	.381030D-06	.836284D-07	4.556	.0000	.560350D+08

GDM4	-2.85914614	2.22275023	-1.286	.1983	-.131986D-12
GDM42	.06388403	.07144986	.894	.3713	220.444785
GDM5	.76954909	1.89476996	.406	.6846	.359504D-13
GDM52	-.05362784	.02145868	-2.499	.0125	1625.00965
GDM6	1.91768955	1.62960722	1.177	.2393	-.942581D-12
GDM62	.03143775	.01336731	2.352	.0187	3647.35640
GDM7	-1.48443444	1.32073479	-1.124	.2610	-.340150D-12
GDM72	.00184478	.00788379	.234	.8150	5614.09200
GDM8	-.08209652	1.26416061	-.065	.9482	-.184494D-11
GDM82	-.00782620	.00942541	-.830	.4064	5016.13001
R	.80543302	.55922906	1.440	.1498	.492280D-13
R2	.03025127	.00420187	7.199	.0000	2994.54695
SN	-1.79534410	.79064022	-2.271	.0232	.612292D-13
SN2	.01069315	.01086602	.984	.3251	547.427475
FFD	4.71069083	3.08944926	1.525	.1273	13.8752801
RH	4.30317438	5.44305925	.791	.4292	.479581D-12
RH2	-.21656220	.41166906	-.526	.5988	25.7153897
PW	7.91993834	3.62681964	2.184	.0290	134.829397
PC	4.61941698	2.34995941	1.966	.0493	63.5451314
Constant	-212.689509	1104.63654	-.193	.8473	

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Group	Coefficient	Standard Error	t-ratio
1	6.68585	46.50405	.14377
2	-91.95427	15.54297	-5.91613
3	429.61653	80.46818	5.33896

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Period	Coefficient	Standard Error	t-ratio
1	338.39965	176.40473	1.91831
2	-373.04757	180.36189	-2.06833
3	25.18371	25.46021	.98914

Test Statistics for the Classical Model

Model	Log-Likelihood	Sum of Squares	R-squared
(1) Constant term only	-11304.31008	.7840701399D+09	.0000000
(2) Group effects only	-11157.86875	.6367247026D+09	.1879238
(3) X - variables only	-10699.08991	.3316896447D+09	.5769643
(4) X and group effects	-10672.61874	.3194407822D+09	.5925865
(5) X ind.&time effects	-10669.95235	.3182323356D+09	.5941277

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1210.440	33	.00000	56.745	33	1373	.00000
(4) vs (1)	1263.383	35	.00000	56.975	35	1371	.00000
(4) vs (2)	970.500	33	.00000	41.265	33	1371	.00000
(4) vs (3)	52.942	2	.00000	26.285	2	1371	.00000
(5) vs (4)	5.333	2	.06950	2.599	2	1369	.07469
(5) vs (3)	58.275	5	.00000	11.578	5	1369	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i) + w(t)
Estimates:  Var[e]              =   .232456D+06
            Var[u]              =   .511818D+05
            Corr[v(i,t),v(i,s)] =   .180448
            Var[w]              =   .847611D+05
            Corr[v(i,t),v(j,t)] =   .267202
Lagrange Multiplier Test vs. Model (3) =   26.93
( 2 df, prob value =  .000001)
(High values of LM favor FEM/REM over CR model.)
Fixed vs. Random Effects (Hausman)     =     .00
(33 df, prob value = 1.000000)
```

(High (low) values of H favor FEM (REM).)	
Sum of Squares	.356473D+09
R-squared	.558941D+00

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	37.9316981	4.90488171	7.733	.0000	14.9706563
POPDEN	14.8597944	1.06140747	14.000	.0000	10.3281815
POPDEN2	-.01091524	.00084662	-12.893	.0000	8165.47251
NETMIG	.02770578	.00463066	5.983	.0000	393.283582
HIDIST	-1.81228487	.37619609	-4.817	.0000	45.8647532
GOVPAY	.04044534	.00993151	4.072	.0000	1407.84663
X_COORD	6.92069590	7.51072214	.921	.3568	-105.177028
BLACK_SZ	123.547513	114.615770	1.078	.2811	.42643923
BROWN_SZ	-141.028586	133.309104	-1.058	.2901	.15138593
DBROWN_S	13.8362706	125.119074	.111	.9119	.22459133
GRAY_SZ	74.6810750	119.152867	.627	.5308	.08599858
DGRAY_SZ	105.666494	116.539343	.907	.3646	.09523810
TPT	.04231695	.01088392	3.888	.0001	.190653D-11
TPT2	.381223D-06	.836104D-07	4.560	.0000	.560350D+08
GDM4	-2.70724172	2.22156375	-1.219	.2230	-.131986D-12
GDM42	.05905071	.07140544	.827	.4082	220.444785
GDM5	.75838765	1.89226152	.401	.6886	.359504D-13
GDM52	-.05339865	.02145675	-2.489	.0128	1625.00965
GDM6	1.89707546	1.62874770	1.165	.2441	-.942581D-12
GDM62	.03070420	.01336294	2.298	.0216	3647.35640
GDM7	-1.53725106	1.31990328	-1.165	.2442	-.340150D-12
GDM72	.00162271	.00787747	.206	.8368	5614.09200
GDM8	-.03477521	1.26301372	-.028	.9780	-.184494D-11
GDM82	-.00702388	.00940929	-.746	.4554	5016.13001
R	1.03537257	.54990981	1.883	.0597	.492280D-13
R2	.02954777	.00418233	7.065	.0000	2994.54695
SN	-1.86839716	.78984560	-2.366	.0180	.612292D-13
SN2	.01134199	.01086195	1.044	.2964	547.427475
FFD	4.61645110	3.08757438	1.495	.1349	13.8752801
RH	3.50311927	5.41312190	.647	.5175	.479581D-12
RH2	-.21640845	.41049138	-.527	.5981	25.7153897
PW	4.81129550	2.76167437	1.742	.0815	134.829397
PC	2.64963585	1.81037229	1.464	.1433	63.5451314
Constant	163.654612	993.415645	.165	.8691	

Panel Model 1(No Prices)

```
+----------------------------------------------------+
| OLS Without Group Dummy Variables                  |
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:36:42PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         30     |
|              Degrees of freedom   =       1377     |
| Residuals    Sum of squares       =   .3301030E+09 |
|              Standard error of e  =   489.6184     |
| Fit          R-squared            =   .5789880     |
|              Adjusted R-squared   =   .5701213     |
| Model test   F[ 29,  1377] (prob) =  65.30 (.0000) |
| Diagnostic   Log likelihood       =  -10695.72     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 29]  (prob) =1217.19 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.40835     |
|              Akaike Info. Criter. =   12.40834     |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel Data Analysis of LVAL       [ONE way]        |
|          Unconditional ANOVA (No regressors)       |
| Source      Variation   Deg. Free.     Mean Square |
| Between      .147345E+09       2.     .736727E+08  |
| Residual     .636725E+09    1404.     453508.      |
| Total        .784070E+09    1406.     557660.      |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	36.2525715	4.31437956	8.403	.0000	14.9706563
POPDEN	14.9882052	1.05691772	14.181	.0000	10.3281815
POPDEN2	-.01097553	.00084540	-12.983	.0000	8165.47251
NETMIG	.02665532	.00463943	5.745	.0000	393.283582
HIDIST	-1.94340161	.37209692	-5.223	.0000	45.8647532
GOVPAY	.05209117	.00951165	5.477	.0000	1407.84663
X_COORD	-10.9638451	5.11857509	-2.142	.0322	-105.177028
BLACK_SZ	-46.3273859	115.413287	-.401	.6881	.42643923
BROWN_SZ	-372.330118	130.136771	-2.861	.0042	.15138593
DBROWN_S	-209.235689	124.056526	-1.687	.0917	.22459133
GRAY_SZ	-95.2008010	119.175381	-.799	.4244	.08599858
DGRAY_SZ	-12.1079839	116.736079	-.104	.9174	.09523810
TPT	.04506069	.01081322	4.167	.0000	.190653D-11
TPT2	.404457D-06	.828170D-07	4.884	.0000	.560350D+08
J	23.1286290	8.88565244	2.603	.0092	-.378397D-13
J2	-.70277390	.32024874	-2.194	.0282	17.2055766
A	22.5789970	13.2460662	1.705	.0883	.420096D-14
A2	3.59836049	1.86253761	1.932	.0534	1.90715584
JU	-15.1217059	17.1936807	-.879	.3791	-.408549D-14
JU2	-3.80830101	4.02927316	-.945	.3446	1.72974345
SE	18.3342765	14.7669383	1.242	.2144	-.638595D-16
SE2	3.50647056	6.11721263	.573	.5665	1.51791524
R	2.70220704	.47737987	5.660	.0000	.492280D-13
R2	.02627240	.00405996	6.471	.0000	2994.54695
SN	-2.10682022	.81685986	-2.579	.0099	.612292D-13
SN2	.01283443	.01081958	1.186	.2355	547.427475
FFD	2.32049050	2.84319382	.816	.4144	13.8752801
RH	12.2786115	4.29728847	2.857	.0043	.479581D-12
RH2	.16785096	.38075698	.441	.6593	25.7153897
Constant	-768.285665	555.240170	-1.384	.1665	

```
+----------------------------------------------------+
| Least Squares with Group Dummy Variables           |
| Ordinary    least squares regression               |
| Model was estimated Nov 23, 2009 at 02:36:42PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         32     |
|              Degrees of freedom   =       1375     |
| Residuals    Sum of squares       =   .3190298E+09 |
|              Standard error of e  =   481.6863     |
| Fit          R-squared            =   .5931106     |
|              Adjusted R-squared   =   .5839371     |
| Model test   F[ 31,  1375] (prob) =  64.65 (.0000) |
| Diagnostic   Log likelihood       =  -10671.71     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 31]  (prob) =1265.19 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.37707     |
|              Akaike Info. Criter. =   12.37707     |
| Estd. Autocorrelation of e(i,t)     .438350        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
+----------------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 INCCAP  |    38.6320592      4.26833204     9.051   .0000   14.9706563
 POPDEN  |    14.7667261      1.04083112    14.187   .0000   10.3281815
 POPDEN2 |    -.01078445       .00083254   -12.954   .0000   8165.47251
 NETMIG  |     .02512003       .00457081     5.496   .0000   393.283582
 HIDIST  |   -1.72816575       .36739389    -4.704   .0000   45.8647532
 GOVPAY  |     .04123218       .00949720     4.342   .0000   1407.84663
 X_COORD |    16.6044163      8.28791419     2.003   .0451  -105.177028
 BLACK_SZ|    56.1819243      115.088291      .488   .6254    .42643923
 BROWN_SZ|   -228.939023      130.745807    -1.751   .0799    .15138593
 DBROWN_S|   -69.0078020      124.188719     -.556   .5784    .22459133
 GRAY_SZ |    20.6538338      118.615954      .174   .8618    .08599858
 DGRAY_SZ|    61.3732482      115.587908      .531   .5954    .09523810
 TPT     |     .04056840       .01070086     3.791   .0001  .190653D-11
 TPT2    |    .369090D-06     .819466D-07    4.504   .0000  .560350D+08
 J       |    17.0724928      8.80516208     1.939   .0525 -.378397D-13
 J2      |    -.50923045       .31638965    -1.610   .1075   17.2055766
 A       |    21.4106156      13.0350959     1.643   .1005  .420096D-14
 A2      |    3.01886360      1.83729254     1.643   .1004   1.90715584
 JU      |   -30.7474856      17.0934022    -1.799   .0721 -.408549D-14
 JU2     |   -5.46168580      3.97126818    -1.375   .1690   1.72974345
 SE      |    17.4676736      14.5686888     1.199   .2305 -.638595D-16
 SE2     |    6.25297932      6.03755870     1.036   .3004   1.51791524
 R       |     .72133184       .55210016     1.307   .1914  .492280D-13
 R2      |     .02818251       .00415863     6.777   .0000   2994.54695
 SN      |   -1.88915226       .80515107    -2.346   .0190  .612292D-13
 SN2     |     .00924549       .01065708      .868   .3856   547.427475
 FFD     |    4.08001308      2.80900459     1.452   .1464   13.8752801
 RH      |    8.70530158      4.30318398     2.023   .0431  .479581D-12
 RH2     |    -.39452552       .38341101    -1.029   .3035   25.7153897

        Estimated Fixed Effects
        Group       Coefficient        Standard Error       t-ratio
            1        2007.54289             838.82845       2.39327
```

2	1878.26202	861.83719	2.17937
3	2365.56277	926.57831	2.55301

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10695.71658	.3301029768D+09	.5789880
(4)	X and group effects	-10671.71309	.3190298155D+09	.5931106

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1217.187	29	.00000	65.300	29	1377	.00000
(4) vs (1)	1265.194	31	.00000	64.655	31	1375	.00000
(4) vs (2)	972.311	29	.00000	47.215	29	1375	.00000
(4) vs (3)	48.007	2	.00000	23.862	2	1375	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i)
Estimates:  Var[e]              =   .232022D+06
            Var[u]              =   .770452D+04
            Corr[v(i,t),v(i,s)] =   .032139
Lagrange Multiplier Test vs. Model (3) =   23.94
( 1 df, prob value =  .000001)
(High values of LM favor FEM/REM over CR model.)
Baltagi-Li form of LM Statistic =          10.83
Fixed vs. Random Effects (Hausman)     =     .00
(29 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares          .351012D+09
            R-squared               .563934D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.4314266	4.26536713	9.010	.0000	14.9706563
POPDEN	14.8516582	1.04035994	14.275	.0000	10.3281815
POPDEN2	-.01085336	.00083217	-13.042	.0000	8165.47251
NETMIG	.02534314	.00457000	5.546	.0000	393.283582
HIDIST	-1.77380158	.36712060	-4.832	.0000	45.8647532
GOVPAY	.04403657	.00945509	4.657	.0000	1407.84663
X_COORD	4.87994239	6.96427174	.701	.4835	-105.177028
BLACK_SZ	21.2569790	114.429714	.186	.8526	.42643923
BROWN_SZ	-278.197999	129.583177	-2.147	.0318	.15138593
DBROWN_S	-111.282282	123.375650	-.902	.3671	.22459133
GRAY_SZ	-11.6713811	118.145994	-.099	.9213	.08599858
DGRAY_SZ	37.0440950	115.277294	.321	.7479	.09523810
TPT	.04049949	.01068995	3.789	.0002	.190653D-11
TPT2	.369000D-06	.818678D-07	4.507	.0000	.560350D+08
J	19.0331799	8.77914031	2.168	.0302	-.378397D-13
J2	-.55943305	.31598428	-1.770	.0767	17.2055766
A	21.3845088	13.0344517	1.641	.1009	.420096D-14
A2	3.03014302	1.83652523	1.650	.0990	1.90715584
JU	-28.4084903	17.0709559	-1.664	.0961	-.408549D-14
JU2	-5.07918705	3.96948160	-1.280	.2007	1.72974345
SE	18.8419832	14.5521852	1.295	.1954	-.638595D-16
SE2	5.35283873	6.02948906	.888	.3747	1.51791524
R	1.20187166	.53110993	2.263	.0236	.492280D-13
R2	.02653771	.00408813	6.491	.0000	2994.54695
SN	-1.97831451	.80444536	-2.459	.0139	.612292D-13
SN2	.01008000	.01065390	.946	.3441	547.427475

FFD	3.65199790	2.80578846	1.302	.1931	13.8752801
RH	8.81258616	4.29192630	2.053	.0400	.479581D-12
RH2	-.28057936	.38175801	-.735	.4624	25.7153897
Constant	867.267140	741.932750	1.169	.2424	

```
+----------------------------------------------------+
| Least Squares with Group and Period Effects         |
| Ordinary    least squares regression                |
| Model was estimated Nov 23, 2009 at 02:36:43PM      |
| LHS=LVAL     Mean                 =   993.3796      |
|              Standard deviation   =   746.7664      |
| WTS=none     Number of observs.   =       1407      |
| Model size   Parameters           =         34      |
|              Degrees of freedom   =       1373      |
| Residuals    Sum of squares       =   .3190249E+09  |
|              Standard error of e  =   482.0333      |
| Fit          R-squared            =   .5931168      |
|              Adjusted R-squared   =   .5833374      |
| Model test   F[ 33,  1373] (prob) =  60.65 (.0000)  |
| Diagnostic   Log likelihood       =  -10671.70      |
|              Restricted(b=0)      =  -11304.31      |
|              Chi-sq [ 33]  (prob) =1265.22 (.0000)  |
| Info criter. LogAmemiya Prd. Crt. =   12.37990      |
|              Akaike Info. Criter. =   12.37989      |
| Estd. Autocorrelation of e(i,t)     .438470         |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3  |
|                Smallest  183,   Largest        880  |
|                Average group size           469.00  |
| Panel: Prds:   Empty       0,   Valid data       3  |
|                Smallest    0,   Largest        473  |
|                Average group size           469.00  |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.2981950	4.91713914	7.789	.0000	14.9706563
POPDEN	14.7852976	1.04945636	14.089	.0000	10.3281815
POPDEN2	-.01079859	.00083883	-12.873	.0000	8165.47251
NETMIG	.02511441	.00457666	5.487	.0000	393.283582
HIDIST	-1.72828946	.37169654	-4.650	.0000	45.8647532
GOVPAY	.04098396	.00991120	4.135	.0000	1407.84663
X_COORD	16.7038696	8.32357096	2.007	.0448	-105.177028
BLACK_SZ	57.3563500	115.463484	.497	.6194	.42643923
BROWN_SZ	-228.609529	132.082106	-1.731	.0835	.15138593
DBROWN_S	-68.2411419	124.918615	-.546	.5849	.22459133
GRAY_SZ	22.1944836	119.238362	.186	.8523	.08599858
DGRAY_SZ	62.7873947	116.153723	.541	.5888	.09523810
TPT	.04066768	.01073853	3.787	.0002	.190653D-11
TPT2	.369841D-06	.822118D-07	4.499	.0000	.560350D+08
J	16.8563540	8.95084258	1.883	.0597	-.378397D-13
J2	-.50233348	.32036507	-1.568	.1169	17.2055766
A	21.4420800	13.0486030	1.643	.1003	.420096D-14
A2	3.02336411	1.83893529	1.644	.1002	1.90715584
JU	-30.5072178	17.1913826	-1.775	.0760	-.408549D-14
JU2	-5.39430568	4.00145054	-1.348	.1776	1.72974345
SE	17.1474004	14.7770997	1.160	.2459	-.638595D-16
SE2	6.18095963	6.06524115	1.019	.3082	1.51791524
R	.71405188	.55570763	1.285	.1988	.492280D-13
R2	.02823485	.00418252	6.751	.0000	2994.54695
SN	-1.88477305	.80808033	-2.332	.0197	.612292D-13
SN2	.00910192	.01072744	.848	.3962	547.427475

FFD	4.07575744	2.81228509	1.449	.1473	13.8752801
RH	8.40053955	5.47184420	1.535	.1247	.479581D-12
RH2	-.40159748	.39798587	-1.009	.3129	25.7153897
Constant	1987.98588	871.094665	2.282	.0225	

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Group	Coefficient	Standard Error	t-ratio
1	34.12672	46.12604	.73986
2	-95.39041	15.36756	-6.20726
3	394.55719	81.36846	4.84902

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Period	Coefficient	Standard Error	t-ratio
1	-3.46102	25.56690	-.13537
2	2.11478	23.67796	.08931
3	1.39990	22.68848	.06170

Test Statistics for the Classical Model

Model		Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10695.71658	.3301029768D+09	.5789880
(4)	X and group effects	-10671.71309	.3190298155D+09	.5931106
(5)	X ind.&time effects	-10671.70233	.3190249343D+09	.5931168

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1217.187	29	.00000	65.300	29	1377	.00000
(4) vs (1)	1265.194	31	.00000	64.655	31	1375	.00000
(4) vs (2)	972.311	29	.00000	47.215	29	1375	.00000
(4) vs (3)	48.007	2	.00000	23.862	2	1375	.00000
(5) vs (4)	.022	2	.98929	.011	2	1373	.98955
(5) vs (3)	48.028	5	.00000	9.535	5	1373	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i) + w(t)
Estimates:  Var[e]              =   .232356D+06
            Var[u]              =   .222895D+04
            Corr[v(i,t),v(i,s)] =   .009502
            Var[w]              =   .514114D+04
            Corr[v(i,t),v(j,t)] =   .021647
Lagrange Multiplier Test vs. Model (3) =   24.60
( 2 df, prob value =  .000005)
(High values of LM favor FEM/REM over CR model.)
Fixed vs. Random Effects (Hausman)     =     .00
(29 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares          .351012D+09
            R-squared               .563934D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	39.2039733	4.81274018	8.146	.0000	14.9706563
POPDEN	14.8438248	1.04798573	14.164	.0000	10.3281815
POPDEN2	-.01085315	.00083774	-12.955	.0000	8165.47251
NETMIG	.02571493	.00457379	5.622	.0000	393.283582
HIDIST	-1.82228543	.37061290	-4.917	.0000	45.8647532
GOVPAY	.04793599	.00973834	4.922	.0000	1407.84663
X_COORD	-3.41866492	5.98999943	-.571	.5682	-105.177028
BLACK_SZ	-11.0890220	114.165930	-.097	.9226	.42643923
BROWN_SZ	-319.959780	129.814273	-2.465	.0137	.15138593

DBROWN_S	-152.208062	123.255929	-1.235	.2169	.22459133
GRAY_SZ	-47.2838145	118.144753	-.400	.6890	.08599858
DGRAY_SZ	12.2730923	115.444380	.106	.9153	.09523810
TPT	.04109525	.01070978	3.837	.0001	.190653D-11
TPT2	.373837D-06	.820019D-07	4.559	.0000	.560350D+08
J	21.4234300	8.86495114	2.417	.0157	-.378397D-13
J2	-.63393405	.31850582	-1.990	.0466	17.2055766
A	21.5287031	13.0466588	1.650	.0989	.420096D-14
A2	3.13597611	1.83699670	1.707	.0878	1.90715584
JU	-25.5600750	17.1284655	-1.492	.1356	-.408549D-14
JU2	-4.90988566	3.99577879	-1.229	.2192	1.72974345
SE	20.3855101	14.7065385	1.386	.1657	-.638595D-16
SE2	4.86513685	6.05178266	.804	.4214	1.51791524
R	1.73485946	.51035579	3.399	.0007	.492280D-13
R2	.02566093	.00405928	6.322	.0000	2994.54695
SN	-2.06097912	.80626855	-2.556	.0106	.612292D-13
SN2	.01147014	.01070582	1.071	.2840	547.427475
FFD	3.21404076	2.80597967	1.145	.2520	13.8752801
RH	10.4979391	5.26404074	1.994	.0461	.479581D-12
RH2	-.12332075	.39142699	-.315	.7527	25.7153897
Constant	-3.73986293	643.503927	-.006	.9954	

Scenario1 (2020s)

```
+-----------------------------------------------------+
| OLS Without Group Dummy Variables                   |
| Ordinary    least squares regression                |
| Model was estimated Nov 24, 2009 at 01:15:51PM      |
| LHS=LVAL     Mean                 =   993.3796      |
|              Standard deviation   =   746.7664      |
| WTS=none     Number of observs.   =       1407      |
| Model size   Parameters           =         32      |
|              Degrees of freedom   =       1375      |
| Residuals    Sum of squares       =   .3392374E+09  |
|              Standard error of e  =   496.7073      |
| Fit          R-squared            =   .5673379      |
|              Adjusted R-squared   =   .5575834      |
| Model test   F[ 31,  1375] (prob) =  58.16 (.0000)  |
| Diagnostic   Log likelihood       =  -10714.92      |
|              Restricted(b=0)      =  -11304.31      |
|              Chi-sq [ 31]  (prob) =1178.78 (.0000)  |
| Info criter. LogAmemiya Prd. Crt. =   12.43849      |
|              Akaike Info. Criter. =   12.43848      |
+-----------------------------------------------------+

+-----------------------------------------------------+
| Panel Data Analysis of LVAL       [ONE way]         |
|           Unconditional ANOVA (No regressors)       |
| Source      Variation   Deg. Free.     Mean Square  |
| Between       .147345E+09       2.     .736727E+08  |
| Residual      .636725E+09    1404.     453508.      |
| Total         .784070E+09    1406.     557660.      |
+-----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	37.2555230	4.46648221	8.341	.0000	14.9706563
POPDEN	14.9672081	1.08432704	13.803	.0000	10.3281815
POPDEN2	-.01096247	.00086616	-12.656	.0000	8165.47251
NETMIG	.02713895	.00474041	5.725	.0000	393.283582
HIDIST	-2.01787427	.38628051	-5.224	.0000	45.8647532
GOVPAY	.05059775	.00971315	5.209	.0000	1407.84663
X_COORD	-9.21023905	5.47375839	-1.683	.0924	-105.177028
BLACK_SZ	-86.8518649	123.476795	-.703	.4818	.42643923
BROWN_SZ	-402.143357	141.800195	-2.836	.0046	.15138593
DBROWN_S	-244.133911	133.401220	-1.830	.0672	.22459133
GRAY_SZ	-92.8954528	128.109868	-.725	.4684	.08599858
DGRAY_SZ	-50.5130826	125.031021	-.404	.6862	.09523810
TPTSIM1	.01059084	.11260363	.094	.9251	.234413D-13
TPTSIM12	-.141561D-04	.356051D-04	-.398	.6909	21904.4238
JSIM1	20.8843283	9.22665123	2.263	.0236	.108771D-13
JSIM12	-.62641619	.32983195	-1.899	.0575	17.2055766
ASIM1	20.3455499	13.4644583	1.511	.1308	.132189D-13
ASIM12	4.04751488	1.88885623	2.143	.0321	1.90715584
JUSIM1	-21.9249670	17.5422581	-1.250	.2114	-.409330D-14
JUSIM12	-5.24522277	4.09762046	-1.280	.2005	1.72974345
SESIM1	16.6465482	15.1765394	1.097	.2727	-.296691D-13
SESIM12	4.26486798	6.23391314	.684	.4939	1.51791524
RSIM1	2.70449884	.48751030	5.548	.0000	.622301D-12
RSIM12	.02575201	.00414153	6.218	.0000	2994.54695
SN	-2.02056786	.82955612	-2.436	.0149	.612292D-13
SN2	.01356291	.01110389	1.221	.2219	547.427475
FFD	2.88152682	2.88804793	.998	.3184	13.8752801
RH	13.5289017	5.55531138	2.435	.0149	.479581D-12
RH2	.19688970	.39788032	.495	.6207	25.7153897
PWSIM1	-.26809231	.45537269	-.589	.5560	141.570867
PCSIM1	-.40918190	.50637310	-.808	.4191	66.7223880

Constant	-480.309803	590.446798	-.813	.4159

```
+----------------------------------------------------+
| Least Squares with Group Dummy Variables           |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:15:51PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         34     |
|              Degrees of freedom   =       1373     |
| Residuals    Sum of squares       =   .3270423E+09 |
|              Standard error of e  =   488.0527     |
| Fit          R-squared            =   .5828915     |
|              Adjusted R-squared   =   .5728663     |
| Model test   F[ 33,  1373] (prob) =  58.14 (.0000) |
| Diagnostic   Log likelihood       =  -10689.16     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 33]  (prob) =1230.29 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.40472     |
|              Akaike Info. Criter. =   12.40471     |
| Estd. Autocorrelation of e(i,t)     .438035        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.9627096	4.40134507	8.852	.0000	14.9706563
POPDEN	14.8168337	1.06663153	13.891	.0000	10.3281815
POPDEN2	-.01082754	.00085198	-12.709	.0000	8165.47251
NETMIG	.02539203	.00466599	5.442	.0000	393.283582
HIDIST	-1.80339320	.38074544	-4.736	.0000	45.8647532
GOVPAY	.04044886	.00966368	4.186	.0000	1407.84663
X_COORD	18.0359469	8.49984574	2.122	.0338	-105.177028
BLACK_SZ	-1.94905807	122.478622	-.016	.9873	.42643923
BROWN_SZ	-284.302292	141.140223	-2.014	.0440	.15138593
DBROWN_S	-125.877407	132.519111	-.950	.3422	.22459133
GRAY_SZ	7.61502727	126.859761	.060	.9521	.08599858
DGRAY_SZ	9.25420453	123.370047	.075	.9402	.09523810
TPTSIM1	.05426932	.11081019	.490	.6243	.234413D-13
TPTSIM12	-.378702D-04	.351427D-04	-1.078	.2812	21904.4238
JSIM1	12.8610827	9.15601293	1.405	.1601	.108771D-13
JSIM12	-.37100259	.32614447	-1.138	.2553	17.2055766
ASIM1	20.0393697	13.2316943	1.514	.1299	.132189D-13
ASIM12	3.37955778	1.86110779	1.816	.0694	1.90715584
JUSIM1	-36.2422723	17.3689501	-2.087	.0369	-.409330D-14
JUSIM12	-6.52807664	4.03045463	-1.620	.1053	1.72974345
SESIM1	14.2722297	14.9512991	.955	.3398	-.296691D-13
SESIM12	6.67940159	6.14180413	1.088	.2768	1.51791524
RSIM1	.60870452	.56420631	1.079	.2806	.622301D-12
RSIM12	.02791036	.00423489	6.591	.0000	2994.54695
SN	-1.78527367	.81657862	-2.186	.0288	.612292D-13
SN2	.00903415	.01092981	.827	.4085	547.427475
FFD	4.55982477	2.84798792	1.601	.1094	13.8752801
RH	6.29599820	5.60445580	1.123	.2613	.479581D-12
RH2	-.49958303	.40299945	-1.240	.2151	25.7153897
PWSIM1	.13496044	.45102050	.299	.7648	141.570867
PCSIM1	-.06988149	.50113736	-.139	.8891	66.7223880

Estimated Fixed Effects

Group	Coefficient	Standard Error	t-ratio
1	2227.58451	860.32904	2.58922
2	2074.65849	883.05624	2.34941
3	2576.70971	947.29477	2.72007

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10714.91900	.3392374161D+09	.5673379
(4)	X and group effects	-10689.16342	.3270423175D+09	.5828915

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1178.782	31	.00000	58.161	31	1375	.00000
(4) vs (1)	1230.293	33	.00000	58.143	33	1373	.00000
(4) vs (2)	937.411	31	.00000	41.939	31	1373	.00000
(4) vs (3)	51.511	2	.00000	25.599	2	1373	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i)
Estimates:  Var[e]              =   .238195D+06
            Var[u]              =   .852270D+04
            Corr[v(i,t),v(i,s)] =   .034544
Lagrange Multiplier Test vs. Model (3) =   29.26
( 1 df, prob value =  .000000)
(High values of LM favor FEM/REM over CR model.)
Baltagi-Li form of LM Statistic =          13.24
Fixed vs. Random Effects (Hausman)     =     .00
(31 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares            .363319D+09
            R-squared                 .549931D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.8702839	4.39966812	8.835	.0000	14.9706563
POPDEN	14.8952087	1.06609578	13.972	.0000	10.3281815
POPDEN2	-.01089066	.00085157	-12.789	.0000	8165.47251
NETMIG	.02560265	.00466507	5.488	.0000	393.283582
HIDIST	-1.84939035	.38046861	-4.861	.0000	45.8647532
GOVPAY	.04303163	.00962585	4.470	.0000	1407.84663
X_COORD	6.95792901	7.26838791	.957	.3384	-105.177028
BLACK_SZ	-31.3175689	121.985224	-.257	.7974	.42643923
BROWN_SZ	-323.943475	140.376935	-2.308	.0210	.15138593
DBROWN_S	-160.283855	131.975763	-1.214	.2246	.22459133
GRAY_SZ	-19.8765467	126.515196	-.157	.8752	.08599858
DGRAY_SZ	-10.6314100	123.152652	-.086	.9312	.09523810
TPTSIM1	.04532577	.11077461	.409	.6824	.234413D-13
TPTSIM12	-.334909D-04	.351155D-04	-.954	.3402	21904.4238
JSIM1	15.1094441	9.12344587	1.656	.0977	.108771D-13
JSIM12	-.43023525	.32558963	-1.321	.1864	17.2055766
ASIM1	19.8716905	13.2311384	1.502	.1331	.132189D-13
ASIM12	3.40417526	1.86037402	1.830	.0673	1.90715584
JUSIM1	-34.2000461	17.3529060	-1.971	.0487	-.409330D-14
JUSIM12	-6.22677814	4.02928546	-1.545	.1223	1.72974345
SESIM1	15.8307505	14.9342591	1.060	.2891	-.296691D-13
SESIM12	5.88555863	6.13491439	.959	.3374	1.51791524
RSIM1	1.08352510	.54347993	1.994	.0462	.622301D-12

RSIM12	.02628578	.00416503	6.311	.0000	2994.54695
SN	-1.87047105	.81593392	-2.292	.0219	.612292D-13
SN2	.01009375	.01092449	.924	.3555	547.427475
FFD	4.16563069	2.84515466	1.464	.1432	13.8752801
RH	6.91981352	5.58753327	1.238	.2156	.479581D-12
RH2	-.37149352	.40096262	-.927	.3542	25.7153897
PWSIM1	.06202830	.45042734	.138	.8905	141.570867
PCSIM1	-.09871471	.50071626	-.197	.8437	66.7223880
Constant	1148.56285	772.318798	1.487	.1370	

```
+----------------------------------------------------+
| Least Squares with Group and Period Effects        |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:15:54PM     |
| LHS=LVAL     Mean                  =   993.3796    |
|              Standard deviation    =   746.7664    |
| WTS=none     Number of observs.    =       1407    |
| Model size   Parameters            =         36    |
|              Degrees of freedom    =       1371    |
| Residuals    Sum of squares        =   .3263599E+09|
|              Standard error of e   =   487.8987    |
| Fit          R-squared             =   .5837619    |
|              Adjusted R-squared    =   .5731358    |
| Model test   F[ 35,  1371] (prob) =  54.94 (.0000) |
| Diagnostic   Log likelihood        =  -10687.69    |
|              Restricted(b=0)       =  -11304.31    |
|              Chi-sq [ 35]  (prob) =1233.23 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.40548    |
|              Akaike Info. Criter. =   12.40547    |
| Estd. Autocorrelation of e(i,t)      .437821       |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
| Panel: Prds:   Empty       0,   Valid data       3 |
|                Smallest    0,   Largest        473 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.7277083	4.98407002	7.770	.0000	14.9706563
POPDEN	14.6836346	1.07258122	13.690	.0000	10.3281815
POPDEN2	-.01073419	.00085585	-12.542	.0000	8165.47251
NETMIG	.02627697	.00469601	5.596	.0000	393.283582
HIDIST	-1.79982962	.38199784	-4.712	.0000	45.8647532
GOVPAY	.04001212	.01007030	3.973	.0001	1407.84663
X_COORD	16.5585457	8.55257345	1.936	.0529	-105.177028
BLACK_SZ	15.3795744	122.956610	.125	.9005	.42643923
BROWN_SZ	-257.828809	142.054840	-1.815	.0695	.15138593
DBROWN_S	-100.323089	133.459399	-.752	.4522	.22459133
GRAY_SZ	18.5280025	127.062466	.146	.8841	.08599858
DGRAY_SZ	18.9757539	123.504621	.154	.8779	.09523810
TPTSIM1	.05097926	.11079885	.460	.6454	.234413D-13
TPTSIM12	-.334817D-04	.352851D-04	-.949	.3427	21904.4238
JSIM1	12.0113187	9.23064533	1.301	.1932	.108771D-13
JSIM12	-.34625577	.32833642	-1.055	.2916	17.2055766
ASIM1	20.4813642	13.2301035	1.548	.1216	.132189D-13
ASIM12	3.41992816	1.86086908	1.838	.0661	1.90715584
JUSIM1	-37.5545006	17.4071329	-2.157	.0310	-.409330D-14
JUSIM12	-6.61134725	4.04391036	-1.635	.1021	1.72974345
SESIM1	13.3569429	15.0121394	.890	.3736	-.296691D-13

SESIM12	6.31417485	6.14763422	1.027	.3044	1.51791524
RSIM1	.47805118	.57213726	.836	.4034	.622301D-12
RSIM12	.02821414	.00424143	6.652	.0000	2994.54695
SN	-1.70235137	.81996561	-2.076	.0379	.612292D-13
SN2	.00865396	.01094755	.790	.4292	547.427475
FFD	4.45539931	2.84795419	1.564	.1177	13.8752801
RH	7.43542003	5.64427607	1.317	.1877	.479581D-12
RH2	-.43515253	.40530225	-1.074	.2830	25.7153897
PWSIM1	6.00124280	3.49401120	1.718	.0859	141.570867
PCSIM1	3.64840117	2.25477808	1.618	.1056	66.7223880
Constant	927.794460	1155.83324	.803	.4221	

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Group	Coefficient	Standard Error	t-ratio
1	43.36594	46.77754	.92707
2	-97.64645	15.82127	-6.17185
3	388.03820	82.89998	4.68080

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Period	Coefficient	Standard Error	t-ratio
1	300.31339	178.20134	1.68525
2	-306.19279	181.67798	-1.68536
3	-1.88871	23.30490	-.08104

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10714.91900	.3392374161D+09	.5673379
(4)	X and group effects	-10689.16342	.3270423175D+09	.5828915
(5)	X ind.&time effects	-10687.69390	.3263598833D+09	.5837619

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1178.782	31	.00000	58.161	31	1375	.00000
(4) vs (1)	1230.293	33	.00000	58.143	33	1373	.00000
(4) vs (2)	937.411	31	.00000	41.939	31	1373	.00000
(4) vs (3)	51.511	2	.00000	25.599	2	1373	.00000
(5) vs (4)	2.939	2	.23004	1.433	2	1371	.23885
(5) vs (3)	54.450	5	.00000	10.819	5	1371	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i) + w(t)
Estimates:  Var[e]              =   .238045D+06
            Var[u]              =   .416192D+05
            Corr[v(i,t),v(i,s)] =   .148818
            Var[w]              =   .613085D+05
            Corr[v(i,t),v(j,t)] =   .204803
Lagrange Multiplier Test vs. Model (3) =   30.05
( 2 df, prob value =  .000000)
(High values of LM favor FEM/REM over CR model.)
Fixed vs. Random Effects (Hausman)     =     .00
(31 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares          .363319D+09
            R-squared               .549931D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	39.0826215	4.97169173	7.861	.0000	14.9706563
POPDEN	14.7710420	1.07090569	13.793	.0000	10.3281815

POPDEN2	-.01079779	.00085480	-12.632	.0000	8165.47251
NETMIG	.02586434	.00468123	5.525	.0000	393.283582
HIDIST	-1.81329483	.38192755	-4.748	.0000	45.8647532
GOVPAY	.04141006	.01003785	4.125	.0000	1407.84663
X_COORD	13.4551177	8.12750344	1.656	.0978	-105.177028
BLACK_SZ	-4.19028066	122.560307	-.034	.9727	.42643923
BROWN_SZ	-285.703207	141.344396	-2.021	.0432	.15138593
DBROWN_S	-125.873187	132.823985	-.948	.3433	.22459133
GRAY_SZ	3.12051353	126.849100	.025	.9804	.08599858
DGRAY_SZ	6.79343261	123.356717	.055	.9561	.09523810
TPTSIM1	.04963928	.11077698	.448	.6541	.234413D-13
TPTSIM12	-.341316D-04	.352219D-04	-.969	.3325	21904.4238
JSIM1	13.3279993	9.20803217	1.447	.1478	.108771D-13
JSIM12	-.38263484	.32787243	-1.167	.2432	17.2055766
ASIM1	20.1866459	13.2286404	1.526	.1270	.132189D-13
ASIM12	3.39992099	1.86059810	1.827	.0677	1.90715584
JUSIM1	-36.3404962	17.3932408	-2.089	.0367	-.409330D-14
JUSIM12	-6.50507659	4.04338730	-1.609	.1077	1.72974345
SESIM1	14.5223211	14.9985187	.968	.3329	-.296691D-13
SESIM12	6.25746861	6.14389046	1.018	.3084	1.51791524
RSIM1	.70917151	.56203145	1.262	.2070	.622301D-12
RSIM12	.02746113	.00421574	6.514	.0000	2994.54695
SN	-1.78120347	.81890409	-2.175	.0296	.612292D-13
SN2	.00927283	.01094347	.847	.3968	547.427475
FFD	4.37527086	2.84658315	1.537	.1243	13.8752801
RH	7.00175949	5.62035544	1.246	.2128	.479581D-12
RH2	-.42982898	.40388165	-1.064	.2872	25.7153897
PWSIM1	2.92931117	2.46184377	1.190	.2341	141.570867
PCSIM1	1.71724077	1.61480733	1.063	.2876	66.7223880
Constant	1292.01530	1018.21265	1.269	.2045	

Scenario2 (2050s)

```
+----------------------------------------------------+
| OLS Without Group Dummy Variables                  |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:17:35PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         32     |
|              Degrees of freedom   =       1375     |
| Residuals    Sum of squares       =   .3392615E+09 |
|              Standard error of e  =   496.7249     |
| Fit          R-squared            =   .5673072     |
|              Adjusted R-squared   =   .5575520     |
| Model test   F[ 31,  1375] (prob) =  58.15 (.0000) |
| Diagnostic   Log likelihood       =  -10714.97     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 31]  (prob) =1178.68 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.43856     |
|              Akaike Info. Criter. =   12.43855     |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel Data Analysis of LVAL       [ONE way]        |
|           Unconditional ANOVA (No regressors)      |
| Source      Variation   Deg. Free.     Mean Square |
| Between      .147345E+09       2.     .736727E+08  |
| Residual     .636725E+09    1404.     453508.      |
| Total        .784070E+09    1406.     557660.      |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	37.1688654	4.47531945	8.305	.0000	14.9706563
POPDEN	14.9727492	1.08430873	13.809	.0000	10.3281815
POPDEN2	-.01096563	.00086616	-12.660	.0000	8165.47251
NETMIG	.02705277	.00474666	5.699	.0000	393.283582
HIDIST	-1.99127678	.38358651	-5.191	.0000	45.8647532
GOVPAY	.05027433	.00970511	5.180	.0000	1407.84663
X_COORD	-8.99196320	5.46598609	-1.645	.1000	-105.177028
BLACK_SZ	-75.9319866	124.264902	-.611	.5412	.42643923
BROWN_SZ	-394.306308	142.451688	-2.768	.0056	.15138593
DBROWN_S	-234.092461	134.057425	-1.746	.0808	.22459133
GRAY_SZ	-79.1929903	126.632955	-.625	.5317	.08599858
DGRAY_SZ	-38.1759882	124.507734	-.307	.7591	.09523810
TPTSIM2	-.31181547	1.11103092	-.281	.7790	.829319D-13
TPTSIM22	.00069593	.00375566	.185	.8530	1175.21750
JSIM2	20.3027119	10.0443817	2.021	.0432	.128918D-13
JSIM22	-.60444404	.35711816	-1.693	.0905	17.2055766
ASIM2	19.6086697	13.5658418	1.445	.1483	.691070D-15
ASIM22	4.06315138	1.88859655	2.151	.0314	1.90715584
JUSIM2	-23.0144503	17.7698712	-1.295	.1953	.308639D-13
JUSIM22	-5.30237212	4.09636245	-1.294	.1955	1.72974345
SESIM2	15.3548033	15.7971592	.972	.3311	-.655942D-16
SESIM22	4.34789350	6.28797624	.691	.4893	1.51791524
RSIM2	2.75888335	.51039207	5.405	.0000	-.148791D-12
RSIM22	.02566827	.00414719	6.189	.0000	2994.54695
SN	-1.97010801	.86877975	-2.268	.0233	.612292D-13
SN2	.01343542	.01112707	1.207	.2273	547.427475
FFD	2.94693625	2.89517772	1.018	.3087	13.8752801
RH	13.5474028	5.56294182	2.435	.0149	.479581D-12
RH2	.19321686	.39902666	.484	.6282	25.7153897
PWSIM2	-.25308371	.41661189	-.607	.5435	155.053806

PCSIM2	-.36749363	.46372151	-.792	.4281	73.0769011
Constant	-468.482947	590.318753	-.794	.4274	

```
+----------------------------------------------------+
| Least Squares with Group Dummy Variables           |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:17:35PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         34     |
|              Degrees of freedom   =       1373     |
| Residuals    Sum of squares       =   .3271680E+09 |
|              Standard error of e  =   488.1464     |
| Fit          R-squared            =   .5827313     |
|              Adjusted R-squared   =   .5727022     |
| Model test   F[ 33,  1373] (prob) =  58.10 (.0000) |
| Diagnostic   Log likelihood       =  -10689.43     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 33]  (prob) =1229.75 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.40511     |
|              Akaike Info. Criter. =   12.40510     |
| Estd. Autocorrelation of e(i,t)      .438395       |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.9455422	4.41066457	8.830	.0000	14.9706563
POPDEN	14.8328932	1.06676643	13.905	.0000	10.3281815
POPDEN2	-.01083871	.00085209	-12.720	.0000	8165.47251
NETMIG	.02542092	.00467238	5.441	.0000	393.283582
HIDIST	-1.77302989	.37821422	-4.688	.0000	45.8647532
GOVPAY	.04017982	.00965619	4.161	.0000	1407.84663
X_COORD	18.3498102	8.51564325	2.155	.0312	-105.177028
BLACK_SZ	13.8666796	123.397194	.112	.9105	.42643923
BROWN_SZ	-265.069814	142.091725	-1.865	.0621	.15138593
DBROWN_S	-108.012518	133.385636	-.810	.4181	.22459133
GRAY_SZ	26.3126138	125.543777	.210	.8340	.08599858
DGRAY_SZ	26.0366559	122.948168	.212	.8323	.09523810
TPTSIM2	.29633329	1.09610453	.270	.7869	.829319D-13
TPTSIM22	-.00260437	.00372081	-.700	.4840	1175.21750
JSIM2	13.7072079	9.92518255	1.381	.1673	.128918D-13
JSIM22	-.40352604	.35209214	-1.146	.2518	17.2055766
ASIM2	20.0012245	13.3348465	1.500	.1336	.691070D-15
ASIM22	3.40979734	1.86105884	1.832	.0669	1.90715584
JUSIM2	-36.1661045	17.5823918	-2.057	.0397	.308639D-13
JUSIM22	-6.66697267	4.03037843	-1.654	.0981	1.72974345
SESIM2	14.4740136	15.5479074	.931	.3519	-.655942D-16
SESIM22	6.92533504	6.19596495	1.118	.2637	1.51791524
RSIM2	.59267509	.58983678	1.005	.3150	-.148791D-12
RSIM22	.02794293	.00424496	6.583	.0000	2994.54695
SN	-1.83093688	.85440024	-2.143	.0321	.612292D-13
SN2	.00951326	.01094961	.869	.3849	547.427475
FFD	4.63401134	2.85543738	1.623	.1046	13.8752801
RH	6.07904344	5.61926138	1.082	.2793	.479581D-12
RH2	-.49152734	.40388735	-1.217	.2236	25.7153897
PWSIM2	.13430107	.41304523	.325	.7451	155.053806
PCSIM2	-.07907865	.45884604	-.172	.8632	73.0769011

```
        Estimated Fixed Effects
        Group       Coefficient       Standard Error       t-ratio
            1         2242.63615           861.54952       2.60303
            2         2090.48734           884.25099       2.36413
            3         2592.97985           948.84756       2.73277
+-----------------------------------------------------------------------+
|             Test Statistics for the Classical Model                   |
+-----------------------------------------------------------------------+
|       Model              Log-Likelihood  Sum of Squares    R-squared  |
|(1)  Constant term only   -11304.31008  .7840701399D+09    .0000000    |
|(2)  Group effects only   -11157.86875  .6367247026D+09    .1879238    |
|(3)  X - variables only   -10714.96887  .3392614656D+09    .5673072    |
|(4)  X and group effects  -10689.43365  .3271679641D+09    .5827313    |
+-----------------------------------------------------------------------+
|                         Hypothesis Tests                              |
|         Likelihood Ratio Test           F Tests                       |
|         Chi-squared   d.f.  Prob.        F    num. denom.   P value   |
|(2) vs (1)   292.883      2  .00000  162.451     2    1404   .00000    |
|(3) vs (1)  1178.682     31  .00000   58.154    31    1375   .00000    |
|(4) vs (1)  1229.753     33  .00000   58.104    33    1373   .00000    |
|(4) vs (2)   936.870     31  .00000   41.906    31    1373   .00000    |
|(4) vs (3)    51.070      2  .00000   25.376     2    1373   .00000    |
+-----------------------------------------------------------------------+
+----------------------------------------------------+
| Random Effects Model: v(i,t) = e(i,t) + u(i)       |
| Estimates:  Var[e]              =   .238287D+06    |
|             Var[u]              =   .844867D+04    |
|             Corr[v(i,t),v(i,s)] =   .034242        |
| Lagrange Multiplier Test vs. Model (3) =   28.25   |
| ( 1 df, prob value =  .000000)                     |
| (High values of LM favor FEM/REM over CR model.)   |
| Baltagi-Li form of LM Statistic =          12.78   |
| Fixed vs. Random Effects (Hausman)     =     .00   |
| (31 df, prob value = 1.000000)                     |
| (High (low) values of H favor FEM (REM).)          |
|             Sum of Squares          .363185D+09    |
|             R-squared               .549988D+00    |
+----------------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 INCCAP  |    38.8230964      4.40907154     8.805   .0000   14.9706563
 POPDEN  |    14.9101748      1.06623545    13.984   .0000   10.3281815
 POPDEN2 |   -.01090095       .00085169   -12.799   .0000   8165.47251
 NETMIG  |    .02560181       .00467150     5.480   .0000   393.283582
 HIDIST  |   -1.81982059      .37792848    -4.815   .0000   45.8647532
 GOVPAY  |    .04276460       .00961868     4.446   .0000   1407.84663
 X_COORD |    7.13106755      7.26536005      .982   .3263  -105.177028
 BLACK_SZ|   -17.4379158      122.846486     -.142   .8871    .42643923
 BROWN_SZ|   -308.329640      141.207119    -2.184   .0290    .15138593
 DBROWN_S|   -145.156484      132.760438    -1.093   .2742    .22459133
 GRAY_SZ |   -2.81732909      125.156254     -.023   .9820    .08599858
 DGRAY_SZ|    4.63218175      122.699257      .038   .9699    .09523810
 TPTSIM2 |    .12594673       1.09456963      .115   .9084  .829319D-13
 TPTSIM22|   -.00184564       .00371297      -.497   .6191   1175.21750
 JSIM2   |    15.5303032      9.90597673     1.568   .1169  .128918D-13
 JSIM22  |   -.44680858       .35182916     -1.270   .2041   17.2055766
 ASIM2   |    19.6132126      13.3334808     1.471   .1413  .691070D-15
 ASIM22  |    3.43271020      1.86032421     1.845   .0650   1.90715584
 JUSIM2  |   -34.4536872      17.5685665    -1.961   .0499  .308639D-13
 JUSIM22 |   -6.34893424      4.02909769    -1.576   .1151   1.72974345
 SESIM2  |    15.5506882      15.5383472     1.001   .3169 -.655942D-16
 SESIM22 |    6.11677375      6.18926199      .988   .3230   1.51791524
```

RSIM2	1.09494851	.56765406	1.929	.0537	-.148791D-12
RSIM22	.02627043	.00417263	6.296	.0000	2994.54695
SN	-1.88675689	.85411905	-2.209	.0272	.612292D-13
SN2	.01044900	.01094548	.955	.3398	547.427475
FFD	4.24220390	2.85269795	1.487	.1370	13.8752801
RH	6.76685448	5.60164924	1.208	.2270	.479581D-12
RH2	-.36508821	.40190912	-.908	.3637	25.7153897
PWSIM2	.06183292	.41241427	.150	.8808	155.053806
PCSIM2	-.09996423	.45845685	-.218	.8274	73.0769011
Constant	1151.52271	772.017077	1.492	.1358	

```
+----------------------------------------------------+
| Least Squares with Group and Period Effects        |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:17:37PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         36     |
|              Degrees of freedom   =       1371     |
| Residuals    Sum of squares       =   .3264133E+09 |
|              Standard error of e  =   487.9387     |
| Fit          R-squared            =   .5836937     |
|              Adjusted R-squared   =   .5730659     |
| Model test   F[ 35,  1371] (prob) =  54.92 (.0000) |
| Diagnostic   Log likelihood       =  -10687.81     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 35]  (prob) =1233.00 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.40564     |
|              Akaike Info. Criter. =   12.40563     |
| Estd. Autocorrelation of e(i,t)     .437713        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
| Panel: Prds:   Empty       0,   Valid data       3 |
|                Smallest    0,   Largest        473 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.6996149	4.98772335	7.759	.0000	14.9706563
POPDEN	14.6903708	1.07270855	13.695	.0000	10.3281815
POPDEN2	-.01073855	.00085596	-12.546	.0000	8165.47251
NETMIG	.02632049	.00470058	5.599	.0000	393.283582
HIDIST	-1.77718111	.37936562	-4.685	.0000	45.8647532
GOVPAY	.03979427	.01006530	3.954	.0001	1407.84663
X_COORD	16.6633227	8.57731806	1.943	.0521	-105.177028
BLACK_SZ	22.8361466	123.615412	.185	.8534	.42643923
BROWN_SZ	-246.604108	142.613228	-1.729	.0838	.15138593
DBROWN_S	-90.7535576	133.914103	-.678	.4980	.22459133
GRAY_SZ	29.4249740	125.642194	.234	.8148	.08599858
DGRAY_SZ	27.7955015	122.985685	.226	.8212	.09523810
TPTSIM2	.14797937	1.10124255	.134	.8931	.829319D-13
TPTSIM22	-.00236514	.00373242	-.634	.5263	1175.21750
JSIM2	12.0413890	10.0003535	1.204	.2286	.128918D-13
JSIM22	-.35137562	.35420208	-.992	.3212	17.2055766
ASIM2	20.3136726	13.3308329	1.524	.1276	.691070D-15
ASIM22	3.44306425	1.86058632	1.851	.0642	1.90715584
JUSIM2	-37.8975001	17.6371494	-2.149	.0317	.308639D-13
JUSIM22	-6.75981257	4.04310729	-1.672	.0945	1.72974345

SESIM2	12.8970431	15.6014292	.827	.4084	-.655942D-16
SESIM22	6.69143155	6.19952232	1.079	.2804	1.51791524
RSIM2	.47063115	.59748096	.788	.4309	-.148791D-12
RSIM22	.02823291	.00425123	6.641	.0000	2994.54695
SN	-1.69902815	.85840080	-1.979	.0478	.612292D-13
SN2	.00907924	.01096381	.828	.4076	547.427475
FFD	4.55686607	2.85466649	1.596	.1104	13.8752801
RH	7.25906036	5.65691724	1.283	.1994	.479581D-12
RH2	-.43115599	.40589145	-1.062	.2881	25.7153897
PWSIM2	5.76730833	3.19087446	1.807	.0707	155.053806
PCSIM2	3.50164716	2.06434210	1.696	.0898	73.0769011
Constant	872.519806	1158.83151	.753	.4515	

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Group	Coefficient	Standard Error	t-ratio
1	42.83554	46.79416	.91540
2	-97.37733	15.84508	-6.14559
3	387.74110	83.27570	4.65611

Estimated Fixed Effects - Full sets of effects, normalized to sum to 0

Period	Coefficient	Standard Error	t-ratio
1	316.14376	178.25553	1.77354
2	-322.03359	181.75757	-1.77178
3	-2.28015	23.33032	-.09773

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10714.96887	.3392614656D+09	.5673072
(4)	X and group effects	-10689.43365	.3271679641D+09	.5827313
(5)	X ind.&time effects	-10687.80914	.3264133494D+09	.5836937

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1178.682	31	.00000	58.154	31	1375	.00000
(4) vs (1)	1229.753	33	.00000	58.104	33	1373	.00000
(4) vs (2)	936.870	31	.00000	41.906	31	1373	.00000
(4) vs (3)	51.070	2	.00000	25.376	2	1373	.00000
(5) vs (4)	3.249	2	.19701	1.585	2	1371	.20537
(5) vs (3)	54.319	5	.00000	10.793	5	1371	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i) + w(t)
Estimates:  Var[e]              =   .238084D+06
            Var[u]              =   .255132D+04
            Corr[v(i,t),v(i,s)] =   .010602
            Var[w]              =   .610016D+04
            Corr[v(i,t),v(j,t)] =   .024982
Lagrange Multiplier Test vs. Model (3) =   29.01
( 2 df, prob value =  .000001)
(High values of LM favor FEM/REM over CR model.)
Fixed vs. Random Effects (Hausman)     =     .00
(31 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares          .363185D+09
            R-squared               .549988D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	39.7625867	4.90541683	8.106	.0000	14.9706563

POPDEN	14.8912278	1.06902721	13.930	.0000	10.3281815
POPDEN2	-.01089271	.00085358	-12.761	.0000	8165.47251
NETMIG	.02594633	.00467327	5.552	.0000	393.283582
HIDIST	-1.85439455	.37882486	-4.895	.0000	45.8647532
GOVPAY	.04686204	.00989288	4.737	.0000	1407.84663
X_COORD	-.95127671	6.35415233	-.150	.8810	-105.177028
BLACK_SZ	-44.2776487	122.489094	-.361	.7177	.42643923
BROWN_SZ	-345.122166	140.633837	-2.454	.0141	.15138593
DBROWN_S	-180.334365	132.359038	-1.362	.1731	.22459133
GRAY_SZ	-32.5108440	124.845200	-.260	.7945	.08599858
DGRAY_SZ	-14.7849697	122.505469	-.121	.9039	.09523810
TPTSIM2	-.08370679	1.09449272	-.076	.9390	.829319D-13
TPTSIM22	-.00086093	.00370961	-.232	.8165	1175.21750
JSIM2	17.5180209	9.91300827	1.767	.0772	.128918D-13
JSIM22	-.50557183	.35224539	-1.435	.1512	17.2055766
ASIM2	19.4190105	13.3272491	1.457	.1451	.691070D-15
ASIM22	3.55112186	1.85864249	1.911	.0561	1.90715584
JUSIM2	-32.3394876	17.5721890	-1.840	.0657	.308639D-13
JUSIM22	-6.21918647	4.03993664	-1.539	.1237	1.72974345
SESIM2	16.3959157	15.5529478	1.054	.2918	-.655942D-16
SESIM22	5.56463344	6.18868772	.899	.3686	1.51791524
RSIM2	1.64875056	.54615804	3.019	.0025	-.148791D-12
RSIM22	.02538920	.00412489	6.155	.0000	2994.54695
SN	-1.93864222	.85471226	-2.268	.0233	.612292D-13
SN2	.01170704	.01094823	1.069	.2849	547.427475
FFD	3.81033312	2.84881853	1.338	.1811	13.8752801
RH	8.41041650	5.57220788	1.509	.1312	.479581D-12
RH2	-.21411533	.40029476	-.535	.5927	25.7153897
PWSIM2	.49643291	1.01904575	.487	.6261	155.053806
PCSIM2	.21905512	.74870327	.293	.7698	73.0769011
Constant	203.742321	711.047792	.287	.7745	

Scenarion3 (2080s)

```
+----------------------------------------------------+
| OLS Without Group Dummy Variables                  |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:19:28PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         32     |
|              Degrees of freedom   =       1375     |
| Residuals    Sum of squares       =   .3391820E+09 |
|              Standard error of e  =   496.6667     |
| Fit          R-squared            =   .5674086     |
|              Adjusted R-squared   =   .5576557     |
| Model test   F[ 31,  1375] (prob) =  58.18 (.0000) |
| Diagnostic   Log likelihood       =  -10714.80     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 31]  (prob) =1179.01 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.43833     |
|              Akaike Info. Criter. =   12.43832     |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel Data Analysis of LVAL       [ONE way]        |
|           Unconditional ANOVA (No regressors)      |
| Source      Variation   Deg. Free.     Mean Square |
| Between      .147345E+09        2.      .736727E+08 |
| Residual     .636725E+09     1404.      453508.    |
| Total        .784070E+09     1406.      557660.    |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	37.0700324	4.47638287	8.281	.0000	14.9706563
POPDEN	14.9644395	1.08428701	13.801	.0000	10.3281815
POPDEN2	-.01095861	.00086616	-12.652	.0000	8165.47251
NETMIG	.02691354	.00475098	5.665	.0000	393.283582
HIDIST	-1.99167430	.38094967	-5.228	.0000	45.8647532
GOVPAY	.05003559	.00970973	5.153	.0000	1407.84663
X_COORD	-9.02381096	5.44665906	-1.657	.0976	-105.177028
BLACK_SZ	-73.6382287	122.698042	-.600	.5484	.42643923
BROWN_SZ	-399.922016	141.094067	-2.834	.0046	.15138593
DBROWN_S	-234.854261	132.296493	-1.775	.0759	.22459133
GRAY_SZ	-77.3441978	124.459781	-.621	.5343	.08599858
DGRAY_SZ	-36.0005218	122.614670	-.294	.7691	.09523810
TPTSIM3	-1.28998011	2.04266228	-.632	.5277	.988879D-13
TPTSIM32	.01004487	.02050128	.490	.6242	458.404076
JSIM3	18.9908668	10.1404095	1.873	.0611	.616868D-14
JSIM32	-.55336358	.36240869	-1.527	.1268	17.2055766
ASIM3	18.9397132	13.5706117	1.396	.1628	.635142D-14
ASIM32	4.05256714	1.88836309	2.146	.0319	1.90715584
JUSIM3	-24.2786601	17.8311599	-1.362	.1733	.524602D-14
JUSIM32	-5.22573404	4.10046715	-1.274	.2025	1.72974345
SESIM3	13.9949945	15.8305579	.884	.3767	.624381D-14
SESIM32	4.11566338	6.32017832	.651	.5149	1.51791524
RSIM3	2.88328159	.55314450	5.213	.0000	.227346D-12
RSIM32	.02538728	.00418617	6.065	.0000	2994.54695
SN	-1.85438308	.89275353	-2.077	.0378	.612292D-13
SN2	.01277313	.01120063	1.140	.2541	547.427475
FFD	2.89948471	2.89901622	1.000	.3172	13.8752801
RH	13.8272792	5.59383285	2.472	.0134	.479581D-12
RH2	.17987958	.39942713	.450	.6525	25.7153897
PWSIM3	-.25681169	.38593785	-.665	.5058	168.536746

PCSIM3	-.32827543	.42654155	-.770	.4415	79.4314142
Constant	-469.197891	589.896898	-.795	.4264	

```
+----------------------------------------------------+
| Least Squares with Group Dummy Variables           |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:19:28PM     |
| LHS=LVAL     Mean                  =   993.3796    |
|              Standard deviation    =   746.7664    |
| WTS=none     Number of observs.    =       1407    |
| Model size   Parameters            =         34    |
|              Degrees of freedom    =       1373    |
| Residuals    Sum of squares        =   .3271932E+09|
|              Standard error of e   =   488.1652    |
| Fit          R-squared             =   .5826991    |
|              Adjusted R-squared    =   .5726693    |
| Model test   F[ 33,  1373] (prob)  =  58.10 (.0000)|
| Diagnostic   Log likelihood        =  -10689.49    |
|              Restricted(b=0)       =  -11304.31    |
|              Chi-sq [ 33]  (prob)  =1229.64 (.0000)|
| Info criter. LogAmemiya Prd. Crt.  =   12.40519    |
|              Akaike Info. Criter.  =   12.40518    |
| Estd. Autocorrelation of e(i,t)     .437753        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.9501389	4.41312133	8.826	.0000	14.9706563
POPDEN	14.8386748	1.06685260	13.909	.0000	10.3281815
POPDEN2	-.01084313	.00085217	-12.724	.0000	8165.47251
NETMIG	.02545954	.00467640	5.444	.0000	393.283582
HIDIST	-1.74635398	.37603358	-4.644	.0000	45.8647532
GOVPAY	.04014224	.00965844	4.156	.0000	1407.84663
X_COORD	18.6822262	8.54375410	2.187	.0288	-105.177028
BLACK_SZ	17.8919408	121.876731	.147	.8833	.42643923
BROWN_SZ	-256.732932	141.082608	-1.820	.0688	.15138593
DBROWN_S	-102.278213	131.811020	-.776	.4378	.22459133
GRAY_SZ	34.0600174	123.538129	.276	.7828	.08599858
DGRAY_SZ	32.1528328	121.136057	.265	.7907	.09523810
TPTSIM3	.51233770	2.02639840	.253	.8004	.988879D-13
TPTSIM32	-.01356218	.02043661	-.664	.5069	458.404076
JSIM3	13.8686463	10.0024276	1.387	.1656	.616868D-14
JSIM32	-.41260918	.35675954	-1.157	.2475	17.2055766
ASIM3	19.6232831	13.3423993	1.471	.1414	.635142D-14
ASIM32	3.43859625	1.86089137	1.848	.0646	1.90715584
JUSIM3	-36.4010616	17.6333986	-2.064	.0390	.524602D-14
JUSIM32	-6.80092492	4.03667840	-1.685	.0920	1.72974345
SESIM3	13.8848847	15.5809655	.891	.3729	.624381D-14
SESIM32	7.28529029	6.23535768	1.168	.2427	1.51791524
RSIM3	.56479654	.63826708	.885	.3762	.227346D-12
RSIM32	.02823685	.00429428	6.575	.0000	2994.54695
SN	-1.82763827	.87774095	-2.082	.0373	.612292D-13
SN2	.00991495	.01101671	.900	.3681	547.427475
FFD	4.77883224	2.86224655	1.670	.0950	13.8752801
RH	5.85440250	5.66112093	1.034	.3011	.479581D-12
RH2	-.48676660	.40383423	-1.205	.2281	25.7153897
PWSIM3	.13879938	.38342349	.362	.7174	168.536746
PCSIM3	-.07189533	.42203046	-.170	.8647	79.4314142

Estimated Fixed Effects			
Group	Coefficient	Standard Error	t-ratio
1	2267.48727	864.52199	2.62282
2	2115.67491	887.05957	2.38504
3	2619.22755	952.29217	2.75045

Test Statistics for the Classical Model

	Model	Log-Likelihood	Sum of Squares	R-squared
(1)	Constant term only	-11304.31008	.7840701399D+09	.0000000
(2)	Group effects only	-11157.86875	.6367247026D+09	.1879238
(3)	X - variables only	-10714.80400	.3391819682D+09	.5674086
(4)	X and group effects	-10689.48785	.3271931731D+09	.5826991

Hypothesis Tests

	Likelihood Ratio Test			F Tests			
	Chi-squared	d.f.	Prob.	F	num.	denom.	P value
(2) vs (1)	292.883	2	.00000	162.451	2	1404	.00000
(3) vs (1)	1179.012	31	.00000	58.178	31	1375	.00000
(4) vs (1)	1229.644	33	.00000	58.097	33	1373	.00000
(4) vs (2)	936.762	31	.00000	41.900	31	1373	.00000
(4) vs (3)	50.632	2	.00000	25.154	2	1373	.00000

```
Random Effects Model: v(i,t) = e(i,t) + u(i)
Estimates:  Var[e]              =   .238305D+06
            Var[u]              =   .837250D+04
            Corr[v(i,t),v(i,s)] =   .033941
Lagrange Multiplier Test vs. Model (3) =   27.15
( 1 df, prob value =  .000000)
(High values of LM favor FEM/REM over CR model.)
Baltagi-Li form of LM Statistic =          12.28
Fixed vs. Random Effects (Hausman)     =     .00
(31 df, prob value = 1.000000)
(High (low) values of H favor FEM (REM).)
            Sum of Squares             .362995D+09
            R-squared                  .550131D+00
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.7987664	4.41148233	8.795	.0000	14.9706563
POPDEN	14.9132608	1.06634722	13.985	.0000	10.3281815
POPDEN2	-.01090323	.00085179	-12.800	.0000	8165.47251
NETMIG	.02560171	.00467561	5.476	.0000	393.283582
HIDIST	-1.79954697	.37566503	-4.790	.0000	45.8647532
GOVPAY	.04271228	.00962166	4.439	.0000	1407.84663
X_COORD	7.24572236	7.26573732	.997	.3186	-105.177028
BLACK_SZ	-13.6495128	121.327041	-.113	.9104	.42643923
BROWN_SZ	-303.434043	140.085953	-2.166	.0303	.15138593
DBROWN_S	-140.940619	131.144428	-1.075	.2825	.22459133
GRAY_SZ	3.67171017	123.121529	.030	.9762	.08599858
DGRAY_SZ	10.0970946	120.879441	.084	.9334	.09523810
TPTSIM3	.03215377	2.02016836	.016	.9873	.988879D-13
TPTSIM32	-.00794732	.02035809	-.390	.6963	458.404076
JSIM3	15.3817157	9.98885886	1.540	.1236	.616868D-14
JSIM32	-.44262779	.35663630	-1.241	.2146	17.2055766
ASIM3	19.1460299	13.3406091	1.435	.1512	.635142D-14
ASIM32	3.45432324	1.86015501	1.857	.0633	1.90715584
JUSIM3	-34.9122435	17.6210236	-1.981	.0476	.524602D-14
JUSIM32	-6.42743748	4.03492539	-1.593	.1112	1.72974345
SESIM3	14.7803039	15.5729592	.949	.3426	.624381D-14
SESIM32	6.31406815	6.22611731	1.014	.3105	1.51791524

RSIM3	1.11429298	.61381055	1.815	.0695	.227346D-12
RSIM32	.02641069	.00421531	6.265	.0000	2994.54695
SN	-1.85599181	.87762929	-2.115	.0344	.612292D-13
SN2	.01060254	.01101451	.963	.3357	547.427475
FFD	4.33387880	2.85873889	1.516	.1295	13.8752801
RH	6.68734985	5.64248389	1.185	.2359	.479581D-12
RH2	-.36220094	.40192391	-.901	.3675	25.7153897
PWSIM3	.06127541	.38265768	.160	.8728	168.536746
PCSIM3	-.08981564	.42167563	-.213	.8313	79.4314142
Constant	1156.80980	772.633395	1.497	.1343	

```
+----------------------------------------------------+
| Least Squares with Group and Period Effects        |
| Ordinary    least squares regression               |
| Model was estimated Nov 24, 2009 at 01:19:29PM     |
| LHS=LVAL     Mean                 =   993.3796     |
|              Standard deviation   =   746.7664     |
| WTS=none     Number of observs.   =       1407     |
| Model size   Parameters           =         36     |
|              Degrees of freedom   =       1371     |
| Residuals    Sum of squares       =   .3264259E+09 |
|              Standard error of e  =   487.9480     |
| Fit          R-squared            =   .5836777     |
|              Adjusted R-squared   =   .5730495     |
| Model test   F[ 35,  1371] (prob) =  54.92 (.0000) |
| Diagnostic   Log likelihood       =  -10687.84     |
|              Restricted(b=0)      =  -11304.31     |
|              Chi-sq [ 35]  (prob) =1232.95 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   12.40568     |
|              Akaike Info. Criter. =   12.40567     |
| Estd. Autocorrelation of e(i,t)     .437103        |
+----------------------------------------------------+

+----------------------------------------------------+
| Panel:Groups   Empty       0,   Valid data       3 |
|                Smallest  183,   Largest        880 |
|                Average group size           469.00 |
| Panel: Prds:   Empty       0,   Valid data       3 |
|                Smallest    0,   Largest        473 |
|                Average group size           469.00 |
+----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
INCCAP	38.6787927	4.98774471	7.755	.0000	14.9706563
POPDEN	14.6950630	1.07292334	13.696	.0000	10.3281815
POPDEN2	-.01074224	.00085613	-12.547	.0000	8165.47251
NETMIG	.02636803	.00470509	5.604	.0000	393.283582
HIDIST	-1.75146102	.37702398	-4.645	.0000	45.8647532
GOVPAY	.03971757	.01006648	3.946	.0001	1407.84663
X_COORD	16.9827317	8.60936625	1.973	.0485	-105.177028
BLACK_SZ	26.7759008	122.091610	.219	.8264	.42643923
BROWN_SZ	-238.271303	141.669916	-1.682	.0926	.15138593
DBROWN_S	-85.0131283	132.366826	-.642	.5207	.22459133
GRAY_SZ	36.9352552	123.653144	.299	.7652	.08599858
DGRAY_SZ	33.7150455	121.177999	.278	.7808	.09523810
TPTSIM3	.27532954	2.04022291	.135	.8927	.988879D-13
TPTSIM32	-.01318514	.02054121	-.642	.5209	458.404076
JSIM3	12.1605234	10.0677605	1.208	.2271	.616868D-14
JSIM32	-.35898386	.35849196	-1.001	.3166	17.2055766
ASIM3	19.9298385	13.3385320	1.494	.1351	.635142D-14
ASIM32	3.47302041	1.86043007	1.867	.0619	1.90715584
JUSIM3	-38.1515679	17.6953591	-2.156	.0311	.524602D-14
JUSIM32	-6.88954540	4.04772103	-1.702	.0887	1.72974345

```
SESIM3  |    12.2770992      15.6286525      .786   .4321  .624381D-14
SESIM32 |    7.03616633      6.23680325     1.128   .2592   1.51791524
RSIM3   |     .45040530       .64707326      .696   .4864  .227346D-12
RSIM32  |     .02853152       .00430351     6.630   .0000   2994.54695
SN      |   -1.68538514       .88149960    -1.912   .0559  .612292D-13
SN2     |     .00946151       .01102581      .858   .3908   547.427475
FFD     |    4.69801906      2.86168413     1.642   .1007   13.8752801
RH      |    7.05117880      5.69796592     1.237   .2159  .479581D-12
RH2     |   -.42607807        .40587709    -1.050   .2938   25.7153897
PWSIM3  |    5.36434938      2.93598468     1.827   .0677   168.536746
PCSIM3  |    3.24932844      1.89931042     1.711   .0871   79.4314142
Constant|    887.667664      1161.54609      .764   .4447

      Estimated Fixed Effects - Full sets of effects, normalized to sum to 0
      Group        Coefficient       Standard Error       t-ratio
           1           42.34002             46.79813          .90474
           2          -97.40074             15.90883        -6.12243
           3          388.78516             83.81330         4.63870
      Estimated Fixed Effects - Full sets of effects, normalized to sum to 0
      Period       Coefficient       Standard Error       t-ratio
           1          318.66268            178.27972         1.78743
           2         -324.82851            181.76895        -1.78704
           3           -2.07507             23.40348         -.08866
+--------------------------------------------------------------------+
|             Test Statistics for the Classical Model                |
+--------------------------------------------------------------------+
|       Model               Log-Likelihood  Sum of Squares    R-squared |
|(1)  Constant term only   -11304.31008  .7840701399D+09    .0000000 |
|(2)  Group effects only   -11157.86875  .6367247026D+09    .1879238 |
|(3)  X - variables only   -10714.80400  .3391819682D+09    .5674086 |
|(4)  X and group effects  -10689.48785  .3271931731D+09    .5826991 |
|(5)  X ind.&time effects  -10687.83612  .3264258638D+09    .5836777 |
+--------------------------------------------------------------------+
|                         Hypothesis Tests                           |
|         Likelihood Ratio Test           F Tests                    |
|         Chi-squared   d.f.  Prob.         F    num. denom.   P value |
|(2) vs (1)   292.883      2  .00000  162.451     2    1404   .00000 |
|(3) vs (1)  1179.012     31  .00000   58.178    31    1375   .00000 |
|(4) vs (1)  1229.644     33  .00000   58.097    33    1373   .00000 |
|(4) vs (2)   936.762     31  .00000   41.900    31    1373   .00000 |
|(4) vs (3)    50.632      2  .00000   25.154     2    1373   .00000 |
|(5) vs (4)     3.303      2  .19172    1.611     2    1371   .19999 |
|(5) vs (3)    53.936      5  .00000   10.715     5    1371   .00000 |
+--------------------------------------------------------------------+
+----------------------------------------------------------+
| Random Effects Model: v(i,t) = e(i,t) + u(i) + w(t)      |
| Estimates:  Var[e]              =   .238093D+06          |
|             Var[u]              =   .248957D+04          |
|             Corr[v(i,t),v(i,s)] =   .010348              |
|             Var[w]              =   .609497D+04          |
|             Corr[v(i,t),v(j,t)] =   .024960              |
| Lagrange Multiplier Test vs. Model (3) =   27.88         |
| ( 2 df, prob value =  .000001)                           |
| (High values of LM favor FEM/REM over CR model.)         |
| Fixed vs. Random Effects (Hausman)     =     .00         |
| (31 df, prob value = 1.000000)                           |
| (High (low) values of H favor FEM (REM).)                |
|             Sum of Squares          .362995D+09          |
|             R-squared               .550131D+00          |
+----------------------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 INCCAP  |    39.7453767      4.90509516     8.103   .0000   14.9706563
```

POPDEN	14.8879617	1.06923388	13.924	.0000	10.3281815
POPDEN2	-.01089007	.00085375	-12.756	.0000	8165.47251
NETMIG	.02589767	.00467795	5.536	.0000	393.283582
HIDIST	-1.84207885	.37635400	-4.895	.0000	45.8647532
GOVPAY	.04684183	.00989311	4.735	.0000	1407.84663
X_COORD	-1.00147962	6.33029588	-.158	.8743	-105.177028
BLACK_SZ	-41.1012336	120.962876	-.340	.7340	.42643923
BROWN_SZ	-344.740000	139.445193	-2.472	.0134	.15138593
DBROWN_S	-178.390187	130.711283	-1.365	.1723	.22459133
GRAY_SZ	-28.0157484	122.782535	-.228	.8195	.08599858
DGRAY_SZ	-10.5074570	120.676044	-.087	.9306	.09523810
TPTSIM3	-.56618319	2.02012633	-.280	.7793	.988879D-13
TPTSIM32	-.00081678	.02033474	-.040	.9680	458.404076
JSIM3	16.9621478	9.99397748	1.697	.0897	.616868D-14
JSIM32	-.48446683	.35692897	-1.357	.1747	17.2055766
ASIM3	18.8493514	13.3341049	1.414	.1575	.635142D-14
ASIM32	3.56501581	1.85848870	1.918	.0551	1.90715584
JUSIM3	-33.0821165	17.6320707	-1.876	.0606	.524602D-14
JUSIM32	-6.23613468	4.04411031	-1.542	.1231	1.72974345
SESIM3	15.3911599	15.5839432	.988	.3233	.624381D-14
SESIM32	5.57580010	6.22158647	.896	.3701	1.51791524
RSIM3	1.72702441	.59084272	2.923	.0035	.227346D-12
RSIM32	.02535759	.00416417	6.089	.0000	2994.54695
SN	-1.87275370	.87794778	-2.133	.0329	.612292D-13
SN2	.01156099	.01101561	1.050	.2939	547.427475
FFD	3.83645849	2.85408116	1.344	.1789	13.8752801
RH	8.52764405	5.60892435	1.520	.1284	.479581D-12
RH2	-.21405514	.40046105	-.535	.5930	25.7153897
PWSIM3	.45081178	.93861680	.480	.6310	168.536746
PCSIM3	.20849731	.68859101	.303	.7621	79.4314142
Constant	193.993157	709.716294	.273	.7846	

APPENDIX B Mean Annual and seasonal Temperature and Precipitation (2020s and 2050s)

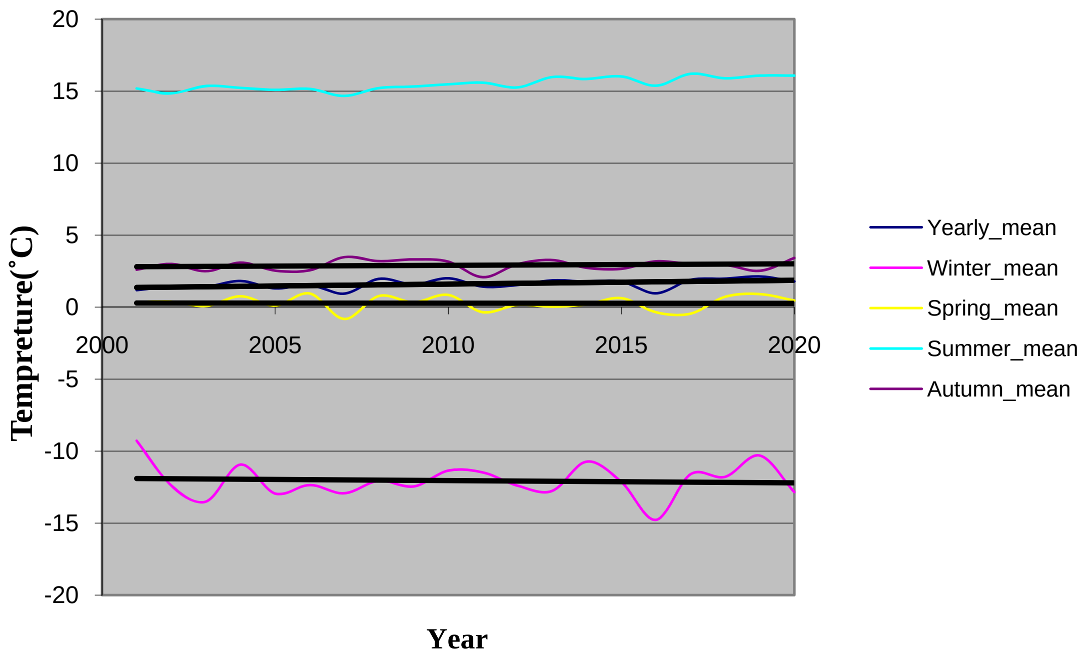

Figure B.1 Mean Annual and seasonal Temperature for 2020s

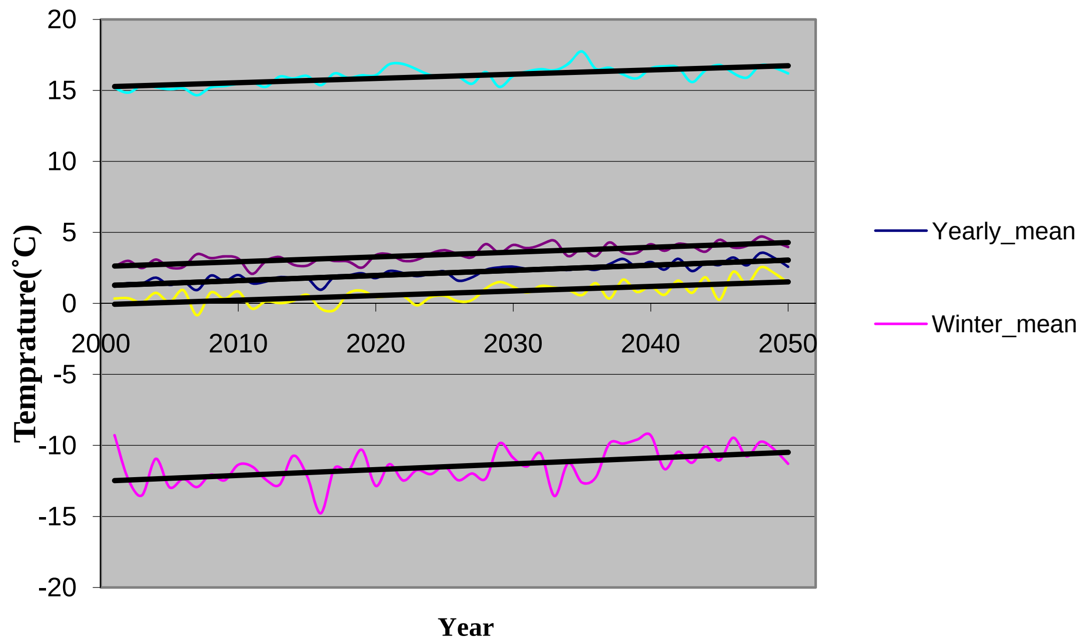

Figure B.2 Mean Annual and seasonal Temperature for 2050s

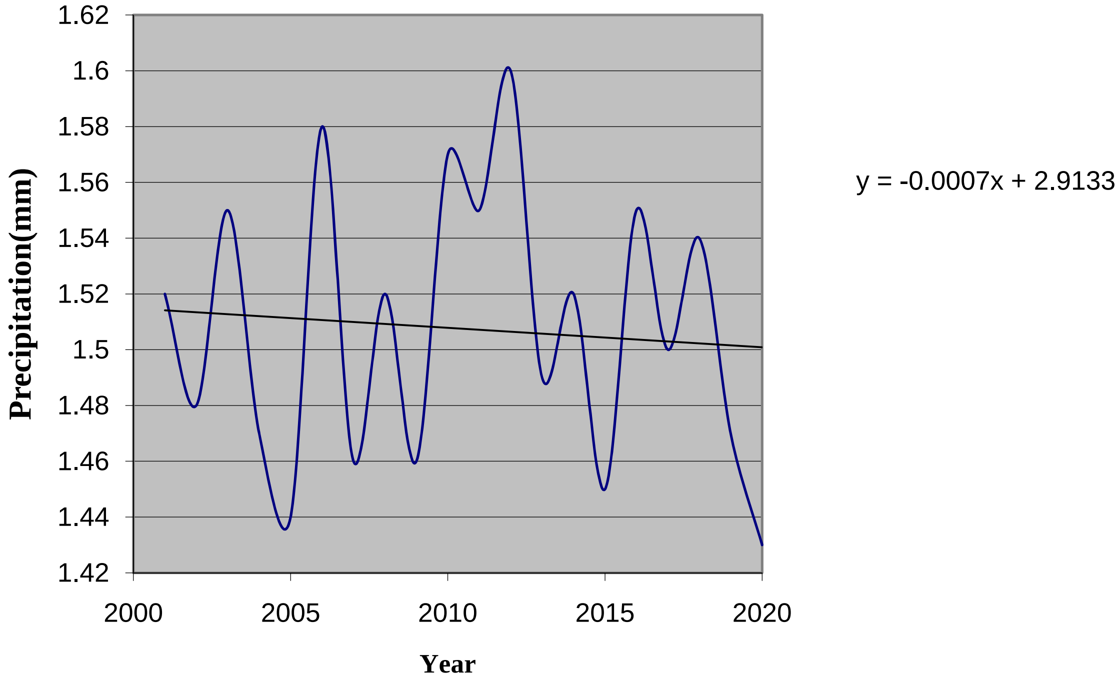

Figure B.3 Mean Annual Precipitations for 2020s

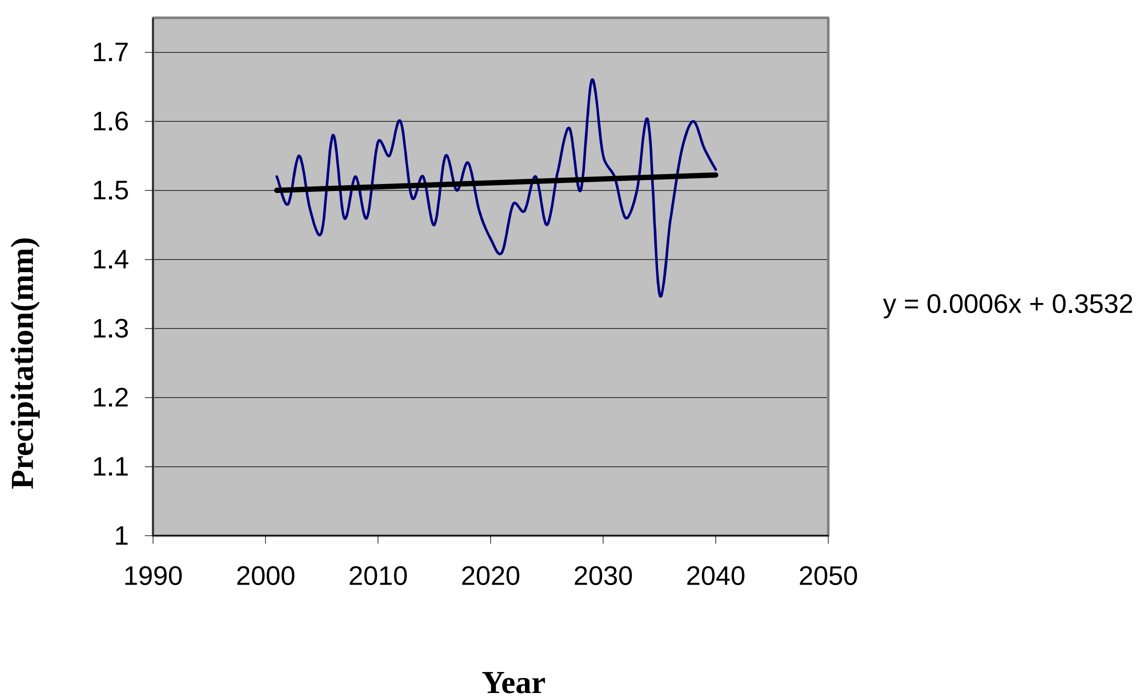

Figure B.4 Mean Annual Precipitations for 2050s

APPENDIX C Sensitivity Analysis of Removing Alberta's Data from Base Model

Table C.1 Complete and Subsample Estimation Results (with and without Alberta)

Variable	Total sample (With Alberta)	Subsample(Without Alberta)
Control		
Income per Capita	37.85***	26.00***
Population Density	14.62***	23.38***
Population Density Squared	-0.01***	-0.01***
Net Migration	0.03***	-0.02
Distance to nearest Highway	-1.71***	-1.32***
Government transfer payment	0.04***	0.01
Longitude	14.76*	7.85
Dummy		
Black Soil Zone	71.33	-8.81
Brown Soil Zone	-217.33	-155.54
Dark Brown Soil Zone	-52.71	-62.01
Gray Soil Zone	31.52	-24.12
Dark Gray Soil Zone	70.37	66.37
Market prices		
Price of Wheat	6.67*	10.03***
Price of Canola	4.08*	6.71***
Climate		
Evapo-transpiration Proxy	0.04***	0.03***
Evapo-transpiration Squared	0.37×10^{-6}***	0.27×10^{-6}***
January Temperature	15.25*	-16.67*
January Temperature Squared	-0.46	0.56
April Temperature	22.04*	32.56**
April Temperature Squared	3.05*	4.25*
July Temperature	-31.70*	-26.13
July Temperature Squared	-5.40	-9.20*
September Temperature	15.50	9.90
September Temperature Squared	5.77	10.66*
Rainfall	0.57	0.04
Rainfall Squared	0.03***	0.03***
Snow fall	-1.79**	-1.70**
Snowfall Squared	0.01	0.01***
Frost Free Days	3.95	2.50
July Relative Humidity	9.15*	-2.77
July Relative Humidity Squared	-0.35	-1.33***
Constant	617.98	-536.28
Province Fixed Effects		
Manitoba	26.72	119.04***
Saskatchewan	-90.59***	-46.55***
Alberta	385.40***	N/A
Year Fixed Effects		
1991	314.46**	456.56***
1996	-323.89**	-480.73***
2001	1.21	1.20
R^2	0.59	0.44
Adjusted R^2	0.58	0.41

*** denotes significant at 1% level, ** denotes significant at 5% level and * denotes significant at 10% level.