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**Causes and Consequences of Economic Centrality: Evidence from Canadian Provinces**

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**Abstract:** In this paper, I employ a network approach to examine regional economic integration in Canada. To do so, I study both the causes and consequences of economic centrality of Canadian provinces. Firstly, I estimate the exogenous determinants of economic centrality. I find that geographic centrality and land area have positive effects on economic centrality. Secondly, I analyze the consequences of economic centrality on Canadian provinces using panel data. I test for the impact of economic centrality on three dependent variables, namely the gross domestic product (GDP) per capita, education and life expectancy. The results show that economic centrality positively affects each of these outcomes, demonstrating that economic networking has a positive effect on welfare.

**Key words:** Economic Centrality, Geographic Centrality, Network Economics, Weighted Network, Binary Network, Panel Data Approach, Gross Domestic Product.

**Résumé:** Dans cet article, j'emploie une approche des réseaux pour examiner l'intégration économique régionale au Canada. Pour ce faire, j'étudie les causes et les conséquences de la centralité économique des provinces canadiennes. Premièrement, j'estime les déterminants exogènes de la centralité économique. Je trouve que la centralité géographique et la superficie territoriale d'une province affectent positivement sa centralité économique. Deuxièmement, j'analyse les conséquences de la centralité économique en utilisant des données de panel. Je teste l'impact de la centralité économique sur trois variables dépendantes que sont le produit intérieur brut (PIB) par habitant, l'éducation, et l'espérance de vie. Les résultats révèlent un impact positif et significatif de la centralité économique sur chacune de ces variables, démontrant que les interactions économiques accroissent le bien-être.

**Mots Clés :** Centralité Économique, Centralité Géographique, Économie des Réseaux, Réseau Pondéré, Réseau Binaire, Approche en Données de Panel, Produit Intérieur Brut.

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## 1. Introduction

The last few decades have witnessed a variety of politico-economic developments, such as the increase of interactions among people, economies and nations. These developments have led to the so-called present process of “Globalization”. From an economic point of view, globalization shapes economic outcomes in a new manner as it is directly associated with the growing international economic integration among countries. Indeed, the world’s nations are more connected and interdependent, and these deeper connections between countries are important in analysing countries’ economic integration. In this context, traditional measures of international integration such as countries’ openness to trade, which is widely employed in the literature as a determinant of economic growth, fall short of effectively measuring countries’ integration into the world economy (e.g., Kali and Reyes, 2007; Fagiolo *et al.*, 2010). However, a network approach that has been recently used in economics, especially in studying economic integration, is a more suitable perspective in the sense that it takes into account higher connections among countries.

As Duernecker *et al.* (2012) highlight, the importance and degree of connection that one country has with the rest of the world in this context of globalization should be a better measure of economic integration, rather than only accounting for the intensity of trade (i.e., openness).<sup>1</sup> This point of view is shared by other studies (e.g., Serrano and Barguna, 2003; Garlaschelli and Loffredo, 2005; Kali and Reyes, 2007; Fagiolo *et al.*, 2008; Arribas *et al.*, 2009; Fagiolo *et al.*, 2010). The key point in these studies is the fact that they use a network approach in order to study countries’ economic integration. These studies demonstrate that the degree of connectiveness as well as the structure of countries into a network is important in studying economic integration.

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<sup>1</sup> See Duernecker, Meyer and Vega-Redondo (2012), page 3.

The purpose of my paper is to apply a network approach through the use of economic centrality in order to analyze the degree of Canadian provinces' regional integration. Indeed, Smith and White (1992) argue that a network approach gives a powerful tool to describe and analyze interactions between systems or states.<sup>2</sup> In the literature, the measure of centrality can be built on direct flows (e.g., bilateral exports) or indirect flows (e.g., foreign direct investment) from any given country to others. Garlaschelli and Loffredo (2005) call the network of trade relationship between countries the World Trade Web (WTW) or World Trade Network (WTN), where each country represents a vertex (or node), and the trading flow between two countries represents the link between them.<sup>3</sup> The scope of my paper is limited to the Canadian intra-trading system as an entire network, where each province represents a vertex (or node), and the export flows between two provinces represent the link between them. To the best of my knowledge, this paper is the first to apply a network approach to analyze intra-country economic integration by focusing on regional integration instead of international integration.

The issue of regional integration is of particular interest in the Canadian context. Indeed, a recent trend in Canadian trade policy is involvement in negotiating free trade deals with other countries around the world (e.g., The Comprehensive Economic and Trade Agreement with the European Union). However, it is within the provincial jurisdiction that all these trade deals will come into force. Coulombe (2003) points out the fact that a change in the orientation of trade occurred in Canada in the 1990s. Indeed, international or north-south trade seems to have overtaken interprovincial or east-west trade.<sup>4</sup> For instance, interprovincial trade exports increased by 4.7 percent on average from 1992 to 1998, while international trade exports increased by 11.9

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<sup>2</sup> See Smith, and White (1992), page 858.

<sup>3</sup> See Garlaschelli, and Loffredo (2005), page 139.

<sup>4</sup> See Coulombe (2003), page 1.

percent during the same period.<sup>5</sup> Coulombe (2003) also argues that the presence of interprovincial trade barriers (e.g., rules and regulations as well as quotas) is a persistent problem in the Canadian regional economy, while international trade barriers have been considerably reduced.<sup>6</sup> Beaulieu (2013) confirms that the existence of interprovincial barriers to trade reduces the growth, efficiency and productivity of Canada.<sup>7</sup> However, non-tariff barriers to trade increased in a substantial way in the last decades. There is no doubt that if Canada wants to stay competitive in the global market, the country needs to have an efficient market at home. I believe that an improvement of the Canadian intra-country trading system will lead to an increase in economic welfare in the provinces. This is the reason why I put my attention on Canadian provinces' regional integration in my paper.

My paper is based on the work of Duernecker *et al.* (2012), who use a network-based approach to study globalization: specifically economic integration of 125 countries between 1962 and 2005. Using a dynamic panel framework of the United Nations Comtrade database, Duernecker *et al.* (2012) claim that not only trade intensity, namely openness, matters, but also the level of integration into the world trade network. This level of integration is of importance to explain economic growth. Based on a weighted-network, Duernecker *et al.* (2012) build a measure of centrality that captures the position of an economy in the world trade network. They find that this measure takes into account deeper trade links between countries. Thus, their study highlights the importance of economic centrality in understanding economic growth as a supplement to the traditional openness measure.

In my paper, I study both the causes and consequences of economic centrality within Canadian provinces. To do so, I use the Statistics Canada CANSIM database from 1992 to 2008.

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<sup>5</sup> See Statistics Canada (2000), page 15.

<sup>6</sup> Under The Constitution Act of 1897, section 121, explicit barriers to trade that are mostly tariffs are prohibited between Canadian provinces. In the same manner, under the General Agreement on Tariffs and Trade, tariffs are prohibited between countries.

<sup>7</sup> See Beaulieu (2013), page 3.

The goal of my paper is to make use of a measure of economic centrality to examine Canada's regional economic integration. I use a weighted-network approach to construct my measure of economic integration among Canadian provinces. This measure of economic centrality measures the distance or step required for one province to reach the others. The assumption here is that the smaller the distance or step (i.e., economic centrality) required for one province to reach the others, the more the province will interact with others, and thus the province will be more integrated in the provincial trade network. In the first part of my paper, I estimate the exogenous determinants of economic centrality. I find that geographic centrality and land area have positive effects on economic centrality. In the second part, I test the impact of economic centrality on province-level outcomes using the Ordinary Least Squares (OLS) estimating technique in a panel data framework. I put my attention on three dependent variables: GDP per capita, secondary education and life expectancy. In the entire paper, secondary education refers to the share of the labor force with at least a secondary-level education. The objective of focusing on these three dependent variables is to examine the consequences of economic centrality from different angles. In addition, I use the Generalised Least Squares (GLS) estimating technique in order to correct for serial correlation. Noting that endogeneity, stemming from the fact that one independent variable may be correlated with the error term in the model, is a major problem in econometrics, I also use a Generalized Method of Moments with instrumental variables (IV-GMM) as additional specification in my empirical models. I find that economic centrality positively affects each of these outcomes, demonstrating that economic networking has a positive effect on welfare. In particular, I find that a one unit decrease in economic centrality is associated with an average of four percent increase in the provincial GDP per capita.

The contribution of my paper is twofold. First of all, I analyze the causes of economic centrality in the Canadian context. By focusing on the exogenous determinants of economic

centrality, this paper gives more insights into economic centrality. Secondly, this paper contributes to the growing literature that employs a network approach in economics by applying this approach to intra-country export flows.

In order to really understand the relevance of the network approach, it is important to present some background information in the following part of this section.

## 1.1 Background

The study of the real world in the framework of a network approach is not new to the academic literature. Indeed, as Fagiolo *et al.* (2010) point out that, sociologists and psychologists have employed network analysis to study the trend of interactions among people and groups.<sup>8</sup> In addition, scholars from physics and computer science have analyzed the properties of biological and technological information with the statistical tool of a network approach. For instance, peer-to-peer network, train routes and airline connections, or metabolism and protein interaction can be cited as fields of application of a network approach, among others. Fagiolo *et al.* (2010) also claim that from an economic point of view, market, industries and the world economy can be considered as networked structures. This point of view has increased among economists, such that the use of a network approach in analyzing economic systems has increased in the last few decades. In particular, a network approach has been used in the study of international trade (e.g., Kali and Reyes, 2007; Arribas *et al.*, 2009; and Duernecker *et al.*, 2012). However, what exactly is a network in international trade study?

Fagiolo *et al.* (2010) describe a network to be a mathematical representation of a system in terms of links and nodes at a given time.<sup>9</sup> This description is close to the definition of the WTN – World Trade Network – given by Garlaschelli and Loffredo (2005), who claim that in an

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<sup>8</sup> Fagiolo *et al.* (2010) refer to Wasserman and Faust (1994); Freeman (1996); Scott (2000); Newman (2003), among others.

<sup>9</sup> See Fagiolo, Reyes and Schiavo (2010), page 480.

economic network, each country represents a vertex and the trading flow between two countries (i.e., exports or imports) represents the link between them. Fagiolo *et al.* (2010) highlight the fact that the methodology used in a network approach gives a better understanding of trade dynamics. They argue that a network approach helps to capture how each country is connected with others in the WTN, which in turn explains the degree of economic integration. In fact, the traditional measure of openness, which is the ratio of the total trade to GDP, cannot capture how each country is connected with others. Thus, the relevance of using a network approach in the study of international trade is related to the fact that there exists a certain dependency and influence of a given country on others.

In the literature, some reasons why a network approach is used in the study of international economic trade are examined. Smith and Douglas (1992) provide components of the network analysis of international economics. Indeed, the theories of international trade focus on five main components. First, the focus is on the economies (i.e., cities, regions and nations) that produce, distribute, consume and exchange (e.g., export and import) goods and services in order to form a network. Secondly, the analysis is made of the link between these economies that trade together, as well as the level of countries and international policies that regulate the trade in the network. Thirdly, the political economy of the network that has been formed by the trading links is examined. Fourthly, the position that one economy occupies in the network is analyzed through the use of measures such as economic centrality or degree centrality. Finally, the patterns of trade flows and the structure of the network are analyzed. Thus, a network approach is particularly appropriate in analyzing the world system in the context of a more globalized world.

In addition, Jackson (2010) surveys social network and their economic application. In his paper, Jackson (2010) analyzes the role of a network in markets and exchange, learning and diffusion, and network games. The author mentions that network determine many economic

outcomes, such as economic integration. Indeed, two main aspects of the use of a network approach in economics integration are: the comprehension of how the structure of the network influences the economy, and how to model and analyze network from an economic perspective. He notes that economic tools are really important to model the network. As for the first aspect, we can see how trade in networked markets is based on the structure of the network. Concerning the second aspect, we can study, for instance, if the distance between economies in terms of the shortest path in the network could explain a deeper economic integration. In the literature, some papers applying a network approach to analyze economic integration have used instruments such as degree centrality or closeness centrality to model network.<sup>10</sup> Borgatti (2005) defines degree centrality to be the number of links each vertex (or node) has, and closeness centrality to be the measure of the path the link takes from one node to reach the others. The concept of centrality is one of the most common concepts used in a social network approach. My measure of economic centrality can be seen in terms of closeness centrality in the sense that I measure the distance or step required for one province to reach the other ones.

## **1.2 Plan of the paper**

The remainder of the paper proceeds as follows. In the next section, I examine the underlying theoretical framework of the paper. In the third section, I review some empirical papers that use a network approach in order to analyze economic integration. In this section, I present two streams of contributions in the literature: binary-network and weighted-network. The fourth section presents the database used in order to conduct my analysis and points out some trends of the data. The fifth section is dedicated to the causes of economic centrality. In this section, I first present the construction of the measure of economic centrality and highlight some patterns within Canadian provinces. Then I turn to the examination of causes of economic

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<sup>10</sup> For instance see: Kali and Reyes (2007), Fagiolo *et al.* (2008) and Arribas *et al.* (2009), among others.

centrality. In the sixth section, I analyze the consequences of economic centrality by testing its impact on the outcomes of GDP per capita, secondary education and life expectancy. I conclude in the seventh section of the paper.

## 2. Theoretical Framework

The purpose of this section is to present the underlying theoretical framework of my paper. Indeed, the empirical literature on economic growth recognizes that a country's participation in the international trading system (i.e., a country's openness) is a major determinant of economic growth. The economic growth literature establishes that a country that is open and trades with the other countries in the world tends to have a high level of GDP per capita.<sup>11</sup> The underlying question is why do economies trade with each other, and how does trade affect the economy of each country?

The classical theory of international trade helps to answer these questions. The basis of this theory was established by Adam Smith (1779) in his book *Wealth of Nations*. In addition, important contributions have been made toward understanding international trade (e.g., David Ricardo). Smith's theory of international trade is based on absolute advantage. By focusing on labor as the only factor of production and without barriers to trade, the author defines the absolute advantage to be the ability of one country to produce more goods using less, or at most the same amount of inputs, as do other countries.<sup>12</sup> Smith's principle of absolute convergence in international trade is based on two countries, let us say C and S, and two goods, A and B. Suppose that country C is better at producing good A in the sense that workers in country C

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<sup>11</sup> For instance, see Frankel and Romer (1999). Most of these studies employ the concept of convergence, especially absolute convergence and conditional convergence to the steady state. Absolute convergence states that poor economies tend to catch up to rich economies, and all these economies will converge to the same steady state in the long run. Conditional convergence implies that each country will converge to its own steady state given the heterogeneous characteristics within each country.

<sup>12</sup> See Husted and Melvin (2007). They mention that other assumptions in Smith's (1779) model are: constant returns to scale, labor cannot move between countries and exports must pay for imports.

produce more good A in an hour than do workers in country S. However, country S is better at producing good B in the sense that it takes fewer hours for workers in country S to produce one unit of good B. In that case, country C will specialize in production of good A, and country S will specialize in production of good B. Smith (1779) advocates that one country will trade with another because of absolute advantage and vice versa, and thus, both countries will gain in terms of wealth by exporting each of the goods in which they have an absolute advantage.

Husted and Melvin (2007) mention that Ricardo (1819) contributes to the theory of international trade by focussing on the role of opportunity cost. In economics, the opportunity cost is the best offer that is given up in order to choose another offer. Indeed, Ricardo questions whether in the case where one single country (e.g., United States) has an absolute advantage in producing all goods, it means that the other world countries will not be able to specialize in the production of one good and thus export to raise their wealth. The response to that question is no. Husted and Melvin (2007) explain that Ricardo demonstrates that there are benefits to trading with others even if one country does not have absolute convergence. He develops the principle of comparative advantage in international trade theory. Here, the opportunity cost of producing one additional unit of one good is the quantity of other goods that is given up in order to produce that additional good. The principle of comparative advantage is the fact that one country will specialize and export goods that it produces at a lower opportunity cost in production, and import goods that it produces at a higher opportunity cost. Ricardo highlights the fact that one country will trade with another in the presence of comparative advantage and vice versa, and thus, both countries will gain by exporting each of the goods in which they have a comparative advantage.

In addition, based on the same principle of comparative advantage, the Hecksher-Ohlin theorem states that one country will have a comparative advantage in producing a good if the country is well endowed in the factor of production (e.g., labor or capital) that is used intensively

in the production of that good. In other words, one country will export a good if it is relatively abundant in the factor of production that is intensively used in the production of that good.<sup>13</sup> The difference between these two principles of advantage is that absolute advantage is based on the efficiency of labor in producing one good, while comparative advantage is based on the relative advantage that one country will have to produce one good.

In the 1980s, the New Trade Theory (NTT), led by Paul Krugman, recipient of the 2008 Nobel Memorial Prize in Economics, emerges in the study of international economics. Krugman (1979) notes that trade occurs between countries even if they have similar characteristics, such as absolute advantage or factor endowments. However, the classical theory of international trade emphasizes the role of differences in characteristics in giving rise to trade, and thus increasing a country's welfare. Krugman relaxes the assumption of constant returns to scale and argues that increasing returns to scale drive international trade. Scale economies (i.e., increasing returns to scale) and monopolistic competition (i.e., imperfect competition) are the main assumptions behind Krugman's NTT.<sup>14</sup> Economies of scale imply that average cost decreases as production increases. Thus, in the presence of economies of scale, consumers have access to a variety of goods (that are produced more cheaply than what would otherwise be the case), and that increase their well-being.

The latter trade theory presented in this section can help to understand the network approach employed in my paper. In the presence of increasing returns to scale, the more a country or a province produces one good in order to export it into the network of world trading countries, the more the average cost of production will decrease for that country. The country will

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<sup>13</sup> See Pugel (2009), page 63.

<sup>14</sup> In a monopolistic competitive market, there exist many competitors but not every firm produces perfectly substitutable goods.

therefore be connected with many others in the future within the network, and this will increase social welfare.

### **3. Related Literature Review**

This section aims to provide an overview of some empirical papers that use network approaches in order to analyze economic integration in the context of international trade. As mentioned, papers applying a network approach in studying economic integration have used instruments such as degree centrality or closeness centrality to model network effects. Fagiolo *et al.* (2009) point out two streams of contributions that employ network approaches in economics. The first stream uses a binary-network approach, while the second stream examines economies in terms of weighted-network. In a binary-network approach, the direct link between two countries exists if the metric of the trade flows between them falls between certain fixed thresholds. The threshold can be based on a certain ratio of one country's total exports to another country with regard to its overall total exports (e.g., 1%, 2% or 5%); or based on a certain value of the total exports of one country to another. I rely on Kim and Shin (2002); Serrano and Baguna (2003); Kali and Reyes (2007) in order to summarize the first stream of contributions. Noting that a binary-network approach cannot fully extract the overall information on the trade flows that one country has with its counterparts, the trading link between two countries is weighted in a weighted-network approach. The literature here is more recent (i.e., Reyes *et al.*, 2008; Fagiolo *et al.*, 2010; Duernecker *et al.*, 2012).

To begin with the first stream of contribution, Kim and Shin (2002) estimate the degree of globalization and regionalization within a social network approach framework. In their paper, Kim and Shin employ longitudinal data on all trade commodities to analyze changes in the world network structure in three different years (1959, 1975 and 1996) for 105 countries. Their data for

1959 and 1975 come from the International Monetary Fund Direction of Trade, and the data for 1996 come from the International Bank for Reconstruction and Development. In terms of the construction, Kim and Shin construct three matrices of international trade flows for the three years under consideration. To do so, they use dollar value of the trade between countries. The authors take into consideration two cut-off points or threshold values, that are respectively at \$1 million and at \$10 million<sup>15</sup>. For instance, if country i's imports from country j represent more than \$1 million (or \$10 million), the link between country i and country j is present at a \$1 million (or \$10 million) threshold value, otherwise it is not in their network. In terms of results, the authors find that the mean values for the number of links among the 105 countries reviewed from 1959 to 1996 increased from .23 to .30 at \$1 million threshold, and from .09 to .13 at \$10 million threshold. They identify the fact that the world became more globalized and denser over the period considered, in the sense that countries have now more connections with others. The network approach used in the paper and the outcome of their study enables the authors to demonstrate that the density and scope of interdependence between countries can be addressed through a network approach.

Moreover, Serrano and Baguna (2003) attempt to analyze the world trade web (WTW) by using a network approach based on direct trade relationships between world countries. First of all, Serrano and Baguna argue that a network approach is relevant in examining the world trading system. The reason is that this approach can explain the propagation of economic crisis in the world trade system (e.g., the Asiatic crisis in 1998). In order to build their network, the authors use the COMTRADE database on the United Nations Statistics Division to extract export and import data for 179 countries. Serrano and Baguna construct their binary directed network by considering exports to be out-degree centrality, and imports to be in-degree centrality. As

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<sup>15</sup> Threshold values are in real \$.

explained by Borgatti (2005), degree centrality refers to the total number of links that each vertex (or node) has. Serrano and Baguna (2003) indicate that they consider an unweighted WTW because the given weight to be assigned depends either on the export point of view or on the import one. They build two types of matrices that are the adjacency matrices for exports and imports, where, for instance, the value in the matrix is equal to 1 if a country  $i$  exports to a country  $j$  and zero otherwise. Based upon that analytical framework, Serrano and Baguna explain that their network of trading relations exhibits the same properties of the more complex network employed by other authors, such as degree correlation between vertices or scale degree distribution.

Finally, the last paper making use of a binary-network approach that I reviewed is Kali and Reyes (2007). To begin with, the authors mention that countries' participation in the worldwide trading system is a major determinant of economic growth. In addition, Kali and Reyes argue that the standard analyses of economic growth that focus on exports and/or imports as a percentage of GDP cannot capture higher connections among countries in a more interconnected world. Thus, they define a network to be a set of points or nodes, which are connected by links or edges. In order to construct their network, the authors use different threshold values on the COMTRADE database of the United Nations. For instance, the presence of a link from country  $i$  to country  $j$  is based on the ratio of exports from country  $i$  to country  $j$  over country  $i$ 's total exports. Their dataset contains values of international trade linkages (i.e., exports and imports) between 182 countries in 1992 and 1998. A country's low level threshold can be at 1 percent of the total exports, while a high level threshold can be at 5 percent of the total exports. Kali and Reyes' empirical test demonstrates that the GDP per capita grew by 0.27 percent on average when they rely on the measure of integration based on their binary-network. In fact, they find a statistically and significant impact of the measure of economic integration on

the GDP per capita. Kali and Reyes claim that their measure of economic integration provides new insights into the study of world countries' economic integration in the sense that the measure captures not only the volume of trade but also the influence of a given country in the international trading system.

With regard to the second stream of contributions, Reyes *et al.* (2008) investigate the evolution of East Asia and Latin America economies using a random walk betweenness centrality statistic. The authors argue that the regular openness indicator in literature cannot fully explain the high economic performance of some emerging Asian economies, noting that emerging Latin American economies with similar characteristics have not reached the same level of success as their Asian counterparts. To explain this divergence, Reyes *et al.* construct an indicator of integration, specifically betweenness centrality in a weighted-network approach. They employ bilateral trade data from the COMTRADE database of the United Nations for 171 countries from 1980 to 2005. They build an adjacency trade matrix reporting the presence of trade relationship between countries. Then, they make use of this adjacency matrix of trade flow to construct a weighted-network. As weights, Reyes *et al.* use the share of each link over the total links in the network for one country. Using this framework, Reyes *et al.* conclude that the high performing Asian countries were more integrated into the WTN than their Latin America counterparts. Indeed, they find that most of them moved from the periphery in the 1980s to the core-periphery on the WTN. On the other hand, Latin American economies remain stable in the network by ranking the betweenness centrality measure.

Furthermore, Fagiolo *et al.* (2010) examine the evolution of the WTW by employing a weighted-network approach among countries. For them, a weighted-network approach allows for a better description of the connectivity among countries, and hence helps to understand international economic integration. In order to construct their weighted-network, Fagiolo *et al.*

use international data on export and import flows that come from Gleditsch (2002) for the years 1981 to 2000 for 159 countries. They make use of an adjacency matrix, where the weight of each link is based on the share of the trade flows in the total trade and in the GDP. Fagiolo *et al.* focus on the trend between their network indicator and countries' GDP per capita in order to investigate if higher-income countries are more integrated than others. As a result, Fagiolo *et al.* find that most countries are characterized by small trade links. However, they note that there is a set of countries that present strong relationships between them, especially those in the core of the periphery structure. In addition, they find that countries that have similar levels of industrialization form trade clubs in the WTW. They demonstrate also that all network properties are stable across time.

To conclude, Duernecker *et al.*'s (2012) paper studies economic globalization through a network-based analysis. To begin with, the authors highlight the fact that trade intensity (i.e., openness) is not the only determinant that needs to be considered in economic growth studies. Duernecker *et al.* argue that a country's degree of integration into the world trading network is the most important factor in analyzing a country's performance. To back up their argument, the authors create a measure of economic integration based on a weighted-network approach that identifies the network position of an economy into the world network. Thus, they claim that their measure of economic integration accounts for higher order links between economies that can explain deep economic growth. They exploit the COMTRADE database of the United Nations that contains information on bilateral imports and exports flows between 125 countries from 1962 to 2005. The construction of their network departs from a matrix of bilateral flows (e.g., exports), where the weighting factor for one country is based on the ratio of the total bilateral flows in this country over the country's GDP and the share of the country's GDP in the world GDP. In other words, the weight is based on a normalization of the export flow of each country in

the network by its aggregate trade volume. In terms of their empirical modeling, Duernecker *et al.* use a dynamic panel framework in their paper. The estimating techniques are the generalized method of moments as well as the limited information maximum likelihood method. The authors find a positive impact of centrality on economic growth. In particular, their results show that an increase in centrality by 1 unit increase the GDP per capita by 1.43 percent in the next period. Duernecker *et al.*'s paper highlights the importance of economic centrality in addition to openness in understanding economic growth.

To summarize, the importance of using a network approach has been demonstrated through either a binary-network approach or a weighted-network approach in the literature. My paper follows Duernecker *et al.* (2012) in the sense that I use a weighted-network approach and the same weighting procedure to construct my measure of economic centrality among Canadian provinces.

#### **4. Data**

The goal of this section is to present the database used in order to conduct my analysis on economic centrality among Canadian provinces. My data come from the Statistics Canada CANSIM database, which is the main and official socioeconomic source of data in Canada. Indeed, the Statistics Canada CANSIM database contains detailed information related to all the economic activity of Canadian provinces. As mentioned, I will employ the panel structure of my data in order to analyze economic centrality. My panel data refer to  $T=17$  years (from 1992 to 2008) and  $N=10$  Canadian provinces, which leads to 170 observations in my sample.<sup>16</sup> The covered period from 1992 to 2008 is chosen because of data availability, especially data related

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<sup>16</sup> See appendix A for the complete list of Canada's provinces' acronyms in the panel.

to interprovincial export flows among the ten Canadian provinces, which is the key measure I use to create the economic centrality measure.

#### **4.1 Dependent Variables**

In my study, I first use the GDP per capita as a dependent variable as a proxy for the welfare level of each province. For the period under review, I compute for each province the per capita GDP by dividing the total provincial GDP, retrieved from Table 384-0002 on CANSIM, by the estimate of each province's population that can be found in the CANSIM Table 051-0001.<sup>17</sup> In addition, I use two other dependent variables that are educational attainment and life expectancy. The measure of educational attainment is the share of the labor force population with at least a secondary level education. My prior is that the more one country trades with others in the network, the more the welfare of this country increases through human capital accumulation. This implies a positive effect of secondary education on economic centrality. The share of the labor force population with at least a secondary education level (i.e., high school degree diploma and above) is obtained by subtracting from the total labor force those who have less than a secondary school diploma. The CANSIM Table 282-0074 contains information on the provincial labor force estimate. In the same manner, I use life expectancy as a proxy for the welfare level of each province. My view is that economic centrality can impact life expectancy through additional human capital information captured by the health of the population. The life expectancy variable is taken from the CANSIM Table 102-0512.

To begin with my main dependent variable, Figure 1 shows Canadian provincial GDP per capita. Based on Figure 1, it is evident that the GDP per capita for each province rose from 1992 to 2008. The same figure seems to identify three main groups of Canadian provinces related to

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<sup>17</sup> The GDP used in this analysis is taken at constant 2002 prices (\$CAN x 1,000,000), and the estimate of each province's population is taken by sex and age groups on July 1<sup>st</sup> of each year (annual persons).

the GDP per capita. Alberta alone forms the first group. Indeed, Alberta is the province with the highest GDP per capita, and this applies for the entire period under review. The GDP per capita in Alberta rose from \$37,165 in 1992 to \$50,887 in 2008, which represents an increase of 36 percent. This can be explained by Alberta's natural resources exports, which increase the overall provincial GDP, therefore the GDP per capita. The second group includes the two Central provinces, Québec and Ontario; three Western provinces, Manitoba, Saskatchewan and British Columbia; and Newfoundland and Labrador. Ontario, Saskatchewan and British Columbia are respectively the second, third and fourth provinces for GDP per capita. On average, their GDP per capita rose from between \$25,000 to \$31,000 in 1992 to approximately between \$34,000 and \$39,000. Starting at the very lowest level in 1992, the GDP per capita of Newfoundland and Labrador rose from \$19,950 to \$37,310 in 2008. This represents an increase of almost 45 percent in 17 years. The recent performance of this province can be attributed to the Newfoundland and Labrador offshore oil developments. This increase raised the province into the second group of provinces, starting in the 2000s. The third group refers to three Atlantic provinces, which are Prince Edward Island, Nova Scotia and New Brunswick. At the beginning of the period under review, these provinces had the lowest levels of GDP per capita compared to the other provinces. While their GDP per capita increased from 1992 to 2008, on average the GDP per capita was below \$23,000 in 1992 and below \$32,000 in 2008.

As for the total population that enters into the calculation of the GDP per capita, Figure 2 presents Canadian provinces' population evolution from 1992 to 2008. One major point from this figure is that the province of Ontario has the largest population in Canada. Ontario's population increased by more than two million from 1992 to 2008. This represents an increase of almost twenty one percent in seventeen years. Ontario is followed by Québec, British Columbia and Alberta, with respective increases of nine percent, twenty five percent and thirty six percent.

Clearly, two Western provinces have benefited from relatively high increases in population in 2008 compared to 1992. For the remaining provinces, namely the four Atlantic provinces with Manitoba and Saskatchewan, the population has increased very slowly. Figure 2 presents a smooth flat trend for those provinces, with the population of Newfoundland and New Brunswick decreasing between 1992 and 2008.

Concerning attainment of a secondary education, Figure 3 seems to identify two main groups of Canadian provinces. British Columbia, Alberta, and Ontario are the provinces in which the highest percentage of people in the labor force have at least a high school diploma. For the period under review, the labor force with at least a high school diploma increased by ten percent points in these three provinces. For instance in 1992, the estimate of the labor force with at least a high school diploma was seventy-two percent in British Columbia, and the estimate reached eighty-two percent in 2008. The second group is composed of the other seven Canadian provinces, where the percentage of people in the labor force with a secondary level education increased from between fifty-five and sixty-one percent to between sixty-nine and seventy-five percent. In addition, note that Manitoba and Saskatchewan are ranked fourth and fifth respectively with respect to secondary educational attainment.

Figure 4 presents the evidence on the evolution of the life expectancy for each province, which clearly increased between 1992 and 2008. Starting between 76.8 and 78.6 living years at birth in 1992, the window moved to reach 78.9 to 81.7 living years. This means that although life expectancy increased within Canadian provinces, the gap between the lowest and the highest level also increased. Here again, it seems to identify three main groups within Canadian provinces. The first group is composed of British Columbia, Ontario, Québec and Alberta. One interesting point is that, while Québec was not in the first group at the beginning of the period under review, the life expectancy in this province rose by 5 percent. Saskatchewan however,

where the life expectancy at birth was the highest in 1992, dropped to reach the eighth position in 2008. In the second group, we have five provinces: Prince Edward Island, New Brunswick, Nova Scotia, Saskatchewan and Manitoba. Newfoundland and Labrador, with the lowest living years at birth, is the third group.

## 4.2 Independent Variables

The selection of the independent variables in my main model follows the standard set of variables in the empirical growth literature. They are: interprovincial export (in particular goods and services) flows that enter into the construction of economic centrality variable, investment share to the GDP, and government share to the GDP.<sup>18</sup> I also have to mention that attainment of at least a secondary level of education is one of the independent variables that I use in analyzing both GDP per capita and life expectancy variables. Interprovincial trade flows are of interest in order to create my economic centrality variable. From 1997 to 2008, I use the CANSIM Table 386-0002 that contains indications on interprovincial trade flows.<sup>19</sup> The interprovincial trade flows between 1992 and 1996 are borrowed from Statistics Canada's publication on *Interprovincial and International Trade Flows in Canada from 1992 to 1998*.<sup>20</sup> The following section will explain the measure of economic centrality in more detail. In addition, the ratio of investment to GDP, namely the investment share, is one of my variables of interest. The reason is that the investment share, which characterizes the saving rate, is a key factor in economic growth theory.<sup>21</sup> This variable explains the physical capital accumulation in an economy that leads to economic growth. I construct the investment share variable by taking the ratio of the stock of fixed non-residential investment, retrieved from Table 031-0002 on

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<sup>18</sup> The government share to the GDP is based on the total government expenditure.

<sup>19</sup> Table 386-0002 contains interprovincial trade flows, especially goods and services, at producer prices for both exports and imports between provinces, nominal \$ (\$ CAN x 1,000,000).

<sup>20</sup> See Statistics Canada (2000), pages: 32, 42, 52, 62, 72, 83, 92, 102, 112, and 122.

<sup>21</sup> See Duernecker, Meyer and Vega-Redondo (2012), page 20.

CANSIM, over each province's GDP. The government share variable is derived by dividing the total provincial government expenditure, obtained from the CANSIM Table 385-0002, by the provincial GDP. The government share to the GDP characterizes the involvement of government in the economy. After this brief presentation of the database, I will highlight some summary statistics of the data.

Regarding the interprovincial export flows, Figures 5 through 14 present the evolution of interprovincial exports of goods and services among Canadian provinces. From these figures, it is clear that interprovincial exports increased within Canadian provinces. This means that Canadian provinces trade more with each other as time passes. In the case of the Atlantic provinces, interprovincial exports rose consistently in the period under review. For instance, the total interprovincial exports in Newfoundland and Labrador rose from \$978 million in 1992 to a level of \$9 billion in 2008 (nominal \$). An interesting fact is that the trading relationship between the Atlantic provinces and the two Central provinces, Québec and Ontario, increased more compared to their exports with the Western provinces. Starting in the 2000s, Nova Scotia increased its exports toward Western provinces, while the other Atlantic provinces did not follow that trend. From Figure 9, it is evident that Québec only increased its exports to Ontario. Indeed, Québec's total exports to Ontario grew from \$18 billion in 1992 to approximately \$35 billion in 2008, which represents almost a doubling of goods and services exports in seventeen years. Ontario, however increased exports not only to its closest neighbor, Québec, but also to Alberta and British Columbia. Regarding Western provinces, the same pattern as with the Atlantic provinces can be seen. In other words, the Western provinces increased their exports with other Western provinces as well as with the Central provinces, while exports to the Atlantic provinces flat lined.

Finally, the government share of GDP and the investment share of GDP are presented in Figures 15 and 16. It is clear from Figure 15 that the Atlantic provinces are the ones where the ratio of government expenditure to the overall GDP is the highest. For instance, in Newfoundland and Labrador in 2006, the government share to the GDP reached the highest level, at 38 percent. In addition, the province of Québec is among the provinces with the highest government share to the GDP. The second set of provinces with respect to the government share of GDP is composed of Manitoba, Saskatchewan and British Columbia – most of the Western provinces – where between 20 and 26 percent of the GDP is attributed to government expenditure. In 1999, for instance, British Columbia reached a peak of 26 percent, which can be attributed to the sustainable measures that the government of British Columbia implemented in that period.<sup>22</sup> Ontario and Alberta constitute the third group of provinces with respect to the government share of GDP. In these two provinces, the evolution of the percentage of government expenditure to the GDP was below 20 percent from the period under review. Between 1997 and 1999, the government share to the GDP was relatively low – between 11 and 14 percent. This trend can be explained by the fact that these two provinces are the two largest provincial economies in Canada. Thus, governments do not have to spend as much compared to the Atlantic provinces, in order to sustain development. Finally, Figure 16 shows the ratio of investment to the GDP. From this figure, Alberta is the only province that can be distinguished from the others in terms of investment share to GDP. In this province, the share of investment in the overall GDP reached almost 40 percent in 2008. Alberta is followed by Saskatchewan and New Brunswick, with respectively 28 percent and 21 percent as investment share to the GDP in 2008. In terms of evolution for the other provinces, the investment share to the GDP increased slowly, remaining below 20 percent for the entire period of the study in these provinces.

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<sup>22</sup> See British Columbia Financial and Economic Review (2009), page 39.

## 5. Causes of Economic Centrality

The purpose of this section is to estimate the exogenous determinants of economic centrality. I first outline the construction of my measure of economic centrality, which follows the technique of Duernecker *et al.* (2012). Then, I highlight some patterns within Canadian provinces. In the last part of this section, I estimate the exogenous determinants of economic centrality. In my network approach, Canada is a microcosm for the entire world, in which each province represents a country in this world. In other words, each province represents a vertex (or node) in my network, and the export flows between provinces represent the link between them. As pointed out by Borgatti (2005), there exist many approaches in modelling centrality in a network approach. For instance, degree centrality captures the number of links each vertex (or node) has, while closeness centrality measures the path's length of the link taken by one node to reach the other nodes. My construction of the measure of economic centrality between Canadian provinces is based on closeness centrality.

### 5.1 Construction of the measure

The starting point in the construction of my measure of economic centrality is a matrix of bilateral trade flows between Canadian provinces. Let  $N$  represent the number of Canadian provinces (of which there are 10), and  $x_{ij,t}$  the export flows from province  $i$  to province  $j$  in year  $t$ .  $X_t = (x_{ij,t})_{i,j=1}^{10}$  is the matrix of all bilateral export flows.  $x_{ii,t}$  is equal to zero for all  $i = 1, \dots, 10$  and  $t = 1992, \dots, 2008$ .

I then make use of this matrix to normalize the exports from province  $i$  to  $j$  by  $i$ 's total exports. Duernecker *et al.* (2012) argue that this normalization helps to determine the real weight of each partner with which one country trades compared to the overall trade partners.

$Z_t$  stands for the matrix of normalized export flows, where  $Z_{ij,t} = x_{ij,t} / \sum_{k=1}^{10} x_{ik,t}$ .<sup>23</sup> To measure the magnitude of each province's export flows relative to its own size, which is captured by the GDP variable, as well as the size of the remaining provinces, I compute for each year what is called the true openness variable  $\theta_{i,t}$ .<sup>24</sup> This true openness variable is such that:  $\theta_{i,t} = \sum_{k=1}^{10} x_{ik,t} / (1 - \beta_{i,t}) * Y_{i,t}$ , where  $\beta_{i,t}$  is the fraction of one province's GDP over the total Canadian GDP at period  $t$  (i.e.,  $\beta_{i,t} = Y_{i,t} / \sum_{k=1}^{10} Y_{k,t}$ ); and  $Y_{i,t}$  is the GDP of province  $i$  at period  $t$ .  $\theta_{i,t}$  is the weighting factor for province  $i$  at period  $t$ .

Based upon matrices  $Z_t$  and  $\theta_{i,t}$ , I compute an adjacency matrix  $A$  of interactions between the ten Canadian provinces each year such that:  $A_t = (a_{ij,t})_{i,j=1}^{10}$ . Here  $a_{ij,t} = (1 - \theta_{i,t}) Z_{ij,t}$ . Duernecker *et al.* (2012) demonstrate that each entry  $a_{ij}$  in this adjacency matrix is a probability with which one node  $i$  can be connected with node  $j$ . This matrix  $A_t$  is the weighted directed network matrix over the ten Canadian provinces. Finally, I employ the weighted-network matrix to create my measure of economic centrality. The measure of economic centrality for each province is generated such that:  $\phi_{i,t} = \sum_{i \neq j} \beta_{i,t} \varphi_{ij,t}$ , where  $\beta_{i,t}$  is the fraction of one province's GDP of the total Canadian GDP in period  $t$  as previously presented, and  $\varphi_{ij,t} = (I - A_j)^{-1} e$ .<sup>25</sup>  $\phi_{i,t}$  measures the distance or path required for province  $i$  to reach the other provinces at time  $t$ . The smaller that  $\phi_{i,t}$  is, the shorter the path from province  $i$  to reach the other provinces, and thus the more province  $i$  will interact with the other provinces. Generally speaking, if the economic centrality measure of one province is small, this province will be more connected with the other provinces, and thus the province will be more integrated.

<sup>23</sup> Note that the sum of each row of the matrix  $Z$  is equal to 1.

<sup>24</sup> Following Arribas *et al.* (2009), Duernecker *et al.* (2012) compute the true openness of a country to be the normalization of one of its exports taking into account its size, which is captured by the GDP, and the size of the rest of the world.

<sup>25</sup> Duernecker *et al.* (2012) mention that  $I$  stands for the identity matrix and  $e$  the transpose of the vector  $(1, \dots, 1)^{10}$ .

## 5.2 Patterns within Canadian provinces

This part of the section summarizes some key findings of my measure of economic centrality among the ten Canadian provinces, based on a weighted-network approach. Figure 17 illustrates the measure of economic centrality of the ten Canadian provinces. Based upon this figure, it is clear that the measure of economic centrality decreases in value over the period of study. Starting at 4.4 as the highest value of economic centrality in 1992, the highest value for economic centrality decreased to 3 in 2008. Indeed, Duernecker *et al.* (2012) demonstrate that their measure of integration is expected to have a negative sign, which suggests that more world countries are integrated in a network of trade flows over time. Noting that the construction of my measure of economic centrality is derived from Duernecker *et al.* (2012), the negative slope as highlighted by Figure 17 confirms that this measure is also valid looking into intra-country trading systems. My quantitative findings are as expected.

It is clear from Figure 17 that Ontario is the province in Canada that has the lowest value for economic centrality. Ontario's economic centrality measure presented a smooth path for the period under review. This means that from the 1990s, Ontario showed a trend towards deeper economic integration in Canada. It is also evident that Canadian provinces present three groups related to economic centrality. The first consists of Ontario, which is the province with the lowest value of economic centrality. The second group comprises Québec, Alberta and British Columbia. For these provinces, the measure of economic centrality was on average between 2 and 2.5 in 1992 compared to between 1.5 and 2 in 2008. The third group contains Manitoba, Saskatchewan and the four Atlantic provinces. For the third group of provinces, the measure of economic centrality was on average between 3.5 and 4.5 in 1992 compared to between 3 and 3.5 in 2008. The gap has narrowed among provinces in the third group. Prince Edward Island is less integrated than the other Canadian provinces. This could be the case because Prince Edward

Island is a very small provincial economy in Canada and has the smallest GDP. Note that GDP enters into the weighting I use to calculate the measure of economic centrality. In the same manner, the case of Ontario could be well explained by this province having the highest level of GDP among the Canadian provinces. Another point to note in Figure 17 is that around 2000 and 2001, the measure of economic centrality increases – representing a decrease in integration – in Ontario, while it decreases – denoting an increase in integration – in the third group of provinces. To my knowledge, this can be attributed to the fact that interprovincial export flows increased at that period for the provinces included in the third group, while interprovincial export flows slightly decreased in Ontario. The database shows that in 2001, the total exports from Ontario to the provinces included in the third group decreased, and similarly, the total exports from these provinces to Ontario decreased. For instance, the export flows from Prince Edward Island to Ontario decreased from \$242 million in 2000 to \$232 million in 2001, while the export flows from Ontario to Prince Edward Island decreased from \$633 million in 2000 to \$618 million in 2001.

This configuration of the economic centrality measure in three groups based on a weighted-network approach points out the fact that Canadian provinces are not fully integrated among themselves. This means that it takes long paths for some provinces, especially those in the third group, to reach the other provinces. Ontario seems to be close to all provinces according to this measure. Indeed, Reyes *et al.* (2008), in their comparison of the evolution of East Asia and Latin America economies, conclude that East Asia became more integrated in the 1990s than Latin America economies. This highlights regional disparity in terms of economic integration among world countries. In addition, Fagiolo *et al.* (2010) find that countries that have similar levels of industrialization form trade clubs in the WTW. In the Canadian context, Hamit-Hagggar (2013) shows that there exist three distinct clubs of convergence looking at the real provincial

GDP per capita. The author claims that Canadian provinces did not converge to the same steady state but to different clubs. The first club of convergence is composed of Ontario, Alberta, Saskatchewan, Alberta, British Columbia and Newfoundland and Labrador. The second club of convergence refers to Québec, Manitoba and New Brunswick, and the third club of convergence comprises Nova Scotia and Prince Edward Island. The list of provinces in the first club, as described by Hamit-Hagggar (2013), is close to my first group of provinces grouped according to the GDP per capita. Hamit-Hagggar (2013) also mentions in his paper that the Canadian provinces with the highest levels GDP form the first club of provinces. In this case, what are the determinants of economic centrality? In other words, what are the factors that can explain economic centrality?

### **5.3 Determinants of Economic Centrality**

In this part, I estimate the exogenous determinants of economic centrality. Based on the weighting procedure used in the construction of the measure of economic centrality, many variables, such as the GDP, can influence economic centrality. In order to analyze the influences of economic centrality, I compute a measure called geographic centrality that accounts for alternative specification in the construction of centrality. The rationale behind this measure of geographic centrality is that the more one province is geographically central, the smaller will be its measure of geographic centrality in the sense that the province will be situated in the center of the network. Thus, the more central is one province geographically, the smaller will be the measure of economic centrality of this province because the distance to reach the other provinces will be short. Geographic centrality is expected to be positively correlated with economic centrality.

The construction of this geographic centrality measure follows the same steps as presented in the previous part of this section. The point of departure here is the matrix  $D =$

$(d_{ij})_{i,j=1}^{10}$ , which measures distances between the capital cities of provinces.  $d_{ij}$  stands for the distance between the capital of province  $i$  and the capital of province  $j$ . Note that the distance between two provinces is static over time rather than dynamic. Thus, as opposite to the construction of the measure of economic centrality, the measure of geographic centrality is static over time. The distance between two provinces is denominated in kilometres and taken from the source *TransCanada Highway*.<sup>26</sup> Then I normalize this matrix of distances between Canadian provinces' capitals such that  $w_{ij} = d_{ij} / \sum_{k=1}^{10} d_{ik}$ . The weighting factor  $\theta_i'$  for province  $i$  in this case is as follows:  $\theta_i' = \sum_{k=1}^{10} d_{ik} / (1 - \beta_i) * S_i$ , where  $\beta_i$  is the share of one province's land size over the total Canadian land size (i.e.,  $\beta_i = S_i / \sum_{k=1}^{10} S_k$ ); and  $S_i$  is the size of province  $i$ . Canadian provinces' land size data are obtained from Natural Resources Canada. Based upon matrices  $w_{ij}$  and  $\theta_i'$ , I compute a weighted-network matrix as previously described in order to create my measure of geographic centrality.

In addition, I add a time variant portion to the measure of geographic centrality in order to make geographic centrality dynamic over time instead of static. The steps for the construction of this time variant measure of geographic centrality is the same as presented above. However here, I construct:  $\theta_{i,t}' = \sum_{k=1}^{10} d_{ik} / (1 - \beta_{i,t}) * S_i$ , where  $\beta_{i,t}$  is the share of one province's population over the total Canadian population in period  $t$  (i.e.,  $\beta_{i,t} = \text{Pop}_{i,t} / \sum_{k=1}^{10} \text{Pop}_{k,t}$ ); and  $S_i$  is the size of province  $i$ . In that case, the weighting factor is based on the population that varies over time, instead of the province's land size.

Figures 18 and 19 present the trend in the measure of geographic centrality. From Figure 18, the province with the highest measure of geographic centrality is Prince Edward Island. The measure of geographic centrality for this province is above 3, while it is below 1.5 for the rest of

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<sup>26</sup> See Mileage Distances between Canadian Cities available at: <http://transcanadahighway.com/General/mileage.htm#UOCGPle51Ft> (consulted March 1<sup>st</sup> 2014).

the provinces. The fact that the land size of Prince Edward Island is the smallest in Canada could be the reason associated with such result as well as this province location. However, Prince Edward Island is the province with the highest measure of economic centrality, as shown in Figure 17. In addition, Ontario and Québec are the Canadian provinces where the measure of geographic centrality is the smallest among the ten Canadian provinces. Note that Ontario and Québec are historically considered to be the two central provinces in Canada. The measures of economic centrality in these two provinces are also the two smallest among the Canadian provinces. The two Central Canadian provinces have the smallest measure of geography centrality, followed by the Western provinces and the Atlantic provinces in third position. This illustrates that the higher the measure of geographic centrality for one province, the further is that province from the center. Thus, the higher will be the measure of economic centrality, and the less integrated will be the province. Figure 19 shows that the use of the population in the weighting procedure of the construction of the measure of geographic centrality makes the variable more dynamic. However, there is a really small change over time for geographic centrality. From Figure 19, it is clear that Prince Edward Island is the province that shows the highest value as for geographic centrality. As in Figures 17 and 18, Ontario and Québec have the smallest measure of geographic centrality, followed by the Western provinces and the Atlantic provinces.

To formally investigate the determinants of economic centrality, I estimate the following equation using simple OLS:

$$\text{Cen\_eco}_i = a + b \text{Cen\_geo}_i + c \text{Pop}_i + d \text{Sup}_i + e, \quad (1)$$

where  $\text{Cen\_eco}_i$  is the measure of economic centrality of province  $i$ ,  $\text{Cen\_geo}_i$  is the measure of geographic centrality of province  $i$ ,  $\text{Pop}_i$  is the total population of province  $i$ ,  $\text{Sup}_i$  is the land size of province  $i$ , and  $e$  is the error term.

Table 1 contains results for the estimation of Equation 1. Column (I) presents the result using the province size in the weighting procedure, contained in  $\theta_i'$ , and column (II) shows the result using the population in the weighting procedure contained in  $\theta_{i,t}'$ . For both columns, the estimated coefficient for the geographic centrality variable presents an expected sign. I find that a unit increase in geographic centrality is associated with an average of 0.119 unit increase in economic centrality, and an average of 0.075 unit increase using the population in the weighting procedure. This indicates a positive correlation between geographic centrality and economic centrality. By construction, I explain that the more one province is central, the smaller will be its measure of geographic centrality in the sense that this province will be relatively close to the others. One province that is close to the others geographically will be able to trade more efficiently with the other provinces, and thus, this province will be more tightly connected with others in the economic network. Their central position in the country makes them close to the others. In addition, both provinces present the lowest levels of economic centrality. On the other hand, provinces such as Prince Edward Island or New Brunswick have the highest levels of both geographic centrality and economic centrality. Thus, it is evident that the more one province is central geographically, the more this province will be economically integrated as well, because the distance to reach the other provinces will be short. Geographic centrality is then an exogenous determinant of economic centrality.

With regards to the two other explanatory variables, namely the total population and the province's size, the coefficients estimated are negative and significant. Regarding the population, I find that a unit increase in the total population is associated with a decrease of 1.85e-07 and 1.80e-07 units in economic centrality.<sup>27</sup> The negative sign means that when the population increases, economic centrality decreases. By construction, it is true that the smaller is the measure

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<sup>27</sup> The total population is in million persons.

of economic centrality for one province, the more integrated this province will be. Thus, an increase in one province's population, which leads to a decrease in economic centrality, will be beneficial for that province in the sense that the province will interact more with others and will be more integrated in the network. This means that the population is also an exogenous determinant of economic centrality. Finally, concerning the province's land size, I find that a unit increase in the province land size is associated with respectively a decrease of  $2.93e-07$  and  $3.15e-07$  in economic centrality.<sup>28</sup> This implies that the larger is the land size for a province, the lower economic centrality will be, and hence the more integrated will be the province. This is consistent with the trend presented in Figure 17, in the sense that Ontario and Québec, the two biggest provinces in terms of the land size, had the lowest value for economic centrality. Provincial land size is also an exogenous determinant of economic centrality.

## 6. Impact of Economic Centrality

The objective of this section is to empirically analyze the impact of economic centrality on indicators of economic welfare of Canadian provinces using a panel data approach. As mentioned earlier, I will test three different equations where respectively the GDP per capita, secondary education and life expectancy are the dependent variables.

### 6.1 Empirical models

With regards to the GDP per capita variable, the basic empirical framework consists of a regression equation of the form:

$$\text{Log YPC}_{i,t} = \alpha_0 + \alpha_1 \text{Centrality}_{i,t} + \alpha_2 X_{i,t} + \eta_i + \gamma_t + \varepsilon_{i,t} \quad , \quad (2)$$

where  $\text{YPC}_{i,t}$  is the GDP per capita of province  $i$  at time  $t$ , and  $\text{Centrality}_{i,t}$  is the economic centrality of province  $i$  at time  $t$ .  $\alpha_1$  is the parameter of interest and should enter with a negative

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<sup>28</sup> The provincial land size is in  $\text{km}^2$ .

sign into the regression equation.  $X_{i,t}$  is a vector of independent variables, which are secondary education, the share of investment of GDP and the share of governments spending of GDP.  $\alpha_2$  is a vector of coefficients related to the independent variables.  $\eta_i$  captures the fixed effect by province, which is included because the GDP per capita varies across Canadian provinces.  $\gamma_t$  is the fixed effect by year and  $\varepsilon_{i,t}$  stands for the random error term.

To determine the impact of economic centrality on the level of attainment for secondary education, I use the equation illustrated below:

$$EDU_{i,t} = \lambda_0 + \lambda_1 \text{Centrality}_{i,t} + \lambda_2 Z_{i,t} + \eta_i + \gamma_t + \tau_{i,t} , \quad (3)$$

where  $EDU_{i,t}$  is the share of the labor force population with at least a secondary level education, and  $\text{Centrality}_{i,t}$  is the economic centrality of province  $i$  at time  $t$ . The parameter of interest  $\lambda_1$  should enter into the regression with a negative sign.  $Z_{i,t}$  is a vector of independent variables that are the shares of investment spending and government spend of GDP.  $\lambda_2$  is a vector of coefficients related to the independent variables. As in Equation 2,  $\eta_i$  captures the province fixed effect and  $\gamma_t$  stands for the year fixed effect.  $\tau_{i,t}$  is the random error term.

Finally, to examine the impact of economic centrality on life expectancy, I employ the following equation:

$$LEX_{i,t} = \beta_0 + \beta_1 \text{Centrality}_{i,t} + \beta_2 Z_{i,t} + \eta_i + \gamma_t + \mu_{i,t} , \quad (4)$$

where  $LEX_{i,t}$  is the life expectancy measure of province  $i$  at time  $t$ . Here,  $\beta_1$  is the parameter of interest and should be negatively correlated with life expectancy. Apart from  $\mu_{i,t}$  that is the error term in Equation 4, the other elements included in this equation are the same as in the previous equation.

## 6.2 Regression results

Table 2 presents regression results from the estimation of Equation (2). In column (I), I estimate only the effect of economic centrality on the GDP per capita. The estimated coefficient for the economic centrality variable is significant and has the expected negative sign. The result shows that 1 unit decrease in economic centrality increases the GDP per capita on average by 16.5 percent, considering only economic centrality. This result is particularly of interest for small provinces with low levels of GDP: the more they will interact with other, the more their measure of economic centrality will fall, which will lead to an increase in economic welfare. In addition, columns (II), (III) and (IV) control for the effects of the other independent variables, the provincial fixed effect and the year fixed effect. Column (II) indicates that adding the measure of educational attainment along with the variable of economic centrality increases the explanatory power of the model. The result shows that the GDP per capita increases by an average of 5 percent if economic centrality decreases by 1 unit. The advantage of having a labor force with a high level of educational attainment is that it has a great impact on the GDP per capita. Columns (III) and (IV) show that there is no significant difference by adding both the provincial fixed effect dummies and year fixed effect dummies in the model. The estimated coefficient for the parameter of interest slightly decreases in these two columns, while remaining significant. The results in columns (III) and (IV) reveal that if economic centrality decreases by 1 unit, the GDP per capita will increase by an average of 4 percent. The result presented in column (IV) seems to be more robust based on the significance of all the variables included in the model. Increasing economic centrality, has a positive impact on welfare. In order to correct for serial correlation in my models, I employ GLS estimating technique, and the result is presented in column (V) for all three models. I find that the GDP per capita increases by an average of 3 percent if economic centrality decreases by 1 unit. In addition, it is well-know that endogeneity problems (e.g.,

reversed causality or omitted variable bias) lead to biased estimated coefficients. In order to address possible problems of endogeneity in my model, I employ the IV-GMM method, and the results are contained in column (VI). For all three models, column (VI) represents the result of using the IV-GMM technique instead of OLS. I use geographic centrality as an instrument for economic centrality. As explained in the previous section, geographic centrality is an exogenous cause of economic centrality, and its effect on the GDP per capita is indirect through economic centrality. Thus, geographic centrality meets the criteria for a suitable instrument. The result shows a negative and significant coefficient for economic centrality. Specifically, a decrease of 1 unit in economic centrality will increase the GDP per capita by an average of 26 percent. However, I have to acknowledge that the GMM method is sensitive to the sample size. Noting that my sample is relatively small, this can explain why apart from the economic centrality variable, the estimated coefficients for the other variables are not significant in the model.

Table 3 contains results of the estimation of Equation (3). Column (I), which includes only economic centrality as the independent variable, shows an expected and significant sign. Indeed, the estimated coefficient in this column reveals that one unit decrease in economic centrality is associated with an average of 0.047 unit increases in the level of educational attainment. Noting that the measure employed in my paper is the share of the labor force with at least a secondary level education, the result means that a decrease of 1 unit in economic centrality will lead to an increase in average education of 4.7 percent on estimated. The more a province is integrated in the network and trades with others, the more the welfare of the population will increase, and thus, the more the population will be educated. In addition, column (II) gives more insights in the sense that the estimated coefficients for economic centrality increase while adding other variables in the model. The result shows that a decrease of 1 unit in economic centrality indicates an increase of 0.049 units in educational attainment. It seems that secondary education

is one mechanism through which economic centrality affects welfare. Columns (III) and (IV) add controls that are the provincial fixed effects and the year fixed effects. Column (III) shows that a decrease in economic centrality of 1 unit will increase secondary educational attainment by an average of 0.123 units, and column (IV) indicates that a decrease in economic centrality of 1 unit will increase secondary education by an average of 0.022 units. Using GLS, column (V) indicate that a decrease in economic centrality of 1 unit will increase secondary educational attainment by an average of 0.020 units. For the same reason of endogeneity as discussed previously, in column (VI) I present the results using IV-GMM. The result shows a negative and significant coefficient for economic centrality; specifically, a decrease of 1 unit in economic centrality will increase secondary education by an average of 0.034 units.

Table 4 shows the regression results of the estimation of Equation (4). Here again, column (I) shows the estimates of the effects of economic centrality on life expectancy for a simple regression. The estimated coefficient for the parameter of interest is significant and has the expected negative sign. The result shows that 1 unit decrease in economic centrality increases life expectancy by 0.759 years. This result means that increased trade connection with others in the network, which leads to a decrease of economic centrality, adds almost 9 months to the life of the population, all other factors held constant. In addition, columns (II), (III) and (IV) control for the effects of the other independent variables, the provincial fixed effects and the year fixed effects. Column (II) shows that life expectancy increases by an average of almost 2 years if economic centrality decreases by 1 unit. It seems that having both the province fixed effect and the year fixed effect in the model using OLS causes a change in the estimated coefficient for economic centrality, as shown in column (IV). Using the GLS and the IV-GMM framework respectively, the result indicates that a decrease of 1 unit in economic centrality will increase life expectancy by an average of 0.55 and 0.462 years.

## 7. Conclusion

In the context of a more globalized world with the increase in connections between countries, researchers such as Reyes *et al.* (2008); Fagiolo *et al.* (2010); Duernecker *et al.* (2012) mention that economic centrality provides more insights into the study of economic integration compared with the traditional measures employed to analyze economic integration. Canadian regional integration is analyzed in this paper using a network approach. I assess the causes and consequences of economic centrality through a weighed-network approach, as in Duernecker *et al.* (2012). Economic centrality measures the distance required for one province to reach the others. The smaller the distance required for one province to reach the others, the more the province will interact and trade with others, which in turn leads to an increase in economic welfare.

Using the Statistics Canada CANSIM database from 1992 to 2008, I analyze the determinants of economic centrality in the first part of my paper. In particular, I find that geographic centrality is one main determinant of economic centrality. I find that the more one province is central, the smaller will be its measure of geographic centrality in the sense that the province will be situated more centrally the network. Thus, the province will have an advantage from the fact that it is central, which will positively affect economic centrality. I also find land size and population determine economic centrality.

In addition, I empirically determine the consequences of economic centrality on GDP per capita, educational attainment (in the labor force), and life expectancy, and find that the more a province is central, the better are its outcomes. In particular, I find that one unit decrease in economic centrality is associated with a four percent increase in the GDP per capita. In the same manner, a decrease of 1 unit in economic centrality indicates an increase of 0.049 units in

secondary education, and life expectancy increases by an average of almost 2 years if economic centrality decreases by 1 unit.

From an empirical point of view, my paper contributes to the growing literature that employs a network approach to study the topic of economic integration. In this paper in particular, I demonstrate that the properties of centrality in a network approach are also valid when looking at intra-country exports flows rather than international flows, as the literature has always done. From a policy point of view, the results imply that improving the efficiency Canadian intra-country trading system will lead to an increase in welfare. The increase in interprovincial or east-west trade should go hand in hand with international trade or north-south trade. Progress needs to be made in order to remove all interprovincial trade barriers and others sources of frictions.

Noting that the measure of economic centrality I construct in my paper seems to be sensitive to the weighting scheme as well as the type of flows (i.e., direct or indirect), future research could focus on indirect flows such as foreign direct investment to construct the measure of economic centrality using a network approach.

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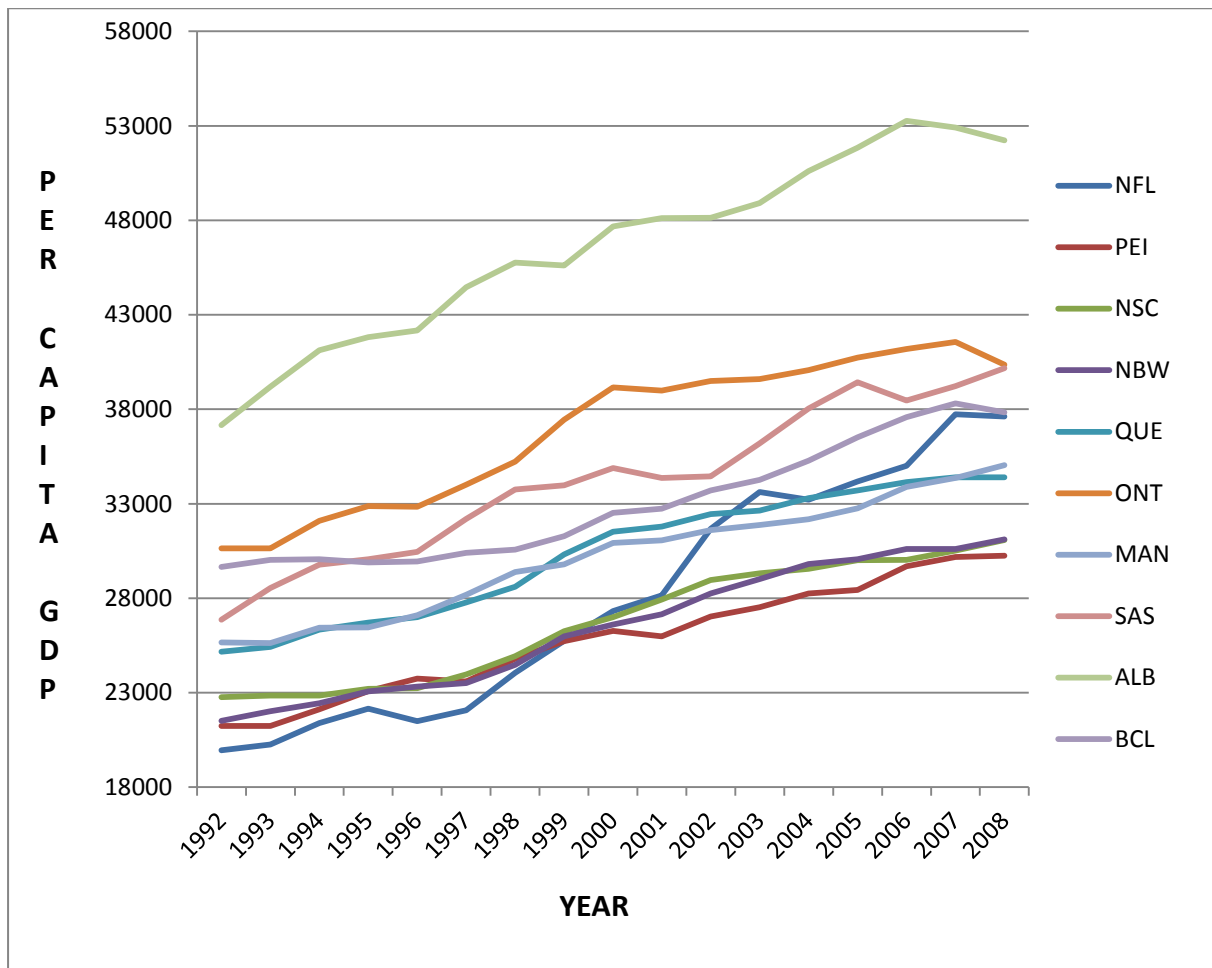
**Appendix A: List of Canada's Provinces' Acronyms in the Panel**

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<u>Provinces</u>	<u>Acronym</u>	<u>ID</u>
Newfoundland and Labrador	NFL	1
Prince Edward Island	PEI	2
Nova Scotia	NSC	3
New Brunswick	NBW	4
Québec	QUE	5
Ontario	ONT	6
Manitoba	MAN	7
Saskatchewan	SAS	8
Alberta	ALB	9
British Columbia	BCL	10

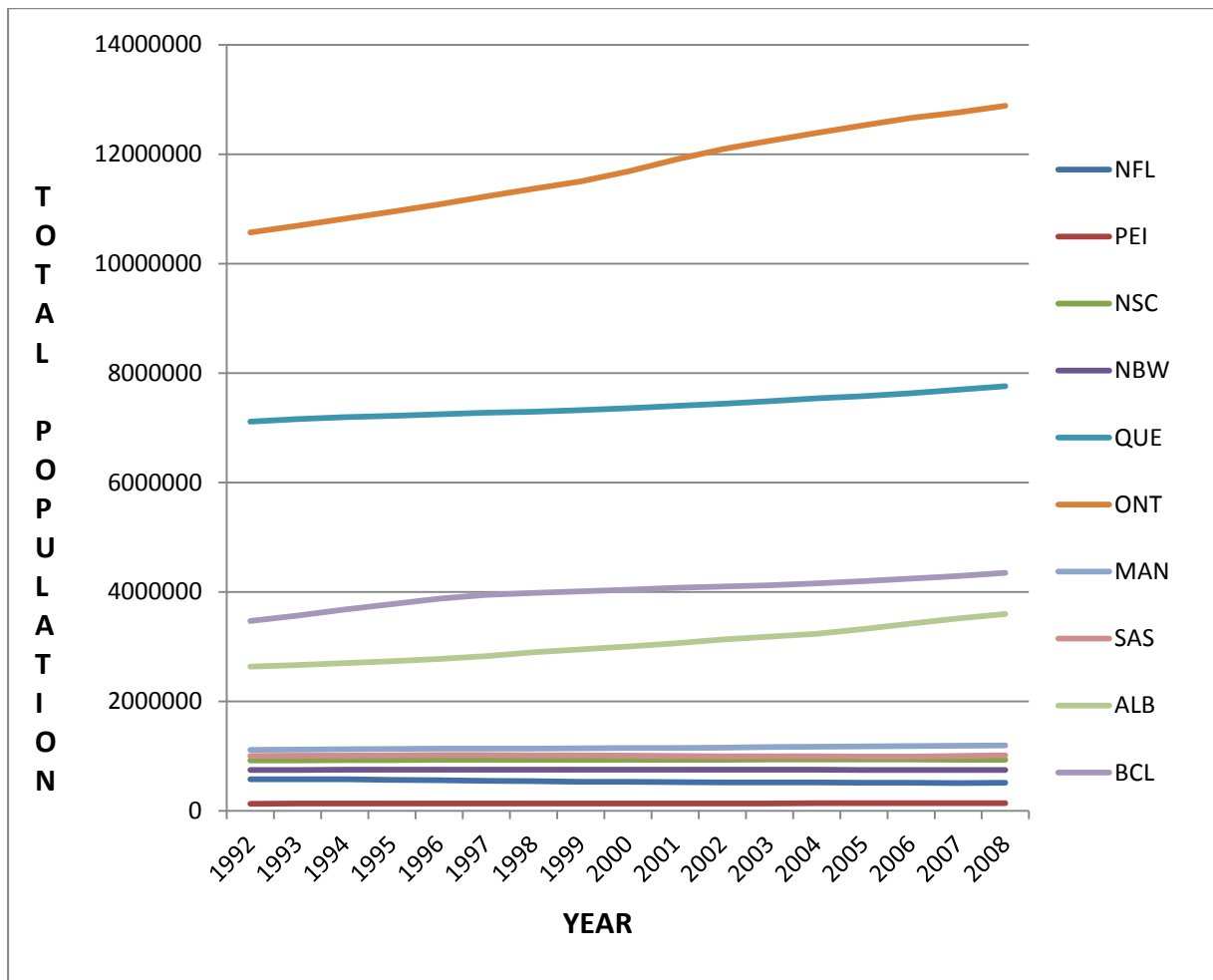
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Figure 1: GDP per capita of Canadian Provinces, 1992-2008 (dollars)



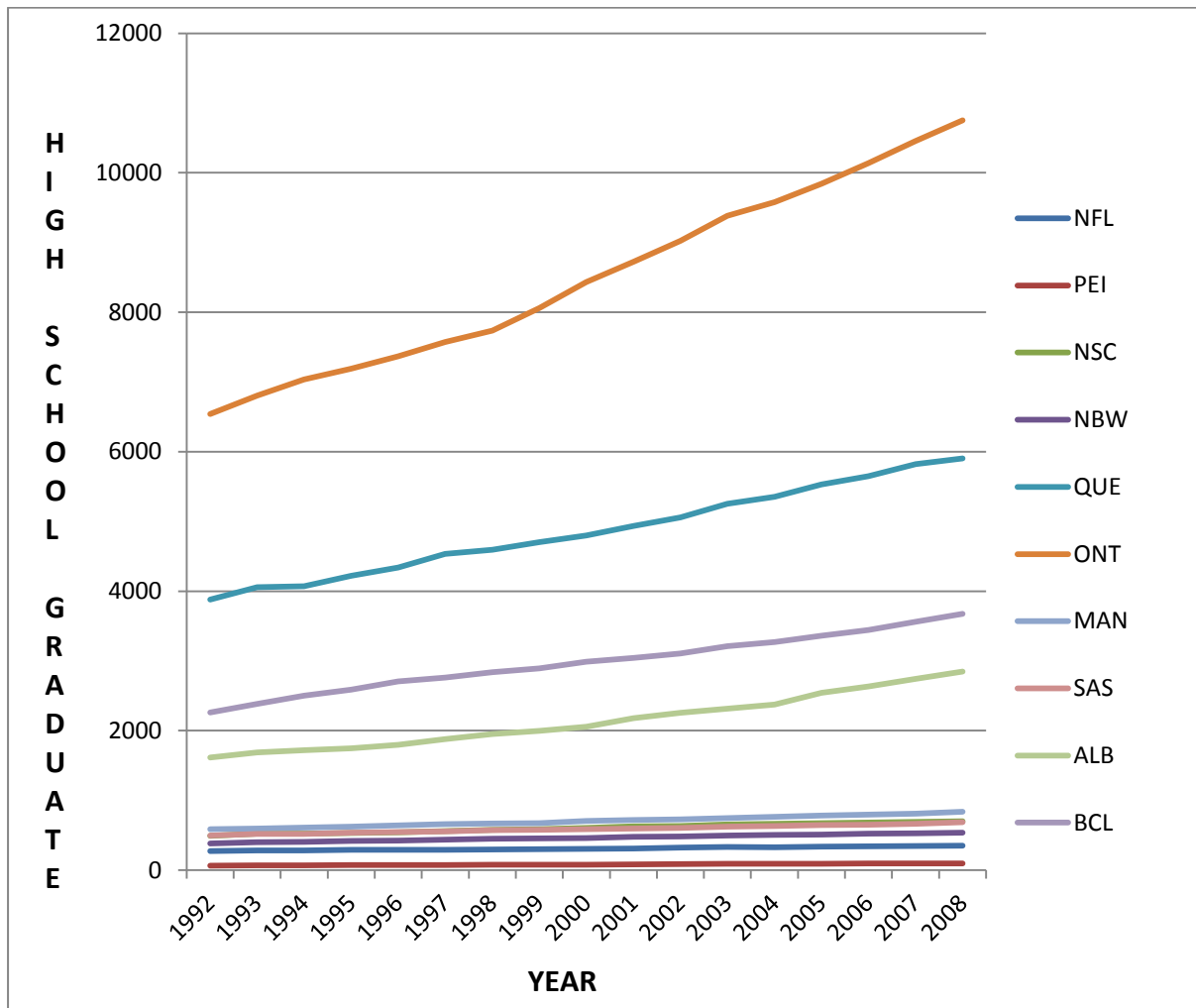
Source: Author's estimates based on CANSIM Tables 384-0002 and 051-0001.

Figure 2: Canadian Provinces Total Population, 1992-2008 (persons)



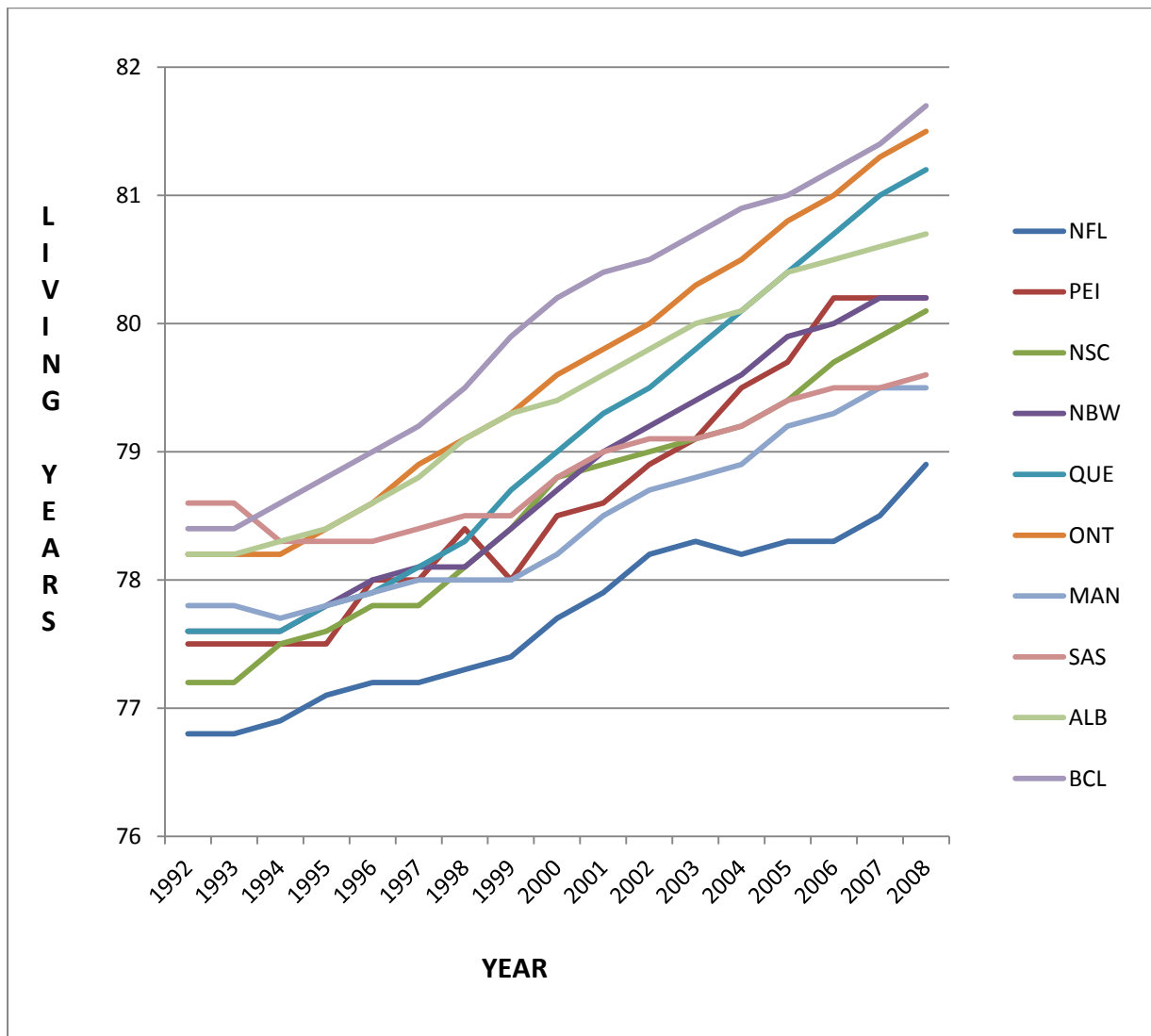
Source: CANSIM Table 051-0001.

Figure 3: Canadian Provinces' Share of the Labor Force with at least a Secondary Level Education, 1992-2008 (%)



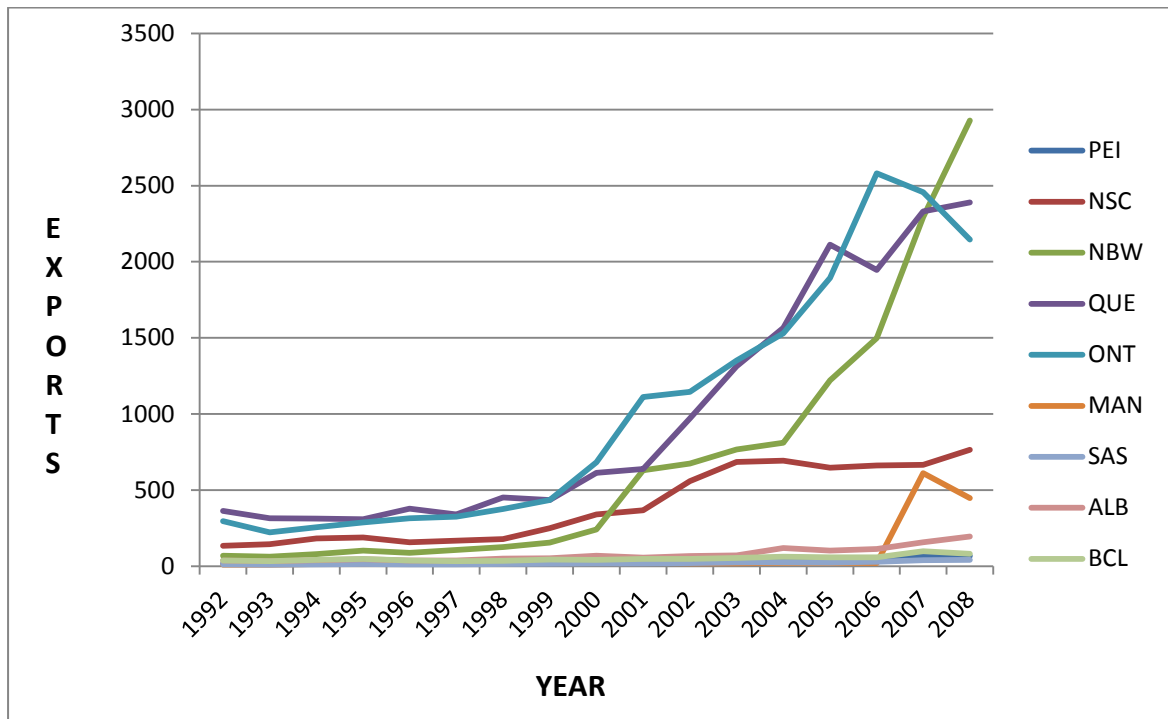
Source: CANSIM Table 282-0074.

Figure 4: Canadian Provinces Life Expectancy at birth, 1992-2008 (years)



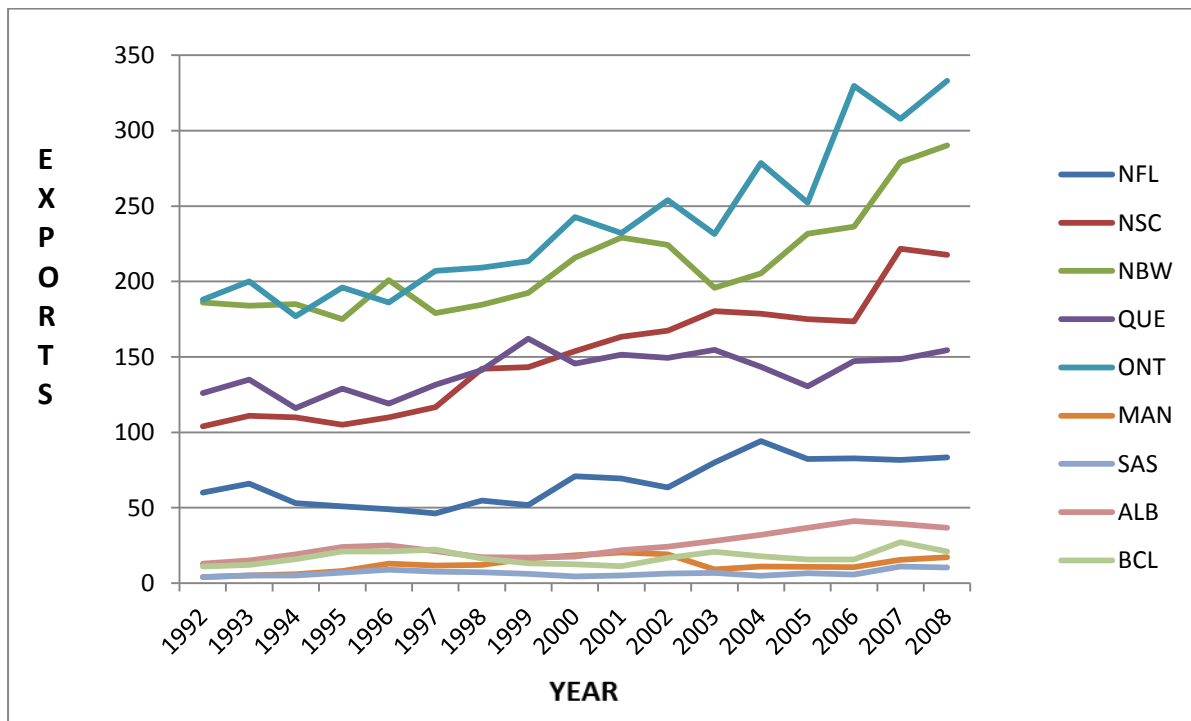
Source: CANSIM Table 102-0512.

Figure 5: Newfoundland and Labrador Interprovincial Exports, Goods and Services, 1992-2008 (millions)



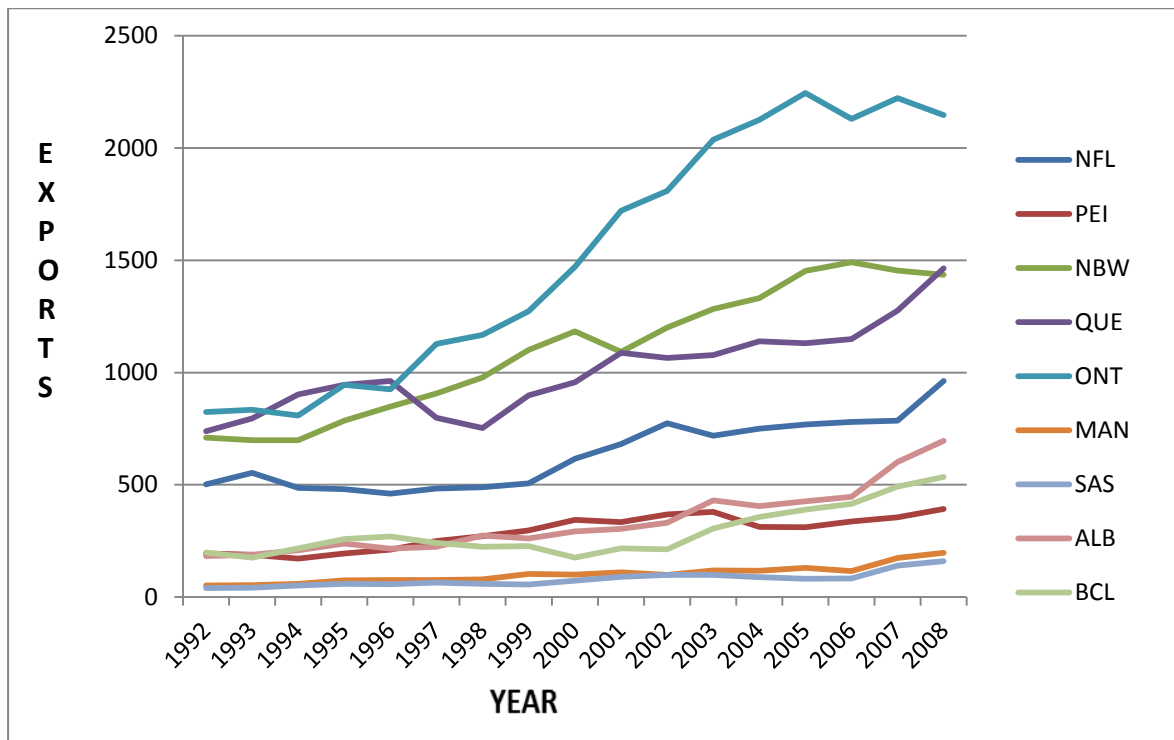
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 6: Prince Edward Island Interprovincial Exports, Goods and Services, 1992-2008 (millions)



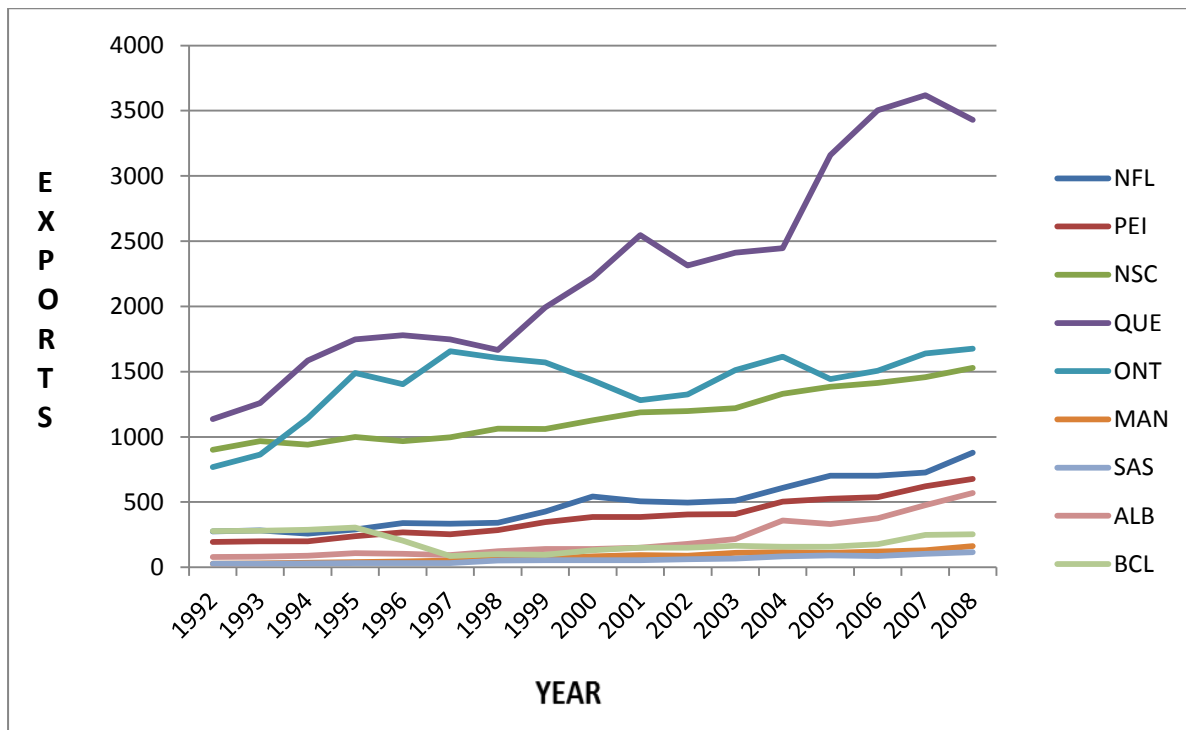
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 7: Nova Scotia Interprovincial Exports, Goods and Services, 1992-2008 (millions)



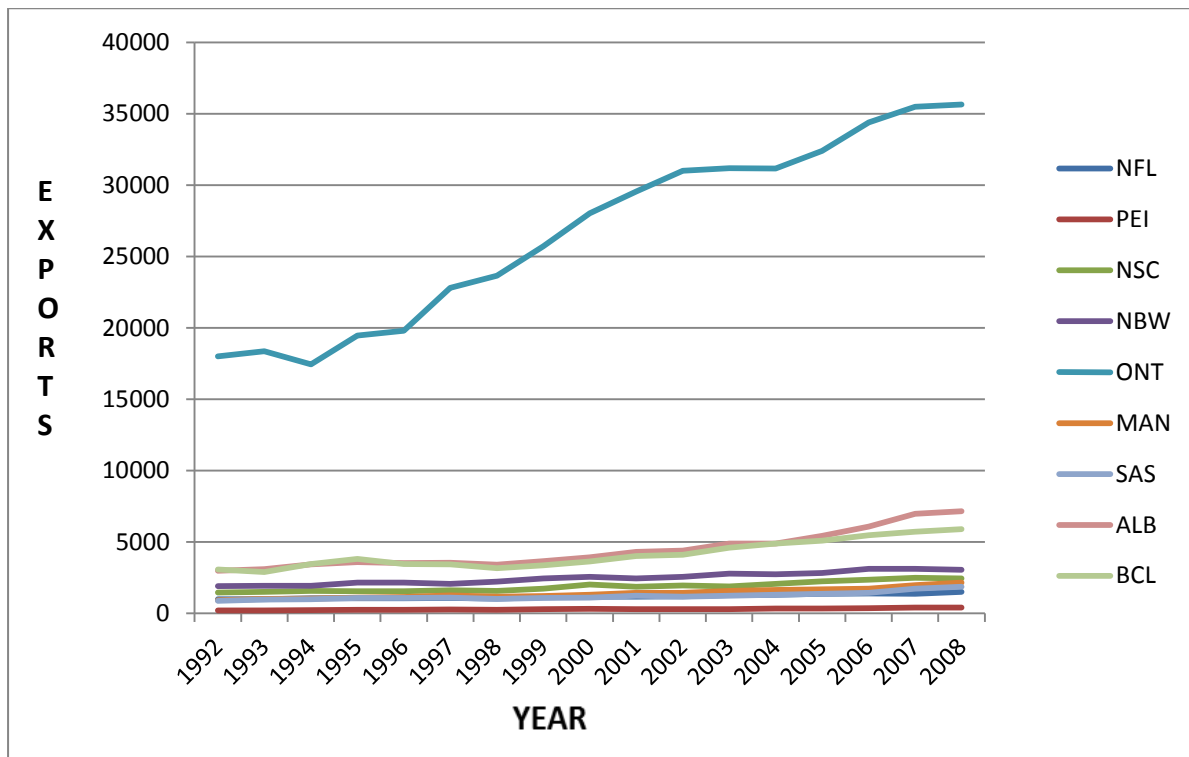
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 8: New Brunswick Interprovincial Exports, Goods and Services, 1992-2008 (millions)



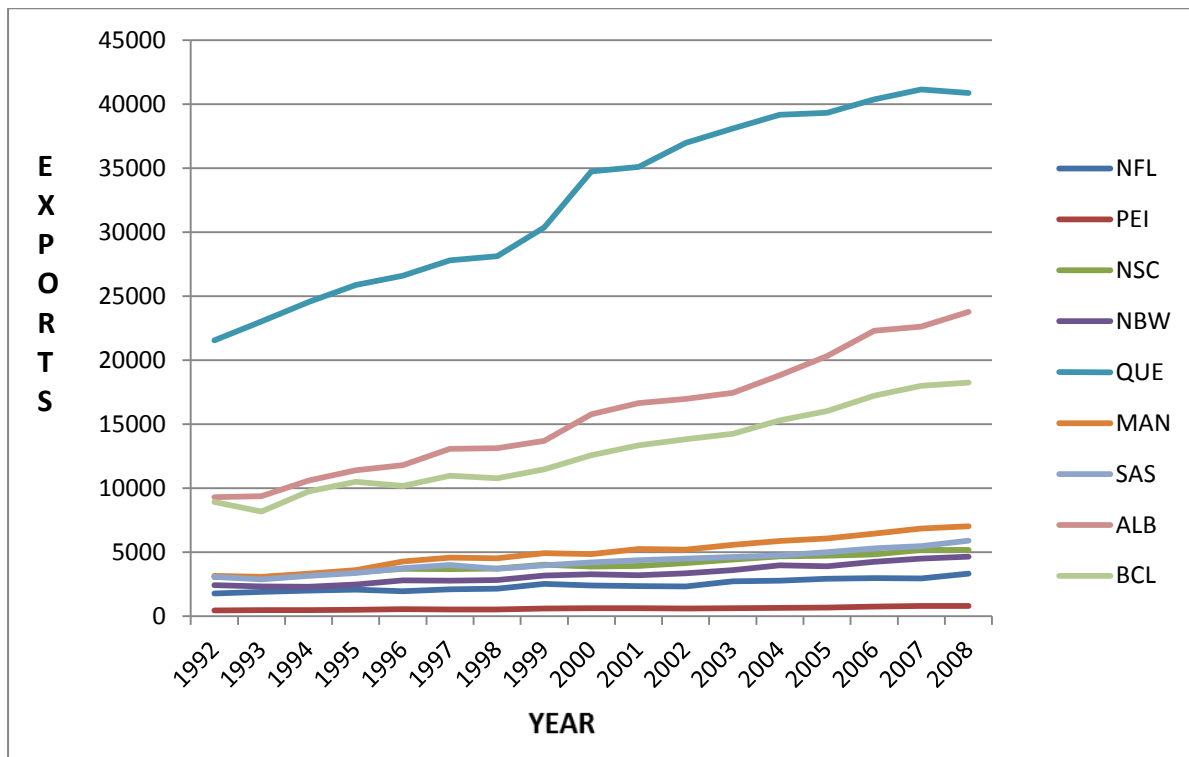
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 9: Québec Interprovincial Exports, Goods and Services, 1992-2008 (millions)



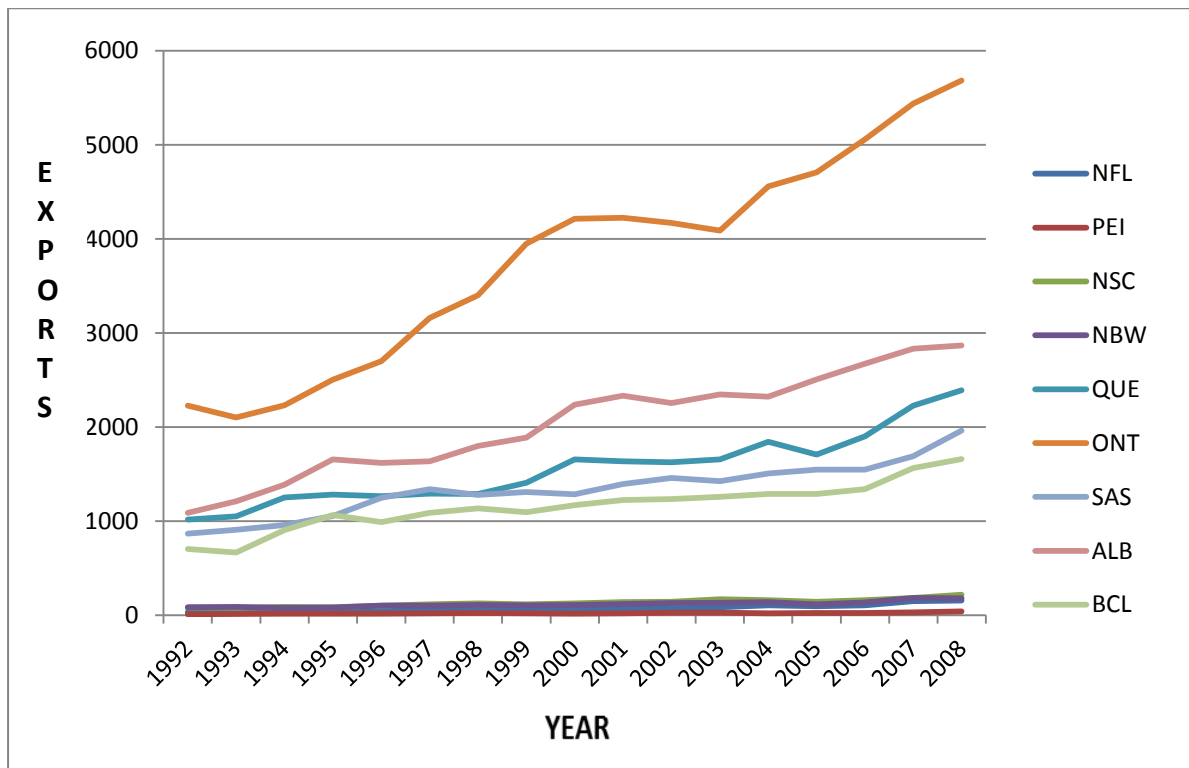
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 10: Ontario Interprovincial Exports, Goods and Services, 1992-2008 (millions)



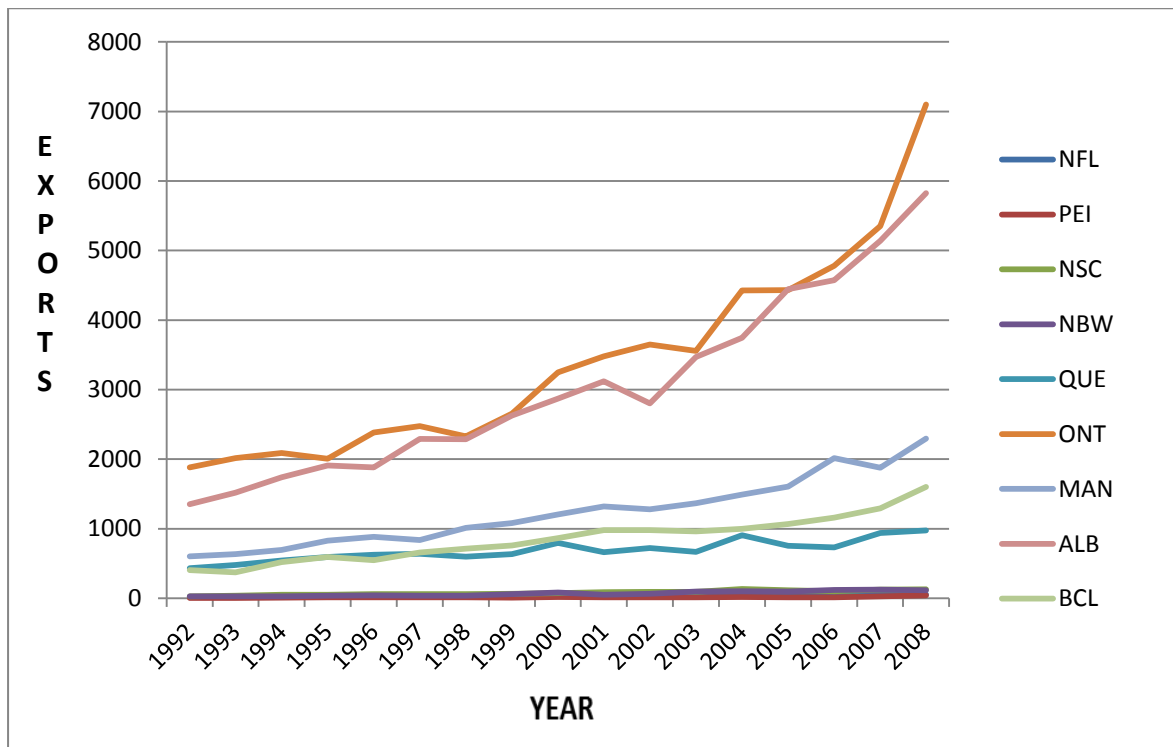
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 11: Manitoba Interprovincial Exports, Goods and Services, 1992-2008 (millions)



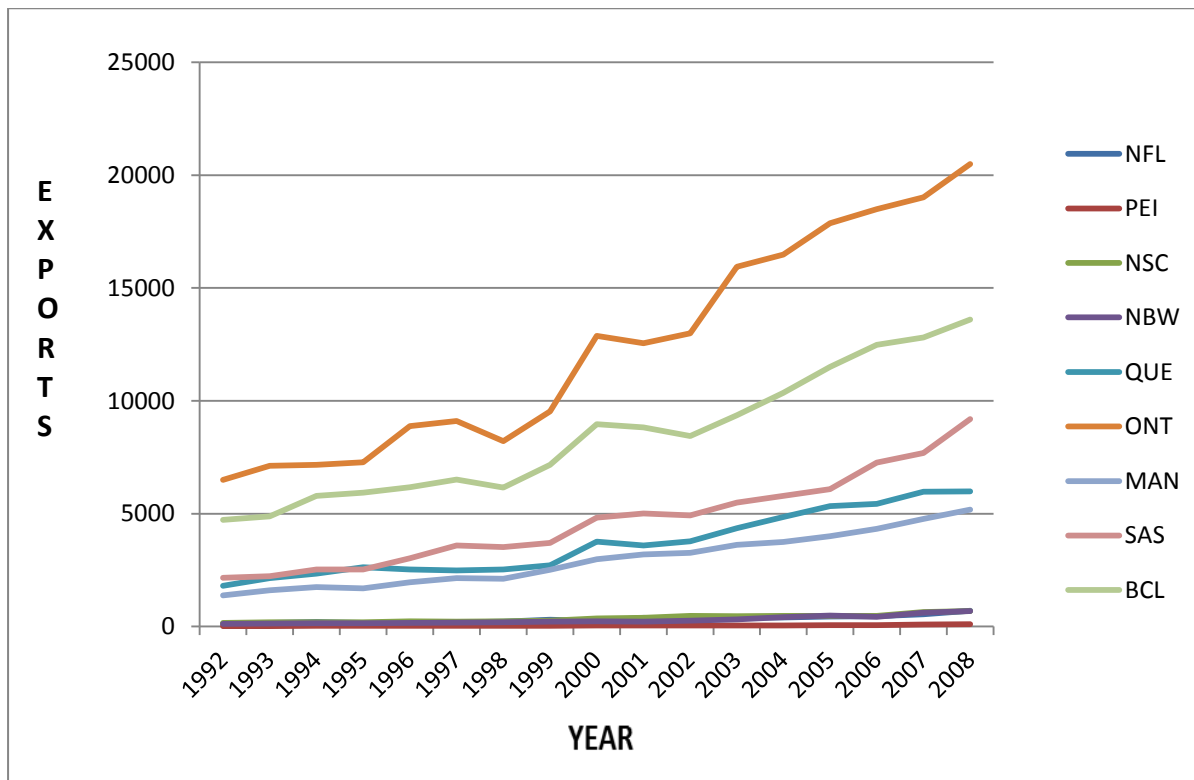
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 12: Saskatchewan Interprovincial Exports, Goods and Services, 1992-2008 (millions)



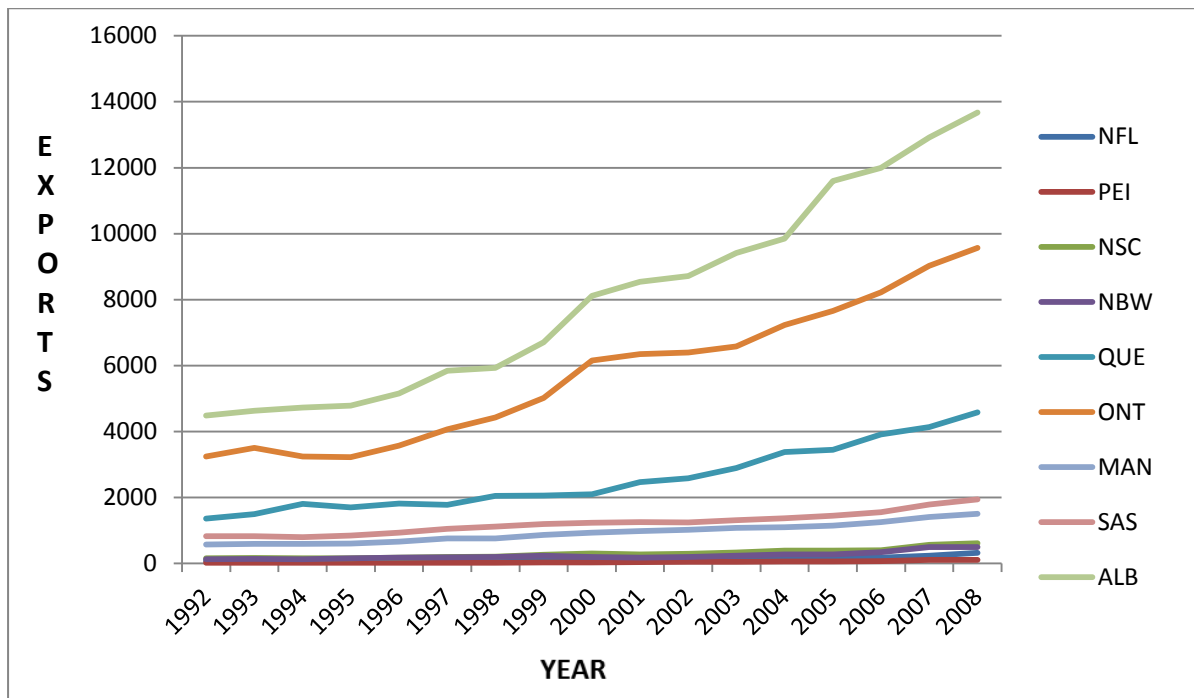
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 13: Alberta Interprovincial Exports, Goods and Services, 1992-2008 (millions)



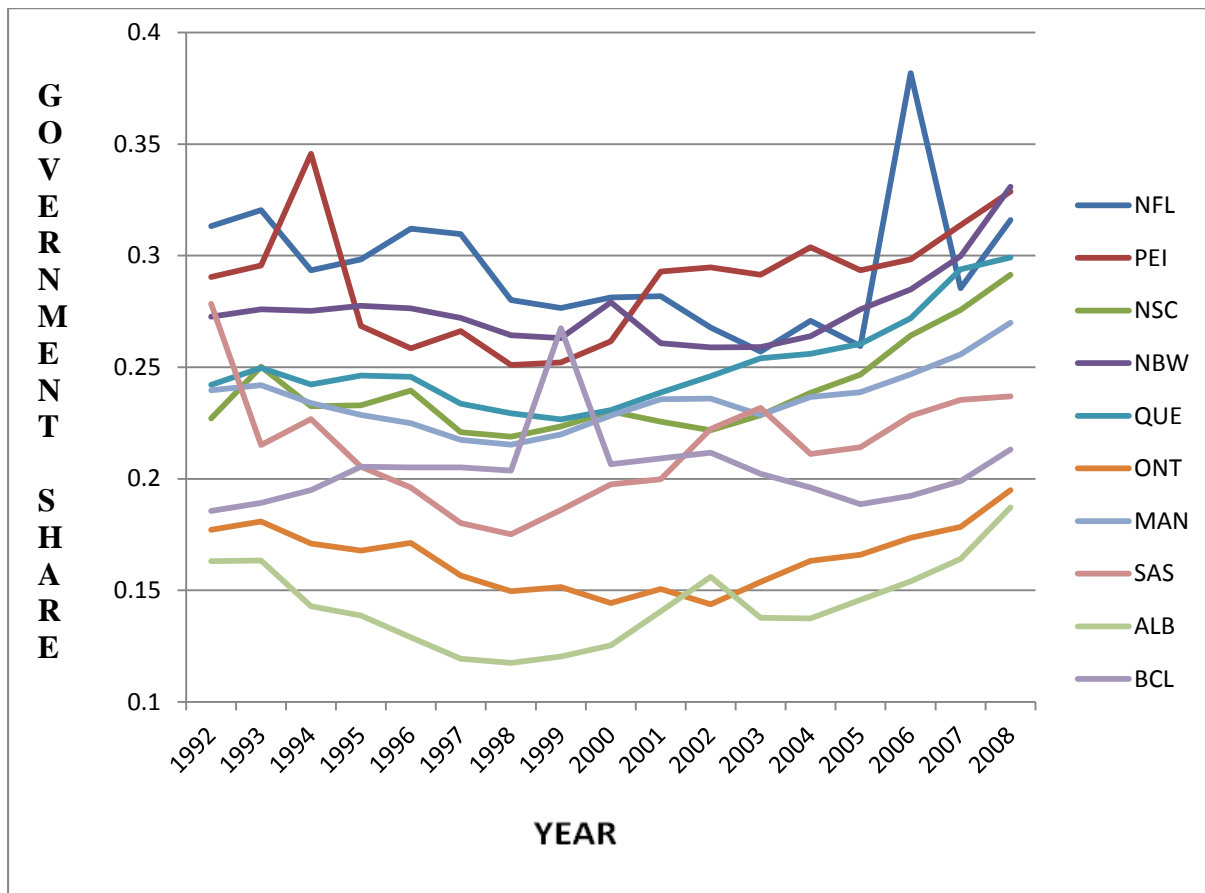
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 14: British Columbia Interprovincial Exports, Goods and Services, 1992-2008 (millions)



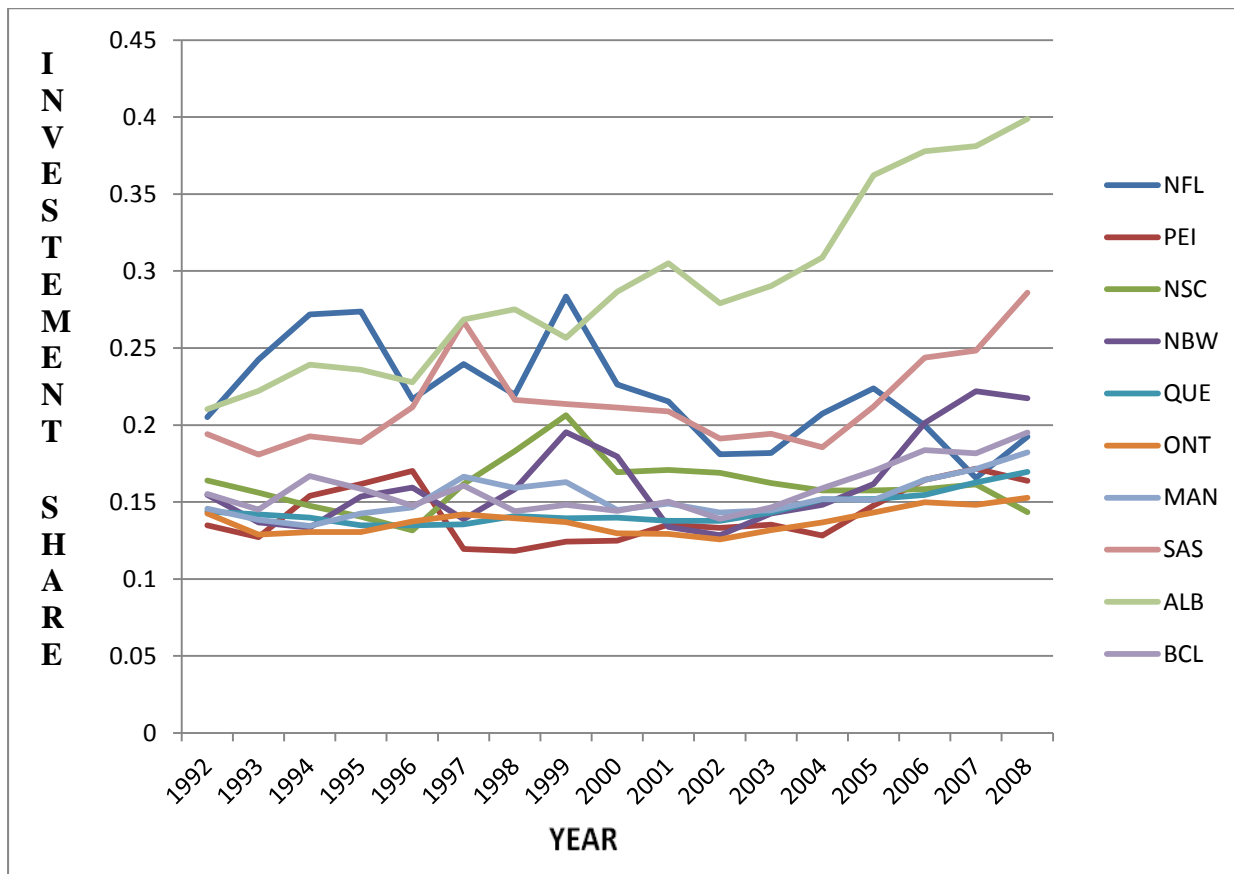
Source: Author's estimates based on CANSIM Table 386-0002, and Statistics Canada's publication on Interprovincial and International Trade Flows in Canada from 1992 to 1998.

Figure 15: Government Share of GDP for Canadian Provinces, 1992-2008 (%)



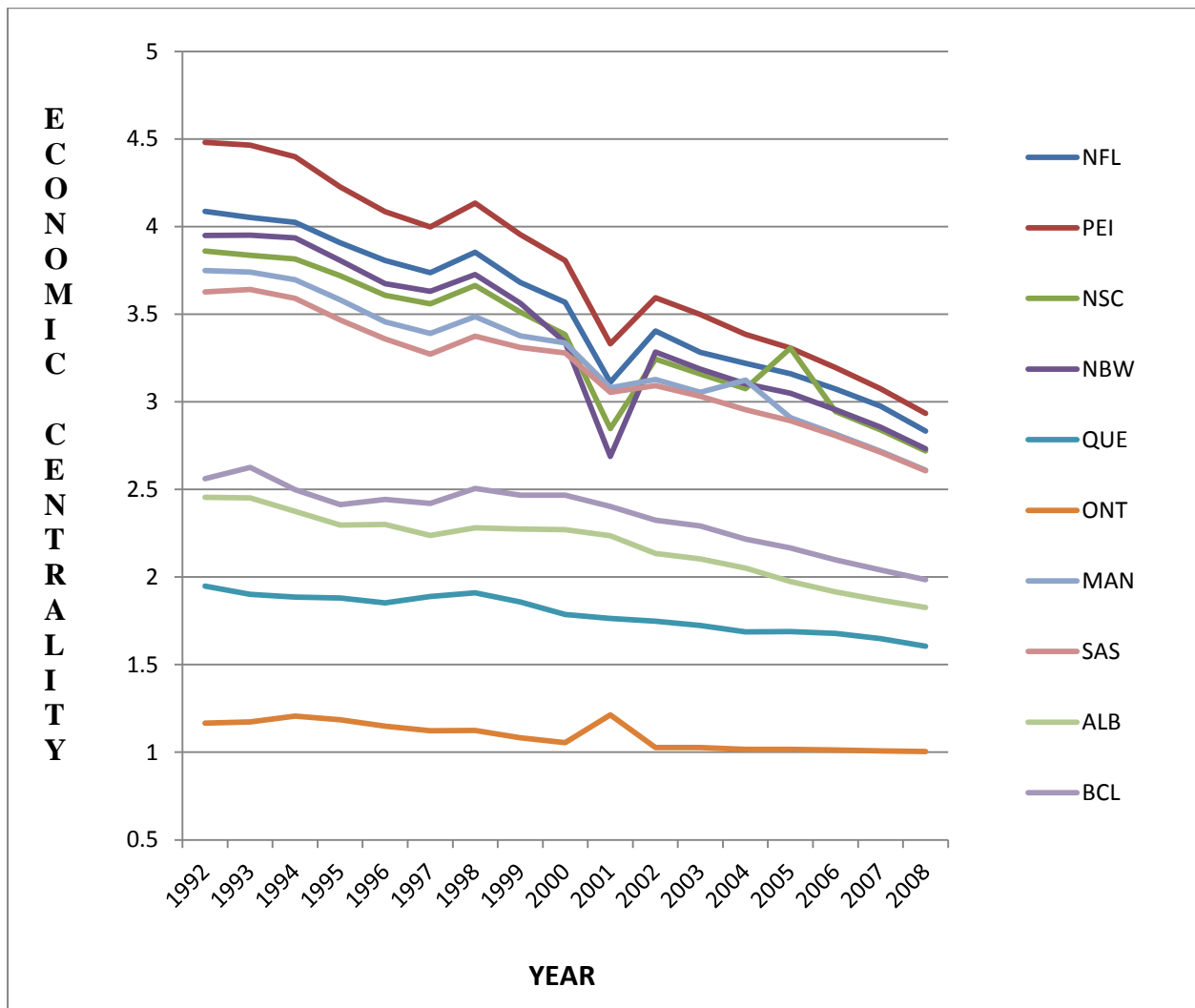
Source: CANSIM Table 385-0002.

Figure 16: Investment Share of GDP for Canadian Provinces, 1992-2008 (%)



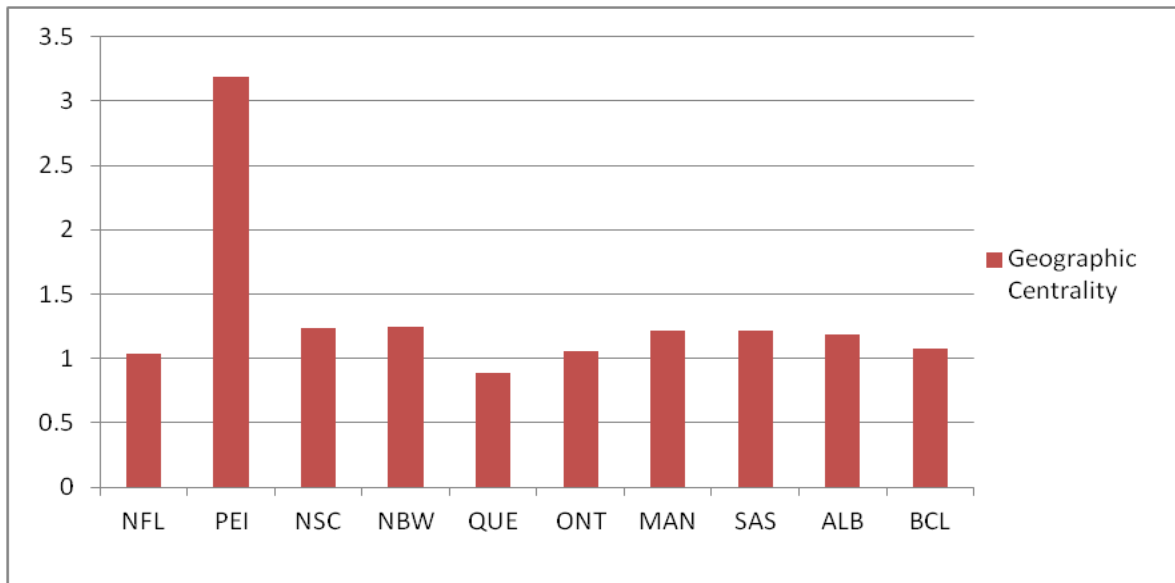
Source: CANSIM Table 031-0002.

Figure 17: Measure of Economic Centrality of Canadian Provinces, 1992-2008 (%)



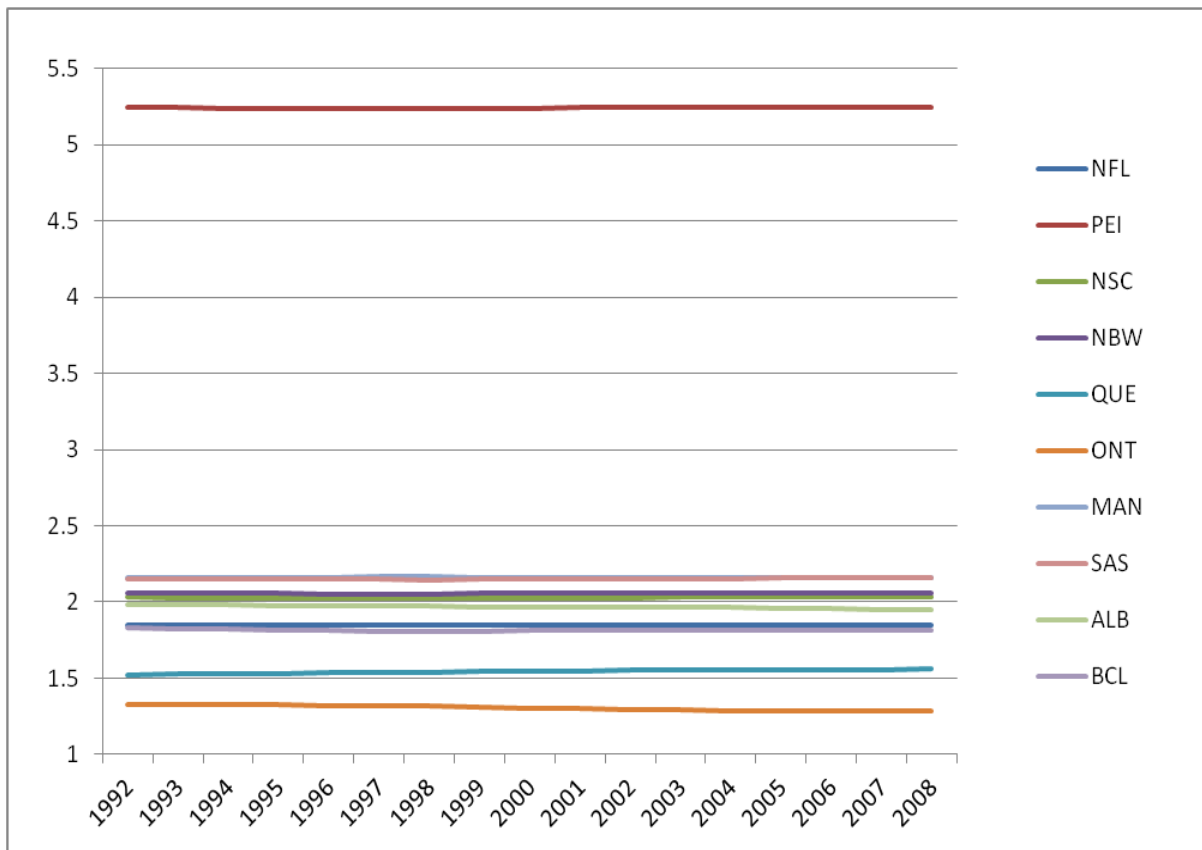
Source: Author's estimates based on CANSIM Table 386-0002

Figure 18: Geographic Centrality Measure of Canadian Provinces (weighted by province size)



Source: Author's estimates.

Figure 19: Geographic Centrality Measure of Canadian Provinces (weighted by population)



Source: Author's estimates.

**Table 1: OLS Economic Centrality Estimation Results**

	I	II
Geographic Centrality	0.119** (0.056)	0.075** (0.034)
Population	-1.85e-07*** (1.29e-08)	-1.80e-07*** (1.29e-08)
Province Land Area	-2.93e-07*** (1.09e-07)	-3.15e-07*** (1.04e-07)
Constant	3.369***	3.360***
Observations	170	170
R <sup>2</sup>	0.816	0.816

Note: The dependent variable is economic centrality. Standard errors are in parentheses. R<sup>2</sup> is the adjusted R-squared. \* Significant at 10%; \*\* Significant at 5%; \*\*\* Significant at 1%.

Table 2: Dependent Variable: GDP per capita

	OLS	OLS	OLS	OLS	GLS	IV-GMM
	I	II	III	IV	V	VI
Economic Centrality	-0.165*** (0.013)	-0.057*** (0.013)	-0.048** (0.018)	-0.043** (0.018)	-.034*** (.009)	-0.262*** (0.030)
Secondary Education		2.254*** (0.186)	2.425*** (0.129)	1.500*** (0.322)	1.546*** (.125)	0.000 (7.279)
Government Share			-0.810*** (0.140)	-1.160*** (0.164)	-.863** (.085)	-0.964 (1.863)
Investment Share			-0.073 (0.108)	-0.335** (0.116)	-.266*** (.052)	-0.306 (0.332)
Constant	10.803***	8.945***	8.924***	9.704***	9.695***	11.020 ***
Province Fixed Effect	No	No	Yes	Yes	Yes	Yes
Year Fixed Effect	No	No	No	Yes	Yes	Yes
Observations	170	170	170	170	170	170
R <sup>2</sup>	0.464	0.712	0.972	0.977	-	0.962

Note: The dependent variable is the log of GDP per capita. Standard errors are in parentheses. R<sup>2</sup> is the adjusted R-squared. \* Significant at 10%; \*\* Significant at 5%; \*\*\* Significant at 1%.

Table 3: Dependent Variable: Share of the Labor Force Population with a Secondary Education

	OLS	OLS	OLS	OLS	GLS	IV-GMM
	I	II	III	IV	V	VI
Economic Centrality	-0.047*** (0.004)	-0.049*** (0.004)	-0.123*** (0.005)	-0.022*** (0.004)	-.020*** (.002)	-0.034*** (0.001)
Government Share		-0.091 (0.088)	0.045 (0.086)	0.059 (0.042)	.038** (.018)	0.065 (0.275)
Investment Share		0.219*** (0.070)	0.090 (0.066)	-0.113*** (0.028)	-.092*** (.014)	-0.100** (0.031)
Constant	0.824***	0.797***	0.850***	0.765***	.763***	0.775 ***
Province Fixed Effect	No	No	Yes	Yes	Yes	Yes
Year Fixed Effect	No	No	No	Yes	Yes	Yes
Observations	170	170	170	170	170	170
R <sup>2</sup>	0.441	0.479	0.879	0.982	-	0.984

Note: The dependent variable is the share of the labor force population with a secondary education. Standard errors are in parentheses. R<sup>2</sup> is the adjusted R-squared. \* Significant at 10%; \*\* Significant at 5%; \*\*\* Significant at 1%.

Table 4: Dependent Variable: Life Expectancy

	OLS I	OLS II	OLS III	OLS IV	GLS V	IV-GMM VI
Economic Centrality	-0.759*** (0.075)	-0.895*** (0.091)	-2.014*** (0.145)	0.720** (0.133)	-.552** (.068)	-0.462*** (0.059)
Government Share		4.014** (1.624)	5.303** (2.209)	2.095 (1.279)	.416 (.639)	2.781 (5.633)
Investment Share		3.207** (1.293)	5.117*** (1.700)	-0.473** (0.864)	-.400 (.325)	-0.809 (8.752)
Constant	81.030***	79.910***	80.259***	78.528***	78.955***	79.598 ***
Province Fixed Effect	No	No	Yes	Yes	Yes	Yes
Year Fixed Effect	No	No	No	Yes	Yes	Yes
Observations	170	170	170	170	170	170
R <sup>2</sup>	0.375	0.401	0.753	0.946	-	0.930

Note: The dependent variable is life expectancy. Standard errors are in parentheses. R<sup>2</sup> is the adjusted R-squared. \* Significance at 10%; \*\* Significance at 5%; \*\*\* Significance at 1%