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Modelling Potential Changes in Demand for Freight Transportation in Atlantic Canada Due to Climate Change Impacts

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Executive Summary

In response to the Kyoto Protocol to limit emissions of greenhouse gases, Canada developed its own climate change agenda, in which transportation sector is recognized as one of the most critical. This study models climate change impacts on demand for freight transportation in Atlantic Canada. These impacts are modeled as productivity shocks in relevant sectors of the regional economy, and then they are imposed on the dynamic model of the regional economy to trace the consequences for the demand for freight transportation. Three different scenarios are evaluated. According to these scenarios, the demand for freight transportation in Atlantic Canada is expected to decrease by up to 3% during this century. The underlying dynamic analysis showed that this loss is permanent, which implies that without some changes to the existing policy the economy will not be able to recover from these climate change impacts.

In addition, sectoral impacts of climate change are evaluated. It appears to be that consequences of the climate change impacts for agriculture, forestry and fisheries are quite different from the consequences for manufacturing. While the former sector benefits from the warmer climate in the long-run, the latter permanently loses in productivity. Consequently, the demand for freight transportation by these sectors is affected differently: climate change increases demand for freight transportation by agriculture, forestry and fisheries and decreases the demand by manufacturing.

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INTRODUCTION

In 1997 in Kyoto, Japan more than 160 nations discussed a possibility of imposing restrictions on greenhouse gases emissions (GHGs) to meet environmental objectives established by the UN Convention on Climate Change in 1992. As a result, the so-called Kyoto Protocol was signed in which the developed nations agreed to limit their GHGs emissions. The Kyoto Protocol contains legal requirements on emission targets for 36 industrialized countries. These countries are obligated to decrease their emissions of six key GHGs by at least 5% by 2008/2012, compared to the 1990 level.

In response to the Kyoto Protocol, Canada developed its own climate change agenda, which includes two major elements: The *National Implementation Strategy* and the *First National Business Plan on Climate Change* (Government of Canada, 2000). These documents emphasise national strategies to adapt to the climate changes by reducing GHGs emissions. They also reflect the willingness of the federal and provincial governments to coordinate their efforts to achieve a common goal of greenhouse gases reduction. In addition, the Government of Canada introduced the *Action Plan 2000 on Climate Change*. According to this plan, Canada has to reduce GHGs emissions by 65 million tonnes per year, which would bring Canada one quarter of the way to Canada's Kyoto target (Government of Canada, 2000).

The transportation sector is recognized as one of the most critical elements of Canada's climate change agenda. To address issues related to the transportation sector, the Action Plan 2000 proposed five programmes:

1. Canadian Transportation Fuel Cell Alliance. The programme goal is to evaluate different fuelling options for fuel cell vehicles.

2. Future Fuel Programme. The primary objective is to increase the supply and use of ethanol produced from biomass, which could result in 25 percent of Canada's total gasoline supply containing 10 percent ethanol.

3. Motor Vehicle Fuel Efficiency Initiative. The initiative encourages vehicle manufacturers to improve vehicle fuel efficiency through advancing the technological component of the production chain.

4. Urban Transportation Showcase Programme. The idea is to stimulate and popularize across Canadian communities the best practices in reducing GHGs emissions from urban transportation.

5. Freight Efficiency and Technology Initiative. Essentially, this is strategy of improving the freight sustainability.

In response to the Action Plan 2000, and projecting an increase in total transportation demand by more than 50 percent from 1990 to 2020, Transport Canada designed a *Sustainable Development Strategy for 2001-2003.* It was aimed at reducing air and water pollution, encouraging urban transportation, advancing technology of auto manufacturing, introducing a variety of Intelligent Transportation Systems (ITS), data gathering and intermodal transportation.

However, there was very little information on potential consequences of climate change impacts on demand for transportation. Moreover, at that moment there was not (and still is not) a single study in Canada, which assessed climate change impacts on demand for transportation. The only mention of the problem is found in the materials of the workshop "Impacts of Climate Change on Transportation", conducted by Transport Canada in January, 2003 in Canmore, Alberta in a note written by Mills and Andrey (2003). They wrote:

> *"… since spatial patterns of agricultural production change in response to drought or extended growing seasons, it seems reasonable to expect new demands for transportation to arise and others to wane. Similarly for energy, climate change may permit the cheaper development of new fossil fuel resources in the Arctic thus increasing demand for supplies and the*

bulk shipment of petroleum" (Mills, and Andrey, 2003).

It is rather ironic that while most of the research has been dedicated to the climate change impacts on transportation infrastructure, which from an economic standpoint represents the supply side of transportation, the demand side deserved just one phrase in official documents that *"…social and economic adjustments to climate change will cause indirect changes in transportation demand" (Transport Canada, 2003).* That is why the goal of this study is to shed some light on the consequences of the climate change impacts on demand for transportation, specifically freight transportation in Atlantic Canada.

The distinguishing features of this study are as follows. First, it considers the demand for freight transportation as flows of freight transportation services, required by other sectors of the economy to deliver various commodities to their final users. It means that the study recognizes that freight transportation is produced to meet the demand for freight transportation by other sectors of the regional economy, implying that demand for freight transportation is a derived or factor demand. It is derived as a by-product of profit maximization or cost minimization by producers of various commodities in respective sectors of the economy. Second, this study has a clear regional perspective, which has not been done before in other climate change studies. Finally, climate change impacts are viewed as productivity shocks in relevant sectors of the regional economy with their spillover effects on demand for freight transportation.

As a result, the main objective of this study was formulated as follows: *to model climate change impacts as productivity shocks in relevant sectors of the regional* *economy, and then to trace the consequences of these shocks for the demand for freight transportation on the basis of computer simulation*.

Implementation of the main objective of this study resulted in the following structure of the final report:

Section one describes the importance and effects of climate change, the structure of the Atlantic Canada economy, and the state of freight transportation in Atlantic Canada. Section two discusses what has been done in previous studies dedicated to climate change impacts, as well as climate related variables used in these economic models. Section three describes the model used in this study along with the data. Finally section four presents the results and findings of this study.

The results of this study should be taken with some caution. It is so because in this study, all supply side effects were artificially removed and only demand side effects were analysed. It was done deliberately to show that the demand side effects or, according to the Transport Canada terminology, "indirect changes" are sizable and therefore, they should be explicitly included in all models of climate change impacts on transportation.

1. Global Climate Change, Atlantic Canada and Freight Transportation

1.1 *Global Climate Change and Atlantic Canada*

There have been a lot of speculations on the issue of global climate changes. Scientists have not reached a unanimous conclusion on whether human activities are the primary reason for the increasing atmospheric concentration of greenhouse gases (GHG) and aerosols, which, in turn, causes global climate change. However, the increasing body of observations suggest that the problem of global climate change does exist.

The Intergovernmental Panel on Climate Change (IPCC), which was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP) in its Climate Change 2001 Synthesis Report (WMO and UNEP, 2001) pointed out: *"There is new and strong evidence that most of the warming observed over the last 50 years is attributable to human activities. Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years."* One of the conclusions of this Report is that the observed changes in regional climate have not only affected physical and biological systems but also social and economic systems.

Since this study is dedicated to the climate change impacts in Atlantic Canada, the important question is whether climate change is taking place in Atlantic Canada. If the answer is yes, then as WMO and UNEP suggest, the regional economy will inevitably be affected. Since transportation is an integral part of the regional economy, the answer to the above-formulated question will shed some light on the consequences of climate change impacts on the demand for transportation in general and, freight transportation in particular.

WMO and UNEP (2001) concluded that globally the 1990s were the warmest decade since recording of the climate began in 1861. However, change in temperature, as the main indicator of the climate change, has not been uniform, and has varied over regions. Based on the existing literature and expert opinion, it is hypothesized in this study that *climate change in Atlantic Canada came about sometime in the period between 1950 and 2000*. This hypothesis was rigorously tested in order to understand the magnitude and duration of the climate change impacts on the regional economy as well as on the demand for freight transportation. Results of the testing are presented later in this report.

There are several impacts associated with the global climate change. According to the US Environmental Protection Agency (1990), an increase in carbon dioxide emissions and atmospheric levels of water vapour supplemented by geophysical and biogenic feedback will result in potential global warming of between 1.5^{o} and $5.5^{o}C$ over the next 100 years. As well global warming will cause sea levels to rise. Models developed by the Intergovernmental Panel on Climate Change (1995) show an average estimated increase in sea level between 20 and 86 cm by 2100 with 50 cm considered as being the most likely. Total economic loss from a one-meter rise in sea level was estimated to be between US$270 and US$475 billion (Titus, 1991). The rising sea level will have significant implications for maritime regions like Atlantic Canada. Potential consequences include erosion of soil, infrastructure damage, change in population density, change in flows of freight transportation, change in consumption patterns and others.

In addition, global warming will cause changes in the hydrologic cycle. The hydrologic cycle traces the movement of water among the oceans, atmosphere, land and vegetation, and ice caps and glaciers. Scientists agree that significant warming will intensify the global hydrologic cycle and will have major impacts on regional water resources (IPCC, 1990). The increase in global temperature could increase average global precipitation from 7 to 15 percent (U.S. Congress Office on Technological Change, 1990). Precipitation will increase at high latitudes and decrease at low to middle latitudes. As well, the potential for more-intense or longer-lasting drought will increase. This means that water-dependent activities such as agriculture are likely to be greatly affected by a change in hydrologic patterns (Innes and Kane, 1995) or, in other words, hydrologic changes are likely to cause changes in production and consumption activities. As a result, transportation flows will be affected as well.

Climate change will increase precipitation patterns causing droughts and frequency of extreme weather events such as thunderstorms, tornados, hailstorms, floods, and heat waves. In general, it is expected that rainstorms will be less frequent but more severe and dry periods will last longer. Other problems that are likely to result from the climate change include increasing risk of fires, pests, and disease to farms and forests, and damage to water resources and wetlands.

Since this study focuses on Atlantic Canada, it is necessary to determine specific impacts of the global climate changes on the regional economy. The Government of Canada projects that over the next fifty years average temperatures in Atlantic Canada will increase by 3 to 4^{o}C. Moreover, these climate changes are expected to be the largest and most rapid of the last 10,000 years (Government of Canada, 2000).

Due to recent warming in the Atlantic region, the number of mild days in winter has been increasing, and large peak flows into the rivers in early spring are becoming more common (Government of New Brunswick, 2003). If this trend continues, ice break-up and flooding on the rivers will become more severe and less predictable. This can cause increasing damage to public and private property, highways, and bridges. As a result of regional warming, businesses may have to change their manufacturing and inventory management strategies, which will eventually lead to the change in the demand for freight transportation. According to the Government of Canada, the Atlantic Provinces can anticipate that:

> The risk of trees blowing down may increase, as storms become more frequent and intense as a result of climate change. For example, a massive blow-down in 1994 caused 30 million trees to be felled and cost $100 million in damages. Warmer winter temperatures may allow invasive insects such as the gypsy moth to become more pervasive. This is because of prolonged temperatures at or above -9°C (2004).

It looks like that the agricultural sector of the economy will be the primary recipient of climate change. Due to warming, the growing season for such crops as corn and other cereals will be prolonged producing larger yields. At the same time, the probability of droughts is going to increase, thus raising the issue of supplementary irrigation. In addition, warmer winters will boost insect reproduction, forcing local farmers to apply bigger amounts of pesticides. Some other natural phenomena such as floods and hail can substantially damage crops as well as livestock. In the worst-case scenario, these extreme events can cut off local power lines changing the pattern of electricity supply.

The entire Atlantic region is influenced by seawater. Forecasts show that the level of the sea will rise from 70 cm to about a meter above its normal level in the Maritime

Provinces. Strong winds combined with the increased water level will flood the areas that have been never exposed to water before.

> *"Low-lying coastal areas will be the most vulnerable. Sinking of coastal land could compound the problem as much of the New Brunswick, Nova Scotia and Prince Edward Island coast is low-lying and sensitive to erosion and flooding"* (Government of *Canada*, 2004).

Climate change may increase the risk to forests in the Maritimes as well. According to the Government of Canada report *"warmer winter temperatures may allow invasive insects, such as the gypsy moth, to become more pervasive, while warmer, drier summers would increase the threat of forest fires in the Atlantic Provinces"* (Government of Canada, 2004). As temperature rises, temperate forests may progressively substitute regional northern forests.

In terms of economic loss to the Atlantic Canada's economy, the growth of gross domestic product is estimated to be about 0.3 percent less by 2010 than it could have been by following the current development scenario. Over the same period, there will be 0.4 percent fewer jobs created. Climate change will also affect personal incomes. It is projected that by 2010 earned income will be approximately 0.2 percent lower than under the "no climate change" alternative (Government of Canada, 2004). Since climate change impacts are cumulative in nature, it is reasonable to assume that the situation will further deteriorate causing economic loss to increase geometrically.

Analysis of the cost structure of the major industrial producers in Atlantic Canada shows that adjustment to the global climate change will result in the following (Government of Canada, 2004):

- The price of pulp and paper will rise by 0.06 percent or about 59 cents per tonne;

- The price of electricity (coal) will rise by 1.94 percent or 0.14 cents per KWH;
- The price of electricity (gas) will rise by 0.60 percent or 0.04 cents per KWH;
- The price of steel (conventional) will rise by 0.29 percent or $2.10 per tonne;
- The price of aluminium will rise by 0.23 percent or $4.73 per tonne.
- The price of natural gas will rise by 0.14 percent or 0.5 cents/million cubic feet.

These changes will inevitably affect the allocation of production, consumption and trade flows in the regional economy and, as a result, will change the pattern of the demand for freight transportation.

1.2 *Atlantic Canada's Economy*

The Atlantic Canada economy heavily relies on export/import activities. The economic strength of the region lies in traditional Canadian export industries such as lumber, paper, minerals, and agriculture. Atlantic Provinces also provide refined petroleum, hydroelectricity, and natural gas. Among the top export activities that generate the largest demand for freight transportation are refined petroleum; lumber, wood and wood pulp; iron ore and scrap; newsprint, coated and treated paper; transport equipment; and, frozen fruit and vegetables.

Three quarters of the Atlantic Canada's exports come from the forestry, mining, and fishing sectors (Statistics Canada, 2002). Although most of the products in these sectors undergo only minimal processing, and correspondingly the value added by them is not as large as by the manufacturing sector, they still play a significant role in the regional economy. Exports have almost tripled from about $6 billion in 1980 to $17 billion in 2000, and represent approximately 30 percent of the regional GDP (Statistic

Canada, 2001). Exports to the US represent over 20 percent of the regional GDP, which shows that the international export activities are a substantial factor that generates the demand for freight transportation in the region (Statistic Canada, 2002).

Despite some new technological services that contributed to the strengthening of the regional economy, shifting it from purely resource-based to the high-tech service economy, some traditional sectors continued to play an important role. For example, Atlantic Canada experienced a significant increase in its exports of fish and other basic marine products from 60,000 to 208,000 tonnes (from $174 million to $839 million in monetary terms) between 1990 and 1999. As well, the marine industry production grew from 15,000 to 40,000 tonnes for the same period (Beaudin and Breau, 2001).

In the pulp and paper sector, the focus gradually shifted from standard paper to fine and glazed glossy paper, while sawmills increased the use of the paper production by-products and the re-use of wood because of high demand for secondary-processed wood products. The overall value of paper and paper products, lumber, sawmill and wood production increased from $1.911 billion at the beginning of the 1980s to $3.593 billion by the second half of the 1990s or by 88 percent in real terms (Beaudin and Breau, 2001).

The region has traditionally depended on natural resources such as oil, natural gas, iron ore, nickel, copper and cobalt. For example, Hibernia, off the coast of Newfoundland and Labrador, is the fifth largest oil field in Canada. The Atlantic region currently produces about 11 percent of the country's oil and 3 percent of its natural gas (Government of Canada, 2004). Most of the oil and gas transportation goes through the region's marine ports of Halifax, Saint John and St. John's.

Imports to Atlantic Canada are even more significant as part of the regional economic activity. Crude oil, motor vehicles, machinery, technology and consumer goods dominate the region's imports. The top import activities include fertilizers, construction materials, road motor vehicles and chassis, and agricultural products. For the most part these sectors of the regional economy generate the highest demand for freight transportation in Atlantic Canada.

Most of the imports to Atlantic Canada come from the US and Asian countries. Two neighbouring US regions, New England and Mid-east, are Atlantic Canada's most important trading partners (Department of Foreign Affairs and International Trade, 2004). Non-conventional and conventional crude oil and natural gas, motor vehicle, refined petroleum, machinery and equipment, construction and mining machinery, ship-building and repair, aluminium products and other smelting, and organic chemical production are amongst the most imports to the region.

In New Brunswick, forestry, petroleum refining, food processing and ship-building are the economic activities that generate the highest demand for freight transportation. Newfoundland and Labrador can be described as the province with a resource-based economy focusing on mining, fisheries and aquaculture, forest products, hydroelectricity, oil and natural gas, manufacturing, construction, agriculture and food processing.

In Nova Scotia, historically mining has been the most important sector of the provincial economy. Coal, gypsum, barite, and salt are mined throughout the province. Although recently mining has begun to decline, it is still one of the most important economic sectors. Fishing and food processing, forestry and wood production, and assembly of automobiles, tires, sugar, and construction materials are other important sectors of the Nova Scotia's economy.

Prince Edward Island's economy is the smallest in Atlantic Canada. It is mostly comprised of agricultural products with abundant rich farmlands. Frozen vegetables, processed potatoes and fish products account for the largest share of the provincial economic activities.

Trade in various commodities accounts for nearly 40 percent of intra-regional import and export activities in Atlantic Canada. Commercial links are strong between adjacent provinces. For example, Nova Scotia and New Brunswick's bi-lateral trade is between 20 and 25 percent of their total intra-regional trade. Almost one-third of Prince Edward Island's exports go to New Brunswick primarily as transportation services and potato-related food products. Bi-lateral trade between Newfoundland and Nova Scotia accounts for 15 percent of their total intra-regional trade. Transportation services, fish and petroleum products represent a major share of this trade.

Since export/import activities play a crucial role in the regional economy, reliable and efficient freight transportation becomes of special value. It points to a strong link between climate change impacts on regional economic sectors and their consequences for the demand for freight transportation. If, as a result of climate change impacts consumption and production patterns in the described sectors of regional economy change, the demand for freight transportation will also change.

1.3 *Overview of Atlantic Canada's Freight Transportation*

There are approximately 67,000 kilometres of highways in the Atlantic Region of which 2,880 kilometres have been designated as part of the National Highway System (Transport Canada, 2003).

In 2001, 1,336,512 road motor vehicles were registered in the Atlantic Region. This constitutes 7.4 percent of the Canadian total. Of these, 42,138 were vehicles that weigh more than 4,500 kilograms. In addition to the motor vehicles, there were 145,905 trailers and 188,825 off-road, construction and farm vehicles (Transport Canada, 2003). Atlantic Canada accounts for 6 percent of the heavy and mid-size truck fleet of Canada. A heavy truck is predominantly a tractor-trailer combination with a separated power unit and cargo area whereas a mid-sized one is a straight truck with an integrated power unit and cargo area. Freight road transportation, especially inter-provincial and trans-border movements, is typically represented by these two categories of trucks.

Freight rail transportation in Atlantic Canada accounts for over 11 percent of all Canadian national railways' total traffic (Transport Canada, 2003). In terms of infrastructure, there are approximately 2,400 kilometres of main railway tracks in the Atlantic Region, of which 925 kilometres are operated by CN, while the rest is owned and operated by five provincial short-line railways. In addition, there are approximately 950 kilometres of spur and yard trackage (Transport Canada, 2003).

There is only one large Class I railway in Atlantic Canada, the Canadian National (CN), and five short-line Class II railways. The latter are: New Brunswick Southern Railway, New Brunswick East Coast Railway, Windsor and Hantsport Railway, Cape Breton and Central Nova Scotia Railway, and Quebec North Shore and Labrador

Railway. There is only one Class III railway. It is operated by a small industrial rail company, Devco Rail. The railway is owned by the Cape Breton Development Corporation (Transport Canada, 2000).

Sea ports and harbours in Atlantic Canada play an important role in economic activities that enable more and more commodities to be transported to inland markets. Intra-, inter-regional and international trades are active since there is a linkage between shipping and trucking/rail.

In Atlantic Canada, there are four Canada Ports Authorities (CPAs): Saint John, St. John's, Belledune and Halifax. Saint John is the second busiest port authority in Canada handling 25.2 million tonnes of cargo (Shipping in Canada 2002). The revenue ratio of Atlantic Pilotage Authority (APA) to the Total Pilotage Authority (TPA) is only around 14%. But, compared with the net income of TPA which is 527 million dollars, the net income of APA was 975 million dollars in 2003 (Transportation Canada 2003). Except the Pacific Pilotage Authority which had 1713 million dollars' net income, APA is the second best authority in Canada, which means it has a steady growth and is one of major contributors to Atlantic economy.

Besides CPAs, specified by Canada Marine Act, there are other 2 categories: regional/local ports and remote ports. In Atlantic region there are one local port in New Brunswick, fifteen local ports in Newfoundland and Labrador, four local ports in Nova Scotia and three local ports in PEI.

In 2003, there were ten airports in Atlantic Canada. Four of them were located in Newfoundland, in St. John's, Gander Intl, Goose Bay and Deer Lake. There was only one airport in PEI, in Charlottetown. There were two airports in Nova Scotia, in Halifax and

Sydney. The last three airports were located in New Brunswick, in Moncton, Saint John and Fredericton (Air carrier traffic at Canadian airports, 2003)

In general with respect to Atlantic Canada, air cargos are carried in the belly-hold of passenger aircraft, in the passenger/cargo combination or in the pure cargo aircraft.

2. Analysis of the Existing Economic Models of Climate Change Impacts

2.1. *Climate Change Impacts and Climate Related Variables*

Most climate change impacts that have been studied can be categorized as follows:

1. Temperature related effects. These effects include extreme hot and cold temperatures, freeze-thaw cycles, permafrost degradation and reduced ice cover.
2. Sea level rise and storm flow effects. These effects are associated with damage on low-lying coastal infrastructure.
3. Precipitation related effects. These effects include rainfall and snowfall. Changes in precipitation patterns may cause landslides and steep slopes failure damaging infrastructure and increasing the costs of its maintenance.
4. Extreme weather events. These events include storms, blizzards, floods, tornados, tsunamis, etc.

In order to obtain a more precise picture of the climate change impacts, recently in their models researchers have started to treat all climate related variables as a single vector. Such an approach is based on the assumption that all climate related variables are inter-correlated, and therefore, only a complete set of these variables can show the real change in climate patterns. However, this approach is relatively new. All current economic studies still use a single variable or some combination of climate related variables to estimate the consequences of climate change. This study constructs a vector of climate variables, and therefore the following analysis of each of the climate related variables in this vector is presented.

2.1.1. *Temperature Related Effects*

It is still debatable whether the global warming occurs because of the greenhouse effect resulting from human activities or from an undiscovered natural cyclical pattern. Nevertheless, average annual temperature is widely accepted to be the primary climate related variable in almost all studies. The impact of temperature change is straightforward and easily understandable. Moreover, the temperature time series is available since 1890. Based on this time series, it was found that the Atlantic Canada region has apparently not followed the national warming trend of an increase of about 1ºC over the last 100 years (Bootsma, 1996). The data indicate that there was a gradual warming between 1890 and the 1950's, followed by a cooling in the 1970's, levelling by 1980s, and return to a warming trend since 1980's (Phillips, 1990; Berry 1991; Bootsma, 1994).

Some studies attempted to predict changes in the regional surface temperature until 2100. They concluded that climate change impacts on Atlantic Provinces in the 21st century will be dramatic: Average annual temperature in Atlantic Canada will likely to increase by as much as 3-4ºC over the next 80 years (Lemmen, 2003). *"These climate changes are expected to be the largest and most rapid of the last 10,000 years and will* *have profound effects on our lives and the ecosystems that support us"* (Government of Canada, 2004).

2.1.2. *Sea Level Rise and Storm Flow Effects*

Sea level rise and storm flow effects are viewed as being the most threatening of all climate change impacts. These impacts are direct, and their consequences can be observed immediately. Frequently these impacts have a disastrous character. Studies of Atlantic Canada's infrastructure (McCulloch, Forbes, and Shaw, 2002; Martec Ltd., 1987; Stokoe, Leblanc, Lane, Belford, Carey, Manzer, and DeWolfe, 1988) show that the Atlantic region is extremely vulnerable to coastal erosion and sea floods. The region has experienced strong damaging coastal flooding over the past decade. As well, sea level rise can have very substantial impacts on local rivers. The northern parts of New Brunswick and Prince Edward Island could be wiped out entirely because of the sea level rise and coastal erosion.

Current studies show that sea level is rising now at an increasing rate along most parts of the coastal zone in Atlantic Canada (Shaw, 1996). There is evidence that, on average, the sea level is rising at a rate of 1 to 2 mm per year. Estimates of potential sea level rise in Atlantic Canada range from 0.3 to 0.9 metre by 2100. The most likely scenario indicates that the sea level will rise by about 50 cm. in the region at the end of this century. This rise should be added to a vertical downward crustal movement that occurs in many parts of Atlantic Canada at the rate of 0.3 metre per century (McCulloch, Forbes, and Shaw, 2002). Therefore, overall the sea level rise could be as high as 0.8 metre by 2100. As a result, some areas will sink, flood risk will be enhanced, and coastal erosion processes will be accelerated.

2.1.3. *Precipitation Related Effects*

Precipitation is an important indicator of climate change because it has a direct impact on agriculture and forestry. There is no unique measure of precipitation, and various studies usually use the annual average level of precipitation, summer national precipitation level or summer national dryness index (Galeotti, Goria, Mobrini, and Spantidaki, 2004; Shaw, 1996). It should be noted, however, that the annual average level of precipitation can be misleading. This is because an increased rainfall with a decreased snowfall can offset each other while calculating the average annual level of precipitation. Therefore, some caution should be taken while choosing the correct precipitation variable.

Precipitation in Atlantic Canada has increased and has become more volatile over the last 100 years. Specifically, an increase in precipitation has been registered since 1948 (Shaw, 1996). Cloud coverage has been increasing by 1 percent in the region since the beginning of the 1950's. Since that time, there has been a statistically significant increasing trend in the number of daily precipitation events above 20 mm, and a slightly increasing trend in the number of daily snowfall events above 15 cm (Canavan, 1996).

One positive effect of the increased total precipitation in the region is a reduced drought stress. At the same time, the downside of the increased precipitation is the problem of handling the excess of moisture. In addition, the increased variability of precipitation may result in greater fluctuations of crop yields and timber biomass (Danard, El-Sabh, and Murty, 1990; Bootsma, 1994).

2.1.4. *Extreme Weather Events*

Extreme weather events are usually ignored while modeling climate change impacts on the economy. Since extreme events do not occur on a regular basis, their impacts do not have a continuous pattern while most of the existing studies evaluate the economic climate change impacts based on the long-term, continuous patterns (Hallegatte, 2004; Peck and Teisberg, 1992; Tol, 1997). As Hallegatte (2005) put it *"in these models, climate change impacts on the economy are represented only through continuous and regular changes in the mean productivity, linked to the increase in temperature"*. Eventually such an approach leads to underestimated consequences of the climate change impacts due to ignoring consequences of the short-term, discontinuous extreme weather events. Actually the latter point sparked a discussion about the validity of the existing projections (Gerlagh and Papyrakis, 2003; Azar and Schneider, 2003).

Extreme weather events have enormous impacts on the economy in the year they occur. For example, in eastern Ontario, southern Quebec and New Brunswick the ice storm in winter of 1998 resulted in massive power outages affecting 4.7 million people. More than 600,000 people had to be evacuated from their homes, and there were 28 deaths and 945 injuries. Total damage was estimated as $5.4 billion (Government of Canada, 2005).

Most researchers in the field of climate change agree that extreme weather events will accompany the climate change patterns in the future. Moreover, according to the existing forecasts, they will become more frequent, unpredictable and severe. Technically, the problem of incorporating extreme weather events into climate change models is a problem of one-time shocks occurring irregularly imposed on climate change variables that are continuous time series. The existing long-run models do not take into account these one-time shocks (Goodes, Hanson, Hulme, and Osborn, 2003).

A few studies that do attempt to capture consequences of the extreme weather events are based on the Non-Equilibrium Dynamic Modelling. Non-Equilibrium Dynamic Models are long-run growth models that use a specific module to take into account extreme events with short-run dynamics (Hallegatte, 2005). This approach assumes that extreme weather events destroy physical capital, infrastructure and housing in the short-run.

Indeed, a decrease in the amount of physical capital due to an extreme weather event is instantaneous. When such an event occurs, it definitely decreases productivity in the short-run, and sometimes may affect the long-run dynamics of fundamental economic variables. Therefore, if such impacts are ignored, the long run consequences of climate change impacts will be evaluated incorrectly. That is why this study incorporates short-term extreme weather events while evaluating long-run consequences of the climate change impacts.

There are some other climate related variables that provide a more detailed picture of the climate changes. They include air pressure, wind velocity and direction, sunshine and cloudiness, fog, solar radiation, and sea surface temperature. However, all these variables alone cannot describe long-term patterns of climate change. They can only provide additional information if coupled with the above described variables. Therefore, in this study temperature, precipitation and sea level rise were used as primary climate related variables.

2.2. *Economic Models of Climate Change Impacts*

In terms of scale, all economic impact studies can be classified as global, regional and local, as well as those studies that focus on the impacts on a particular sector of the economy (Gambarelli, and Goria, 1994). Currently the majority of economic climate change impacts studies are either global or continental. Fewer of them disaggregate to the national level or beyond. This is not surprising since data availability plays a crucial role in these studies. While aggregate economic data on the national level is relatively easily available, obtaining disaggregate data becomes more and more problematic.

With respect to climate change impacts on individual sectors, typically the target economic sectors are agriculture, forestry and fishing, and transportation (Deschenes, and Greenstone, 2004). Transportation sector is primarily studied from the supply side prospective, and the major concern of the researchers is to determine to what extent climate change impacts affect transportation infrastructure.

As analysis of the existing literature shows, theoretically all economic models of the climate change impacts can be broadly divided in two categories: (i) partial equilibrium models, and (ii) general equilibrium models. Partial equilibrium models examine climate related impacts on different economic sectors separately. After impacts on individual economic sectors are estimated, they are summed up to obtain the overall climate impact on the economy as a whole (Gambarelli, and Goria, 1994; Mendelsohn, Dinar, Kurukulasuriya, Ajwad, 2004).

Alternatively, general equilibrium models evaluate consequences of climate change impacts on the entire economy by treating it as a system of integrated individual sectors (Kemfert, 2001; Roson, 1996; Darwin and Tol, 2001; Deke, Hooss, Kasten, Klepper, and Springer, 2002; Bosello, Lazzarin, and Tol, 2004). As a rule, such analysis captures the spillover effect of the direct climate change impacts through interaction of various economic sectors.

For example, using a dynamic computable general equilibrium model, Kemfert (2001) studied the overall economic effect of climate change impacts on nature, human health, forestry, water resources, and energy sector. Using a similar methodology, Scheraga *et al.* (1993) were able to obtain some useful results based on now obsolete climate change scenarios and impact studies. Studies by Tol and Darwin (2001) and Deke, Hooss, Kasten, Klepper, and Springer (2001) were dedicated to the climate change impacts on the coastal zone and agriculture. The advantage of computable general equilibrium models is that a researcher can trace the economy-wide consequences of different shocks, including climate related, to various economic sectors. Growth models can be another alternative as pointed out by Roson and Tol (2003): *"If the shock to the economy is uniform, and only affects investments, one might as well use a growth model"*.

However, there is one drawback associated with the computable general equilibrium models. Some of these models estimate the climate change impacts on international trade. In these models, output of a particular sector is stated as a composite commodity without separating exports from domestic consumption. Meanwhile, climate related shocks have different impacts on different sectors and geographical areas. Some sectors are more vulnerable than others and more integrated into domestic or global economy. Therefore, if this is the case, computable general equilibrium models may not correctly capture consequences of the climate change impacts.

In terms of microeconomic foundations, both types of models use the same techniques. The primary microeconomic techniques are hedonic price approach and production function approach. The hedonic price approach tries to measure the direct impacts of climate changes on inputs (factors) of production (Deschenes, 2004). By contrast, a production function approach attempts to measure climate change impacts on output of different economic sectors.

The hedonic price approach, also known as the direct cost approach, assumes that negative impacts of climate change can be approximated by the value of direct damages multiplied by the losses in corresponding factors of production due to climate change impacts (Bosello, Lazzarin, Roson, and Tol, 2004; Pearce, Cline, Achanta, Fankhauser, Pachauri, Tol, Vellinga, 1996; and Smith, Schellnhuber, Mirza, 2001).

One obvious advantage of the direct cost approach is that if markets for factors of production were perfectly competitive, then prices of these factors would reflect the present worth of the future output in the corresponding sectors of the economy. This approach is simple and relatively easy to use. However, it is based on the cost structure, which doesn't take into account demand side effects.

For example, suppose that the reproductive cycle of insects accelerates due to an increase in temperature, and, as a result, the insect population increases. A larger population of insects can destroy a larger number of trees. Timber supply decreases while timber demand in the short-run remains the same. The final outcome is an increase in the price of timber in the short-run and substitution of timber by other materials in the long-run. However, the direct cost approach would assume fixed price of timber over the entire study period. In addition, the direct cost approach overlooks the spillover effects when changes in one particular sector of economy (e.g. timber) affect other sector(s) (e.g. paper production).

The production function approach is based on empirical data that shows the effect of climate change indicators on the output of different sectors of the economy (Deschenes, and Greenstone, 2004). As Deschenes and Greenstone point out: *"The appealing feature of the experimental design is that it provides estimates of the effect of weather on [the sectoral outputs] that are purged of bias due to the determinants of these outputs that are beyond [human] control"*.

A typical model for estimating climate change impacts includes function $Q_{ij}(W, Y_i)$, where Q_{ij} is the so-called "impact index" for sector *i* in region *j*; *W* is a climate (weather) variable; and Y_i is per capita income. Usually Q_{ij} shows a fraction of annual output in region *j* that is lost due to climate change. To determine the impact of climate change over time, the model assumes that the future impact index takes the following form:

$$Q_{ij}(W, Y_i) = Q_{ij}(W)\left(\frac{Y_t}{Y_{t-1}}\right)^n \tag{2.1}$$

In (2.1), the impact index is represented by a loss function as a function of a climate variable multiplied by the income adjustment ratio to capture the demand side effect. The adjustment ratio is the ratio of current GDP per capita to the previous year GDP per capita, raised to the power *n*, where *n* is the income elasticity of the impact index. Collecting time-series data on per capita GDP and climate variable, and calculating the income elasticity of the impact index, it is possible to trace the climate change impacts on the economy over time (Nordhaus, Boyer, 1999).

In a microeconomic sense, this study uses the production function approach, however, coupled with the advanced time series analysis. The latter allows us to study interaction between transportation and regional economy over time.

3. Methodology and data

3.1. *Methodology*

Traditionally, transportation services are consumed by two broad groups: passengers and shippers of various commodities. That is why transportation demand is traditionally divided into demand for passenger transportation and demand for freight transportation. This report focuses on the demand for freight transportation in Atlantic Canada, and this chapter describes the methodology applied to study climate change impacts on the demand for freight transportation in Atlantic Canada.

3.1.1. *The Relationship between Freight Transportation and GDP*

Freight transportation is an important contributor to the Atlantic Canada regional economy. According to the Annual Report by Transport Canada, it contributes around 4.0% as measured by the value added by commercial transportation. To capture the importance of this, instead of treating transportation as a market, a more appropriate approach is to analyze it as a part of the regional economy.

According to economic theory, demand for transportation is a derived demand. It is derived as a by-product of profit maximization or cost minimization by producers of various commodities in relevant sectors of the regional economy. However, in general, it is not clear whether GDP enhances the volume of freight transportation in the regional economy or freight transportation increases GDP because the two are interrelated.

In statistical terms, there is no strong one-way causality between the regional GDP and the volume of freight transportation. Therefore, in such a case, it is appropriate to treat both variables as endogenous with the help of a vector autoregression (VAR). Typically, VAR is used to describe a causal relationship amongst mutually interdependent economic variables to study their evolution over time. It explains each variable by its own past values as well as the past values of all other variables included in the VAR. In a mathematical sense, the VAR is a statistical representation of a system's dynamics.

The traditional view on VAR requires all series included in the vector to be stationary. If they are not stationary, de-trending or differencing is typically applied. However, Sims (1980) and Doan (1992) recommend against de-trending and differencing even if the variables included in VAR contain a unit root. On the other hand, in order for VAR to be meaningful, all variables should be at least integrated of the same order. In our case, this means that it is necessary to test the last requirement for two series, GDP and volume of freight transportation in Atlantic region. The process is described below:

(i) The order of integration of the GDP time series Y_t.

First, we test whether or not the GDP time series has a unit root, and then, if it does, we test whether or not the first difference of GDP has a unit root. Therefore, the testing model is:

$$Y_t = \phi_0 + \phi_1 Y_{t-1} + \mu_{Y_t} \tag{3.1}$$

$$\Delta Y_t = \varphi_0 + \varphi_1 \Delta Y_{t-1} + \nu_{Y_t} \tag{3.2}$$

(ii) The order of integration of the volume of freight transportation time series T_t:

We have to repeat the steps describe above, but with respect to the T_t series. This pre-testing must precede the VAR analysis.

Since in our case, VAR represents an economic system, its specification has to be based on economic theory or at least has to have a rigorous economic justification. After pre-testing, this can be done through the so-called structural VAR.

Structural VAR is a system of simultaneous equations describing an economic system's dynamics on the basis of economic theory. A system's dynamics implies that an increase in the value of one economic variable affects all variables in the system in all future periods. In other words, an increase in output in a given time period will increase output and all associated variables in all future periods.

In this study, the system was formulated as follows. Since freight transportation is a part of the regional economy, it is reasonable to assume that the regional GDP time path is affected by current and past realizations of the volume of freight transportation and, at the same time, the time path of the volume of freight transportation is affected by current and past realizations of GDP. If Y_t is regional GDP in time period t and T_t is the volume of freight transportation in the region in time period t, then the following system arises:

$$Y_t = b_{10} + b_{11} T_t + \gamma_{11} Y_{t-1} + \gamma_{12} T_{t-1} + \varepsilon_{Y_t} \tag{3.3}$$

$$T_t = b_{20} + b_{21} Y_t + \gamma_{21} Y_{t-1} + \gamma_{22} T_{t-1} + \varepsilon_{T_t} \tag{3.4}$$

In this system, ε_{Y_t} and ε_{T_t} are pure innovations or independent productivity shocks. In classical structural VAR they are called random uncorrelated structural disturbances

(Enders, 1995; Gordon and Boccanfuso, 2001). Hence, ε_{Y_t} is a pure productivity shock in the regional economy as a whole, while ε_{T_t} is a pure productivity shock in the transportation sector.

In turn, VAR in standard form, which can be derived from the system (3.3)-(3.4), is:

$$Y_t = a_{10} + a_{11}Y_{t-1} + a_{12}T_{t-1} + e_{1t} \tag{3.5}$$

$$T_t = a_{20} + a_{21}Y_{t-1} + a_{22}T_{t-1} + e_{2t} \tag{3.6}$$

Notice that, in equations (3.5) and (3.6), error terms e_{1t} and e_{2t} are composites of the two shocks ε_{Y_t} and ε_{T_t} expressed as:

$$e_{1t} = \frac{1}{1-b_{11}b_{21}}\varepsilon_{Y_t} + \frac{b_{11}}{1-b_{11}b_{21}}\varepsilon_{T_t} \tag{3.7}$$

$$e_{2t} = \frac{b_{21}}{1-b_{11}b_{21}}\varepsilon_{Y_t} + \frac{1}{1-b_{11}b_{21}}\varepsilon_{T_t} \tag{3.8}$$

Since the main goal of this study is to measure climate change impacts on demand for freight transportation through productivity shocks, it was postulated that these shocks have long run impacts on the variables in the model. Furthermore, in order to separate demand side shocks from supply side shocks, the following two assumptions were added:

Assumption 1: Transportation has no contemporaneous effect on GDP

The assumption says that the volume of freight transportation *T* depends on income *Y* (as any demand does) in period *t* but GDP or *Y* does not depend on the current volume of freight transportation because such dependence comes from the supply side. However, in the next period GDP does depend on the current volume of freight transportation. This assumption underlines the idea that only demand for freight transportation effect is taken into consideration. Mathematically, the assumption implies $b_{11} = 0$. Actually, in order to recover structural VAR from standard VAR, $(n^2 - n)/2$ restrictions should be imposed where n is the number of variables in VAR. In our case when $n = 2$, one restriction must be imposed which is $b_{11} = 0$. Moreover, this restriction is totally consistent with economic theory and the goal of this study.

Assumption 2: There are no productivity shocks in the transportation sector itself.

With this assumption transportation supply side shocks are ignored. Mathematically, it implies that $\varepsilon_{T_t} = 0$.

As a result of the above two assumptions:

$$e_{1t} = \varepsilon_{Y_t} \tag{3.9}$$

$$e_{2t} = \rho\varepsilon_{Y_t} \tag{3.10}$$

in which ε_{Y_t} reflects productivity shocks in sectors other than transportation, and ρ is the correlation coefficient between the overall productivity in the regional economy and the volume of freight transportation demanded. The two systems of equations (3.5), (3.6) and (3.9), (3.10) combined show that the demand for freight transportation is driven by the overall productivity shock ε_{Y_t}.

3.1.2. *Dynamic Analysis of Climate Change*

Climate has an important effect on our every day life. The 20th century was the warmest century in the history of mankind. Moreover, the 1990s were the warmest decade of the last century (Climate Change Plan for Canada, 2002). However, in order to make meaningful conclusions about climate change, it is necessary to establish an analytical framework and then test the hypothesis of the climate change statistically. In this study, a method to be designed looks for a structural break in climate variables as a one-time jump in the trending time series. The statistical model for this method can be presented as follows:

$$C_t = \lambda_0 + \lambda_1 C_{t-1} + \eta_1 D_t + \upsilon_t \tag{3.11}$$

where C_t is a climate vector in period *t*, D_t is a dummy variable of time and υ_t is the error term. In order to detect the break year, we need to test each year within a specified period as follows: set the dummy variable equal to 1 for all years since that year and to 0 otherwise. According to Yevdokimov (1998), the break year should satisfy the following criteria:

- The t-value of the coefficient η_1 should be higher than 1.96, which is the Student's critical value at 95% significant level.
- If the above criterion is satisfied, then the break year is the one in which t-value and R^2 are the highest.

Finding the break year is necessary to ensure that there was a real change in the dynamics of climate related variables. On the other hand, it can provide us with the right specification of climate change as a productivity shock

3.1.3. *Climate Change Measured As Productivity Shocks*

The primary goal of this study is to analyze the climate change impacts on demand for freight transportation in Atlantic Canada as productivity shocks. Following the methodology, introduced by Blanchard and Quah (1989) on decomposition of productivity shocks, in this study the aggregate productivity shock is decomposed into (i) aggregate, climate-unrelated productivity shock, (ii) climate-related productivity shock, and (iii) other influences:

Productivity shock = aggregate, climate-unrelated productivity shock
+ climate-related shock + other influences

In addition, extra assumptions were made to be able to capture the climate-related productivity shock. They are:

Assumption 3. Aggregate, climate-unrelated productivity shock is permanent and time invariant.

Assumption 4. Climate-related productivity shock depends on climate variables such as temperature, precipitation, sea level and others expressed by vector C.

Assumption 5. Climate-related productivity shock is permanent and autoregressive, which reflects its cumulative dynamic nature.

Assumption 6. Other influences are totally random events. Statistically, they can be specified as a white-noise process with zero mean and constant variance.

Given these assumptions, mathematically the decomposition can be presented as:

$$e_{1t} = \varepsilon_{Y_t} = \alpha_0 + \alpha_1 C_t + \alpha_2 C_{t-1} + \mu_t \qquad (3.12)$$

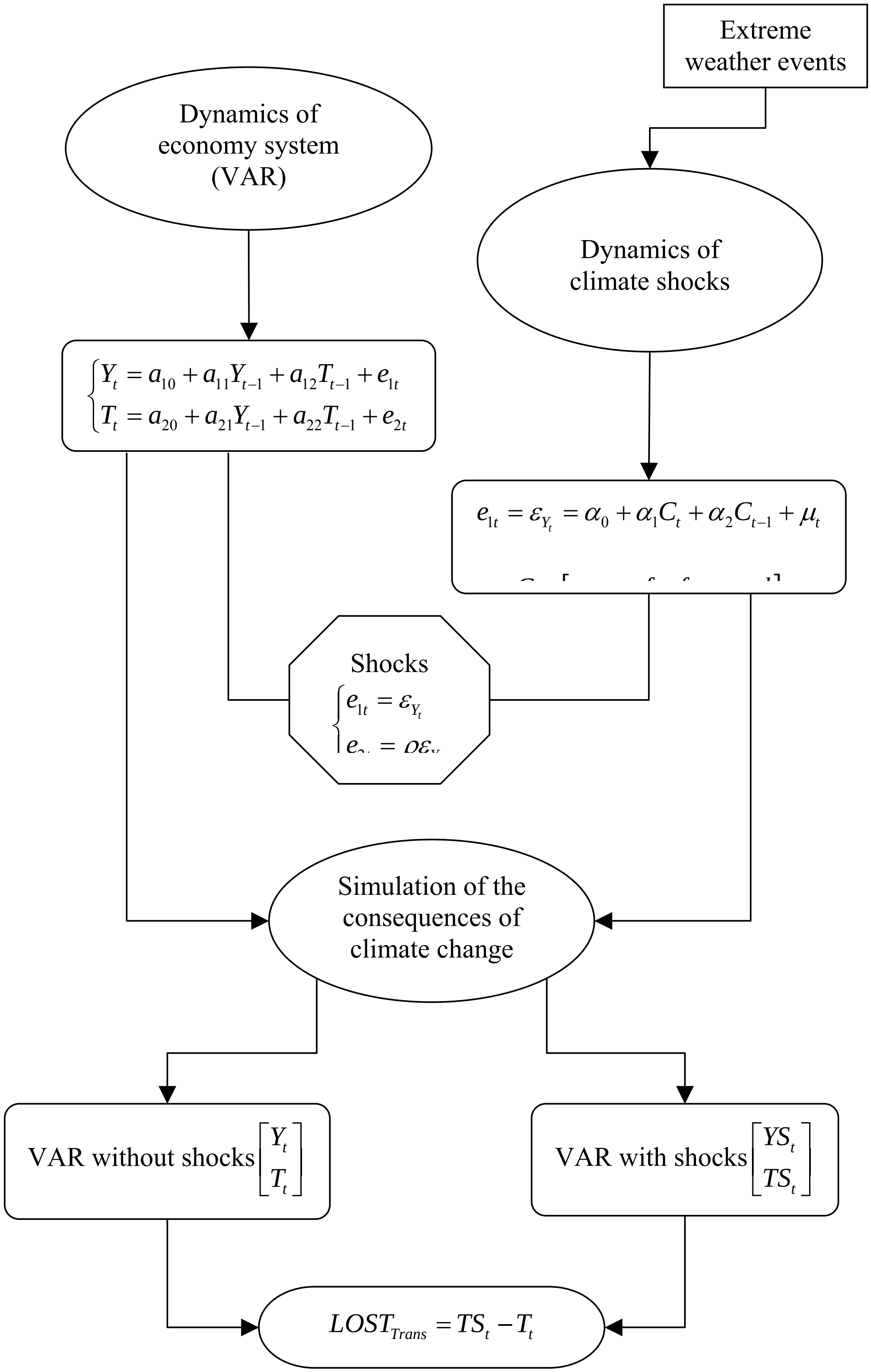
where α_0 is the aggregate, climate-unrelated productivity shock, C is the vector of climate related variables which, in our case, includes mean temperature, total rain fall, total snow fall, total precipitation and sea level adjusted for variations in atmospheric pressure in Atlantic Canada, and μ_t is the white-noise process.

3.1.4. *Productivity Shock Dynamics in the VAR Model*

In order to trace consequences of the climate change impacts on the demand for freight transportation over the 21st century, impulse response functions can be applied. In our case, we need to model the response of economic system, represented by the VAR, to the climate-related shock, using the shock's dynamics obtained in section 3.1.3. Comparing it with the dynamics of the economic system without the shock, we can derive a loss function, which will illustrate the consequences of the climate change impacts for the demand for freight transportation. In addition, the effect of extreme weather events should be organically incorporated.

The following flow chart summarizes the simulation process:

Figure 3.1 Flowchart of Simulating Consequences of Climate Change from 2001 to 2100



3.2. *Data*

There are two sets of data involved in this study. The first one is related to the economic system, which includes regional GDP and volume of freight transportation. The second one reflects climate related variables.

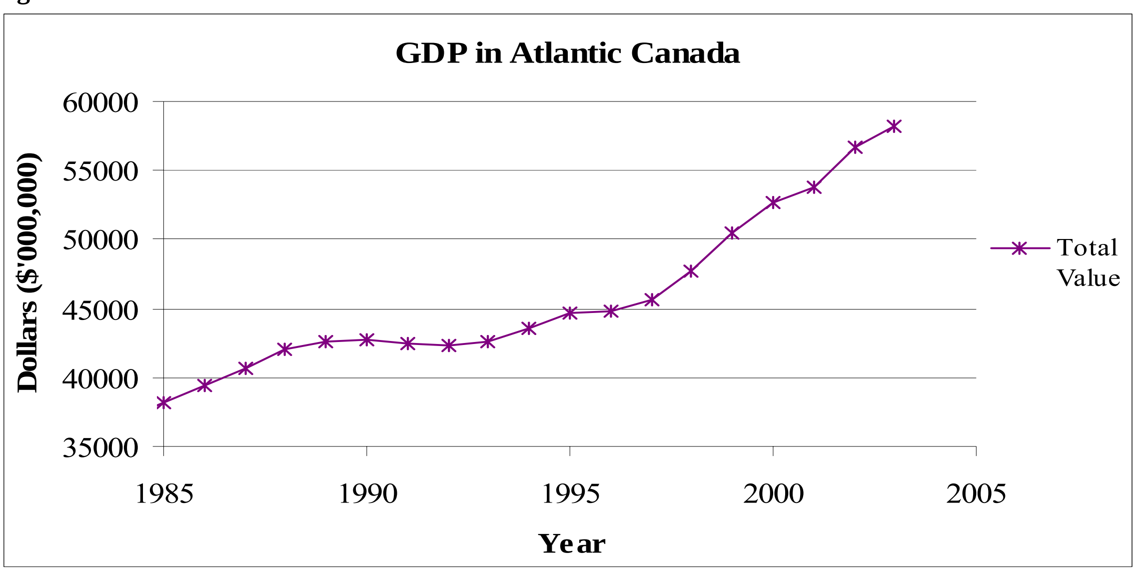
3.2.1. *Atlantic Canada GDP and Volume of Freight Transportation*

The data on GDP and volume of freight transportation were collected from Statistics Canada in the interval from 1985 to 2002.

3.2.1.1. *GDP Data in Atlantic Canada*

The data source of GDP (see Table 4) is Statistics Canada, CANSIM II. The following figure shows the calculated Atlantic Canada GDP in 1997 constant dollars.

Figure 3.2 GDP Growth of Atlantic Canada in 1997 constant dollars



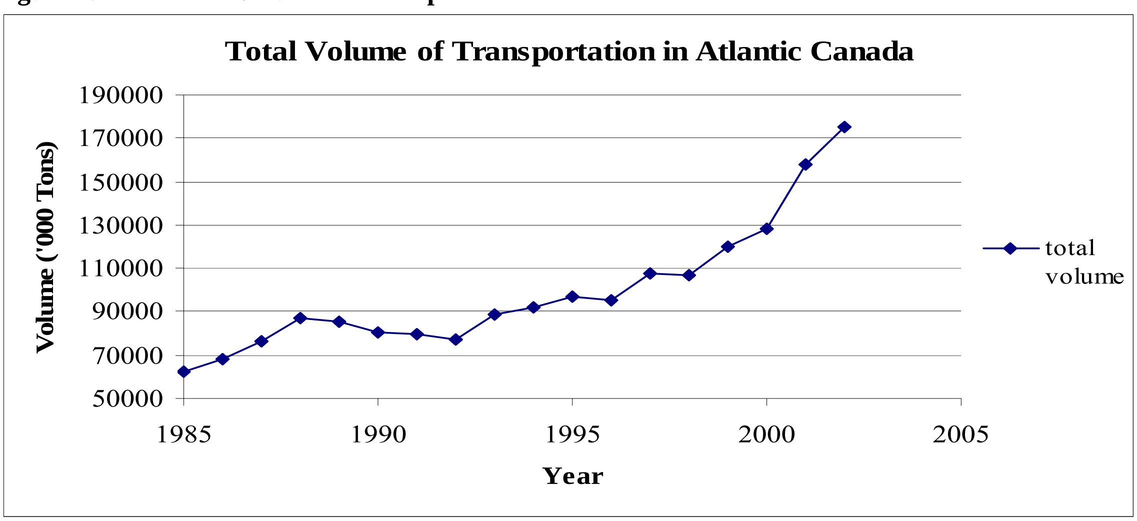
Source: Statistics Canada and CANSIM II

It is easy to see that the Atlantic Canada GDP has been growing since 1985. Figure 3.2 shows that there was a recession at the beginning of 1990s, however the economy in Atlantic region has grown rapidly since 1996. By the end of 2002, GDP increased by 26% compared to the value in 1996. The basic reason for that was a dramatic increase in mining, oil and natural gas sectors of the regional economy. After 1996, the offshore gas and oil deposits located in Newfoundland started to produce hydrocarbon products. During only six years, production in mining, oil and gas sectors has increased by 194% to $3,276 million. Without a doubt, it is one of major contributions to the growth of GDP in Atlantic region within the study period.

3.2.1.2. *Volume of Freight Transportation Data in Atlantic Canada*

In this study, four modes of freight transportation are covered: trucking, rail, shipping and air. As mentioned previously, transportation in Atlantic region plays an important role. Now this conclusion can be verified by the data. As shown in Figure 3.3 below, the volume of freight transportation tonnage time series has almost the same shape as the Atlantic Canada GDP. There was a recession at the beginning of 1990s, and then the volume of freight transportation has been growing faster since 1996.

Figure 3.3 The Total Volume of Transportation in Atlantic Canada



Source: Trucking in Canada, Rail in Canada, Shipping in Canada, and Air Carrier Traffic at Canadian Airports, Statistics Canada

Unlike the GDP data, the information on volume of freight transportation in individual provinces is incomplete. For example, Trucking in Canada and Rail in Canada do not include provincial data. Therefore, it is impossible to study the dynamics of the system at provincial level without some additional assumptions.

In this study, the transportation data are measured as traffic volume. In order to make each mode of transportation comparable, I did not use a tonne-kilometre as a unit, although tonne-kilometre is a standard measurement. Instead, I chose tonnage, because only this measurement was available for each mode in Statistics Canada database. For example, Statistics Canada does not provide data in tonne-kilometres for shipping and air, but does for trucking and rail.

3.2.1.2.1. *Trucking*

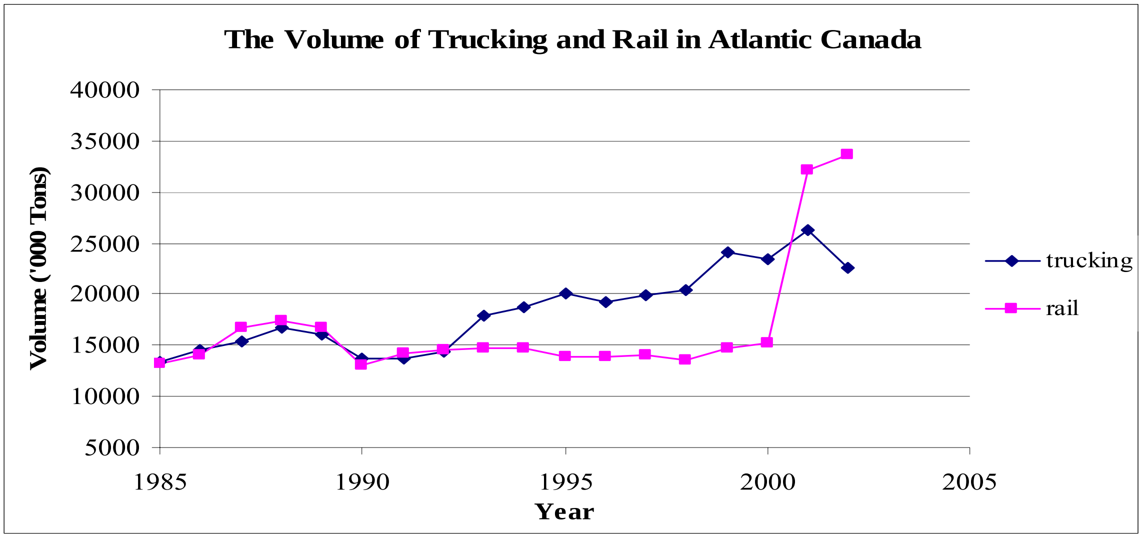
In general, the Canadian trucking industry includes two components, for-hire and private trucking. By definition given in *Trucking in Canada*, for-hire carrier means any carrier, which undertakes transport of goods for compensation, and private carrier reflects owners/operators of motor vehicles carrying their own freight (Trucking in Canada 2003). Also, in the introduction to the for-hire trucking survey, it divides all carriers into three classes, class I, class II and class III. Here, class I refers to carriers with revenues of $3 million and more, class II defines carriers with revenues of $350,000 to $2,999,999, and class III means carriers with revenues of $100,000 to $349,999 (Trucking in Canada, 2003).

In this study, only the data on for-hire trucking in class I and class II (refer to Table 6) were collected. Of course, if the private trucking were included, it would reflect the structure of trucking industry much better; however, it accounts for only a small share in trucking. In addition, from 1989 and on the data on private careers is not available.

The data on trucking in this study includes the domestic traffic which is transported within intra- and inter-regional and international traffic which is transported between either Canada and U.S. or Canada and Mexico. In 1987, Canada-US Free Trade Agreement was established which removed several trade restrictions to increase cross-border trade. At that moment, a special fund was granted to Statistics Canada to use for collecting international trade data between Canada and U.S. Therefore, the data before 1987 are not available from the International Merchandize Trade database (Trucking in Canada, 1986). Under these circumstances, an approximate amount of the volume of freight transportation in 1985 and 1986 was calculated by comparing the volume of private trucking between Canada and U.S., and using simple time series analysis.

Figure 3.4 shows the resulting volume of trucking from 1985 to 2002. We can see that since there was a recession at the beginning of 1990s, it affected the transportation sector as well. On the other hand, unlike GDP, trucking volume has been growing at a slower rate. The reason for that is that production of mining, oil and gas sectors is not shipped by trucks.

Figure 3.4 Total Volume of For-Hire Trucking, Class I & II, and Rail in Atlantic Canada, Classes I



Source: Trucking in Canada, Statistic Canada

3.2.1.2.2. *Rail*

Rail transportation in this study includes the data from Canadian National Railway and Canadian Pacific Limited which are classified into Class I. As with trucking, the database of rail transportation (refer to Table 7 in the Appendix) has two parts. One is the domestic shipping, including intra- and inter-regional carriers. Another one is international carriers, commonly, transport between Canada and U.S.

According to Figure 3.4, the volume of rail transportation decreased at the beginning of 1990s because of the depression in Atlantic economy. But, when other sectors moved from recession to growth, the volume of rail did not have a positive change until 2001. As we can see from Figure 3.4, the rail transportation had a sizable increase in 2001. The volume doubled compared to the 2000 volume. The giant jump within one year was almost 17 million tonnes of iron ore, in addition, concentration and around 400 thousand tonnes of mixed carloads or unidentified freight were transported from Atlantic to Quebec. Based on the number shown in *Rail in Canada* 2001, 95.9% of the total tonnage carried from Atlantic to Quebec was iron ore and concentration. They also represented 68.5% of all commodities originating from Atlantic region (Rail in Canada, 2001).

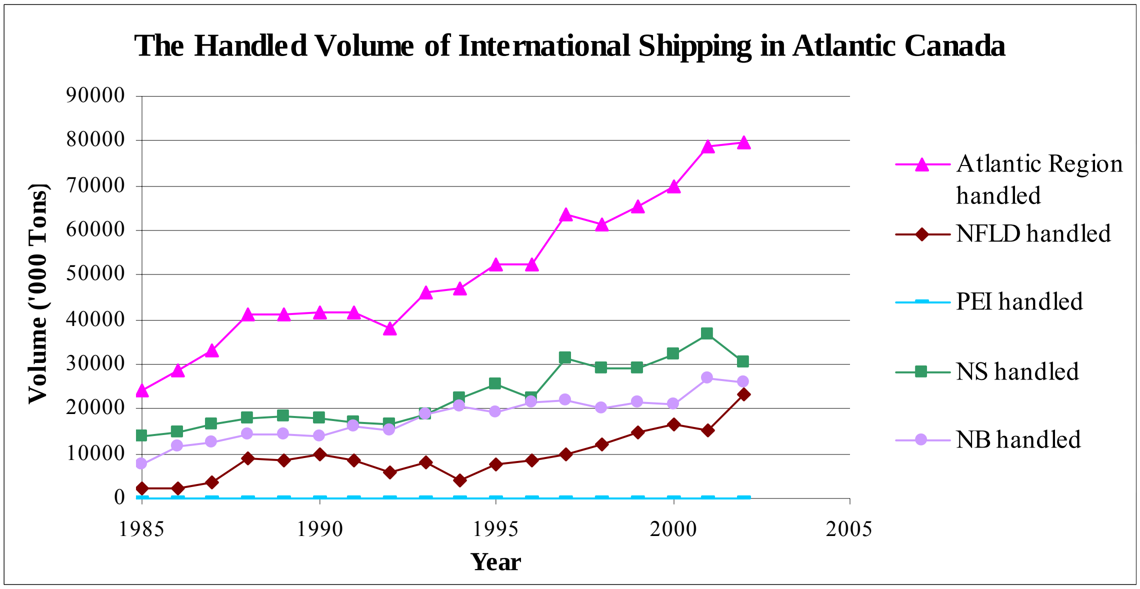
3.2.1.2.3. *Shipping*

Again, the data on shipping has two components, domestic shipping and international shipping. Domestic shipping refers to commodities delivered from one port to another within Canada. International shipping transports commodities to all over the world, such as Europe, Middle East, Asia, and so on.

In *Shipping of Canada*, the volume is specified in cargo tonnage loaded, cargo tonnage unloaded and cargo tonnage handled. Cargo tonnage loaded is freight that arrives to a port by rail or truck and is uploaded to ships for transportation to other ports. Cargo tonnage unloaded is a cargo that arrives to a port by ships and is offloaded from ships to rail or trucks for delivering to somewhere else. Cargo tonnage handled reflects cargo loaded and unloaded from a port. To capture the real volume handled in a port, we use the measurement of cargo tonnage handled.

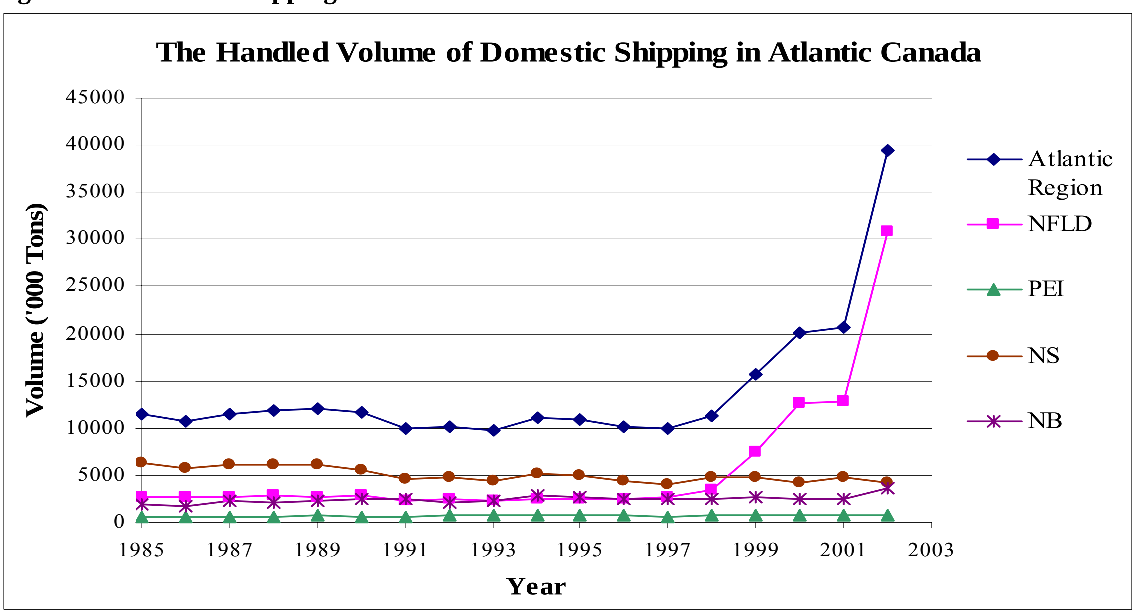
Statistics Canada has a full set of shipping data, which is useful to analyze shipping trends by province (full data is shown in Table 8 and Table 9 in the Appendix). Figure 3.5 and Figure 3.6 show the international and domestic shipping, respectively. For the international part, the volume of shipping grows over time in Atlantic region, even though there was a small decrease at the end of 1980s as well as at the beginning of 1990s, which reflected the economy’s recession. Except for PEI, where there is almost zero international shipping, other provinces continuously increased their shipping volumes. Compared to international shipping, I find that domestic shipping increased dramatically. From 2001 to 2002, it increased by 90%. This jump was driven by the production of the offshore oil field in Newfoundland, which is shown in Figure 3.6. Without this contribution from Newfoundland, the volume of shipping in Atlantic region would have no growth. Moreover, it might even have decreased over time.

Figure 3.5 International Shipping in Atlantic Canada



Source: Shipping in Canada, Statistics Canada

Figure 3.6 Domestic Shipping in Atlantic Canada



Source: Shipping in Canada, Statistics Canada

3.2.1.2.4. *Air*

Air freight transportation in Atlantic Canada represents a tiny portion of the total volume of freight transportation. Based on the data collected from *Air Carrier Traffic at Canadian Airports* (refer to Table 10 in the Appendix), the ratio of the volume of air transportation to the volume of total transportation decreased from 0.06% in 1985 to 0.01% in 2002. Because of its insignificance, in this study air freight transportation is ignored.

3.2.2. *Climate Related Data in Atlantic Canada*

Collecting climate data is a more complicated job. Basically, 14 stations located in Atlantic region (see Table 1) were selected by considering their longitudes and latitudes and the time period from 1950 to 2002.

Table 1 The List of Stations Located in Four Provinces within Atlantic Canada

No.	New Brunswick	Nova Scotia	Newfoundland	PEI
1	Doaktown	Annapolis royal	Corner brook	Alliston
2	Fredericton	Collegeville	Gandr int'l	Charlottetown
3	Miramichi	Halifax	St join's	n/a
4	Moncton	Sydney	n/a	n/a
5	St. John	n/a	n/a	n/a

Source: Climate CD-ROM, 2002 CDEX East CD, Environment Canada

The World Meteorological Organization (WMO) recommends that, in order to classify a region's climate, countries should use climate normals as a calculation method. By definition, climate normals refer to arithmetic calculations based on observed climate values for a given location over a specified time period. To achieve climate normals, WMO established a rule called "3 and 5 rule" as a guideline for calculation. They defines: "*for normals values representing averages, such as temperature, a month was not used if* *more than 3 consecutive days or more than a total of 5 days were missing*; *for normals values representing totals, such as precipitation, degree-days, or days with, an individual month was required to be 100% complete in order for it to be included in the normals calculation"* (Environment Canada website). Once the monthly mean values are determined, the similar rule is applied to the total values in the 30-year period, in which WMO considers that is long enough to eliminate year-to-year variations. In this study, in order to close to the standard WMO requirement, we applied "3 and 5 rule" to both mean temperature and total precipitation's calculation in the 53-year period.

After processing (refer to Table 11 in the Appendix), the data included four climate variables: average mean temperature measured in centigrade, average total rain fall measured in mm, average total snow fall measured in cm, and average total precipitation measured in cm and sea level measured in cm.

In general, mean temperature, rainfall, snowfall, total precipitation and sea level are good enough to capture the whole picture of climate change (see section 2.1). The data shows that, from the beginning of 1980s or earlier, there is a change in climate (more detail please refer to Chapter 4). Temperature tends to go up, or as many researchers pointed out, weather becomes warmer (Harry Caldwell et. al., 2002). The maximum annual average temperature increased to around 7 centigrade by 1999. Rainfall, snowfall and total precipitation have decreased. In many cases, the dry weather in Atlantic region has prevailed. The minimum annual average of rainfall, snowfall and total precipitation were 2mm in 2001, 0.64cm in 1996, and 3.03cm in 2001 repetitively. This phenomenon can be explained by the Greenhouse Effect. In the future, according to some models, global warming due to the Greenhouse Effect will affect precipitation including rainfall and snowfall causing them to decrease. The sea level according to Byelyayev (2005) has been increasing over time. It is a common sense that the warmer weather causes ice to melt which increases the sea level. As shown in the sea level data in the appendix, the maximum level was up to 179.5cm in 1999.

4. Results of Computer Modelling

4.1. *Dynamics of Economic System*

4.1.1. *The Order of Integration of Y_t and T_t Series*

According to the methodology described in section 3.1.1, in order to set up a VAR model, we have to pre-test the integration order of series included in the VAR. First, let us define the order of integration of the GDP series Y_t.

A simple Dickey-Fuller (DF) test was applied to test whether or not the coefficient ϕ_1 of Y_{t-1} in equation (3.1) is less than one. The OLS estimation produced the following relationship:

$$Y_t = \text{-}4051.207 + 1.115515 Y_{t\text{-}1} \qquad (4.1)$$
$$Test\text{-}value = 2.404 \quad 10\% \ critical \ value = \text{-}2.630$$

Under the DF test, the null hypothesis is that the GDP series contains a unit root while the alternative is that the GDP series is generated by a stationary process. Based on the obtained results, the null hypothesis was not rejected at the 10% level. Moreover, DF test statistic (test-value) is a positive number, which directly points to non-stationarity of the series. Therefore, we can conclude that GDP series has a unit root.

Second, let us now test the first difference series for a unit root or whether or not the coefficient φ_1 of ΔY_{t-1} in equation (3.2) is less than one. OLS estimation shows the following result:

$$\underset{}{\Delta Y_t} = \underset{(1.27)}{385.9835} + \underset{(3.00)}{.7003714}\Delta Y_{t\text{-}1} \tag{4.2}$$

in which t-values are reported in the parenthesis. This result means that the first difference series does not contain a unit root. Therefore, the GDP series is obviously integrated of order one or it is $I(1)$.

The procedure was repeated for the volume of freight transportation series T_t, and the results are reported below:

$$T_t = \text{-}11367.92 + 1.190315 T_{t\text{-}1} \tag{4.3}$$

$$Test\text{-}value = 2.334 \quad 10\%\ critical\ value = \text{-}2.630$$

$$\Delta T_t = \underset{(1.76)}{4862.957} + \underset{(1.14)}{.307925}\Delta T_{t\text{-}1} \tag{4.4}$$

Again, we cannot reject the null hypothesis of a unit root at any level for the level variable T_t, but can for the first difference variable ΔT_t. This implies that the volume of freight transportation series is also $I(1)$. Hence, the test results satisfy the requirement for VAR to include Y_t and T_t in order to analyze the dynamics of the economic system under study.

4.1.2. *Vector Autoregression (VAR) Model*

In section 4.1.1, a DF test showed a unit root in GDP and volume of transportation series, which implies that GDP series and the volume of transportation series do not converge to the long run equilibrium over time. Figure 3.2 and Figure 3.3 in section 3.1.1 also tell us the same story. GDP and volume of transportation in Atlantic region began to speed up from the mid 1990s, although they grew up slowly, even decreased at the beginning of 1990s. To reflect this situation, the non-stationarity and different growth rates in different time periods, it is necessary to make an adjustment to the VAR model described in section 3.1.2 In an econometric sense, the following specification can be applied:

$$Y_t = a_{10} + a_{11}Y_{t-1} + a_{12}T_{t-1} + b_{11}t + b_{12}D \cdot t + e_{1t} \tag{4.5}$$

$$T_t = a_{20} + a_{21}Y_{t-1} + a_{22}T_{t-1} + b_{21}t + b_{22}D \cdot t + e_{2t} \tag{4.6}$$

In this specification, the time trend *t* reflects the fact that Y_t and T_t series are trend non-stationary[1]. Non-stationary is divided into difference non-stationary and trend non-stationary. The reasons that this system is not difference non-stationary are that, according to the economic growth process in Atlantic Canada, the potential GDP and transportation, one sector of economy, grow over time. But, for the difference non-stationary, the potential GDP and transportation should remain the same, especially in the short run. In addition, the difference non-stationary reflects a random walk, which, in fact, describes a short-run fluctuation. In such a case, it is not good enough to predict the long run trend, the goal of this study. Therefore, Y_t and T_t series are trend non-stationary. If this trend were removed, the two series would become stationary. However, we keep the trend because it is an integral part of the model containing the long memory of the system

[1] We did not test trend non-stationary statistically, since the result may not be creditable when there are only seventeen observations. If more data resources are available, we believe the test will prove these two series are trend non-stationary.

as suggested by Sims (1980). In such a case we partially satisfy the stationarity requirement[2] of the traditional approach to VAR as well as the Sims' approach.

To reflect the different growth speed in Atlantic Canada from 1985 to 2002, we set a dummy variable D equal to 1 if the year is greater than 1994 and 0 otherwise. And then, we create an interaction variable named $D \cdot t$. It is the Dummy variable D multiplied by year t to explain the faster growth rate of GDP and transportation in Atlantic region since 1995. Hence, the trends of Y_t and T_t series will be captured by variable t before 1995 and by variable $D \cdot t$ for 1995 and after. In other words, the trend has a kink in 1995.

In an economic sense, this specification implies that (4.5) equation above, the part $a_{10} + a_{11}Y_{t-1}$ captures the short-run fluctuations of real GDP around the potential GDP, represented by the $b_{11}t + b_{12}Dyr$ term. In turn, the error term e_{1t} represents the resulting dynamics of different shocks. Therefore, if VAR in this form is estimated and the residuals are saved, they can be used to extract the productivity climate related shock.

Using STATA, the outcome of the VAR estimation is:

$$Y_t = 5819.235 + .8546623Y_{t-1} + .0469025T_{t-1} - 70.07892t + 19.26918D \cdot t \qquad (4.7)$$

(1.17) (4.24) (1.52) (-0.56) (1.27)

$$R^2_{GDP} = 0.9789$$

$$T_t = -85898.38 + 4.034321Y_{t-1} + .6120389T_{t-1} - 1163.935t + 92.38876D \cdot t \qquad (4.8)$$

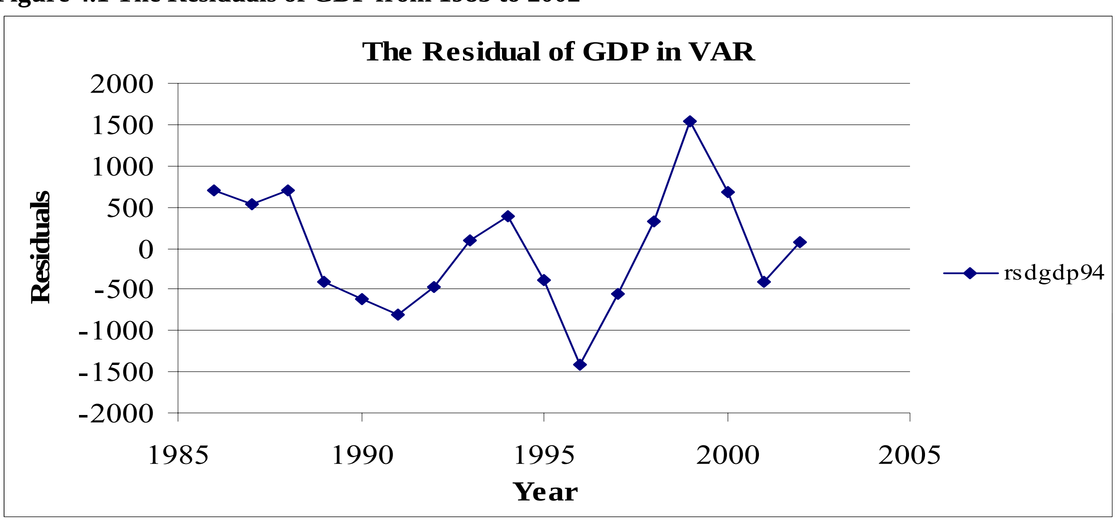
(-1.88) (2.18) (2.16) (-1.02) (0.67)

$$R^2_{Trans} = 0.9491$$

[2] Because the Y_t series is stationary around the trend

High values of R^2 for both equations show that the system we introduced captures dynamics of GDP and volume of freight transportation pretty well. It should be noticed that t-values of some variables (showed in the parentheses) are small. According to traditional statistics point of view, those variables should be dropped, but the aim of this study is to analyze the whole economic system, thus, we need to pick a model which can highly explain the system. For example, if we drop the insignificant variables T & $D \cdot t$, the R^2 for the first equation of the dynamics is 0.9767 which is smaller than the R^2 in equation (4.7), and the R^2 for the second equation is 0.9460 which is smaller than the R^2 in equation (4.8) as well. If we drop $D \cdot t$, then the R^2 for the first equation is 0.9769 and 0.9478 for the second equation. Therefore, the best model to capture the dynamics is the one described in equation (4.7) and (4.8), and the residuals of equation (4.7) can reasonably explain productivity shocks. Figure 4.1 presents these residuals. As described in section 3.1.3, climate-related shock is one of the components of aggregate productivity shock reflected in these residuals.

Figure 4.1 The Residuals of GDP from 1985 to 2002



4.2. *Dynamics of Climate Related Variables*

The climate vector, mentioned in 3, includes five variables: temperature, rainfall, snowfall, total precipitation, and sea level. In order to study dynamics of climate related shocks we have to understand the dynamics of climate related variables.

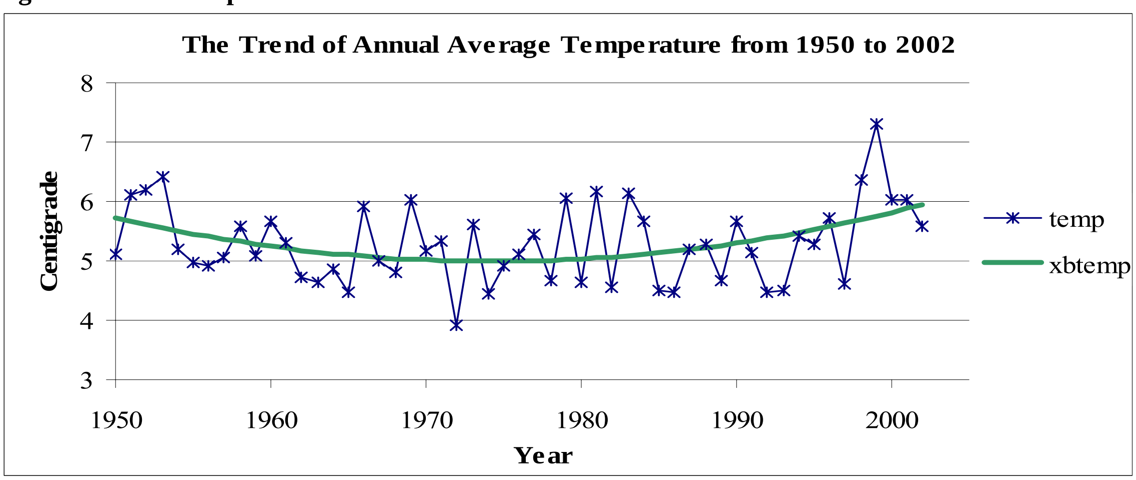
4.2.1. *Mean Temperature*

In order to better illustrate the dynamics of the mean temperature series, the time trend was obtained on the basis of the following regression:

$$\underset{}{Temp_t} = \underset{(21.87)}{5.786594} - \underset{(-2.78)}{.0628477t} + \underset{(3.06)}{.0012413t^2} \qquad (4.9)$$

where the t-values are shown in parentheses. The blue line in Figure 4.2 below is the real temperature while the green line is the fitted line from regression (4.9).

Figure 4.2 The Temperature Trend in Atlantic Canada



According to the graph, there was a cooling from 1950s to 1970s, then the mean temperature remained constant for a few years, but beginning from 1980s, the weather in Atlantic Canada has been warming up. It is also possible to detect the precise dynamics using statistical techniques that were introduced in section 3.1.2. Our study period in this case is from 1950 to 2002.

First, a one-time jump in the series was tested. The results show that the break year in such a case is 1998 with the coefficient, t-value and adjusted R^2 of the dummy variable 1.14, 3.74 and 0.20, respectively. However, because 1998 is close to the end of our study period, the outcome of this method may be biased. Therefore, the model was adjusted as follows:

$$C_t = \lambda_0 + \lambda_1 Temp_{t-1} + \eta_1 Temp_{t-1} \cdot D_t + \upsilon_t \qquad (4.10)$$

In this case, the break year for the mean temperature is still 1998. The coefficient η_1, its t-statistics and adjusted R^2 are 0.19, 3.73 and 0.20 respectively. This result shows that the slope of the mean temperature series changes counter-clockwise. However, because of the same reasons this outcome can be biased.

Therefore, the third model was introduced:

$$C_t = \lambda_0 + \lambda_1 Temp_{t-1} + \eta_1 D_t + \eta_2 Temp_{t-1} \cdot D_t + \upsilon_t \qquad (4.11)$$

In this model, not only the intercept of the mean temperature changes, but also the slope changes. Under this model, the break year is 1986 with $\eta_1 = -2.927449$ and $\eta_2 = 0.5811813$, and their t-values -1.99 and 2.11 respectively. This break year is completely supported by Figure 4.2. More detailed results of the regression (4.11) are shown at the end of this report (Table 12 and Table 13). Probably there was another break year in 1998 but our time series does not allow us to make this conclusion statistically.

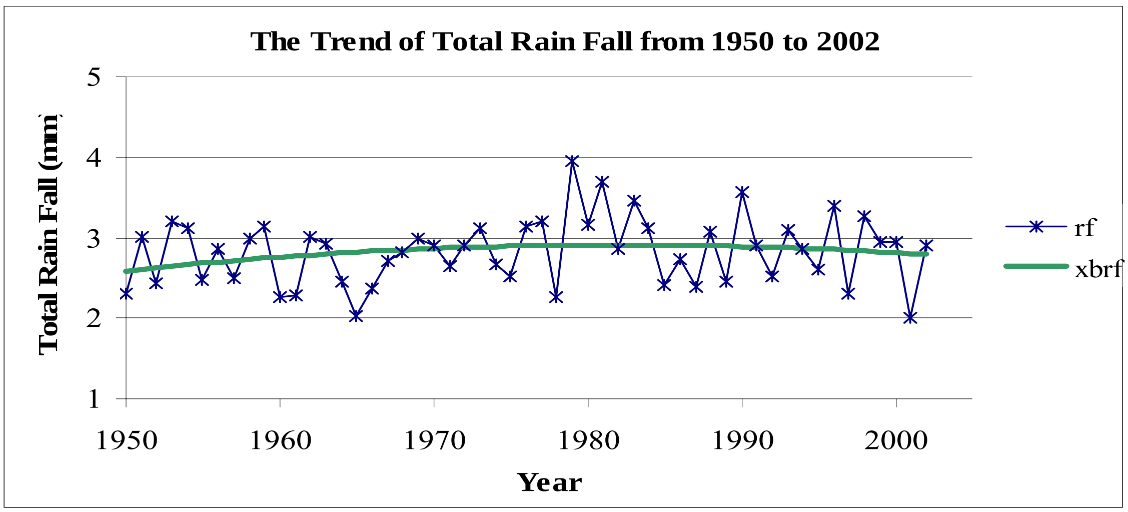
4.2.2. *Total Rainfall*

Figure 4.3 shows that rainfall (the blue line) was increasing from 1950s, and then it became steady in 1980s. After that rainfall started to decrease. The green line is the fitted line that comes from:

$$\underset{}{rf_t} = \underset{(14.53)}{2.571066} + \underset{(1.36)}{.0205541t} - \underset{(-1.14)}{.00031t^2} \tag{4.12}$$

with t-values shown in parentheses. Since t-values are small, rainfall cannot be explained by time trend.

Figure 4.3 The Rain Fall Trend in Atlantic Canada



Following the method described in section 3.1.2, the regression outcome pointed to 1976 as the break year with the coefficient of dummy variable of time, t-value and adjusted R^2 of 0.23, 2, and 0.05 respectively.

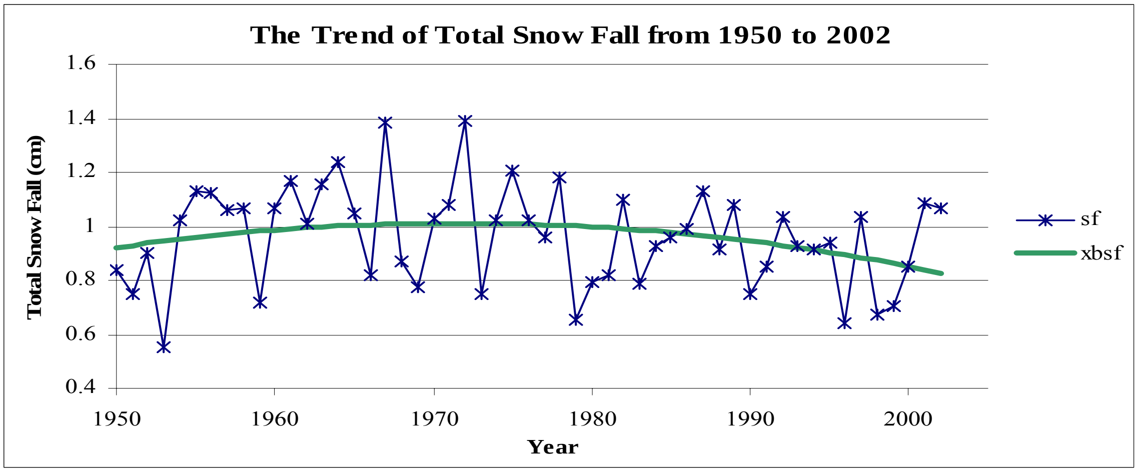
4.2.3. *Total Snowfall*

Total snowfall series has followed inverted U-shape. It increased from 1950s to mid-1970s, remained constant until 1980s and decreased afterwards. The fitted line in Figure 4.4 is the outcome of the following regression:

$$sf_t = .9119723 + .0089004t - .0001978t^2 \qquad (4.13)$$

(11.81) (1.35) (-1.67)

Figure 4.4 The Snow Fall Trend in Atlantic Canada



Using statistical procedure presented in section 3.1.2, the break year is 1979 with coefficient of dummy, t-value and adjusted R^2 of -0.12, -2.37, and 0.07, respectively.

4.2.4. *Total precipitation*

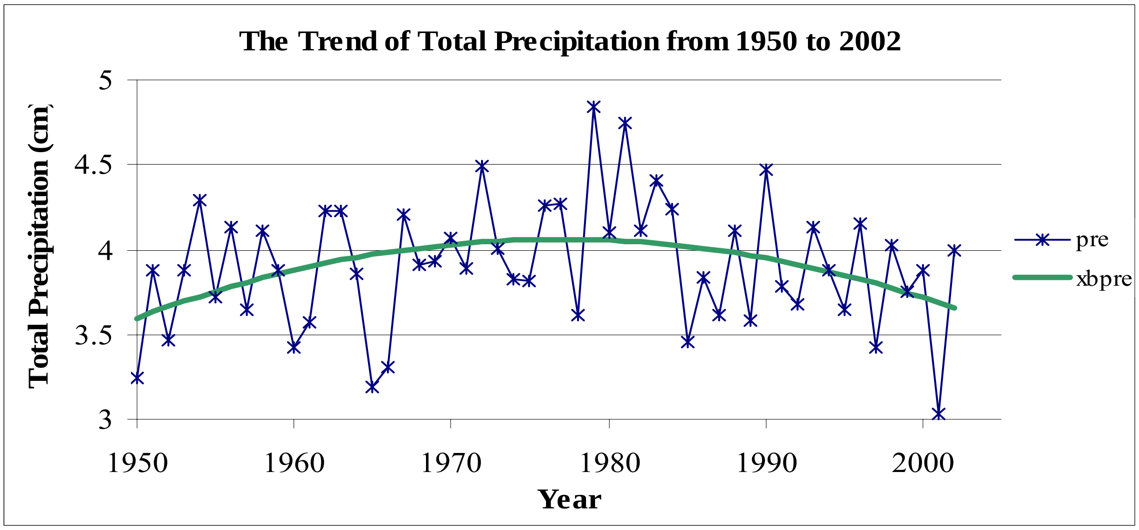
First, a graph is presented to illustrate the total precipitation series. The fitted line in Figure 4.5 is the result of the following regression:

$$pre_t = 3.560877 + .0358517t - .0006434\, t^2 \qquad (4.14)$$

(23.37) (2.75) (-2.75)

It shows that the total precipitation increased from 1950s, and then decreased since the end of 1970s.

Figure 4.5 The Total Precipitation Trend in Atlantic Canada



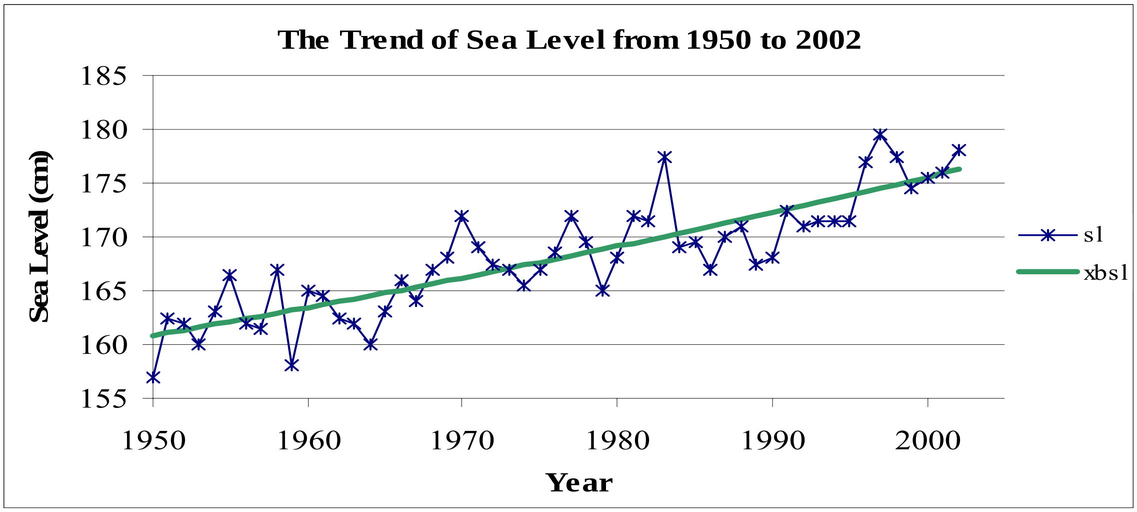
The results of the method described in section 3.1.2 show that the break year for total precipitation is 1985, in which the coefficient of dummy, t-value and adjusted R^2 are -0.19, -1.77 and 0.02 respectively.

4.2.5. *Sea Level Adjusted for Atmospheric Pressure*

According to the following simple regression, we can see that the sea level was increasing during study period:

$$\underset{}{sl_t} = \underset{(208.06)}{160.1517} + \underset{(11.93)}{.29592t} \tag{4.15}$$

Figure 4.6 The Sea Level Adjusted Atmosphere Pressure in Atlantic Canada



Method described in section 3.2.1 pointed to 1980 as the break year. This means that the sea level has increased at a higher rate since 1980.

Therefore, it is possible to conclude that according to our time series analysis, the climate change in Atlantic Canada can be dated back to the period between 1976 and 1986 – actually closer to the mid 1980s.

4.3. *Climate change as productivity shock*

We have already detected that in Atlantic Canada climate had changed since the mid 1980s. As already mentioned, a study period from 1985 to 2002 was chosen for the economic system. Therefore, only dynamics of climate related variables since the break year (climate change) should be taken into account. According to the model presented in equation (3.12),

$$e_{1t} = \varepsilon_{Y_t} = \alpha_0 + \alpha_1 C_t + \alpha_2 C_{t-1} + \mu_t \qquad (3.12)$$

this dynamics is:

Table 2 The Regression Outcome Using Full Set of Climate Variables

residual	Coef.	Std. Err.	t	description
temp	1089.806	343.6643	3.17	Annual average temperature
rf	-4998.991	5234.939	-0.95	Annual rain fall
sf	2171.747	5802.043	0.37	Annual snow fall
pre	7052.374	4721.769	1.49	Annual precipitation
sl	-107.7823	63.33948	-1.7	Sea level
L.temp	-178.1612	352.5318	-0.51	lag of annual average temperature
L.rf	-10887.98	5093.594	-2.14	lag of annual rain fall
L.sf	-13489.02	6124.635	-2.2	lag of annual snow fall
L.pre	9886.726	4687.91	2.11	lag of annual precipitation
L.sl	146.5808	74.77374	1.96	lag of sea level
_cons	-21162.37	17566.6	-1.2	constant

Note: The residual is the dependent variable of productivity shock.

In our model described in section 3.1.3, we assumed that there is permanent aggregate climate unrelated productivity shock α_0. In a microeconomic sense, it means that there is a positive upward shift in the production possibilities frontier over our study period due to innovations; in a macroeconomic sense, there is a positive shift in the potential GDP during study period. It implies that in our dynamic model of productivity shocks, the constant term must be positive to reflect this permanent aggregate climate unrelated productivity shock due to innovations. All other positive and negative climate unrelated productivity shocks are reflected in error term – a random component of the model.

However, in the above two models this constant term is negative. Moreover, as the following regression shows:

$$pre_t = -.1859818 + 1.078968 rf_t + 1.085862 sf_t \qquad R^2 = 0.9823 \tag{4.16}$$

there is a high degree correlation between total precipitation and snowfall and rainfall. Therefore, the resulting model should include only total precipitation or snowfall plus rainfall, but not both.

That is why the following model was eventually chosen to capture the dynamics of the climate related productivity shock:

Table 3 The Dynamic Outcome of Climate Change Impacts on Demand for Transportation

residual	Coef.	Std. Err.	t	description
temp	355.6285	299.6156	1.19	Annual average temperature
pre	-60.25816	718.8955	-0.08	Annual precipitation
sl	-151.7204	76.44021	-1.98	Sea level
L.temp	79.44422	291.1985	0.27	lag of annual average temperature
L.pre	-316.3188	647.4307	-0.49	lag of annual precipitation
L.sl	115.3172	87.73719	1.31	lag of sea level
_cons	5438.807	13513.09	0.4	constant

F-test	Prob>F
Ct	0.1984
Ct-1	0.4747

Note: The residual is the dependent variable of productivity shock.
Ct includes temperature, precipitation and sea level.
Ct-1 includes lags of temperature, precipitation and sea level.

This model completely satisfies our assumptions and the purpose of our analysis. Low R^2 of 0.04 should not be taken as a drawback of the model. In this case, it only tells us that 96% of all productivity shocks in Atlantic Canada are purely random, and only 4% are deterministic. Since the goal was to capture the dynamics of the climate related productivity shock, we are only interested in coefficients of the climate related variables in two periods. In addition, the low values of F-tests should not restrict this study as well, because the goal of this paper is to find out the impacts of dynamics of the climate related shock on our dynamic system which is a time series analyse, and then we should focus on the effects over time.

It is interesting to note that there is a positive effect from temperature. Atlantic Canada is located in the Northern Hemisphere where the weather in general is colder than in other places. The warmer weather is good for some economic activities, such as agriculture, forestry, transportation and so on. In other word, the weather in Canada is getting less cold, not getting warmer (A report on workshop, *Climate change in the western and northern forest of Canada: Impacts and adaptation*, 2003).

4.4. *Productivity shock dynamics in the VAR model*

As a result of the estimation of the climate related shock, mathematically its dynamics can be specified as follows:

$$\begin{aligned} e_{Y_t} = \varepsilon_{Y_t} &= 355.6285 temp_t + 79.44422 temp_{t-1} - 60.25816 pre_t \\ &- 316.3188 pre_{t-1} - 151.7204 sl_t + 115.3172 sl_{t-1} \end{aligned} \quad (4.17)$$

In addition, as estimated by Byelyayev (2005), on average a climate related accident (extreme weather event) in Atlantic Canada costs approximately $1,200 million. In order to model consequences of climate change impacts on demand for freight transportation, the climate related shock should be imposed on economic system in the following format:

$$e_{Y_t}^S = c + \alpha_1 C_t + \alpha_2 C_{t-1} - 1,200 \quad (4.18)$$

where $C = [temp, pre, sl]$ is the vector of climate related variables (temperature, total precipitation, sea level), A_1 and A_2 are coefficients in the above relationship, and c is the vector of average annual changes in relevant climate variables according to the existing forecasts. This shock should be imposed on system (4.7)-(4.8) to trace its consequences.

The economic system, driven by the shock which affects GDP directly and volume of transportation indirectly through correlation coefficient $\rho = 0.44$ obtained from VAR estimation, will produce the after shock dynamics. In addition, it is possible to generate the without shock dynamics of the system and compare it with the one with the climate related shock. In such a case, the loss function, which is the difference between the two time paths of the economic system under study, will show consequences of the climate change impacts.

Using the above-described procedure, the following three scenarios were evaluated:

4.4.1. *The Best-Case Scenario*

The best-case scenario is based on the assumption that every climate variable performs at its best level given the Environment Canada forecast. Therefore, in this scenario the following specific assumptions were applied:

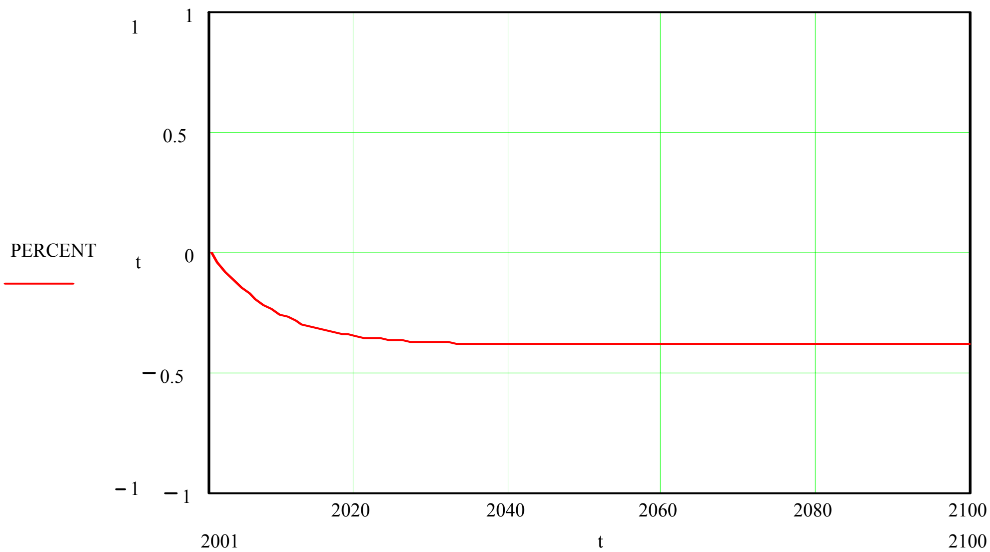
- The mean annual temperature increases by extra 0.01^{o}C per year in addition to the existing 0.03^{o}C or in total it increases by 4^{o}C by the end of the century.
- The sea level rises by extra 0.18 cm per year on top of the existing 0.32 cm or by a total of 50 cm by the end of the century.
- The total precipitation remains the same.
- No extra major climate related disasters occur over the 100-year period.

This means that the vector of annual changes in climate related variables is

$$c = [0.01, 0.18, 0]$$

The loss function, expressed in percentage form, was generated in Mathcad-8 as follows:

Figure 4.7 The Loss Expressed in Percentage under the Best-Case Scenario



As the above figure shows, under this scenario the loss in demand for freight transportation converges to the value of -0.38. Therefore, the demand for freight transportation is expected to decrease by 0.38% on average during 21st century.

4.4.2. *The Expected-Case Scenario*

The expected-case scenario is based on the assumption that every climate variable performs at the most likely level, which is actually a moderate change in the climate variable of interest according to the Environment Canada forecast. In this scenario, the following specific assumptions were applied:

- The mean annual temperature increases by extra 0.02°C per year in addition to the existing 0.03°C or in total it increases by 5°C by the end of the century.

- The sea level rises by extra 0.38 cm per year on top of the existing 0.32 cm or by a total of 70 cm by the end of the century.

- The total precipitation decreases by 1 mm per year or by a total of 100 mm by the end of the century.

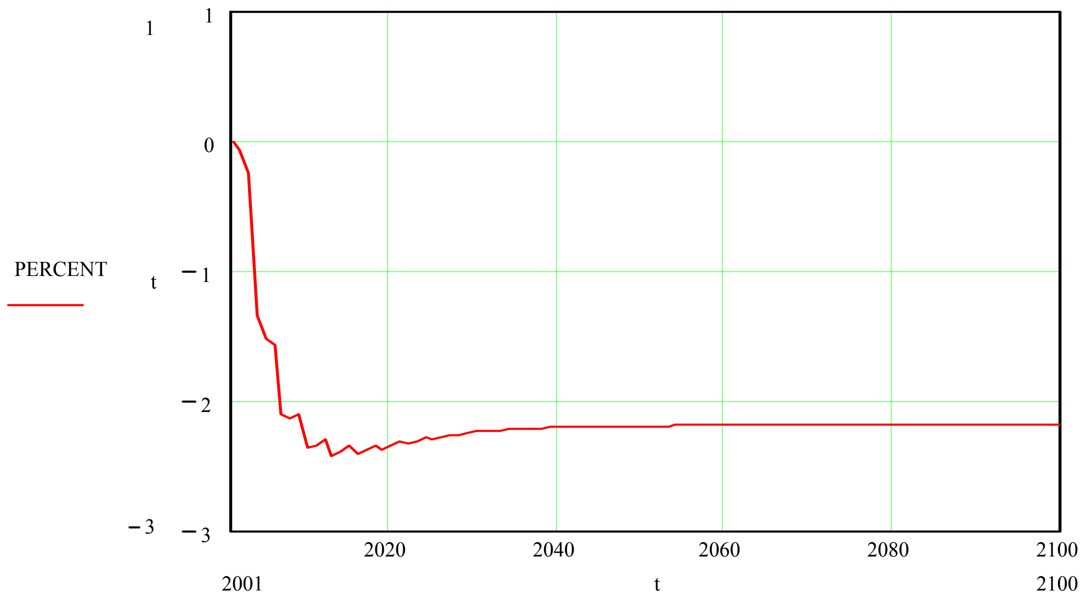
- One additional major climate related disaster occurs every three years.

This means that the vector of annual changes in climate related variables is

$$c = [0.02, 0.38, -0.1]$$

The loss function, expressed in percentage form, was generated in Mathcad-8 as follows:

Figure 4.8 The Loss Expressed in Percentage under the Expected-Case Scenario



As the above figure shows, under this scenario the loss in demand for freight transportation converges to the value of -2.19. Therefore, the demand for freight transportation is expected to decrease by 2.19% on average during 21st century.

4.4.3. *The Worst-Case Scenario*

The worst-case scenario is associated with the largest values of each climate variable as predicted by Environment Canada. The following specific assumptions were applied:

- The mean annual temperature increases by extra 0.03°C per year in addition to the existing 0.03°C or in total it increases by 6°C by the end of the century.

- The sea level rises by extra 0.68 cm per year on top of the existing 0.32 cm or by a total of 100 cm by the end of the century.

- The total precipitation decreases by 2 mm per year or by a total of 200 mm by the end of the century.

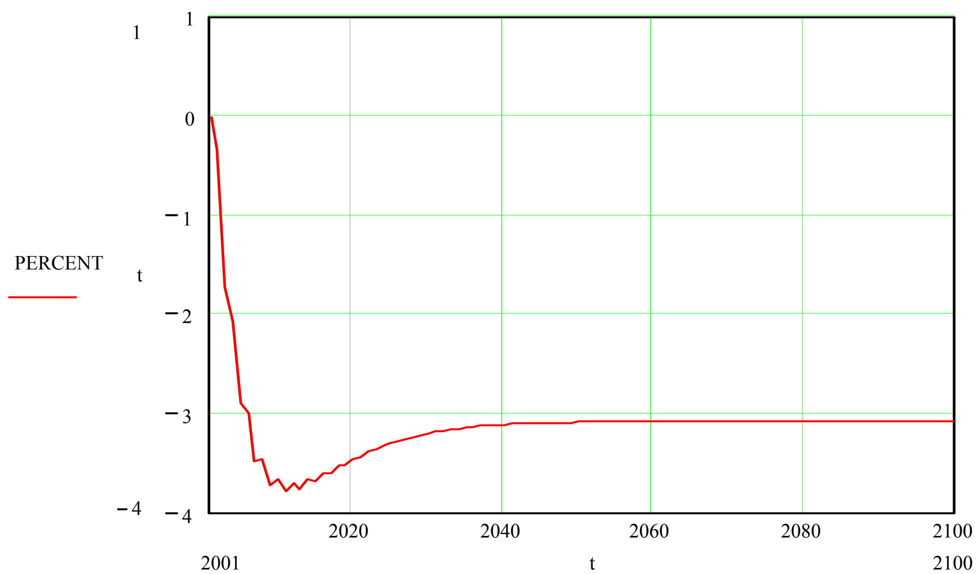
- One additional major climate related disaster every two years.

This means that the vector of annual changes in climate related variables is

$$c = [0.03, 0.68, -0.2]$$

The loss function, expressed in percentage form, was generated in Mathcad-8 as follows:

Figure 4.9 The Loss Expressed in Percentage under the Worst-Case Scenario



As the above figure shows, under this scenario the loss in demand for freight transportation converges to the value of -3.08. Therefore, the demand for freight transportation is expected to decrease by 3.08% on average during 21st century.

Our simulation has shown that demand for freight transportation in Atlantic Canada decreases under all three scenarios. This decrease lies in the range between 0.38% and 3.08%, which is rather significant impact. Of course, if supply side impacts of the climate change impacts were added, the final outcome would be even more impressive.

4.5. *Sectoral Impacts*

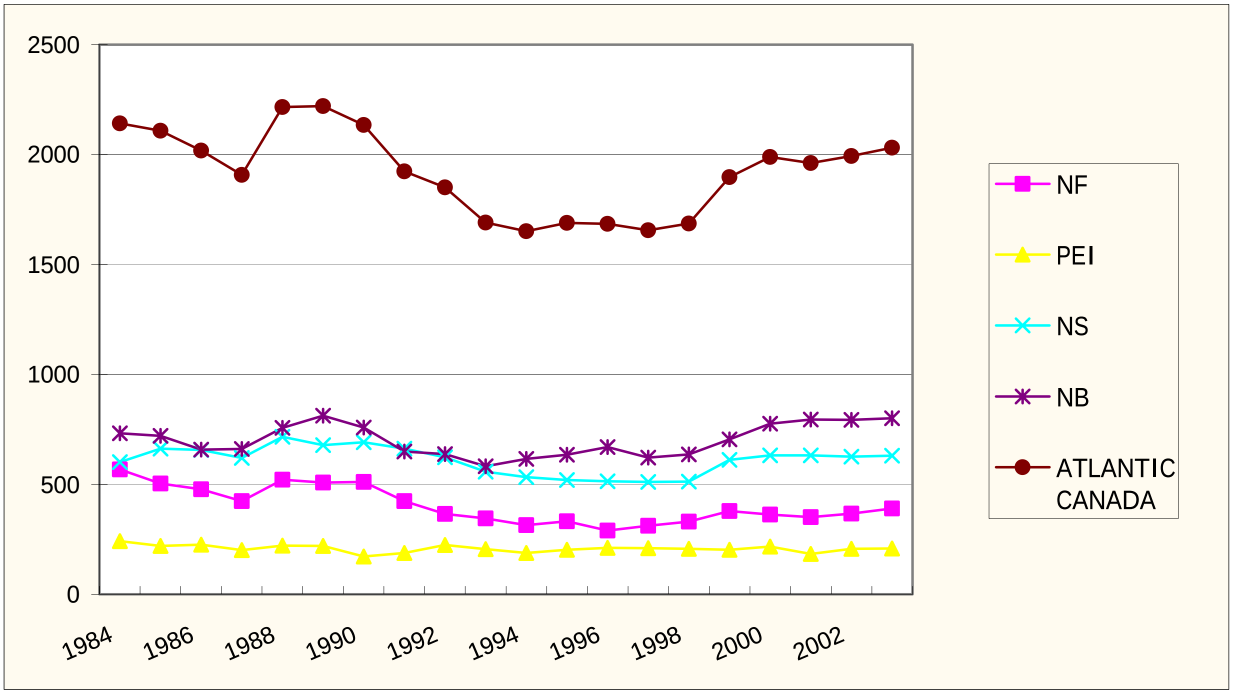
Finally some sectoral effects have been modelled. Because of the lack of detailed data on different sectors, two sectors of the regional economy were analysed. They are:

- Agriculture, forestry, and fisheries (from now on referred to as agriculture)
- Manufacturing

These sectors were chosen because of the following reasons: (i) their historical importance for the regional economy; (ii) different expected consequences of the climate change impacts. According to the existing literature already discussed in this report, climate change impacts on agriculture in Atlantics Canada are viewed as mostly favourable. However, consequences of the climate change impacts on manufacturing are not so clear. The same methodology as before was applied to study the consequences of the climate change impacts on these two sectors.

The following figure shows the value added by agriculture to the regional GDP over the 1984-2003 period.

Figure 4.10. Value Added by Agriculture, Forestry and Fisheries over 1984-2003



The graph shows that the value added by agricultural sector has been steady and has fluctuated around $2,000 million over this period. Therefore, in order to capture the mutual dynamics of the value added and freight transportation, time trend was not included in the VAR specification. The results of the VAR estimation are shown below:

$$Y_t = 349.7039 + 0.704133Y_{t-1} + 0.051782T_{t-1}$$
$$T_t = 915.1938 - 0.738035Y_{t-1} + 1.165408T_{t-1}$$

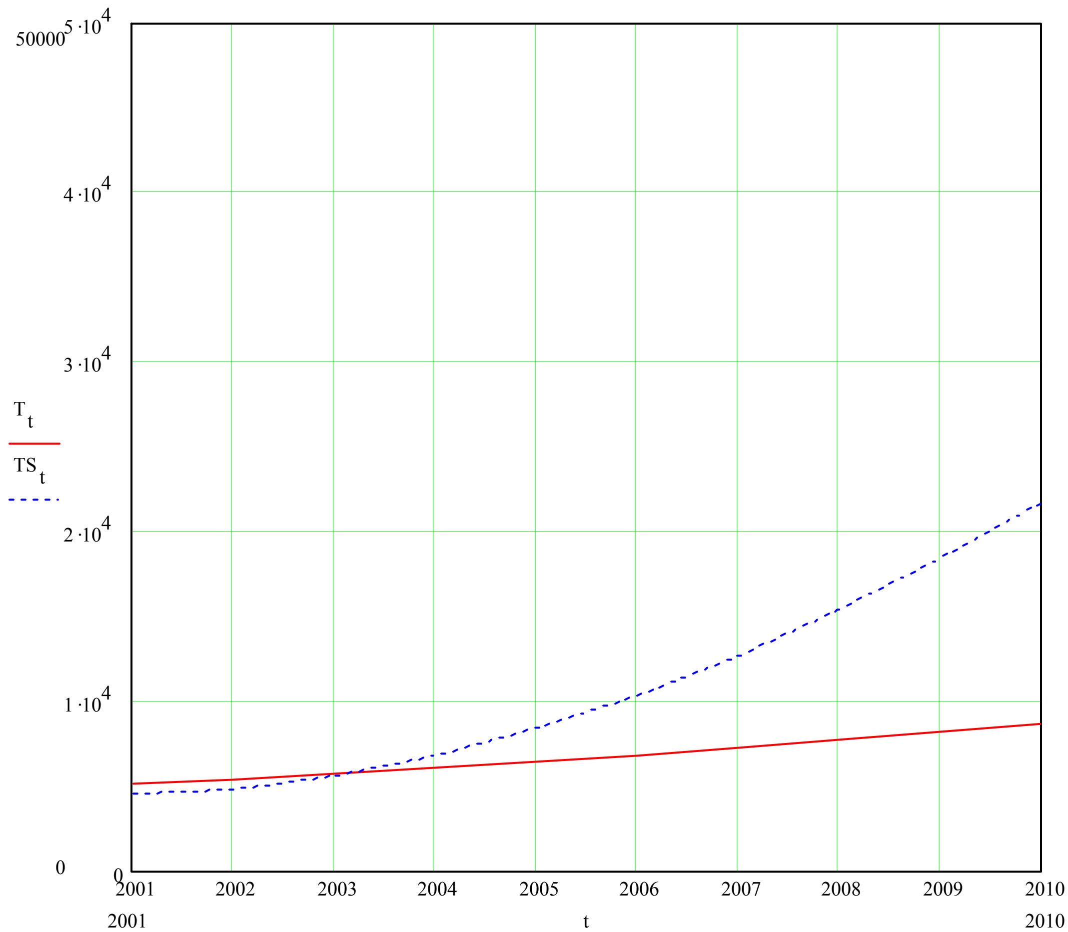
with R^2-adjusted = 0.603477. Regressing climate variables such as mean temperature, total precipitation and sea level on residuals of the VAR estimation, produced the following result:

$$e^A_{Yt} = 6303.11 - 9.83temp_t + 100.31temp_{t-1} + 162.41pre_t + 22.94pre_{t-1} - 39.98sl_t - 3.48sl_{t-1}$$

with R^2-adjusted = 0.401816. This equation shows that temperature has positive impact with a one-period lag, which is very significant. Total precipitation has strong positive effect but sea level has strong negative impact. Actually these results are consistent with the literature and common sense.

The climate related shock specified above was then imposed on the VAR and the following graph shows the simulated time paths for the demand for freight transportation with the shock (TS_t) and without the shock (T_t):

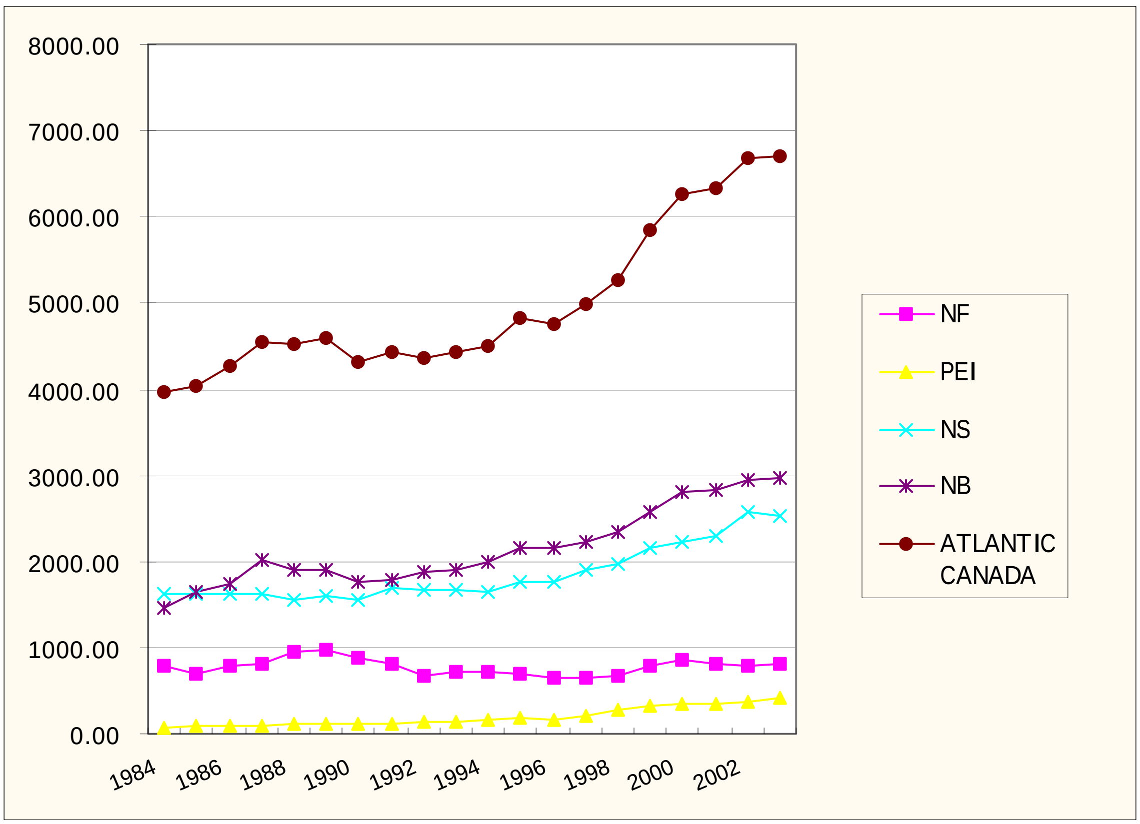
Figure 4.11. Demand for Freight Transportation by Agriculture, Forestry and Fisheries



As our simulation exercise shows only first three years are associated with a decrease in the demand for freight transportation by the agricultural sector. However, beginning from 2004, the impact is positive. Moreover, this positive climate change impact is permanent and increasing over time, which implies it is a long-run positive impact.

The impact of the climate change on manufacturing sector and its consequences for the demand for freight transportation are quite different. The following graph shows the value added by manufacturing sector series over the 1984-2003 period:

Figure 4.12. Value Added by Manufacturing over 1984-2003



The dynamics of this series is quite different from the agriculture sector. Manufacturing sector series exhibits a well-identifiable time trend since 1995. That is why this trend was included in the VAR specification. The results of the VAR estimation are as follows:

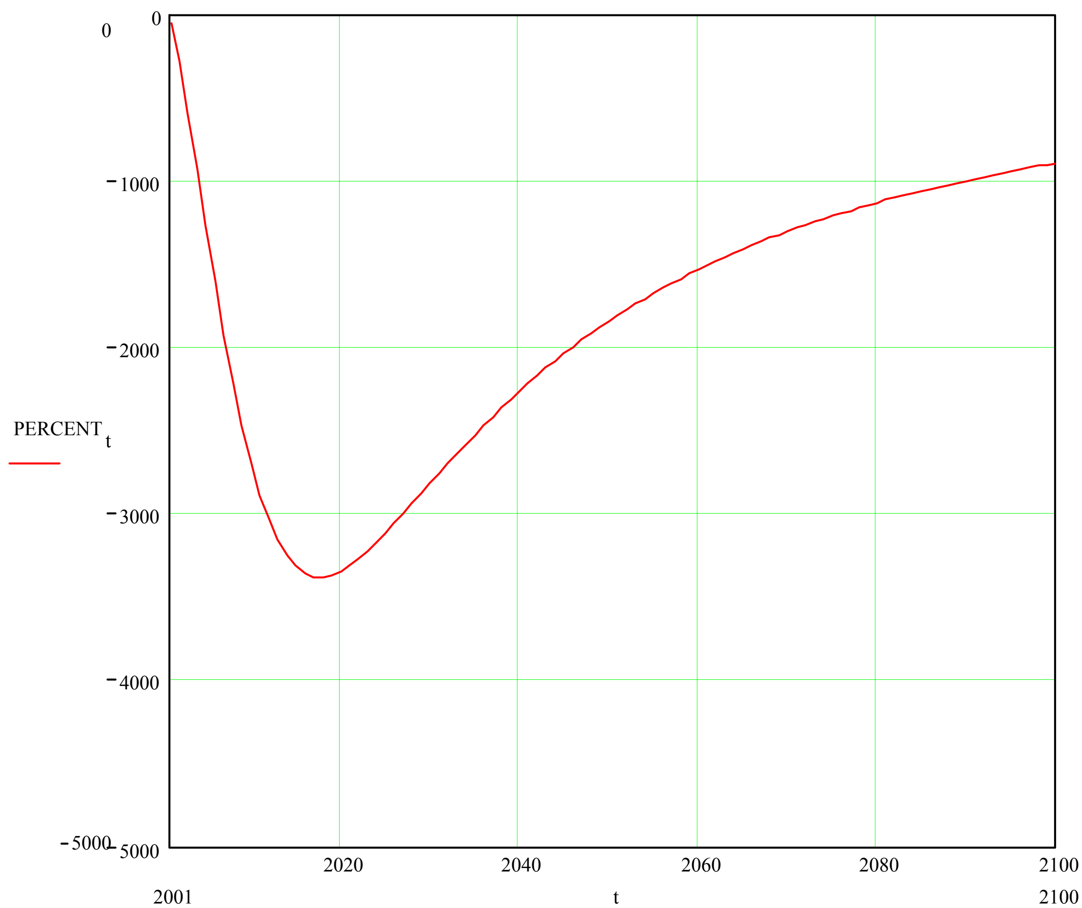
$$Y_t = 102.3452 + 0.969839Y_{t-1} - 0.000219T_{t-1} + 22.40262t$$
$$T_t = -8471.348 + 2.897257Y_{t-1} + 0.511117T_{t-1} + 39.80296t$$

with R^2-adjusted = 0.945465. High R^2 reflects a good fit by our model. Then the same climate change variables were regressed on the residuals of the VAR estimation. As a result, the dynamics of the productivity shock was estimated as follows:

$$e_{Yt}^{M} = 15199.7 + 79.35temp_t + 144.18temp_{t-1} - 287.1pre_t - 350.15pre_{t-1} - 48.56sl_t - 32.5sl_{t-1}$$

with R^2-adjusted = 0.412973. The shock decomposition shows that temperature still has a positive impact on the value added. However, unlike in agricultural sector, precipitation has a strong negative impact as well as the sea level. The climate related shock was then imposed on the VAR to generate two time paths – with the shock and without the shock. The following graph shows the loss in the demand for freight transportation function in percentage form:

Figure 4.13. Loss in Demand for Freight Transportation by Manufacturing



As the graph shows, the impact is permanent and very strong. The shape of the above-presented impulse response function resembles the ones we obtained previously for the regional economy as a whole.

Therefore, based on these results we can make the following conclusions:

- Consequences of climate change impacts on agriculture and manufacturing are dramatically different: climate change has a positive long-run impact on agriculture while at the same time it has negative permanent impact on manufacturing

- As a result of the above, consequences for the demand for freight transportation are also different: climate change increases the demand for freight transportation by agriculture but decreases the demand by manufacturing.
- Since manufacturing accounts for the larger share in the regional GDP (12%) compared to agriculture (3.5%), negative impact of the climate change on manufacturing dominates in the regional economy.

Conclusion

As suggested by the government of Canada forecast, in Atlantic Canada mean temperature will increase by 3 to 5 degrees over this century. Simultaneously the sea level is rising by 0.5-1 cm per year. The most likely scenario indicates that the sea level will rise by about 50-70 cm by the end of the 21st century. Total precipitation is less predictable. Snowfall in winter season will decrease, and in summer season, the weather will become drier. In terms of this study, it is possible to conclude that if climate gets worse, the worst-case scenario will become more likely.

As evaluated in this study, under the worst-case scenario the demand for freight transportation will decrease by 4% by the year of 2010. Although according to our simulation the economic system will recover a little bit, nonetheless the loss of 3.08% is still expected. This loss is permanent and therefore, without some policy changes the economy will not be able to deal with these climate change impacts. As also shown in this report, consequences of the climate change for the demand for freight transportation by different sectors are quite different: climate change increases the demand for freight transportation by agriculture, forestry and fisheries but decreases the demand for freight transportation by manufacturing.

As emphasized in introduction, this study only focuses on the demand side of freight transportation, which means that negative climate change impacts on the supply side were artificially ignored. In an economic sense, it implies that constant price of freight transportation was assumed. Actually this is not a bad assumption taking into account that a decrease in supply of freight transportation coupled with a decrease in demand for freight transportation due to climate change impacts may eventually offset each other. However, more likely if the supply side climate change impacts are added, the consequences for freight transportation will be more dramatic.

Also, because of data limitations, currently, it is impossible to estimate the dynamics of climate change impacts precisely. In the future, when longer time series become available, the model developed in this study can be used to explain the climate change impacts much better. On the other hand, to the best of our knowledge, currently there is no any other model that attempts to explain consequences of the climate change impacts on demand for transportation at any level. Once new evidence and date are collected, this model can be re-examined and improved on the basis of the dynamic general equilibrium model.

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Appendix: Data Tables and Table of Result

Table 4 GDP in 1997 constant value by province ($'000 000)

Year	NFLD	PEI	NS	NB	Atlantic Canada
1985	8519.20	1883.40	15550.40	12167.50	38120.50
1986	8689.60	1960.20	16035.70	12752.70	39438.20
1987	8851.00	2016.30	16358.10	13368.60	40594.00
1988	9437.40	2165.10	16802.40	13667.70	42072.60
1989	9538.50	2178.00	17010.80	13915.00	42642.30
1990	9509.70	2166.90	17217.30	13902.70	42796.60
1991	9206.20	2156.80	17176.50	13862.90	42402.40
1992	9004.00	2185.00	17254.30	13886.00	42329.30
1993	9083.90	2204.80	17318.90	14022.80	42630.40
1994	9410.70	2305.60	17514.90	14388.90	43620.10
1995	9529.80	2453.10	17866.40	14842.90	44692.20
1996	9216.00	2524.90	17899.90	15146.50	44787.30
1997	9406.70	2520.60	18379.90	15270.10	45577.30
1998	9984.50	2655.60	19100.00	15906.70	47646.80
1999	10584.20	2762.40	20271.10	16913.50	50531.20
2000	11255.00	2860.10	20967.90	17636.10	52719.10
2001	11428.10	2874.20	21682.40	17867.40	53852.10
2002	12654.80	3009.50	22535.40	18432.20	56631.90

Source: Statistics Canada and CANSIM II

Table 5 The Data of Total Transportation in Atlantic Canada ('000 Tons)

Year	Trucking	Rail	Shipping	Air	Total Volume	Total without Air
1985	13352.21	13264.66	35662.16	32.85	62311.89	62279.03
1986	14525.37	14046.52	39543.08	32.08	68147.05	68114.97
1987	15317.05	16776.00	44510.66	35.09	76603.70	76568.61
1988	16671.69	17317.00	53028.23	37.48	87016.92	86979.45
1989	16007.30	16652.00	53026.04	44.11	85685.33	85641.22
1990	13742.71	13114.00	53330.96	42.71	80187.67	80144.96
1991	13776.96	14291.00	51829.19	40.17	79897.15	79856.98
1992	14439.00	14613.00	48174.57	33.76	77226.57	77192.82
1993	17901.00	14728.00	55690.73	30.43	88319.73	88289.30
1994	18810.00	14756.00	58286.23	25.98	91852.23	91826.25
1995	20095.00	13799.00	63416.69	27.98	97310.69	97282.72
1996	19187.00	13864.00	62331.05	20.85	95382.05	95361.20
1997	19845.00	14104.00	73328.44	21.64	107277.44	107255.80
1998	20418.00	13520.00	72499.65	25.73	106437.65	106411.92
1999	24156.00	14646.00	81273.38	20.93	120075.38	120054.45
2000	23340.00	15255.00	89990.50	21.66	128585.50	128563.84
2001	26238.00	32068.17	99728.30	23.42	158034.47	158011.05
2002	22575.00	33579.56	119265.40	19.39	175419.96	175400.57

Source: Trucking in Canada, Rail in Canada, Shipping in Canada, and Air Carrier Traffic at Canadian Airports, Statistics Canada

Table 6 The Domestic and International Data of Trucking in Atlantic Canada ('000 Tons)

	Domestic				international			
Year	Incoming	Outgoing	Intra-region	*Subtotal*	From US	To US	*Subtotal*	*Total Volume*
1985	9626	9162	8254	10534	--	--	--	13352
1986	11877	11451	10124	13204	323	999	1321	14525
1987	12663	12227	11066	13824	270	1224	1493	15317
1988	13722	12674	11488	14908	432	1331	1764	16672
1989	12756	12014	10689	14081	325	1601	1926	16007
1990	10700	10315	8934	12081	362	1299	1662	13743
1991	11004	10520	9291	12233	420	1124	1544	13777
1992	11505	10839	9611	12733	502	1204	1706	14439
1993	14034	13526	12009	15551	593	1757	2350	17901
1994	15056	14408	12928	16536	598	1676	2274	18810
1995	15691	14851	13012	17530	615	1950	2565	20095
1996	14695	14193	12172	16716	544	1927	2471	19187
1997	15199	14041	12277	16963	554	2328	2882	19845
1998	15992	14546	12953	17585	601	2232	2833	20418
1999	18728	17317	15214	20831	749	2576	3325	24156
2000	18197	16432	14619	20010	719	2611	3330	23340
2001	19884	18727	16113	22498	779	2961	3740	26238
2002	16390	14698	12368	18720	770	3085	3855	22575

Source: Trucking in Canada, Statistics
Note: -- means data is unavailable.

Table 7 Rail Data Contained Domestic and International Sectors ('000 Tons)

Year	Incoming	Outgoing	Intra-region	Total Volume
1985	--	--	--	13264.66
1986	--	--	--	14046.52
1987	13282.00	12323.00	8829.00	16776.00
1988	13694.00	12583.00	8960.00	17317.00
1989	13441.00	12247.00	9036.00	16652.00
1990	10229.00	10625.00	7740.00	13114.00
1991	11578.00	10501.00	7788.00	14291.00
1992	11825.00	11018.00	8230.00	14613.00
1993	11227.00	10973.00	7472.00	14728.00
1994	11169.00	10631.00	7044.00	14756.00
1995	10233.00	9524.00	5958.00	13799.00
1996	10393.00	9602.00	6131.00	13864.00
1997	9775.00	9893.00	5564.00	14104.00
1998	8997.00	9058.00	4535.00	13520.00
1999	9789.00	9681.00	4824.00	14646.00
2000	9920.00	9955.00	4620.00	15255.00
2001	9697.02	26497.69	4126.54	32068.17
2002	10812.29	28113.25	5345.98	33579.56

Source: Rail in Canada, Statistics Canada
Note: -- means data is unavailable.

Table 8 The International Shipping data by province ('000 Tons)

Year	NF	PEI	NS	NB	Atlantic Canada
1985	2401.00	77.00	14065.00	7636.00	24179.00
1986	2425.00	124.00	14586.00	11714.00	28849.00
1987	3640.00	85.00	16695.00	12518.00	32938.00
1988	8812.00	88.00	17773.00	14479.00	41152.00
1989	8403.00	75.00	18305.00	14237.00	41020.00
1990	9912.00	125.00	18010.00	13696.00	41743.00
1991	8458.00	205.00	16849.00	16315.00	41827.00
1992	5949.00	158.00	16672.00	15170.00	37949.00
1993	8270.79	198.89	18731.69	18751.77	45953.13
1994	3880.34	221.02	22294.07	20727.79	47123.22
1995	7621.57	217.02	25453.48	19285.46	52577.52
1996	8538.52	177.09	22181.56	21353.44	52250.61
1997	10041.18	196.46	31418.39	21734.78	63390.81
1998	12005.01	192.30	28914.55	20013.66	61125.52
1999	14886.90	166.70	28932.50	21540.80	65526.90
2000	16366.00	148.80	32203.10	21157.30	69875.20
2001	15372.70	92.40	36636.90	26869.70	78971.70
2002	23074.40	76.00	30492.10	26189.60	79832.10

Source: Shipping in Canada, Statistics Canada

Table 9 The Domestic Shipping data by province ('000 Tons)

Year	NF	PEI	NS	NB	Atlantic Canada
1985	2594.78	598.07	6305.40	1984.91	11483.16
1986	2668.39	520.05	5701.65	1803.99	10694.08
1987	2619.71	552.67	6126.77	2273.50	11572.66
1988	2893.54	627.74	6171.25	2183.71	11876.23
1989	2735.40	706.22	6174.58	2389.83	12006.04
1990	2799.68	595.89	5614.91	2577.48	11587.96
1991	2237.23	622.52	4612.93	2529.52	10002.19
1992	2550.10	815.30	4822.65	2037.53	10225.57
1993	2258.58	800.22	4464.03	2214.77	9737.59
1994	2479.82	677.19	5189.84	2816.17	11163.01
1995	2408.36	732.80	4932.05	2765.96	10839.17
1996	2552.45	756.76	4315.67	2455.57	10080.44
1997	2764.66	561.15	4060.77	2551.06	9937.63
1998	3378.98	683.37	4810.02	2501.76	11374.13
1999	7530.99	715.23	4772.42	2727.84	15746.48
2000	12567.30	820.50	4272.90	2454.60	20115.30
2001	12745.60	761.80	4761.10	2488.10	20756.60
2002	30878.50	685.10	4138.50	3731.20	39433.30

Source: Shipping in Canada, Statistics Canada

Table 10 The Air data by province (tonnage)

Year	NFLD	PEI	NS	NB	Atlantic Canada
1985	10337.60	968.70	19112.30	2436.30	32854.90
1986	9738.90	1053.60	18830.90	2457.70	32081.10
1987	10874.90	950.90	20644.50	2623.40	35093.70
1988	10898.90	981.10	22514.30	3081.30	37475.60
1989	9778.50	1113.50	27237.60	5982.80	44112.40
1990	8316.90	699.60	27108.30	6581.10	42705.90
1991	7888.40	210.20	25598.10	6473.80	40170.50
1992	7485.60	116.30	21545.80	4607.40	33755.10
1993	6385.10	111.20	18898.60	5037.10	30432.00
1994	6715.20	151.30	17487.40	1627.00	25980.90
1995	6803.60	82.60	20129.70	961.20	27977.10
1996	2225.90	76.20	17926.40	625.80	20854.30
1997	2615.00	109.10	18347.30	571.30	21642.70
1998	2309.80	105.80	22799.40	514.70	25729.70
1999	2914.20	64.20	17546.80	404.40	20929.60
2000	4719.60	53.40	16602.10	288.90	21664.00
2001	5447.40	486.60	16299.60	1187.80	23421.40
2002	3579.90	375.00	14682.00	756.30	19393.20

Source: Air Carrier Traffic at Canadian Airports, Statistics Canada

Table 11 The Data of Climate Vector in Atlantic Canada

Year	Temperature centigrade	Rain fall mm	Snow fall cm	Precipitation cm	Sea level cm
1950	5.1124	2.3129	0.8412	3.2436	157.00
1951	6.1152	3.0031	0.7487	3.8789	162.50
1952	6.1916	2.4424	0.9042	3.4615	162.00
1953	6.4106	3.2088	**0.5517**	3.8757	160.00
1954	5.1908	3.1171	1.0240	4.2925	163.00
1955	4.9823	2.4827	1.1293	3.7198	166.50
1956	4.9046	2.8592	1.1268	4.1352	162.00
1957	5.0538	2.5011	1.0592	3.6410	161.50
1958	5.5901	2.9888	1.0641	4.1108	167.00
1959	5.0884	3.1443	0.7161	3.8746	158.00
1960	5.6667	2.2678	1.0664	3.4210	165.00
1961	5.2943	2.2812	1.1707	3.5750	164.50
1962	4.7091	3.0074	1.0094	4.2316	162.50
1963	4.6362	2.9162	1.1544	4.2225	162.00
1964	4.8493	2.4575	1.2367	3.8544	160.00
1965	4.4739	2.0191	1.0506	3.1872	163.00
1966	5.9160	2.3691	0.8207	3.3115	166.00
1967	5.0052	2.7049	1.3836	4.2060	164.00
1968	4.7979	2.8081	0.8721	3.9096	167.00
1969	6.0356	2.9913	0.7745	3.9338	168.00
1970	5.1666	2.9024	1.0291	4.0669	172.00
1971	5.3339	2.6416	1.0770	3.8909	169.00
1972	3.9289	2.9076	1.3924	4.4870	167.50
1973	5.6062	3.1255	0.7483	4.0017	167.00
1974	4.4342	2.6754	1.0213	3.8216	165.50
1975	4.9089	2.5115	1.2094	3.8160	167.00
1976	5.1173	3.1321	1.0222	4.2566	168.50
1977	5.4506	3.2010	0.9587	4.2729	172.00
1978	4.6687	2.2537	1.1813	3.6161	169.50
1979	6.0598	3.9443	0.6512	4.8431	165.00
1980	4.6326	3.1587	0.7945	4.1024	168.00
1981	6.1751	3.6980	0.8195	4.7408	172.00
1982	4.5609	2.8628	1.0963	4.1161	171.50
1983	6.1434	3.4523	0.7862	4.4067	177.50
1984	5.6732	3.1124	0.9282	4.2378	169.00
1985	4.4907	2.4184	0.9585	3.4598	169.50
1986	4.4818	2.7253	0.9925	3.8358	167.00
1987	5.2080	2.3945	1.1293	3.6102	170.00
1988	5.2836	3.0693	0.9114	4.1074	171.00
1989	4.6741	2.4651	1.0783	3.5824	167.50
1990	5.6734	3.5655	0.7509	4.4729	168.00
1991	5.1498	2.9067	0.8537	3.7816	172.50
1992	4.4669	2.5259	1.0378	3.6734	171.00
1993	4.5048	3.0979	0.9289	4.1337	171.50
1994	5.4073	2.8659	0.9172	3.8745	171.50
1995	5.2642	2.6101	0.9394	3.6447	171.50
1996	5.7163	3.3914	**0.6436**	4.1515	177.00
1997	4.6108	2.3086	1.0332	3.4181	**179.50**
1998	6.3542	3.2716	0.6724	4.0296	177.50
1999	**7.2955**	2.9444	0.7039	3.7509	174.50
2000	6.0291	2.9379	0.8529	3.8779	175.50
2001	6.0322	**2.0012**	1.0875	**3.0317**	176.00
2002	5.5830	2.8963	1.0665	3.9907	178.00

Source: Climate CD-ROM, 2002 CDEX East CD, Environment Canada, and Oleg's paper
Note: Bold numbers are the maximum or minimum values (refer to section 3.2.2)

Table 12 Break Year Test for temperature

	Model I			Modell II			Modell III				
Year	**Dt**	**t**	**A R^2**	**LtempD**	**t**	**A R^2**	**LtempD**	**t_LtempD**	**Dt**	**t_Dt**	**A R^2**
1950	(dropped)	n/a	-0.0059	(dropped)	n/a	-0.0059	(dropped)	n/a	(dropped)	n/a	-0.0059
1951	(dropped)	n/a	-0.0059	(dropped)	n/a	-0.0059	(dropped)	n/a	(dropped)	n/a	-0.0059
1952	-0.8641145	-1.28	0.0069	-0.1690234	-1.28	0.0069	-0.1690234	-1.28	(dropped)	n/a	0.0069
1953	-0.8674508	-1.82	0.0388	-0.1533388	-1.81	0.0381	0.0165328	0.02	-0.960134	-0.18	0.0188
1954	-0.981073	-2.54	0.0926	-0.1693129	-2.54	0.0933	-0.1443935	-0.19	-0.145341	-0.03	0.0744
1955	-0.7226388	-2.04	0.0537	-0.1179477	-1.97	0.049	0.3884057	0.58	-3.02284	-0.76	0.0406
1956	-0.5072922	-1.57	0.023	-0.0884676	-1.59	0.024	-0.1353361	-0.24	0.2727888	0.08	0.0038
1957	-0.3531488	-1.19	0.0024	-0.0663952	-1.27	0.0062	-0.3823722	-0.77	1.798175	0.64	-0.0059
1958	-0.2716256	-0.98	-0.0066	-0.0541414	-1.09	-0.0022	-0.4504275	-1	2.215382	0.89	-0.0065
1959	-0.290462	-1.12	-0.0009	-0.0573447	-1.22	0.0036	-0.4007351	-0.93	1.899058	0.8	-0.0038
1960	-0.2329976	-0.93	-0.0085	-0.0463179	-1.02	-0.005	-0.3821034	-0.88	1.857768	0.78	-0.0131
1961	-0.2639472	-1.11	-0.0013	-0.0516388	-1.19	0.0023	-0.3346003	-0.79	1.554328	0.67	-0.0089
1962	-0.2428032	-1.05	-0.0037	-0.047315	-1.12	-0.0006	-0.3165381	-0.75	1.481749	0.64	-0.0127
1963	-0.1633578	-0.73	-0.0155	-0.0332022	-0.81	-0.0129	-0.3561684	-0.85	1.772072	0.77	-0.0214
1964	-0.0920993	-0.42	-0.0227	-0.0218736	-0.54	-0.0203	-0.468989	-1.2	2.431795	1.15	-0.0137
1965	-0.0513817	-0.24	-0.0252	-0.0152747	-0.39	-0.0233	-0.5049423	-1.37	2.642559	1.34	-0.007
1966	0.0225781	0.11	-0.0262	-0.0025485	-0.07	-0.0263	-0.5873946	-1.65	3.141038	1.65	0.0085
1967	-0.043502	-0.21	-0.0255	-0.0128586	-0.33	-0.0241	-0.37695	-1.1	1.94332	1.07	-0.0211
1968	-0.010815	-0.05	-0.0264	-0.0058117	-0.15	-0.0259	-0.3001328	-0.89	1.578696	0.88	-0.0305
1969	0.0284318	0.14	-0.026	0.0012196	0.03	-0.0264	-0.3280596	-0.99	1.762249	1	-0.0266
1970	-0.0389372	-0.2	-0.0256	-0.0101828	-0.28	-0.0248	-0.2291434	-0.69	1.168456	0.67	-0.0365
1971	-0.0210148	-0.11	-0.0262	-0.0062436	-0.17	-0.0258	-0.1786469	-0.56	0.9242881	0.54	-0.0408
1972	-0.025347	-0.13	-0.0261	-0.0070023	-0.19	-0.0256	-0.1769722	-0.55	0.9104237	0.53	-0.0408
1973	0.0826654	0.43	-0.0225	0.013368	0.37	-0.0235	-0.1632342	-0.51	0.9459068	0.56	-0.0381
1974	0.0447315	0.24	-0.0253	0.0081516	0.23	-0.0253	-0.0154132	-0.05	0.1258662	0.08	-0.0466
1975	0.1134901	0.6	-0.0189	0.021816	0.62	-0.0185	0.0411381	0.14	-0.103326	-0.07	-0.0397
1976	0.1354108	0.72	-0.0157	0.0253165	0.71	-0.0158	-0.0015011	-0.01	0.1433137	0.09	-0.0368
1977	0.1457051	0.77	-0.014	0.0271166	0.76	-0.0143	-0.0098859	-0.03	0.1977495	0.13	-0.0351
1978	0.1320792	0.7	-0.0163	0.0246223	0.69	-0.0165	-0.005529	-0.02	0.1611972	0.1	-0.0374
1979	0.1824692	0.97	-0.0071	0.0343201	0.97	-0.0071	0.0145505	0.05	0.1057816	0.07	-0.028
1980	0.1184124	0.62	-0.0184	0.0237433	0.66	-0.0173	0.1069919	0.37	-0.44589	-0.29	-0.0367
1981	0.1778337	0.94	-0.0083	0.0363701	1.02	-0.005	0.2064266	0.72	-0.912517	-0.6	-0.0183
1982	0.1035925	0.54	-0.0204	0.0243233	0.67	-0.017	0.3173868	1.11	-1.575465	-1.03	-0.0156
1983	0.1723156	0.9	-0.0099	0.0392078	1.09	-0.0021	0.4413003	1.58	-2.163259	-1.46	0.0203
1984	0.0983293	0.5	-0.0212	0.0275521	0.75	-0.0147	0.5662023	2.04	-2.906655	-1.96	0.0409
1985	0.0754579	0.38	-0.0234	0.022772	0.62	-0.0185	0.5240284	1.88	-2.702943	-1.81	0.0268
1986	0.1513684	0.76	-0.0145	0.0380798	1.02	-0.0049	**0.581181**	**2.11**	**-2.92745**	**-1.99**	**0.0523**
1987	0.2228157	1.1	-0.0017	0.049444	1.32	0.0087	0.4801479	1.71	-2.332578	-1.54	0.0359
1988	0.2332811	1.12	-0.0006	0.0511855	1.34	0.0098	0.4876055	1.7	-2.378781	-1.53	0.0362
1989	0.2436601	1.15	0.0005	0.053227	1.37	0.0112	0.484817	1.68	-2.358746	-1.51	0.0364
1990	0.320961	1.49	0.018	0.0673307	1.71	0.0311	0.4704591	1.64	-2.208845	-1.42	0.0509
1991	0.2935579	1.31	0.0081	0.0631592	1.55	0.0214	0.5350805	1.83	-2.607905	-1.63	0.0532
1992	0.3317824	1.44	0.0154	0.070795	1.7	0.0306	0.5438062	1.87	-2.615671	-1.64	0.063
1993	0.4633709	1.97	0.0489	0.0935197	2.21	0.0666	0.4878038	1.68	-2.193272	-1.38	0.0833
1994	0.6227879	2.56	0.0944	0.1160254	2.68	0.1052	0.2981201	0.97	-1.030662	-0.6	0.0933
1995	0.687633	2.63	0.1004	0.1234911	2.72	0.1083	0.2668168	0.78	-0.830233	-0.42	0.0932
1996	0.7822016	2.85	0.1192	0.1375117	2.91	0.125	0.2061947	0.6	-0.402186	-0.2	0.1075
1997	0.8183119	2.74	0.1099	0.1407286	2.79	0.114	0.1748448	0.48	-0.203339	-0.09	0.0957
1998	**1.142047**	**3.74**	**0.2018**	**0.190853**	**3.73**	**0.2003**	0.0671012	0.19	0.7462832	0.36	0.1858
1999	1.172796	3.15	0.1468	0.1849135	3.18	0.1488	0.2080304	0.33	-0.148107	-0.04	0.1311
2000	0.597468	1.36	0.0107	0.0943331	1.37	0.0116	0.1580722	0.24	-0.411063	-0.1	-0.0088
2001	0.4722146	0.95	-0.0079	0.0782925	0.95	-0.0079	-146.7244	-0.47	885.3114	0.47	-0.0242
2002	0.2154032	0.31	-0.0244	0.0357092	0.31	-0.0244	0.0357092	0.31	(dropped)	n/a	-0.0244

Table 13 Break Year Test cont'd

	rainfall			snowfall			precipitation			sea level		
Year	**Coef.**	**t**	**A R^2**	**Coef.**	**t**	**A R^2**	**Coef.**	**t**	**A R^2**	**Coef.**	**t**	**A R^2**
1950	(dropped)	n/a	-0.012	(dropped)	n/a	-0.0187	(dropped)	n/a	-0.02	(dropped)	n/a	0.6112
1951	(dropped)	n/a	-0.012	(dropped)	n/a	-0.0187	(dropped)	n/a	-0.02	(dropped)	n/a	0.6112
1952	-0.127032	-0.3	-0.0308	0.2172634	1.15	-0.0121	0.0476057	0.12	-0.0405	-2.991096	-0.88	0.6094
1953	0.1354408	0.45	-0.0284	0.1418016	1.04	-0.0172	0.2715705	1	-0.02	-0.3257227	-0.13	0.6034
1954	-0.028587	-0.11	-0.0324	0.2459451	2.27	0.0596	0.2080816	0.91	-0.0234	1.281831	0.62	0.6063
1955	-0.106616	-0.49	-0.0276	0.1801481	1.8	0.0251	0.0516048	0.26	-0.0394	0.7674646	0.41	0.6046
1956	-0.013949	-0.07	-0.0325	0.1037524	1.15	-0.0124	0.086286	0.49	-0.0358	0.0887704	0.05	0.6032
1957	-0.010367	-0.06	-0.0326	0.054702	0.66	-0.0304	0.0327754	0.2	-0.04	1.281346	0.83	0.6087
1958	0.0461	0.27	-0.0311	0.0320588	0.42	-0.0359	0.0753091	0.49	-0.0357	1.640307	1.12	0.613
1959	0.0231569	0.14	-0.0322	0.0141224	0.19	-0.0387	0.0395206	0.27	-0.0392	0.817008	0.57	0.6058
1960	-0.022328	-0.15	-0.0322	0.0467001	0.68	-0.0299	0.0420494	0.31	-0.0388	2.439685	1.85	0.629
1961	0.0466209	0.32	-0.0305	0.0295864	0.44	-0.0354	0.1015352	0.77	-0.0283	1.70696	1.25	0.6155
1962	0.1139957	0.8	-0.0192	0.0038344	0.06	-0.0395	0.137322	1.08	-0.0167	1.877853	1.42	0.619
1963	0.0950113	0.68	-0.0228	-0.0005169	-0.01	-0.0395	0.0958518	0.77	-0.0285	2.330971	1.83	0.6285
1964	0.0795387	0.59	-0.0253	-0.0198275	-0.33	-0.0372	0.057622	0.48	-0.036	2.69405	2.13	0.6368
1965	0.1123799	0.86	-0.0173	-0.0449081	-0.77	-0.0272	0.0609698	0.52	-0.0351	3.409392	2.73	0.6555
1966	0.190069	1.5	0.0127	-0.0506414	-0.88	-0.0233	0.1283895	1.13	-0.0145	3.57434	2.73	0.6557
1967	0.2398252	1.93	0.04	-0.0355742	-0.63	-0.0313	0.1844214	1.65	0.0141	3.442115	2.55	0.6498
1968	0.2534012	2.06	0.0494	-0.0715373	-1.3	-0.0047	0.1574338	1.4	-0.0007	3.917784	3	0.6648
1969	0.2511852	2.06	0.0499	-0.0618547	-1.12	-0.0134	0.151323	1.38	-0.002	3.742693	2.77	0.6571
1970	0.2313299	1.91	0.0391	-0.0441142	-0.81	-0.0258	0.1464744	1.35	-0.0035	3.55538	2.66	0.6533
1971	0.2174086	1.82	0.0327	-0.0486191	-0.91	-0.0223	0.1308043	1.22	-0.0104	2.717479	2.03	0.634
1972	0.2287357	1.94	0.0413	-0.0569074	-1.07	-0.0157	0.1301341	1.22	-0.0099	2.783344	2.24	0.6401
1973	0.2229449	1.9	0.038	-0.0906617	-1.75	0.0215	0.0820188	0.77	-0.0284	2.906147	2.42	0.6455
1974	0.1949988	1.66	0.0222	-0.0739397	-1.39	0	0.0730663	0.7	-0.0306	3.026569	2.55	0.6496
1975	0.2018544	1.74	0.0275	-0.0770859	-1.48	0.0047	0.0802171	0.77	-0.0284	3.366039	2.87	0.6603
1976	**0.2299**	**2**	**0.0452**	-0.0966909	-1.87	0.03	0.0883809	0.85	-0.0257	3.428928	2.86	0.6599
1977	0.2110311	1.81	0.032	-0.1031051	-1.98	0.0376	0.062195	0.6	-0.0333	3.34857	2.75	0.6562
1978	0.1763844	1.51	0.0131	-0.1034051	-1.98	0.0374	0.0343088	0.33	-0.0385	2.797001	2.26	0.6406
1979	0.2188304	1.91	0.0386	**-0.122025**	**-2.4**	**0.0671**	0.0579934	0.56	-0.0343	2.888483	2.44	0.6463
1980	0.1381805	1.16	-0.0052	-0.0989641	-1.84	0.0279	-0.013824	-0.13	-0.0404	**3.512727**	**3.09**	**0.6679**
1981	0.0998661	0.85	-0.0178	-0.0827009	-1.55	0.009	-0.028109	-0.27	-0.0393	3.500769	2.93	0.6625
1982	0.0282874	0.24	-0.0315	-0.070766	-1.32	-0.0039	-0.093927	-0.9	-0.0241	3.004806	2.42	0.6457
1983	0.0201392	0.17	-0.032	-0.0826661	-1.55	0.0089	-0.112512	-1.06	-0.0174	2.85195	2.35	0.6436
1984	-0.030773	-0.25	-0.0313	-0.0695922	-1.27	-0.0064	-0.156298	-1.47	0.0032	1.801621	1.46	0.6198
1985	-0.059537	-0.49	-0.0276	-0.0675748	-1.23	-0.0085	-0.190683	-1.77	0.022	2.50654	2.22	0.6395
1986	-0.026838	-0.22	-0.0317	-0.0689746	-1.24	-0.0081	-0.156912	-1.41	-0.0001	2.534057	2.21	0.6392
1987	-0.014306	-0.11	-0.0324	-0.0739811	-1.31	-0.0046	-0.151006	-1.35	-0.0036	2.966865	2.6	0.6512
1988	0.0274832	0.21	-0.0317	-0.0931172	-1.63	0.0136	-0.126384	-1.1	-0.0157	2.83266	2.36	0.6438
1989	0.0097065	0.07	-0.0325	-0.0930718	-1.57	0.0103	-0.149025	-1.28	-0.007	2.766095	2.26	0.6407
1990	0.0461931	0.34	-0.0301	-0.1099666	-1.83	0.027	-0.121901	-1.01	-0.0194	3.362107	2.77	0.6571
1991	-0.026765	-0.19	-0.0318	-0.093014	-1.47	0.0047	-0.188054	-1.55	0.0079	3.701594	2.94	0.6625
1992	-0.04386	-0.31	-0.0306	-0.0840904	-1.3	-0.0048	-0.188526	-1.49	0.004	3.294211	2.42	0.6456
1993	-0.009379	-0.06	-0.0326	-0.0994856	-1.5	0.0062	-0.169674	-1.29	-0.0069	3.57409	2.61	0.6517
1994	-0.041643	-0.27	-0.0311	-0.1041033	-1.5	0.006	-0.211755	-1.56	0.0084	3.678607	2.59	0.6509
1995	-0.053567	-0.33	-0.0303	-0.1074092	-1.47	0.0045	-0.229254	-1.6	0.0108	3.900791	2.64	0.6526
1996	-0.02287	-0.13	-0.0323	-0.1159903	-1.5	0.0064	-0.20893	-1.37	-0.0026	4.226602	2.73	0.6555
1997	-0.126894	-0.7	-0.0224	-0.0687336	-0.82	-0.0255	-0.280496	-1.75	0.0203	3.055366	1.77	0.6271
1998	-0.043386	-0.22	-0.0316	-0.0957937	-1.08	-0.0154	-0.219624	-1.23	-0.0098	1.913717	1.06	0.6121
1999	-0.157989	-0.73	-0.0216	-0.0360471	-0.36	-0.0368	-0.290677	-1.5	0.005	1.990606	1.07	0.6123
2000	-0.261477	-1.05	-0.0098	0.0438907	0.39	-0.0363	-0.324443	-1.45	0.0019	2.909521	1.44	0.6194
2001	-0.449901	-1.5	0.0127	0.117	0.87	-0.0238	-0.454355	-1.68	0.0159	2.945165	1.22	0.6149
2002	-0.014548	-0.03	-0.0326	0.1007545	0.53	-0.0336	0.0773175	0.19	-0.04	3.6167	1.09	0.6126

Note: Bold numbers are break year of each climate variable

Coef. is the coefficient of dummy variable, t is t-value and A-R^2 is the adjusted R^2.

Table 14 The regression outcome of the VAR model

Vector autoregression

Sample:	1986 2002	No. of obs	= 17
Log likelihood	= -306.9538	AIC	= 37.28869
FPE	= 5.56e	HQIC	= 37.33741
Det(Sigma_ml)	= 1.65e	SBIC	= 37.77881

Equation	Parms	RMSE	R-sq	chi2	P>chi2
gdp	5	835.43	0.9789	787.2125	0.0000
trans.	5	7655.37	0.9491	317.2129	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
gdp						
gdp						
L1	.8546623	.2016345	4.24	0.000	.459466	1.249859
Trans.						
L1	.0469025	.0308686	1.52	0.129	-.0135988	.1074038
yr	-70.07892	124.8	-0.56	0.574	-314.6824	174.5245
Dyr	19.26918	15.1525	1.27	0.203	-10.42917	48.96754
_cons	5819.235	4974.39	1.17	0.242	-3930.391	15568.86
Trans.						
gdp						
L1	4.034321	1.847657	2.18	0.029	.4129787	7.655663
Trans.						
L1	.6120389	.282861	2.16	0.030	.0576415	1.166436
yr	-1163.935	1143.592	-1.02	0.309	-3405.335	1077.464
Dyr	92.38876	138.8484	0.67	0.506	-179.7491	364.5267
_cons	-85898.38	45582.32	-1.88	0.060	-175238.1	3441.338

Note: Trans. refers to the volume of freight transportation. yr is the trend t, Dyr is the variable D·t, gdp_L1 is the value of GDP in last period and Trans._L1 is the volume of freight transportation in last period.

Table 15 The estimated results of climate change as the productivity shock

Source	SS	df	MS		
Model	3382428.86	6	563738.143	Number of obs =	17
Residual	4992880.54	10	499288.054	F(6, 10) =	1.13
				Prob > F =	0.4115
				R-squared =	0.4039
				Adj R-squared =	0.0462
Total	8375309.39	16	523456.837	Root MSE =	706.6

Rsdgdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
temp	355.6285	299.6156	1.19	0.263	-311.9565	1023.214
pre	-60.25816	718.8955	-0.08	0.935	-1662.057	1541.541
sl	-151.7204	76.44021	-1.98	0.075	-322.0398	18.59902
temp						
L1	79.44422	291.1985	0.27	0.791	-569.3865	728.2749
pre						
L1	-316.3188	647.4307	-0.49	0.636	-1758.884	1126.247
sl						
L1	115.3172	87.73719	1.31	0.218	-80.17341	310.8079
_cons	5438.807	13513.09	0.40	0.696	-24670.23	35547.84

Note: temp means temperature, pre is precipitation, sl is sea level and the temp_L1, pre_L1 and sl_L1 are the temperature, precipitation and sea level in last period, respectively.