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CONFERENCE PAPERS

Modelling Economic Consequences of Climate Change Impacts on Ground Transportation in Atlantic Canada

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Abstract: Transportation is one of the most important sectors of Atlantic Canada's economy. In a sense it is a backbone of the regional economy since it provides means for moving people and freight throughout the region and eventually stimulates regional economic growth and development through national and international trade. However, according to numerous studies, the region is vulnerable to climate change impacts which among other things will affect transportation infrastructure and operations. In this study, climate change impacts are analyzed with respect to the New Brunswick/Nova Scotia Transport Corridor (NB/NS TC) located in Atlantic Canada – the main trade gateway in the region that connects seaports with the North American continent. First, major climate change impacts in the area are identified. Second, the best economic model to evaluate consequences of the climate change impacts is chosen. Third, using the existing literature and studies that describe future climate changes in the region, various scenarios of future challenges for the NB/NS TC are specified. Finally, economic consequences of the regional climate change impacts on the NB/NS TC are evaluated. The above specified consequences are imposed on a dynamic economic model and their cumulative impacts are traced over time.

Keywords: Transportation, climate change impacts, general equilibrium model, econometric estimation, computer simulation

JEL Classification: Q51, Q54, D58

Analysis of the Climate Change Studies in the Area

The predominant concern amongst researchers regarding climate change impacts in the area of the New Brunswick/Nova Scotia Transport Corridor (NB/NS TC) appears to be the effects and consequences of rising water levels due to sea level rise, flooding, and storm surges. In 2011, T.Webster, McGuigan, and C.Webster, performed

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high water mapping using GPS technology across Prince Edward Island (PEI). The areas that the study identified as "at risk" included the areas associated with the NB/NS TC.

Richards and Daigle (2011) investigated sea level rise (SLR) in Nova Scotia and PEI municipalities of Atlantic Canada. As is duly noted in the report, Atlantic Canada has witnessed extreme cases of coastal flooding, including the increased frequency of these events over the last decade. Using historical climate data to link past and future periods, parameters were established from the Canadian Hydrographic Service (CHS) at key tide prediction sites. Furthermore, estimates of global sea-level rise were extracted from Rahmstorf (2007) to compliment local trends in Halifax and Charlottetown. The trends indicate that in these municipalities, sea levels are rising and will continue to follow the global trend.

Greenberg et al. (2012) predicted global warming to result in a rise in sea level that will lead to increased risk of flooding in the Bay of Fundy. They indicate that two other factors will affect high water: existing trends in mean sea level and changing tides. It is demonstrated that the Bay of Fundy and the Gulf of Maine located in Atlantic Canada share a relationship in their effect on one another. After analyzing long-term sea level records, independent of global warming related to climate change, sea level and tidal range have been increasing in this system. After performing a numerical model investigation, it is apparent that recent changes in sea level are giving rise to increasing tides. The combined effects of modern SLR, global warming induced SLR, and the expanded tidal range they induce, are deemed to produce a significant increase in the high water level. The study concludes with expectations of a dramatic increase in the risk of flooding at elevated high water levels in this region during the twenty-first century.

The Tantramar region associated with the NB/NS TC is particularly vulnerable to climate change impacts (Lieske and Bornemann, 2011). SLR caused by climate change, and combined with increasing storm frequency and intensity, is projected to affect the low-lying area of the Tantramar dykelands. Lieske and Bornemann expect increased water depth will damage the assets within the flood zone. According to current estimates for a 1:10 year flood cycle, such floods will affect 1,049 parcels of land and 156 buildings. In addition, flooding of major and secondary highways will be rendered impassable, the sewage lagoon will be flooded, and agricultural lands will be submerged.

Another case study was performed on the Tantramar region by Wilson et al. (2012), which forecasted the economic damage from storm surge flooding. According to this study, it is expected over the next 100 years that the total present value of expected annual damages will be $59.3 million if future predictions of the climate occur as forecasted. Conversely, in the absence of future climate change, the present value of costs would be $48.6 million. Thus an expected 22% increase in damages from future climate change-induced SLR results.

Daigle (2012) focuses on SLR and flooding estimates on the coasts of New Brunswick in his report. He remarks that the coasts of Atlantic Canada have significant sensitivity to SLR and associated storm impacts. According to the study, areas that contain the highest sensitivity include the NB/NS TC.

To supplement Daigle's findings, the report produced by Turkken, El-Jabi, and Caissie (2011) discusses floods under different climate change scenarios in New Brunswick. They found the increase in high flows for low return floods was generally greater than higher return floods. The increase in low return floods was found to be approximately 30% and approximately 15% for higher return floods, depending on the scenario and time interval. Low flows exhibited increases of approximately 10% for low return droughts and approximately 20% for higher return droughts.

Changes in precipitation and temperature were also taken into account in our review of the latest available literature on climate change in Atlantic Canada. For example, various climate change scenarios were investigated in Nova Scotia and PEI by Richards and Daigle (2011). They state that the consensus is that warmer climates are predicted to experience an increase in precipitation intensity, due to the relationship between saturated water vapour pressure and temperature. Regarding precipitation in the area of the NB/NS TC, Turkkan, El-Jabi and Caissie project the mean annual precipitation to increase by 9-12% in the future, compared to current conditions (2011).

Richards and Daigle use scatter-plots to make observations of the temperature in Nova Scotia and PEI (2011) in Atlantic Canada. All their models indicate an increase in future temperature as the magnitude of the temperature increase increases with progression of time. The model they constructed implies a warmer and wetter future climate in the region. To corroborate these findings, Turkkan, El-Jabi, and Caissie predict for the period 2010-2100, average temperatures are projected to increase between 4.7°C and 4.8°C for the sites in New Brunswick (2011).

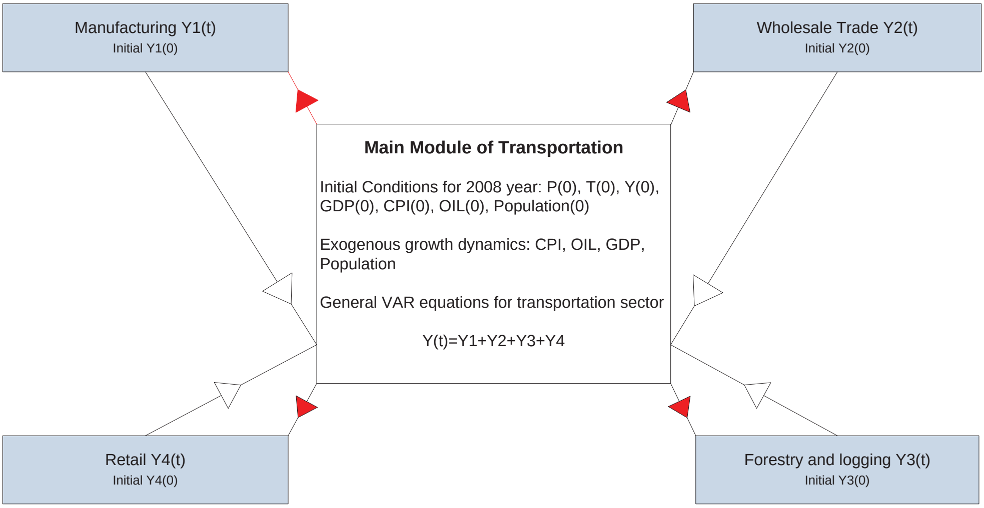
Methodology

Choice of Appropriate Model

Based on our analysis of economic models used for estimation of the climate change impacts, General Equilibrium Model (GEM) appears to be the best in our case. Since climate change impacts have their own dynamics compared to traditional one-time exogenous shocks, GEM was constructed as a dynamic model with dynamic shocks to deal with the climate change issues. There are some examples of application of GEM to climate change impacts in the literature such as the Dynamic Integrated Climate and Economy (DICE) model or Regional Integrated Climate and Economy (RICE) model.

The basic logic behind our model is presented below:

Figure 1. General Equilibrium Model and its basic links



Inputs of the model are: Initial values of transportation price P(0), volume of transportation T(0), sum of overall value added by four regional sectors Y(0), oil price OIL(0), overall price level CPI(0), provincial Gross Domestic Product GDP(0) and population, Population(0) were given by their actual values in 2008. Dynamics of CPI, OIL, GDP and Population was given exogenously as explained later.

Computer realization of the model was done in C programming language. Our C-program includes recursive algorithm that starts with Main Module of Transportation. This Module captures dynamics in the form of Vector Autoregression (VAR) equations, exogenous variables dynamics and climate shocks imposed on VAR. The Module then sends values of transportation price and volume of transportation to other four Modules associated with four regional sectors: Manufacturing, Wholesale Trade, Forestry and Logging, Retail – the largest consumers of transportation in the area. Each of these four sectors is described by its own demand for transportation equation estimated separately. As a result of these four modules, the value added by each sector is calculated and returned to the Main Module. This procedure is then repeated over various time periods.Time paths of the volume of transportation and price of transportation for years 2013-2100 are fundamental outcomes of our dynamic GEM.

Econometric Estimation of the GEM Elements

Vector Autoregression or VAR is a statistical model used to capture linear interdependencies among multiple time series. These interdependent time series are treated as endogenous variables. VAR also allows a set of exogenous variables. In our VAR model, volume of transportation TRAFFIC_VOLUME and price of transportation CPI_TRANS in logarithms are our two interdependent time series. In fact, in our case VAR specification of the model is a reduced form of the demand-supply for transportation system. Therefore, the following exogenous variables were included into VAR: overall price level CPI; value added by four sectors chosen before 4SEC_VALUE, oil price OIL_PRICE and population POPULATION. All variables are in logarithms.

Then we estimated our VAR using data obtained for New Brunswick and Nova Scotia provinces and NB/NS TC within 1991-2011 years. VAR estimation was done in EVIEWS 7. The following results were obtained:

LOG_CPI_TRANS = 0.729721832396*LOG_CPI_TRANS(-1) +
0.0864749971496*LOG_TRAFFIC_VOLUME(-1) - 1.24262038745 +
0.0013539231051*LOG_CPI + 0.141154179292*LOG_4SECT_VALUE(-1) +
0.0354046243147*LOG_OIL_PRICE - 0.0153339709068*LOG_POPULATION
LOG_TRAFFIC_VOLUME = - 0.010684593886*LOG_CPI_TRANS(-1)
+ 0.317155070662*LOG_TRAFFIC_VOLUME(-1) + 8.10684897922 +
0.717366768962*LOG_CPI - 0.0687902457276*LOG_4SECT_VALUE(-1) -
0.101681264474*LOG_OIL_PRICE + 0.00858059027492*LOG_POPULATION

Dynamics of the model was captured rather well with R^2-adjusted around 98%. All variables are significant at 95 % significance level. In addition, demand for transportation functions by four regional sectors – largest consumers of transportation defined above - were estimated using Seemingly Unrelated Regression (SUR) model. SUR model was chosen because it allows error terms to be correlated amongst equations. Below the results of the estimation are presented:

$$\ln(rtrade_t) = -1.9819 + 0.1185\ln(rtrade_{t-1}) - 0.3053\ln(cpi\_trans_t) + 0.1565\ln(cpi_t)$$
$$+1.5813\ln(GDP_t) - 0.4982\ln(pop_t)$$
$$\ln(foresty_t) = 41.4908 + 0.3338\ln(foresty_{t-1}) - 0.3826\ln(cpi\_trans_t) + 0.1458\ln(cpi_t)$$
$$-0.9378\ln(GDP_t) - 2.0236\ln(pop_t)$$
$$\ln(wsale_t) = -1.1252 + 0.5606\ln(wsale_{t-1}) - 0.4317\ln(cpi\_trans_t) + 0.4602\ln(cpi_t)$$
$$+0.2536\ln(GDP_t) + 0.1080\ln(pop_t)$$
$$\ln(mfac_t) = 8.8910 + 0.3504\ln(mfac_{t-1}) - 0.8504\ln(cpi\_trans_t) + 0.8464\ln(cpi_t)$$
$$-0.4931\ln(GDP_t) + 0.0817\ln(pop_t)$$

where *rtrade, forestry, wsale* and *mfac* are the values added by retail trade, forestry, wholesale trade and manufacturing respectively, *cpi_trans* is the price of transportation, *cpi* is the overall price level, *GDP* is gross domestic product in New Brunswick and Nova Scotia, *pop* is population in these provinces. Again all variables are significant at 95% significance level.

Results of Computer Simulation

Simulated time paths of the volume of transportation with climate change impacts for years 2013-2100 are compared to the time path of the volume of transportation in the area without climate change impacts. The difference between the time paths provides information for the evaluation of the loss of value added due to climate change impacts in the area.

Three different scenarios were analyzed:

Base case scenario: Basic assumptions associated with this scenario are
Inflation = 2%
Economic growth = 2.5%
Population growth = 0.5%
Oil price growth = 3%
These assumptions give rise to the exogenous variables dynamics.

This scenario is based on the existing macroeconomic situation and expectations of future developments in the Canadian economy. Based on our dynamic general equilibrium model (GEM) time paths for the price and volume of transportation in the NB/NS TC have been generated according to the existing situation.

High oil price scenario: This scenario is associated with the following assumptions
Inflation = 2%
Economic growth = 2.5%
Population growth = 0.5%
Oil price growth = 5%

Economic slowdown scenario: This scenario is associated with the following assumptions:
Inflation = 2%
Economic growth = 1.0%
Population growth = 0.5%
Oil price growth = 5%

This scenario models a slowdown in the economy from 2.5% economic growth to just 1%. As a result, the price of transportation decreases which increases demand for transportation and consequently volume of transportation over time. Lower price generates higher economic activity in the transportation sector, which eventually increases loss of value added due to climate change impacts compared to scenario 1.

First of all, cumulative nature of climate change impacts was evaluated. It was detected that there is a 52% increase in the loss of value added that occurs in the first 11 years from the time of the first shock compared to static evaluation of the shock. After that dynamic system stabilizes at new steady state.

Based on our simulations, it is possible to make the following conclusions:

- Climate change impacts that affect NB/NS TC via increased flooding, frequency of extreme weather events and worsening of general weather conditions cause loss in value added by transportation by approximately $1.078 million per year in today's dollars with standard deviation of approximately $0.2 million. It means that maximum loss can be as high as $1.278 million and as low as $0.878 million per year
- Dynamic properties of our model suggest that it is necessary to invest in mitigation measures in the first 11 years with minimum of $11.858 million and maximum of $20.235 million. Minimum is associated with favorable economic scenario of economic growth of 2.5% and higher, moderate oil price increase of 3% per year and approximately 1.5% loss in volume of transportation due to climate change impacts. Maximum is associated with lower that 2.5% economic growth, an increase in oil prices by more than 5% per year and higher than 1.5% loss in volume of transportation due to climate change impacts.
- If other consequences of the climate change impacts such as loss of asset value, loss of travel time and an increase in number of accidents in the area are taken into account, the overall annual loss can reach $11.881 million per year in today's dollars.

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