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The Effect of Transportation Hubs in the Canadian Economic Context

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Abstract

This paper analyzes the effect of transportation hubs on economic centrality and four economic and social welfare variables. To do so, we construct the economic centrality variable using a weighted-network approach. We then study its determinants, focusing on whether transportation hubs have an impact on the economic integration of a province. We infer that transportation hubs do have a positive effect on economic centrality. These determinants are then implemented in the analysis of gross domestic product (GDP) per capita, life expectancy, share of the labor force with a secondary education, and infant mortality rate. Our results show that life expectancy and share of the labor force with a secondary education are both positively affected by transportation hubs. On the other hand, we discover that not all methods of transportation have a positive impact on GDP per capita. Lastly, we find that some, but not all, of the determinants of economic centrality explain infant mortality rates.

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1. Introduction

The last few decades have brought on an unprecedented boom in global connectivity. The term ‘globalization’ is ever-present not just in the context of economics, but also politics, law, and culture just to name a few (Defining Globalization, 2017). Within the economic framework, international trade has exponentially grown due to “advances in communication and transportation technology, combined with free-market ideology [that] have given goods, services, and capital unprecedented mobility” (Globalization of the Economy, 2017). In a world where industries do not have to confine themselves to domestic markets, the race to lead the pack within the World Trade Network (WTN) is more than competitive. Countries take advantage of their natural advantages in resources and geographic location, whereas other countries are forced to work around them as constraints. Transportation infrastructure is a good example of a means to combat natural barriers to trade, such as water, or simply lack of proximity to major markets.

This concept can also be applied on a smaller scale, such as interprovincial trade within Canada. Though Canada has made a great effort to erase barriers to international trade, it is only very recently that measures are being put in place to remove internal barriers. The Canadian Free Trade Agreement (CFTA) is to replace the outdated 1995 Agreement on Internal Trade, reducing the barriers to trade from 11 sectors in 1995 to all but 144 specific exceptions in 2017 (FINANCIAL POST, March 7, 2017). The implementation of the CFTA will create a similar environment to the WTN, where trade barriers will almost be solely geographical. This is why we chose to further examine how transportation hubs can affect the ten Canadian provinces, more specifically how an increase in this kind of infrastructure can potentially help some of the smaller, less centrally located provinces.

We will begin with a literature review of previous work on the subject, most notably on the subject of weighted-network analysis in the international trade framework. We will then turn to a detailed description of the variables used in our analysis, simultaneously painting a comprehensive picture of the current Canadian economic landscape. Section 4 will provide both the methodology and the results of our analysis, and lastly, we will conclude with a few closing remarks and a discussion of the shortcomings of this paper and the potential for further exploration.

2. Literature Review

In this section, we will aim to situate this paper by reviewing a few key articles that made an impact in the subject of network analysis in the field of international trade. The evolution of trade network analysis can be broken up into two main stages: the binary network, followed by the weighted network. The binary network looks at the bilateral flows between two countries or nodes, and associates a minimal threshold of trade flow with the presence of a node. As William Chow concisely states in *An Anatomy of the World Trade Network*, in the case of a binary network approach, "only […] the presence of a link matters", thus there is no discrepancy made between a node that barely made the threshold and the most intense bilateral trade partners (Chow, 2013, p. 3). The basis of the literature review on binary networks will be done by summarizing the works of Boguna and Serrano (2003) as well as Kali and Reyes (2007). We will then move to works by Duernecker et al. (2012) and Arvis and Sheperd (2016) to look at the use of weighted networks in the contexts of international trade and air transport respectively. Lastly, Sandé's 2014 paper on trade networks in the Canadian context will receive special mention, as it is this specific piece of work that laid the foundation for the model used throughout this paper.

We begin with Serrano and Boguna's contribution to the binary network approach, which utilizes both import and export data from the United Nations COMTRADE database to generate nodes. Each node appears if there is any kind of exporting or importing activity between two countries, which leads to each country accumulating a total number of out-nodes (exports) and in-nodes (imports). This total number of vertices is then used to determine a country's degree of economic centrality. Ultimately, Serrano and Boguna emphasize that a binary approach such as theirs reveals similar information to the new weighted approach that was beginning to gain popularity amongst economic scholars. For one, they claim that a country's participation in the world trade network (WTN) is a good indicator in itself of economic growth as well as economic trends between trading partners. Additionally, they argue that a weighted network forces the author to choose whether a country's degree of centrality should be determined by its imports or its exports, therefore restricting the lens in which we see that country's role in the WTN.

In their article *The Architecture of Globalization: A Network Approach to International Economic Integration*, Kali and Reyes (2007) also advocate for the use a binary network approach, though their method does differ from that of Serrano and Boguna. Kali and Reyes admit that generating vertices from trade volume alone provides too superficial a view of the global trade network, and thus prefer to create a minimal threshold that relies on the share of a country's exports to another country over its total exports. Based on the statistical analysis delivered in the paper, this measure of economic integration does appear to have a positive and significant impact on GDP per capita, which in turn proves its importance on economic growth. This ratio-based degree of integration is an interesting step away from the more simplistic volume-based binary network, providing a natural segue into the weighted-network approach.

Duernecker et al.'s 2012 paper *Being Close to Grow Faster: An Empirical Analysis of Empirical Globalization* offers us with our first view of a weighted network approach. The authors begin by making an important distinction between trade intensity and trade integration. The degree of intensity, often used as the basis of a binary network model, is only one piece of the puzzle. Duernecker et al. argue that in order to understand deeper links between countries, and ultimately how these countries affect each other's economic growth, the degree of integration in the world trade network is a far more telling measure. Their weighted network approach is constructed with export data available on the United Nation's COMTRADE database, across 125 countries, from 1962 to 2005. The network begins with a matrix of bilateral flows, as a binary network would. The weighted component of the integration variable stems from both the ratio of the country's total exports over its GDP, as well as the share of the country's GDP in the combined GDP of all 125 countries. Duernecker et al.'s analysis estimates that an increase of 1 point in a country's economic centrality index leads to a 1.4 percent increase in GDP in the following year, conveying the importance of integration in the world trade network as a measure of economic growth.

Arvis and Shepherd's 2016 article *Measuring Connectivity in a Globally Networked Industry: The Case of Air Transport* provides an in-depth analysis of trade by air, and its importance to the global trading network. Arvis and Shepherd use an air connectivity index (ACI) as a multi-factored expression of "the importance of a country as a node within the global air transport system" (Arvis, Shepherd, 2017, p. 369). This index is measured by taking into consideration the costs of trading with this country. Furthermore, in order to receive a high connectivity score, the country cannot be limited to a small group of trading partners, even if the price of working with these few partners is low. The idea here is that the ACI takes into account the global context of air trading instead of simple bilateral flows, allowing us to see deeper links within the global air transport network, for example the connectivity between countries even when they do not share direct flights. This principle put forth by Arvis and Shepherd is in line with the method used to compute the economic centrality measure used in this paper. Additionally, this paper clearly highlights the importance of transportation hubs in the trading context, which is the primary focus of this paper.

We finish this section by reviewing Sandé's 2014 paper entitled *Causes and Consequences of Economic Centrality: Evidence from Canadian Provinces.* The author chooses to change the scope of the typical global trade network approach by concentrating her efforts on the Canadian context, each of the ten Canadian provinces representing a node just as a country would within the WTN. Sandé uses Statistics Canada's socio-economic database (CANSIM) to generate an economic centrality variable, a provincial measure that is weighted with a combination of export and GDP data. The interpretation of the degree of economic centrality is that a smaller degree is equivalent to a shorter 'trading distance' to the other provinces, therefore a more influential actor in the Canadian network. However, since this variable is replicated and used throughout this paper, it will be described in greater detail in a later section. Both the causes and effects of economic centrality are analyzed, however we will focus on her findings regarding the effects on GDP per capita, as it is a good measure of economic growth. Sandé's results show that economic centrality is a statistically significant variable in determining GDP per capita, concluding that a one unit decrease in economic centrality leads to a four per cent increase in GDP per capita.

The contributions of network-based analysis, both with binary and weighted approaches, have led to significant strides in the way we define an 'open' and dominant country within the global trade framework. Additionally, Sandé's concept of capturing these deeper trade links on a national scale open numerous doors to analyze the intricacies of other trading systems – national, regional, provincial - across the globe. For the purpose of my analysis, I chose to replicate Sandé's weighted network approach in the Canadian context in my study of the effect of transportation hubs on the Canadian trading network.

3. Data

Our dataset will be in a panel format, ranging over 13 years across the ten Canadian provinces. The dataset is constructed with the use of Statistics Canada's socio-economic database, CANSIM. The timeframe is from 1998-2011, which was chosen primarily for the extensive amount of data available for this particular period. By avoiding major holes in our data, our estimates are less susceptible to large errors, and depict a truer picture of Canada's economic situation in recent years. With that said, some variables did not span the entire timeframe. In this case, yearly growth rates for each province were computed, and an estimate for the missing years was extrapolated. All figures relating to this data exploration section will be located in Appendix A.

3.1 Dependent Variables

Our model will rely on five dependent variables: GDP per capita, secondary education attainment, life expectancy, infant mortality rates, and economic centrality. GDP per capita is an obvious choice, as it is often used to portray the living standards of a specific region. For the sake of being thorough, we use the three other aforementioned variables to give additional insight into the welfare of the population at play. We generate our first variable, GDP per capita, by dividing GDP, found in CANSIM Table 384-0002, by the population found in CANSIM

Table 051-0001. Then, secondary education attainment is depicted as the share of the labor force that has at least a high school diploma. This variable was constructed using Labor Force Survey (LFS) data. Table 282-0004 provides the number of individuals over 15 years of age with at least a secondary education, and Table 282-0087 depicts the number of persons over the age of 15 that belongs to the labor force. By dividing the former with the latter, we obtain the share of the labor force with at least a secondary education, our second variable of interest. Thirdly, our life expectancy variable is derived using Table 102-0512, specifically with life expectancy at birth. These yearly estimates are calculated using a 3-year average, taking the middle year as the output shown in the table. Infant mortality rates are calculated using the number of deaths before the age of 1 per 1000 population. These rates are given in Table 102-0504. Economic centrality requires special mention, therefore will be dealt with in a subsequent section.

Taking a more in-depth look into GDP per capita, Figure 1 clearly allows us to establish a couple of emerging trends. From the graph, we can separate the ten Canadian provinces in three groups. The first group is Alberta as a stand-alone at the forefront of the Canadian economy. Secondly, we have Newfoundland and Labrador, Saskatchewan, Quebec, Ontario, Manitoba, and British Columbia, and thirdly, New Brunswick, Prince Edward Island and Nova Scotia. We clearly see Alberta leading the way, with a GDP per capita of $51,410 in 2011, which is over $12,000 more than the 2nd ranking province. This is an impressive feat, considering Alberta also had the lowest growth rate during this period, most likely because of its dependence on the natural resource sector. In the second group, which consists of middle-of-the-pack provinces, we have Quebec, Manitoba, British Columbia, Newfoundland and Labrador, Ontario and Saskatchewan in ascending order, with GDP per capita ranging from $34,500 to $40,000 in 2011. Though this range is quite small, it is important to note the varying growth rates in this middle group. For example, Ontario barely witnessed any change in GDP per capita, with only a 13% growth from 1998 to 2011, compared to Newfoundland and Labrador who experienced a remarkable 60% growth rate. Our third group has the lowest GDP per capita, ranging from $30,830 in Prince Edward Island to $33,016 in New Brunswick. These three provinces have had fairly similar growth rates between 24%-34%, however since New Brunswick is both highest in growth rate and in GDP per capita in this group, it is highly plausible that it will find itself in the middle group in the upcoming years.

Moving on to the share of the labor force with a secondary education depicted in Figure 2, the numbers tell a slightly different story. The first thing to notice is that there isn't much discrepancy between the lowest and highest-ranking province. British Columbia has remained at the top of the list, with a share increasing from 0.85 in 1998 to 0.9 in 2011. In the remaining nine provinces, we have a range of 0.725 to 0.82 in 1998 to 0.83 to 0.88 in 2011. The general trend for all provinces, and therefore the country as whole, is slow and upward-sloping. We have no unusual dips and spurts, with only Prince Edward Island worth mentioning with a 14.85% growth rate over the thirteen years, about 4% higher than the second-highest growth rate.

Life expectancy, shown in Figure 3, bears a resemblance to our previous dependent variable, which has seen very little movement due to the nature of the variable. Life expectancy in a developed country is unlikely to grow very much, unless there were to be a major breakthrough in medicine causing a positive effect, or a human or natural catastrophe causing a negative one. This was not the case between 1998-2011, therefore we see a small interval of life expectancy estimates across the country and throughout the period, from 77.3 years in Newfoundland and Labrador in 1998 to 82.4 years in British Columbia in 2011. Just as we saw with secondary education estimates, the trend is slowly rising, however the growth rates are much smaller than those previously seen in the share of labor force with a secondary education, with an average increase in life expectancy of 3% across the ten provinces from 1998 to 2011.

Our last variable of interest is infant mortality rates (Figure 4). This variable is closely related to that of life expectancy, as it does depend on health standards in the region, therefore it provides us with a complementary perspective in that domain. However, we do see much more disparity in the growth rates of this variable, fluctuating between 4% in Saskatchewan and 48% in Prince Edward Island throughout the thirteen years observed. Prince Edward Island appears to be an extreme outlier, with significant fluctuations in the data, finishing with the third-lowest infant mortality rate in 2011. New Brunswick also saw an impressive 46% drop in its rate, going from 6.5 per thousand in 1998 to 3.5 in 2011, where it claimed the top spot across all provinces, doing so in a more linear fashion than Prince Edward Island. Most provinces saw steady negative growth rates between 4% and 20%, which is in line with the increases seen in our other measures of living standards and welfare. Yet we have three anomalies in the data, with Alberta, Nova Scotia, Newfoundland and Labrador, and Alberta showing an increase in their infant mortality rates of as much as 15% in the case of the latter.

3.2 Independent Variables

The independent variables are chosen in the hope that they will provide us with some insights into how well Canadian provinces are doing with regards to the four variables mentioned in the previous section. These variables are as follows: interprovincial exports, investment share of the GDP, government share of the GDP, transportation hubs by way of air, transportation hubs by way of land and intermodal transportation hubs.

Interprovincial export data is compiled using a combination of CANSIM tables 386-0002 and 386-0003. Data for years 2007 and 2008 appear in both databases, yet are not the same, thus an average of both values is used to generate the numbers in our analysis. Investment share of GDP comes from Table 031-0007, which illustrates flows and stocks of fixed non-residential capital. This variable is then divided with our GDP data, providing us with the investment share of GDP, also referred to as the savings rate. Government share of GDP is similarly calculated by means of total government expenditures found in Table 385-0002, divided by GDP. The transportation hub variables give us some insight into how reachable each province is, based on all three methods of transportation: air, water, and ground. The assumption here is that a greater number of hubs would help alleviate the burden of poorly situated provinces by way of easing access to them via different transportation systems. In the case of air transport, the 23 certified National Airport System (NAS) airports located in the ten provinces are considered. The list can be found on the Canadian Airport Council website. In the case of ground transportation, we specifically opted to use Canadian National (CN) intermodal ports. The reason for this is again accessibility. The intermodal component allows for the "flexibility to use rail, trucks and vessels" (Intermodal Terminals, 2017) combining all methods of ground transportation. Lastly, the 18 ports that comprise all members of the Canadian Port Authority are considered in the transportation by way of water variable. These can be found on the Canadian Port Authority website, which provides a list of each member as well as the port associated to it.

Figures 5-7 provide us with a closer look at interprovincial export flows, where we can see that exports have increased in every province during the thirteen-year period. All provinces incurred growth rates between 72% and 174%, with Newfoundland and Labrador as the only extreme outlier with an impressive 584% increase in exports from 1998 to 2011. We also notice that Ontario is by far the largest exporter with $ 120 billion in exports out of a total $ 356 billion amongst all ten provinces. Quebec and Alberta have very similar figures, even though Quebec is much larger. This is because of Alberta's natural resource sector, which undoubtedly accounts for a large portion of its interprovincial exports. The ten Canadian provinces are often divided into four regions: The Western region with only British Columbia; the Prairie region comprising of Manitoba, Saskatchewan and Alberta; The Central region with Quebec and Ontario; The Atlantic region which includes Newfoundland and Labrador, Nova Scotia, New Brunswick and Prince Edward Island. The first thing we notice is that most provinces concentrate their exports within their region, and the two central provinces. This means that provinces seem to be more likely to trade with provinces that are geographically closer to them, which is a safe assumption to make. For example, there is hardly any trade between British Columbia and the Atlantic provinces. In 2011, only 5% of British Columbia total exports went to the Atlantic region, and on the flipside, each Atlantic province's exports accounted for a small fraction of their respective totals: 3% for New Brunswick, 1% for Newfoundland and Labrador, 6% for Nova Scotia and 2% for Prince Edward Island.

Investment share to GDP provides us with some key information regarding how much each province manages to save in proportion to its GDP. Across the board, provinces are saving more as we make our way to 2011. In 1998, the average investment to GDP ratio was 18%, whereas in 2011 it is up to 22%. Most provinces in 2011 are hovering just under 20%, however Saskatchewan and Alberta skew the average with savings rates of 35%. Government share, on the other hand, allows us to assess how much spending each province incurs as a proportion of its GDP. A comparison of investment and government share of GDP shows that most provinces spend more than they save, except the two highest-ranked savers previously mentioned, Alberta and Saskatchewan. Alberta is the most peculiar, as it saves a considerable amount more than it spends. This is again most likely thanks to its natural resource sector, which rakes in a high GDP considering its small population, as can be seen in Figure 1 with the GDP per capita variable.

Figure 10 illustrates the allocation of transportation hubs across the ten provinces. The first thing we notice is that British Columbia and Ontario have the largest total number of hubs, with eleven each. Ontario's top rank is not surprising, as it is the most populated, and home to the Great Lakes. British Columbia is who we would expect to see at the top, since it is not geographically central in the Canadian context. With a large number of hubs evenly distributed across methods of transportation - four airports, four ports and 4 intermodal ports - the hypothesis is that these will help increase British Columbia's economic centrality score by promoting more trade, even if the distance to reach it is far greater. On the contrary, the smaller Atlantic region provinces fare poorly, with total counts between one and three per province. This could be due to a lack of resources in smaller regions, however the risk of undertaking the construction of a large transportation hub may be worth the reward.

3.3 Economic Centrality

The economic and geographic centrality variables are constructed in a far more complicated manner, which is why this section is dedicated to explaining in detail the steps to creating them. We rely on Sandé's 2014 paper to compute these two measures that form the crux of the weighted portion of this network approach. Fortunately, both are founded on a series of matrix manipulations; we will therefore present the full process using the economic centrality variable, and simply point out where the variables were interchanged for the geographic centrality measure. This section will conclude with an overview of how these variables fair across provinces and over time.

The starting point for the economic centrality variables is a 10x10 matrix of the bilateral flows between the ten provinces, specifically exports of goods and services from one province in a given year. This gives us matrix $X_t = (x_{ij,t})^{10}$, where export flows are calculated from province i to province j at time t, where $t = 1998, \ldots, 2011$. Exports within a province are nil, thus $x_{ii,t} = 0$ for all $i = 1, \ldots, 10$ and all $t = 1998, \ldots 2011$. We then generate $Z_{t} = (z_{ij,t})^{10}$, a normalized matrix of X_t with respect to total exports of province i at time t, providing us with more insightful information regarding each province's most significant trading partners within the context of the nine other Canadian trading partners. Each normalized matrix of export flows at time t is calculated as follows:

$$Z_{ij,t} = x_{ij,t} / \Sigma_{k=1, \ldots, 10} (x_{ij,t}),$$

where the total export flows of one province are the sum of the total interprovincial exports from our CANSIM trade dataset.

From the normalized matrix, we compute a 'true openness variables' $\theta_{i,t}$ such that:

$$\theta_{i,t} = \Sigma_{k=1,\ldots,10} (x_{ij,t}) / (1 - \beta_{i,t}) * Y_{i,t} \ ,$$

where $\beta_{i,t}$ is the share of province i's GDP over the total GDP across the ten provinces, and $Y_{i,t}$ is the GDP of province i at time t. We then compute an adjacency matrix A_t, providing us with a measure of trade interaction between provinces, where each (i,j) is a probability that province i is connected with province j (Duernecker et al., 2012). The computation for this matrix is done across all ten provinces and thirteen years, as follows:

$$A_t = (a_{ij,t})^{10} = (1 - \theta_{i,t}) * Z_{ij,t} \ ,$$

The adjacency matrix A_t is the weighted component of the centrality variable, which is computed such that:

$$\Psi_{i,t} = \Sigma_{i \neq j} \, (\, \beta_{i,t} * \varphi_{ij,t} \,) \, ,$$

where $\beta_{i,t}$ is the same share of GDP as above, and $\varphi_{ij,t} = (I - A_{-j})^{-1} * E$, where I designates the identity matrix, and E is a column vector of 1's. Sandé explains that $\psi_{i,t}$ is a measure of the distance required for a province to reach another (Sandé, 2014). Otherwise said, it provides us insight into how difficult it is to access a province, thus a low score implies that the associated province will be able to interact with the other provinces more easily. The advantage of such a measure is that this ease of access is taken into account between each pair of provinces, therefore a province's low economic centrality score can only be attained with a short distance between (almost) all of its trading partners, proving why this is a true measure of economic integration into the trading network as a whole.

The results of the economic centrality variable highlighted in Figure 11 are not altogether surprising, with the central region leading the way with 2011 measures of 0.995 in Ontario and 1.568 in Quebec. The Atlantic and Prairie regions trail with scores between 2 and 3, with the exception of Alberta that clearly benefits from its large natural resource sector, boosting its exports as previously mentioned and lowering its economic centrality measure to 1.733 in 2011. Finally, we see British Columbia with a similar score of 1.9 in that same year, demonstrating parallel between the largest exporters in Canada and the provinces considered most economically central. In terms of trends, we note that every province managed to improve their degree of economic centrality, and more importantly, the Atlantic and Prairie regions saw greater changes in their measures, bridging the gap between them and the Central and Western provinces over the 13-year period.

Overall, there is a clear pattern whereby the Central region provinces lead the pack in terms of their centrality as well as their economic indicators. It is at this point that we turn to analyzing the effects of transportation hubs on the interprovincial trading system and the Canadian economic system as a whole, in the hopes that they can provide some aid to the lesser performing provinces in their quest to become more significant trading partners within the Canadian network.

4. Effects of Transportation Hubs

Now that the variables in our model have been properly explained, the focus will shift to the analysis of how these variables interact. More specifically, we are looking to understand the effect, if any, of transportation hubs within the economic framework. Given that this context is extensive, we choose five dependent variables to perform our analysis, in the hopes that they will provide us with a more exhaustive view of the economic context: economic centrality from the point of view of economic trade; GDP per capita and the share of the labor force with at least a secondary education as indicators of economic growth; life expectancy and infant mortality rates as measures of social and economic welfare. We begin by exploring the factors of economic centrality, as these will then be implemented as the independent variables for the additional four dependent variables mentioned above.

4.1. Determinants of Economic Centrality

4.1.1. Methodology

Our point of departure for this section is Sandé's work on the determinants of economic centrality. In her paper, she uses land size, population, and geographic centrality as independent variables. In our analysis, we add investment share of GDP, as well as government share of GDP. These two variables are added in Sandé's analysis of GDP per capita, life expectancy, and share of the labor force with at least a secondary education apart as a separate variable from economic centrality. In this paper, we choose to add them as independent variables for economic centrality instead, in order to determine whether they provide additional information to the model. Furthermore, our transportation variables also appear in the model in two ways: as three separate variables for rail, intermodal, and air hubs, as well as an aggregate of total transportation hubs. The two variations are as follows:

1. $$\text{CEN\_ECO}_{i} = \alpha_0 + \alpha_1 \text{ POP}_{i,t} + \alpha_2 \text{ SUP}_{i} + \alpha_3 \text{ ISH}_{i,t} + \alpha_4 \text{ GSH}_{i,t} + \alpha_5 \textit{AIR}\text{\_CT}_{i} + \alpha_6 \textit{PORT}\text{\_CT}_{i} + \alpha_7 \text{ RAIL\_CT}_{i} + e,$$

2. $$\text{CEN\_ECO} = \eta_0 + \eta_1 \text{ POP}_{i,t} + \eta_2 \text{ SUP}_{i} + \eta_3 \text{ ISH}_{i,t} + \eta_4 \text{ GSH}_{i,t} + \eta_5 \text{ TOT\_CT}_{i} + e,$$

where CEN_ECO is the economic centrality measure, POP is the population of province i at time t, and SUP is the static land size of province i. AIR_CT, RAIL_CT, PORT_CT, and TOT_CT are also static counts of transportation hubs in each province. ISH and GSH refer to the investment share of GDP and government share of GDP respectively, and *e* is the error term.

Three different methods are implemented on the four regressions above: Ordinary Least Squares (OLS), Fixed Effects and Random Effects. The OLS model gives us some insights as to how the model performs in a simple linear fashion. With that said, this particular model assumes that all of the independent variables are exogenous, which is a tough sell when many of the variables are dynamic, and may very well have associated ebbs and flows such as the recession of 2008. Nonetheless, we believe that the OLS model is still noteworthy for the purpose of our analysis. The fixed effects model removes the effects of time-invariant variables that appear in the model, therefore leaving us only with dynamic variables. This particular analysis is useful in determining whether the static variables, most notably the transportation variables, are in fact important in determining economic centrality. Lastly, the random effects model goes by the assumption that there are no fixed effects, however there are still individual effects within the model that must be accounted for. The tables containing these results appear in Appendix B.

4.1.2. Results

Beginning with the OLS results in Table 1, our first observation is that the adjusted R^2 values are quite high for the four regressions, all of which fall between 0.833 and 0.93. This already tells us that the independent variables are a good representation of economic centrality. Furthermore, it seems that both investment share of GDP and government share of GDP are both good additions to the model, as they are both statistically significant at a 99% confidence level, therefore we will focus our attention on equations (2) and (4). Both these equations show similar results, firstly with land size and population as statistically significant variables, yet with negative coefficients hovering around 0, demonstrating that these variables play very little role in the measure of economic centrality. Furthermore, increases in both investment share of GDP and government share of GDP lead to a decrease in the economic centrality measure. In equation (2), an increase of 1 unit of investment share of GDP or government share of GDP reduce the economic centrality measure by 2.537 and 3.855 units respectively, and in equation (4) economic centrality is decreased by 3.606 and 1.474 units respectively. It is important to remember that a decrease in the degree of economic centrality of a province means that it is more easily accessible to other provinces, and therefore more central. Turning to our transportation variables, equation (2) highlights that only railway hubs are statistically significant in this model, as we are relying on confidence levels over 95% in this paper. On a positive note, railway hubs do decrease the economic centrality measure, whereby one additional railway station leads to a decrease of economic centrality by 0.237 units, which is a sizeable amount. Equation (4) on the other hand paints a more general picture, with an increase of one transportation hub leading to a 0.027 decrease in the degree of economic centrality.

Moving on to Table 2, the fixed effects model shifts our focus to the time-variant variables. There are two important things to note in the table. First of all, we notice a large drop in the adjusted R^2, with previous scores hovering around 0.9 now plummeting to around 0.55 for equations (2) and (4). Secondly, we confirm through this table that both investment share of GDP and government share of GDP are statistically significant determinants of economic centrality.

The random effects model provides us with very similar results to the OLS results in Table 1. The importance of investment share of GDP and government share of GDP are once again highlighted by the increased goodness of fit of the model in equations (2) and (4), as is the near-zero impact of land size and population. The statistically significant impact of railway hubs with a coefficient of -0.295 in equation (2) as well as the -0.030 coefficient of total transportation hub counts in equation (4) tell a very similar story to the OLS model.

Through these three models, we gather two key insights into the determinants of economic centrality: investment share of GDP and government share of GDP are two important additions to the model, and transportation hubs do play a role in determining economic centrality. Though airports and intermodal ports did not generate statistically significant results, it is entirely possible that not enough data points were used for our separate counts, therefore explaining the success of the total count variable, which is not only statistically significant, but also yields a realistic coefficient. As we move on to the next section, we will only keep equations (2) and (4) as they are the best indicators of economic centrality, which will now be used as independent variables throughout the rest of the analysis.

4.2. Determinants of Four Economic and Welfare Outcomes

4.2.1. Methodology

The goal in this section is to determine the effect of transportation hubs on four key economic markers: GDP per capita, life expectancy, share of the labor force with a secondary education, and infant mortality rates. Since we have proven in the previous section that transportation hubs are statistically significant determinants of economic centrality, and Sandé's paper concluded that economic centrality was a contributing factor to GDP per capita as well as share of the labor force with a secondary education and life expectancy, we can use the variables that best explained economic centrality including transportation hubs, and use those as independent variables in our regression.

As previously mentioned, equations (2) and (4) in Tables 1-3 best fit the model, therefore we will continue to use these two sets of variables as follows:

$$1.\ Y_k = \lambda_0 + \lambda_1\, POP_{i,t} + \lambda_2\, SUP_i + \lambda_3\, ISH_{i,t} + \lambda_4\, GSH_{i,t} + \lambda_5\, AIR\_CT_i + \lambda_6\, PORT\_CT_i + \lambda_7\, RAIL\_CT_i + e,$$

$$2.\ Y_k = \omega_0 + \omega_1\, POP_{i,t} + \omega_2\, SUP_i + \omega_3\, ISH_{i,t} + \omega_4\, GSH_{i,t} + \omega_5\, TOT\_CT_i + e,$$

where Y_k refers to the four dependent variables of choice. GDP per capita will be the one exception, where share of the labor force with a secondary education will be an added independent variable, as we believe it is an important determinant of GDP per capita. Also, the GDP per capita variable was converted to the natural log of GDP per capita, for the sake of providing a more informative inference.

We will proceed with the same three differing models as we did with economic centrality: OLS, random effects, and fixed effects. The reasoning behind these three particular models is consistent with what was mentioned in section 4.1.1. The results from our analysis will now be discussed, and the associated tables can be found in Appendix B.

4.2.2. Results

Let us begin by analyzing GDP per capita in Tables 4-6, as it is the only one with an added independent variable. The first notable insight is that no matter the model used, the share of the labor force with a secondary education is a statistically significant variable in explaining GDP per capita at a 99% confidence level. Furthermore, the degree to which this variable affects GDP per capita is consistent across the board: a 0.1 unit increase in the share of the labor force with a secondary education, which is to say a 10% increase in that share, will lead to approximately a 35% increase in GDP per capita. Therefore, the hypothesis that this variable was a necessary addition to the economic centrality determinants was in fact correct. When comparing our three models, we see great similarities between the OLS and random effects models as we did in the economic centrality analysis. This tells us that random effects do not play a great role in the model, yet do generate a slight increase in the fit of the model as can be seen through the adjusted R^2 measure going from 0.917 with the OLS model and 0.922 when random effects are considered. Proceeding with the random effects results in Table 5, equation (4) allows us to infer that only airport hubs have a positive effect on GDP per capita. In fact, the results show that one additional airport leads to a 5.8% increase in GDP per capita. However, both ports and intermodal terminals seem to negatively affect GDP per capita, with a one unit increase leading to 9% and 6% decrease, respectively.

The results of Tables 7 and 8 provide a more positive outlook on the impact of transportation hubs. Equation (2) in both tables mentioned highlight a positive impact of total transportation hubs on life expectancy and the share of the labor force with a secondary education, respectively. What we see is that an additional transportation hub positively affects life expectancy by 0.178 units, and share of the labor force with a secondary education by 0.008 units. These small effects captured in the model are in line with what we expected, as these economic indicators will not be quite as affected by a province's capacity to trade, since there are several more socio-economic factors that play a much larger role in their tendencies. However, the positive impact does seem to show that infrastructure in the domain of transportation does promote higher living standards in the region.

Lastly, Table 9 points out the impact of the economic centrality determinants on infant mortality rates. Out of the four dependent variables of choice in this section, infant mortality rate is by far the most rooted in the social welfare context. The Center for Disease Control and Prevention (CDC) highlights this fact by stating that "this rate is often used as an indicator to measure the health and well-being of a nation" (CDC, 2016). This is quite clearly perceived in

Table 9, where the independent variables poorly explain infant mortality rates, with a highest adjusted R^2 of only 0.340 in equation (1). Although the transportation variables are statistically significant, the model is evidently not pertinent enough to make any inferences regarding the importance of transportation hubs on infant mortality rates.

5. Conclusion

As trade takes on a larger role in the wake of global economic exchange, regions that are less accessible must find ways to alleviate their geographic adversity to incur economic growth. The emphasis of this paper is on transportation hubs as a means of boosting trade in regions that require more transportation power in order to participate in the ever-growing trade network. Here, we focus on the Canadian trade network, although this can be easily extrapolated to any network of regions, even going so far as the World Trade Network.

The results present us with some interesting facts regarding the effect of transportation hubs, especially on economic centrality and GDP per capita. Let us reiterate that economic centrality measures the ease of access to a province within the entire network's context, whereby a smaller measure is proof of a more central province. We infer that one new transportation hub leads to a 0.03 decrease in the degree of economic centrality, explaining a positive impact on a province's ability to trade with its partners. In the case of GDP per capita, the effect of transportation hubs was much less consistent, with airports incurring a positive impact whereas ports and intermodal terminals leading to a decrease in GDP per capita. Finally, life expectancy and the share of the labor force with a secondary education saw small yet positive effects with additional transportation hubs in the region, and infant mortality rate was simply poorly explained by the determinants of economic centrality found in section 4.1.2.

The findings from this paper provide a first look into a tangible option to promote economic growth by way of enhancing trade capability in any given region. To provide a more in-depth analysis of transportation hubs' impact on trade and economic growth, more data would be an important next step. With additional transportation data, the results of specific methods of transportation's impact are more likely going to be better contrasted. Furthermore, embedding a 'transportation capacity' measure in the construction of a geographic centrality variable such as the one presented in Sandé's paper would most likely provide us with a better understanding of how these hubs can alleviate some of the natural geographical constraints put on regions across the world.

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Explanation of Variable Names

AB	Alberta
BC	British Columbia
MB	Manitoba
NB	New Brunswick
NFLD	Newfoundland and Labrador
NS	Nova Scotia
ON	Ontario
PEI	Prince Edward Island
QC	Quebec
SK	Saskatchewan

GDP_PC	GDP per capita
SECEC_LABOR	share of the labor force with at least a secondary education
LEX	life expectancy
ISH	investment share of GDP
GSH	government share of GDP
CEN_ECO	economic centrality
SUP	land size
POP	population
INF_MORT	infant mortality rate per 1000
AIR_CT	number of certified airports
PORT_CT	number of certified ports
RAIL_CT	number of intermodal (rail-port-cargo) ports
TOT_CT	total number of transport hubs

Appendix A

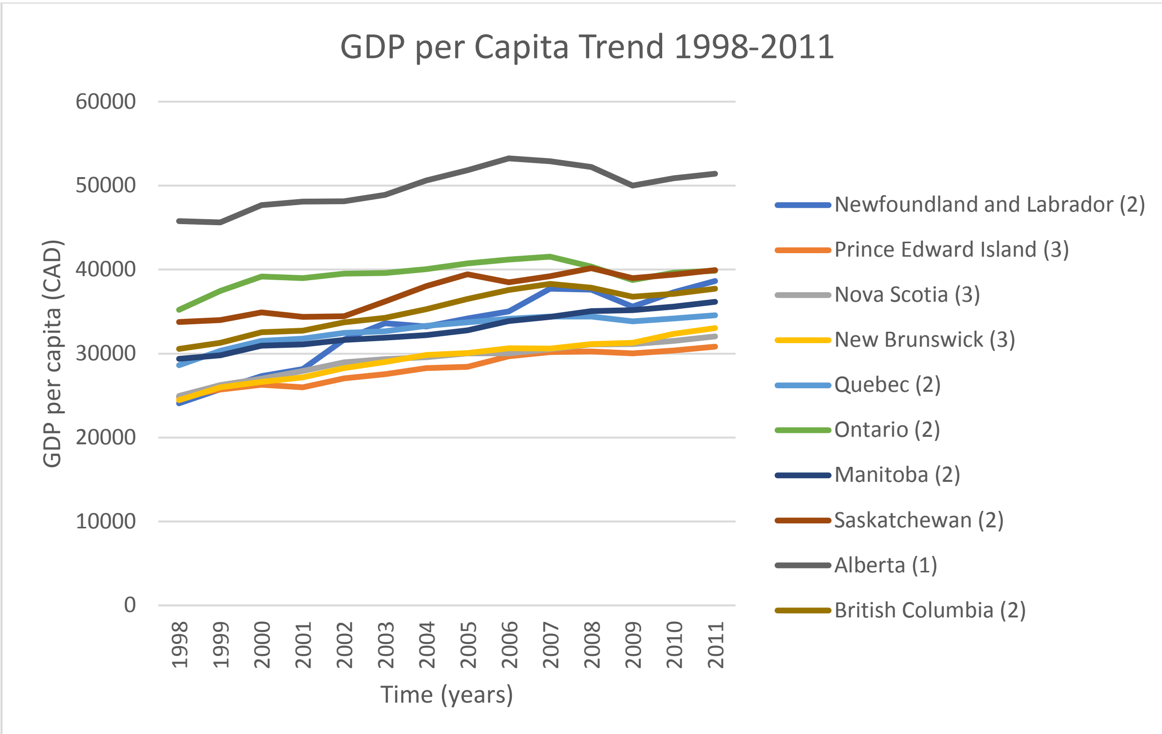

Figure 1

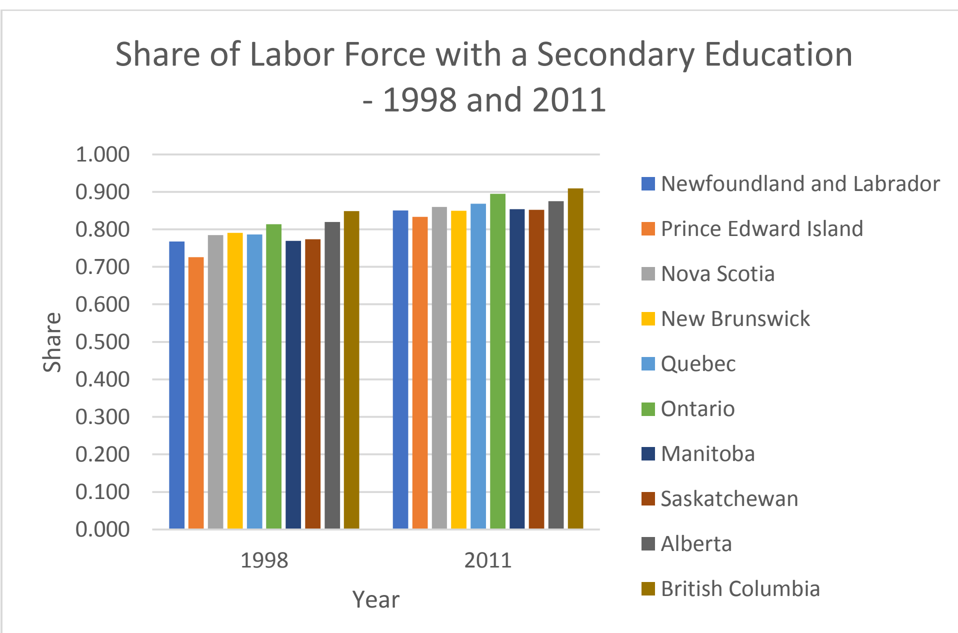

Figure 2

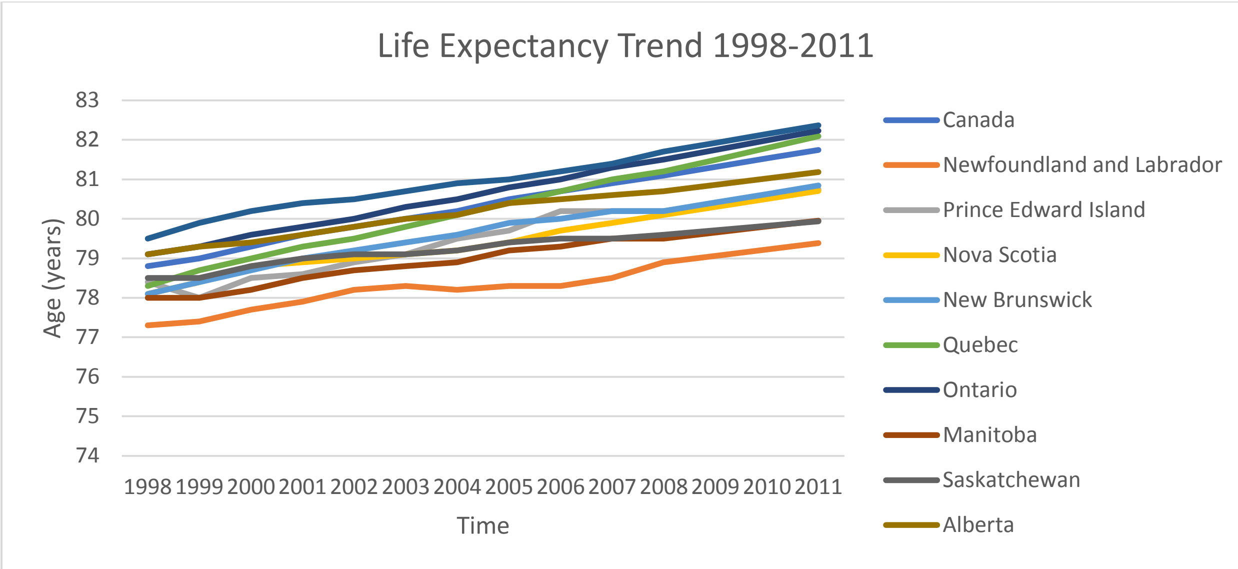

Figure 3

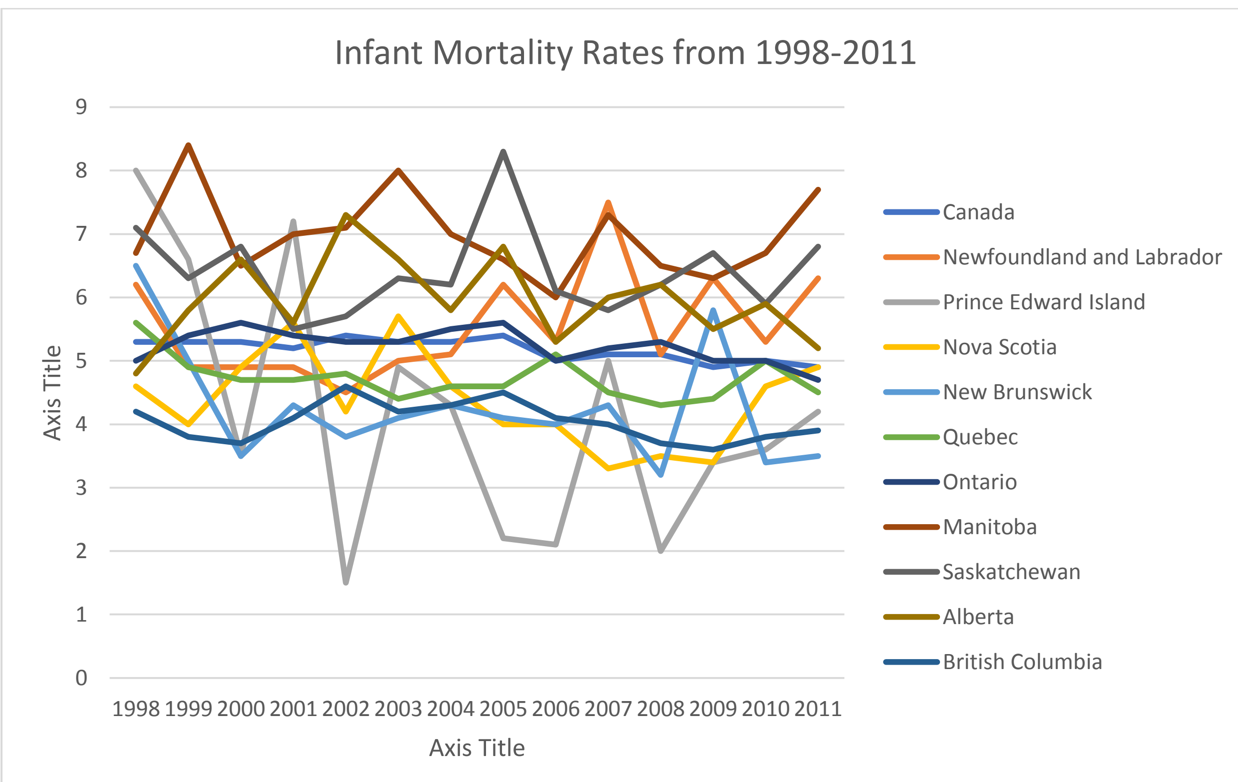

Figure 4

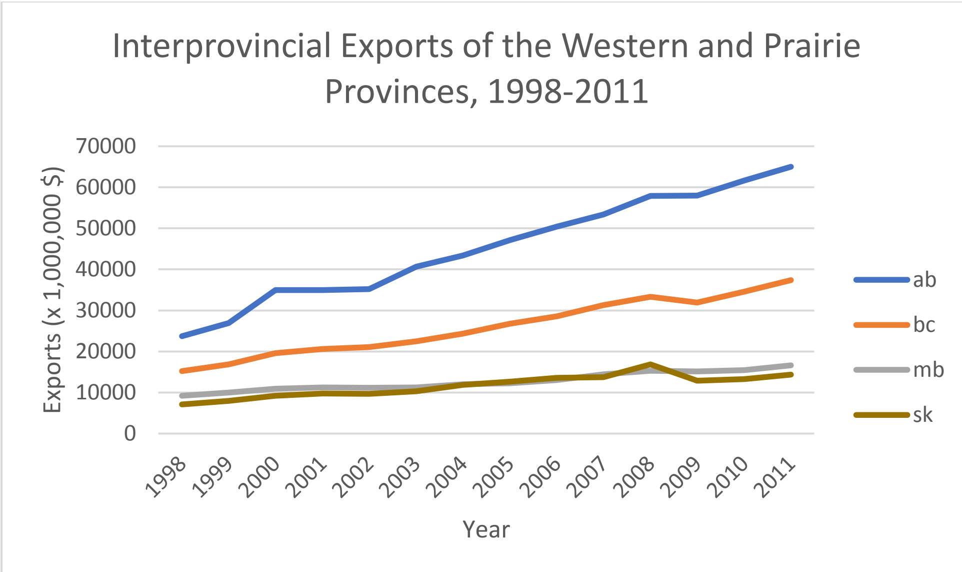

Figure 5

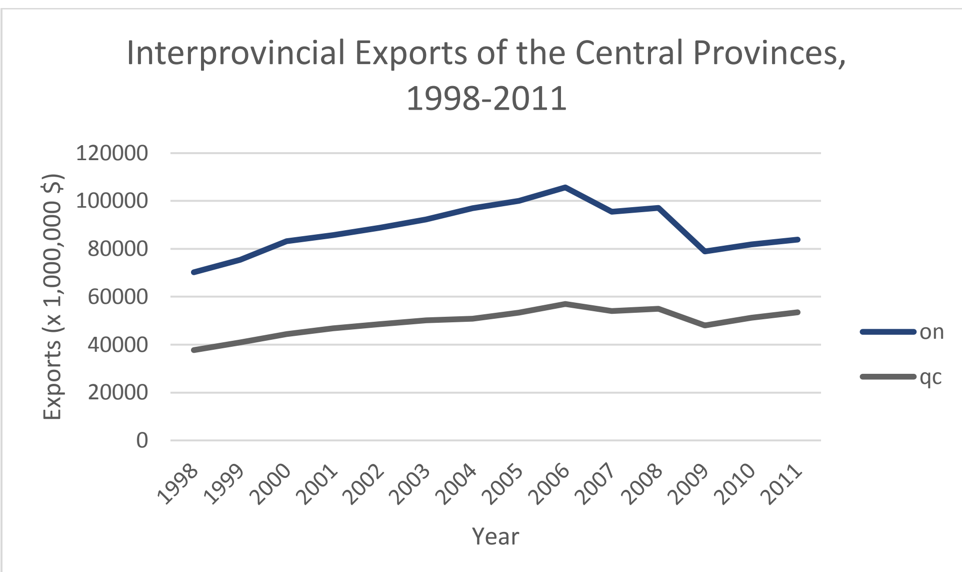

Figure 6

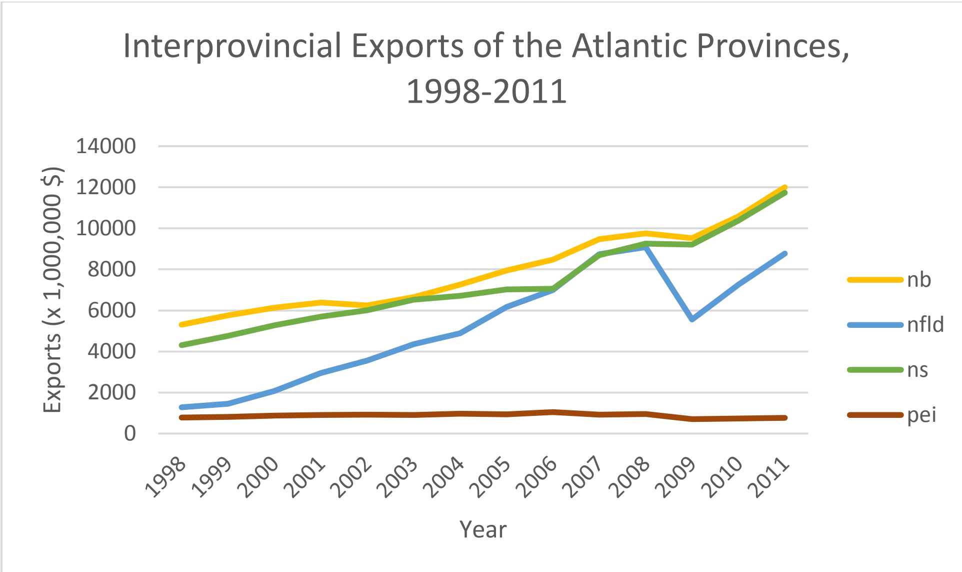

Figure 7

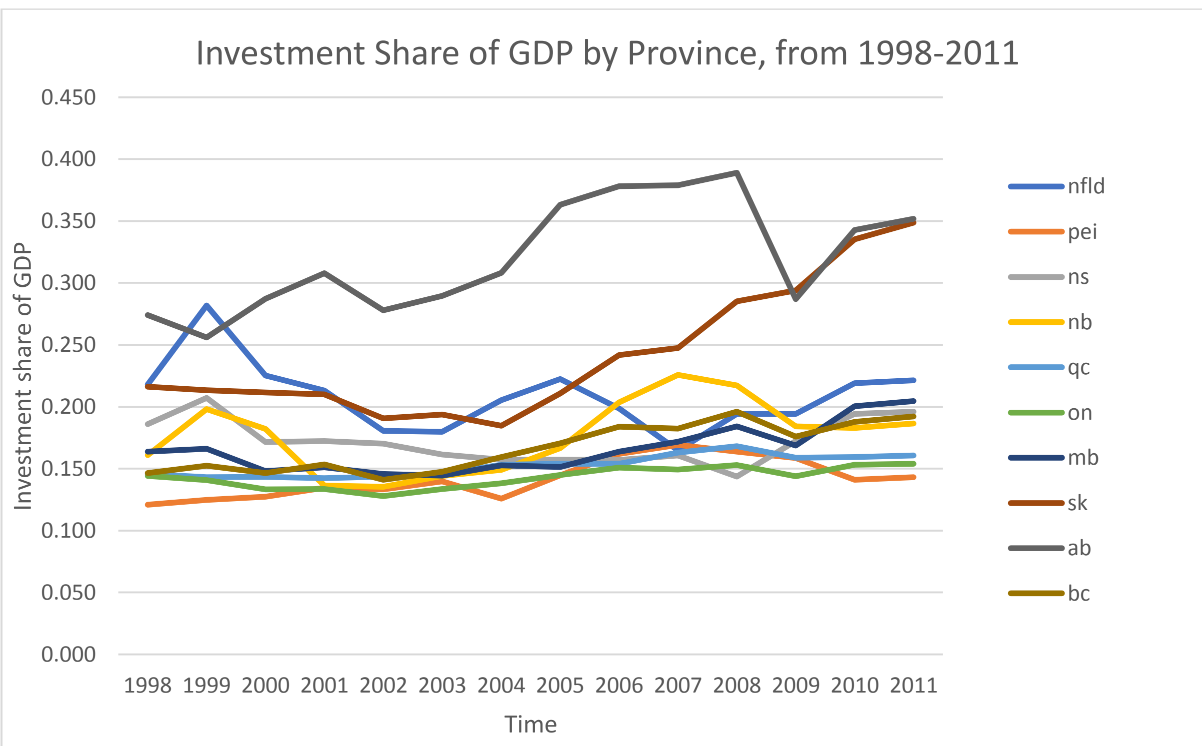

Figure 8

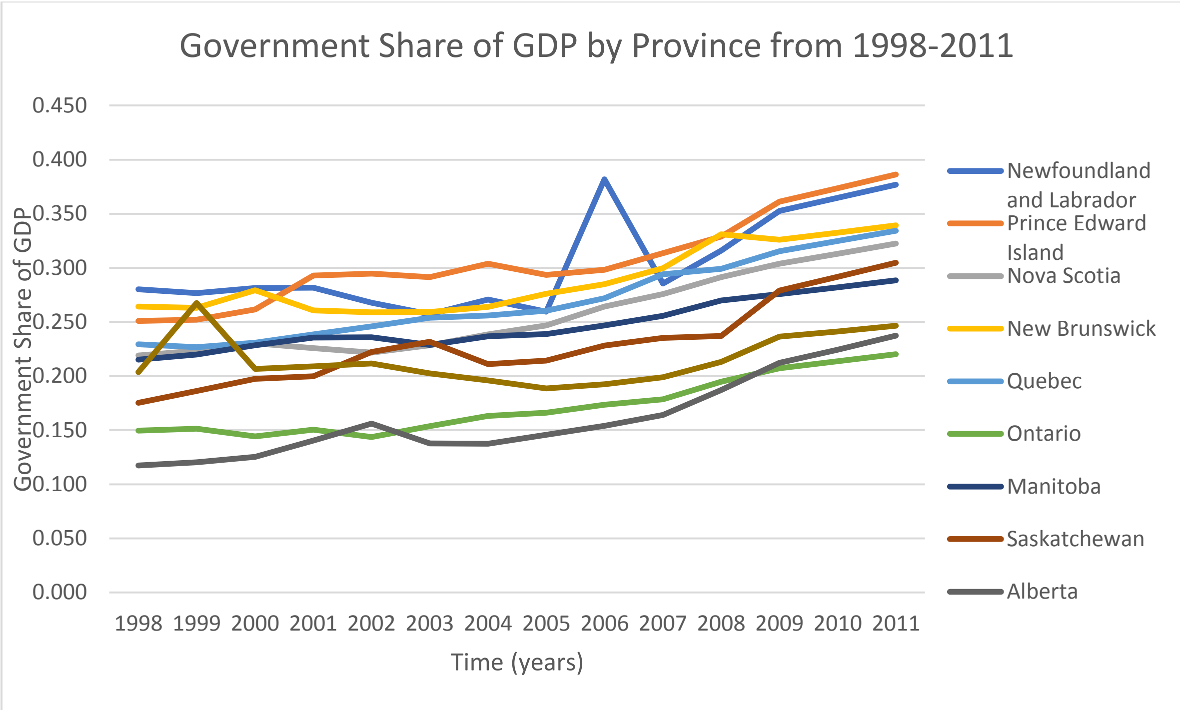

Figure 9

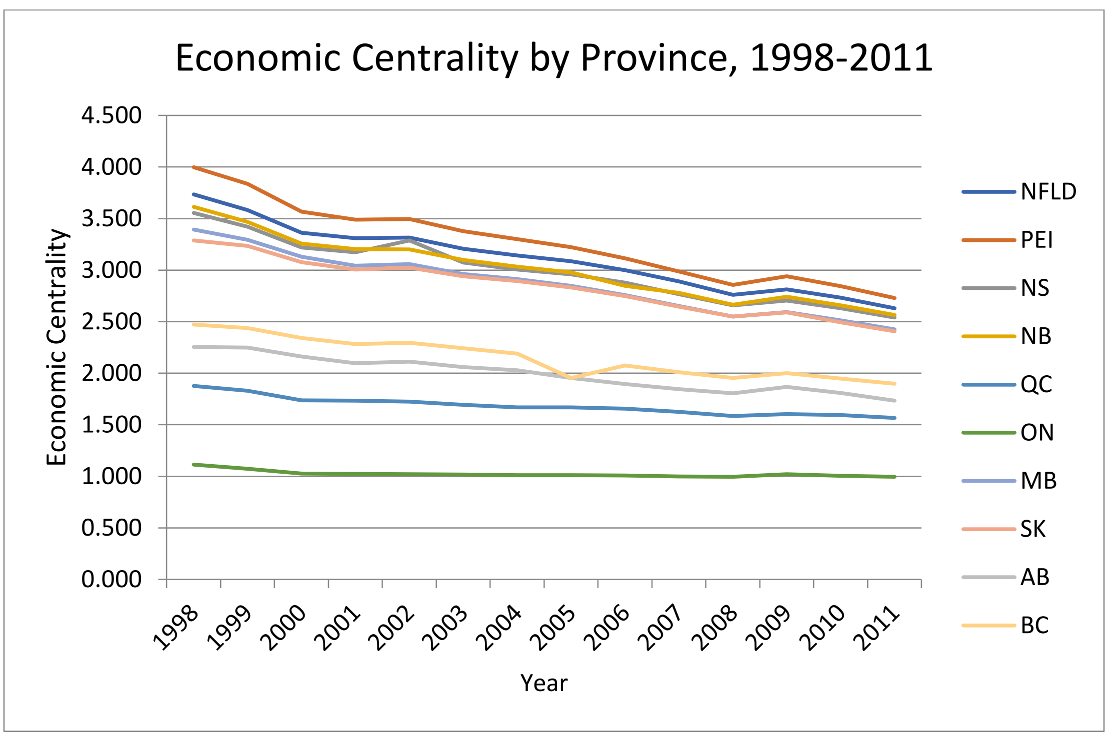

Figure 10

Appendix B

Table 1

OLS

	Dependent variable:			
	CEN_ECO			
	(1)	(2)	(3)	(4)
SUP	-0.00000***	-0.00000***	-0.00000***	-0.00000**
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
POP	-0.00000***	-0.00000***	-0.00000***	-0.00000***
	(0.000)	(0.000)	(0.000)	(0.000)
ISH		-2.537***		-3.606***
		(0.416)		(0.388)
GSH		-3.855***		-1.474***
		(0.472)		(0.415)
AIR_CT	-0.025	0.054		
	(0.049)	(0.038)		
PORT_CT	0.080***	0.061*		
	(0.030)	(0.032)		
RAIL_CT	-0.159***	-0.294***		
	(0.038)	(0.034)		
TOT_CT			-0.010	-0.027***
			(0.013)	(0.010)
Constant	3.291***	4.791***	3.183***	4.309***
	(0.071)	(0.153)	(0.054)	(0.164)
Observations	140	140	140	140
R^2	0.872	0.934	0.836	0.901
Adjusted R^2	0.867	0.930	0.833	0.897
F Statistic	181.783***	265.084***	231.738***	242.735***
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 2

FIXED EFFECTS

	Dependent variable:			
	CEN_ECO			
	(1)	(2)	(3)	(4)
POP	-0.00000**	0.00000***	-0.00000**	0.00000***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
ISH		-1.058*		-1.058*
		(0.596)		(0.596)
GSH		-5.790***		-5.790***
		(0.513)		(0.513)
Observations	140	140	140	140
R^2	0.043	0.588	0.043	0.588
Adjusted R^2	-0.031	0.549	-0.031	0.549
F Statistic	5.790**	60.414	5.790**	60.414
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 3

RANDOM EFFECTS

	Dependent variable:			
	CEN_ECO			
	(1)	(2)	(3)	(4)
SUP	-0.00000**	-0.00000***	-0.00000	-0.00000*
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
POP	-0.00000***	-0.00000***	-0.00000***	-0.00000***
	(0.00000)	(0.000)	(0.00000)	(0.00000)
ISH		-2.490***		-3.243***
		(0.425)		(0.475)
GSH		-3.870***		-2.606***
		(0.473)		(0.448)
AIR_CT	-0.025	0.052		
	(0.079)	(0.040)		
PORT_CT	0.082*	0.063*		
	(0.048)	(0.033)		
RAIL_CT	-0.158**	-0.295***		
	(0.063)	(0.035)		
TOT_CT			-0.006	-0.030*
			(0.029)	(0.016)
Constant	3.290***	4.790***	3.170***	4.558***
	(0.116)	(0.153)	(0.126)	(0.172)
Observations	140	140	140	140
R^2	0.719	0.929	0.487	0.790
Adjusted R^2	0.709	0.925	0.476	0.782
F Statistic	68.675***	247.620***	43.011***	100.986***
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 4

OLS

	Dependent variable:			
	LNGDP_PC			
	(1)	(2)	(3)	(4)
SUP	0.00000***	0.00000	0.00000***	0.00000***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
POP	0.00000***	0.00000***	0.000***	0.00000***
	(0.000)	(0.000)	(0.000)	(0.000)
ISH	1.166***	2.096***	1.129***	0.581***
	(0.158)	(0.158)	(0.132)	(0.118)
GSH	0.720***	-0.421**	-1.091***	-0.925***
	(0.180)	(0.169)	(0.126)	(0.182)
AIR_CT	0.055***			0.059***
	(0.015)			(0.010)
PORT_CT	-0.103***			-0.092***
	(0.012)			(0.008)
RAIL_CT	0.074***			-0.059***
	(0.013)			(0.014)
TOT_CT		-0.003	-0.028***	
		(0.004)	(0.003)	
SECED_LABOR			3.151***	3.347***
			(0.251)	(0.272)
Constant	9.812***	10.069***	7.937***	7.732***
	(0.058)	(0.067)	(0.176)	(0.173)
Observations	140	140	140	140
R^2	0.832	0.714	0.869	0.922
Adjusted R^2	0.823	0.703	0.863	0.917
F Statistic	93.437***	66.822***	147.180***	194.113***
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5

RANDOM EFFECTS

	Dependent variable:			
	LNGDP_PC			
	(1)	(2)	(3)	(4)
SUP	0.00000^{***}	0.00000	0.00000^{***}	0.00000^{***}
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
POP	0.00000^{***}	0.00000^{***}	0.000	0.00000^{***}
	(0.000)	(0.000)	(0.000)	(0.000)
ISH	1.016^{***}	1.656^{***}	0.374^{***}	0.608^{***}
	(0.172)	(0.196)	(0.139)	(0.117)
GSH	0.778^{***}	0.092	-1.106^{***}	-0.915^{***}
	(0.179)	(0.184)	(0.155)	(0.182)
AIR_CT	0.061^{***}			0.058^{***}
	(0.017)			(0.010)
PORT_CT	-0.111^{***}			-0.091^{***}
	(0.014)			(0.008)
RAIL_CT	0.077^{***}			-0.058^{***}
	(0.015)			(0.014)
TOT_CT		-0.005	-0.031^{***}	
		(0.007)	(0.006)	
SECED_LABOR			3.712^{***}	3.322^{***}
			(0.241)	(0.272)
Constant	9.815^{***}	10.018^{***}	7.634^{***}	7.746^{***}
	(0.058)	(0.070)	(0.161)	(0.174)
Observations	140	140	140	140
R^2	0.788	0.445	0.754	0.927
Adjusted R^2	0.777	0.425	0.743	0.922
F Statistic	70.223^{***}	21.514^{***}	67.899^{***}	206.601^{***}
Note:				$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 6

FIXED EFFECTS

	Dependent variable:			
	LNGDP_PC			
	(1)	(2)	(3)	(4)
POP	0.000	0.000	-0.00000***	-0.00000***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
ISH	0.027	0.027	-0.015	-0.015
	(0.226)	(0.226)	(0.135)	(0.135)
GSH	1.337***	1.337***	-0.577***	-0.577***
	(0.194)	(0.194)	(0.171)	(0.171)
SECED_LABOR			3.614***	3.614***
			(0.238)	(0.238)
Observations	140	140	140	140
R^2	0.358	0.358	0.773	0.773
Adjusted R^2	0.298	0.298	0.750	0.750
F Statistic	23.648***	23.648***	107.313***	107.313***
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 7

OLS/RANDOM EFFECTS/FIXED EFFECTS

	Dependent variable:					
	LEX					
	(1)	(2)	(3)	(4)	(5)	(6)
SUP	-0.00000*	-0.00000*	-0.00000	-0.00000		
	(0.00000)	(0.00000)	(0.00000)	(0.00000)		
POP	0.00000***	0.00000***	0.00000***	0.00000***	0.00000***	0.00000***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
ISH	2.362**	6.908***	1.214	4.414***	0.163	0.163
	(1.164)	(1.286)	(1.495)	(1.533)	(1.513)	(1.513)
GSH	17.548***	7.669***	17.529***	14.684***	14.596***	14.596***
	(1.323)	(1.376)	(1.268)	(1.310)	(1.302)	(1.302)
AIR_CT	-0.132		-0.076			
	(0.108)		(0.222)			
PORT_CT	-0.204**		-0.319**			
	(0.089)		(0.154)			
RAIL_CT	1.290***		1.271***			
	(0.096)		(0.180)			
TOT_CT		0.178***		0.091		
		(0.033)		(0.078)		
Constant	73.409***	75.418***	73.599***	74.259***		
	(0.427)	(0.544)	(0.479)	(0.540)		
Observations	140	140	140	140	140	140
R^2	0.760	0.497	0.691	0.601	0.730	0.730
Adjusted R^2	0.747	0.478	0.675	0.587	0.705	0.705
F Statistic	59.673***	26.441***	42.229***	40.438***	114.525***	114.525***
Note:				*p<0.1; **p<0.05; ***p<0.01		

Table 8

OLS/RANDOM EFFECTS/FIXED EFFECTS

	Dependent variable:					
	SECED_LABOR					
	(1)	(2)	(3)	(4)	(5)	(6)
SUP	-0.00000*	-0.000	-0.000	-0.000		
	(0.00000)	(0.000)	(0.000)	(0.000)		
POP	0.00000***	0.000*	0.000***	0.000**	0.00000***	0.00000***
	(0.00000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ISH	2.362**	0.307***	0.116***	0.275***	0.012	0.012
	(1.164)	(0.037)	(0.042)	(0.043)	(0.050)	(0.050)
GSH	17.548***	0.213***	0.524***	0.357***	0.529***	0.529***
	(1.323)	(0.039)	(0.039)	(0.040)	(0.043)	(0.043)
AIR_CT	-0.132		0.001			
	(0.108)		(0.005)			
PORT_CT	-0.204**		-0.007**			
	(0.089)		(0.004)			
RAIL_CT	1.290***		0.041***			
	(0.096)		(0.004)			
TOT_CT		0.008***		0.007***		
		(0.001)		(0.002)		
Constant	73.409***	0.677***	0.620***	0.645***		
	(0.427)	(0.016)	(0.013)	(0.015)		
Observations	140	140	140	140	140	140
R^2	0.760	0.589	0.732	0.560	0.692	0.692
Adjusted R^2	0.747	0.574	0.717	0.543	0.663	0.663
F Statistic	59.673***	38.421***	51.401***	34.085***	95.066***	95.066***
Note:				*p<0.1; **p<0.05; ***p<0.01		

Table 9

	OLS/RANDOM EFFECTS/FIXED EFFECTS					
	Dependent variable:					
	INF_MORT					
	(1)	(2)	(3)	(4)	(5)	(6)
SUP	0.00000***	0.00000***	0.00000***	0.00000**		
	(0.00000)	(0.00000)	(0.00000)	(0.00000)		
POP	0.00000	-0.000	0.00000	0.000	0.00000	0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
ISH	-3.645*	0.992	-2.339	0.500	-0.903	-0.903
	(2.038)	(1.669)	(2.518)	(2.317)	(3.043)	(3.043)
GSH	-5.059**	-8.085***	-4.990**	-6.353***	-5.364**	-5.364**
	(2.315)	(1.786)	(2.264)	(2.039)	(2.618)	(2.618)
AIR_CT	0.386**		0.339			
	(0.189)		(0.308)			
PORT_CT	-0.833***		-0.777***			
	(0.156)		(0.226)			
RAIL_CT	-0.379**		-0.387			
	(0.168)		(0.253)			
TOT_CT		-0.271***		-0.276***		
		(0.043)		(0.099)		
Constant	6.756***	7.571***	6.559***	7.211***		
	(0.748)	(0.706)	(0.783)	(0.798)		
Observations	140	140	140	140	140	140
R^2	0.468	0.387	0.251	0.132	0.048	0.048
Adjusted R^2	0.440	0.364	0.211	0.100	-0.042	-0.042
F Statistic	16.616***	16.938***	6.326***	4.090***	2.134*	2.134*
Note:				*p<0.1; **p<0.05; ***p<0.01		