A Transport-Economic Analysis Framework for Border Crossing Infrastructure Investment Policies

by

Hamed Shahrokhi Shahraki

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Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner	**Dr. Ata M. Khan** Professor, Civil and Environmental Engineering, Carleton University
Supervisor(s)	**Dr. Chris Bachmann** Assistant Professor, Civil and Environmental Engineering, University of Waterloo
Internal Member	**Dr. Liping Fu** Professor, Civil and Environmental Engineering, University of Waterloo
Internal Member	**Dr. Rebecca K. Saari** Assistant Professor, Civil and Environmental Engineering, University of Waterloo
Internal-external Member	**Dr. Trien T. Nguyen** Professor of Economics, University of Waterloo

Author’s Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

This thesis includes materials from journal publications as listed below. In all the enlisted publications Hamed Shahrokhi Shahraki was the primary researcher and author, supervised by Professor Chris Bachmann.

Chapter 2, 3:

- Shahrokhi Shahraki, H., & Bachmann, C. (2018). Designing computable general equilibrium models for transportation applications. *Transport Reviews*, 38(6), 737-764.

Chapters 4:

- Shahrokhi Shahraki, H., & Bachmann, C. (2019). Optimizing Canada–U.S. Border Crossing Investments for Export Competitiveness. *Transportation Research Record*, 2673(3), 225–236.

Chapters 4, 5:

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Abstract

Border crossings serve two critical purposes: ensuring the safety and security of a nation; and facilitating trade and movement of people between countries. Inefficient border crossings resulting from insufficient infrastructure investments create bottlenecks to economies. Despite the importance of border crossings, studies aimed at optimizing border crossing investments are limited.

This thesis introduces an innovative transport-economic modelling framework to optimize border crossing infrastructure investments. The framework migrates from a stylized CGE modelling approach by explicitly linking transportation models of border crossing activities to a Computable General Equilibrium (CGE) model of the global economy. The framework combines the capabilities of a CGE model with several transportation models and datasets to determine border crossing investment priorities. The framework addresses some of the limitations of prior studies in the literature by incorporating queuing theory and mode choice theory to comprehensively measure the economic impacts of border crossing investments.

The developed framework is applied to Canada-US border crossings to determine short- and long-term border crossing investment priorities. Simulation results suggest that reducing delay times at border crossings can have sizeable impacts on the Canadian economy. The impacts on Canada's GDP and welfare are always positive and can range up to $ 92.44M USD and $ 79.83M USD per year, respectively. The impacts of infrastructure investment on the export of Canadian industries varies from a reduction of $ 0.86M USD to an increase of $ 8.47M USD per year. Analysis results suggest that Ambassador Bridge, Sarnia, and Fort Erie are the three most important borders for Canadian economy. The analysis results suggest that the magnitude of the effects of border crossing investment and the border crossing investment priorities are highly sensitive to border crossing delay modelling and less sensitive to mode shifts resulting from investment in one mode of transportation. This research concludes with border crossing priorities and the policy implications.

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Dedication

To my lovely family

Nafise, Shirzad, Zahra,

Ehsan, and Mohammad Javad

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List of Acronyms

BC	Border Crossing
BCS	Border Crossing Share
BCTS	Border Crossing Truck Share
BIIP	The Canada-US Border Infrastructure Plan
CGE	Computable General Equilibrium
CPC	Central Product Classification
CVS	Commercial Vehicle Survey
EBTC	Eastern Border Transportation Coalition
GSC	GTAP Sector Classification
GTAP	Global Trade Analysis Program
HS	Harmonized Systems
IO	Input-Output
ISIC	International Standard Industrial Classification
ITS	Intelligent Transportation Systems
MTO	Ministry of Transportation of Ontario
PF	Payload Factor

VW	Value to Weight ratios
VOT	Value of Time

1. Chapter 1
Introduction

1.1.Background

Canada and the US are among one another's largest trading partners. Canada is the US's second largest trading partner after China and the US is Canada's largest trading partner. The two countries share 3987 miles of border connected via 119 Border Crossings (BCs), which is responsible for about 60% of the trade between the two countries. Rail is responsible for about 20% of the trade between the two countries, while other modes such as air and marine are responsible for the remaining 20% (Transport Canada, 2018). In 2017, the two countries traded $ 673.1B USD in goods and services, which is equivalent to 1.8B USD of daily trade (Office of the United States Trade Representative, 2018). The supply chains of the two countries are intertwined to the extent that for some industries – e.g., automotive industry – products may cross the border up to seven times during the production process (Nguyen and Wigle, 2011).

Considering the magnitude of the trade between the two countries carried via land infrastructure, any changes to BCs can have sizeable impacts on both economies. Inefficiencies in BCs cost to the Canadian economy was previously estimated to range between 15 and 30B CAD annually, while inefficiencies in BCs are estimated to cost the US 7.8B USD, and is expected to double by year 2020 (Sajid and Dade, 2016). Considering the magnitude of trade between the two countries via BCs, any small changes in border crossing efficiencies could have ripple effects on both economies. Governments on both sides of the border must ensure fluid movement of trade across the border to avoid the creation of yet another trade deterrence.

1.2. Problem Statement

Despite the impacts of BCs on economies, only a few studies have attempted to quantify the economic impacts of BC infrastructure investment – partly because of the complexity involved in quantifying the economic impacts of non-tariff barriers. Moreover, the existing literature on BC infrastructure investment suffers from notable limitations. First, a stylized Computable General Equilibrium (CGE) modelling approach with an abstract representation of transportation activities, trade, commodity, and truck flows is often used to investigate the economic impacts of BC investments, which lacks realism and empirical evidence. Second, previous studies have not prioritized BCs for investments and rather have focused on economic impacts analysis of improving a few BCs. Third, often a simplified change in transport cost is applied to simulate the impacts of infrastructure investment instead of an explicit modelling of the impacts of infrastructure investment on transport cost changes. Forth, mode splits and mode shift analysis are often absent from the previous studies despite their importance in analyzing modal infrastructure investments. Fifth, previous studies have focused on aggregated macroeconomic measures such as GDP and overall trade and lack disaggregated measures such as trade changes at an industrial level. Lastly, previous studies often lack simultaneous consideration of long- and short- term effects of BC infrastructure investment.

In addition to the identified limitations in the BC infrastructure investment literature, the literature on CGE models' applications in transportation engineering lacks design guidelines with respect to CGE modelling choices. Consequently, models have been applied with extensive variations in their underling specifications, particularly in their representations of space and time. As explained later in this thesis, CGE modelling choices must be made with caution as these choices ultimately impact the CGE analysis results.

1.3.Research Objectives

Given the identified problems in the literature, the objectives of this thesis are divided into primary and secondary categories as follows:

To address the limitations of the previous studies on BC investment analysis, the primary objectives of this thesis are:

(1) To introduce a BC investment analysis framework that migrates from stylized CGE modelling approaches by explicitly linking empirical transportation datasets and models of border crossing activities– including delay modelling, mode choice modelling, and freight mode splits– to a CGE model of the economy to enable derivation of the unique impacts of individual BC investment on individual industries; and

(2) To apply the proposed framework to a real-world case study to determine short- and long- term BC investment priorities across an international boundary with respect to both aggregated and disaggregated macroeconomics measures (e.g., welfare, GDP, and industry-level trade).

To address the lack of uniformity in the application of CGE models in transportation engineering, the secondary objectives of this thesis:

(1) To deliver an up to date and comprehensive literature review on applications of CGE models in transportation;

(2) To analyze the different methodological approaches and their theoretical and practical advantages and disadvantages, and

(3) To ultimately provide guidance on designing CGE models for various transportation

analyses.

1.4.Scope

The methodological contribution of this thesis is the explicit linking of transportation models and databases to a CGE model of the global economy for investigating the economic impacts of border crossing infrastructure investments; methodological contributions to CGE modelling are not within the scope of this thesis. The developed framework simulates the changes in trade flows, GDP, and welfare for the year 2011, had the borders been improved in that year; the model does not make any predictions of future trade patterns (i.e., forecasting). The application of the framework to Canada-US border crossings investigates which border crossings should be prioritized, to maximize long- and short- term benefits to Canada's economy. The implications of the necessary financing mechanisms needed for border crossing infrastructure investments are not investigated.

1.5.Structure of the thesis

The structure of the thesis is as follows:

Chapter 2 provides an in-depth review of the literature on CGE models applications in transportation. First, a brief introduction to CGE models is provided. The history of CGE models is traced, ranging from their origins and seminal applications in economics, to their eventual adoption in transportation research. This is followed by a comprehensive review of the application of CGE models to transport projects and policies. Various applications in transportation are reviewed in terms of their intended application, as well as their treatment of space and time. Next, Chapter 2 specifically focuses on studies that used CGE modelling for BC infrastructure investments and examines them with respect to their methodological modelling approach and analysis scale and scope, which is followed by noting gaps in this literature. Chapter 2 also includes a brief review of BC delay modelling approaches and identifies the capabilities and limitations of each approach.

Chapter 3 examines CGE model applications in transportation with respect to methodological approaches and closely examines the literature with respect to various influential modelling choices. The essential design choices made within these model applications are explained and debated, to clearly elaborate on the workings of the models and the design choices facing CGE model developers. Chapter 3 concludes with a CGE design model guideline for transportation applications, which provides information and guidance about influential model choices.

Chapter 4 presents the proposed framework. The framework is broken into four stages. In the first stage, the calculation of supply-chain parameters is explained. The second stage focuses on estimating trade variables including the number of trucks, which is how ultimately trade manifests itself on physical transportation infrastructure. The third stage focuses on transportation and logistics modelling, where the two sub-components of the third stage– BC delay modelling and mode choice modelling– are developed. Finally, the fourth stage focuses on economic analysis and CGE modelling. Chapter 4 concludes with a partial application of the framework to Canada-US BCs and the key findings.

Chapter 5 expands on the preliminary application of Chapter 4 by applying the full framework, incorporating BC delay modelling, mode choice modelling, and simultaneous consideration of short- and long- term horizons. The theories of both BC queuing modelling and the mode choice analysis are explained. Next, the calibration process for both the queuing model and the mode choice model are explained. This is followed by an in-depth discussion of the results to identify trends and extract policy insights. The chapter concludes with validating the full framework in terms of observed and simulated trucks trips.

Chapter 6 concludes the thesis: a summary of key findings and policy insights are presented, which is followed by a summary of the contributions of the thesis. Next, the chapter discusses a few potential avenues for future research.

2. Chapter 2
Literature Review

Relevant literature is reviewed in three sub-sections. The first section reviews CGE model applications in transportation and catalog studies with respect to the intended focus of the applications, representation of transportation, and consideration of time dimension (i.e., static vs. dynamic). The second section focuses on studies that used CGE models for quantifying the economic impacts of BC investments. The studies are contrasted with respect to their modelling of transportation, scale, and scope. The second section concludes with the identified gaps in BC investment analysis. The third section reviews the literature on BC delay modelling and contrasts the limitations and capabilities of each modelling approach.

2.1.CGE model applications in transportation literature

This section presents a review of Computable General Equilibrium (CGE) model applications for spatial economic and transport interaction modeling. The content of the section is as follows: first, a brief introduction to CGE models is provided. The history of CGE models is traced, ranging from their origins and seminal applications in economics, to their eventual adoption in transportation research. This is followed by a comprehensive review of the application of CGE models to transport projects and policies. Various applications in transportation are reviewed in terms of their intended application focus, as well as their treatment of space and time.

2.1.1.Introduction

A CGE model is a system of equations that describes an entire economy, representing both macroeconomic constraints on the economy as a whole and the individual microeconomic behavior of interactions between its parts. For example, equations are used to impose market clearing conditions and represent the profit-maximizing and utility-maximizing nature of producers and consumers, respectively. Producers employ factors of production including labor, land, and capital that result in factor payments (wages, rents, and returns) to households. Simultaneously, households spend their income on goods and services provided by producers, and may also pay taxes to the government and put aside savings. The government spends collected taxes on goods, services and savings while investors use savings to buy investment goods. Regardless of the specific nature of the equations, the model is always specified to reproduce an initial economy – a set of equilibrium transactions for a particular year. A model experiment changes an exogenous variable (e.g., a tax rate) and the model is re-solved for the new "counterfactual" equilibrium.

Before continuing, it is assumed the reader understands the basic concept of CGE modeling. Readers may refer to Shoven and Whalley (1984) for a simplified numerical example, or Bröcker (1998b) or Bröcker and Mercenier (2011) for introductory transportation-oriented formulations.

2.1.2.Overview of CGE models

2.1.2.1.Origin

CGE models have a multifaceted history. According to Thissen (1998) and Mitra-Khan (2008) most researchers trace them to either the work of Scarf (1967) or Johansen (1960). On the one hand, theoretical modelers were interested in operationalizing the Walras's general equilibrium framework, and it was Scarf (1967) who first proposed a viable numerical solution. The works of Scarf and Shoven (1984) and Shoven and Whalley (1992) are often credited with operationalizing CGE modeling based on Walrasian theory. On the other hand, macro modellers were interested in extending Input-Output (IO) models, which were developed by Leontief in the mid-1930s (Leontief, 1936, 1951). Johansen (1960) is generally seen as first extending the IO approach to a model of endogenous quantities and prices, maintaining the circular flow of money within the economy through macro balancing equations.

2.1.2.2.CGE models for transport applications

Transportation applications of CGE models do not date back nearly as far as their economic foundations. The study of Bröcker (1998a) is considered as one of the first developed CGE-transport models. Indeed, it was Bröcker (1998b) who presented a simple prototype Spatial CGE (SCGE) model to demonstrate that, contrary to popular belief at the time, SCGE models could be simplified and still satisfying from a methodological point of view. However, prior to Bröcker (1998b), Buckley (1992) seems to have introduced the first transportation-focused CGE model application. As this chapter later shows, CGE models have since been used for a variety of transportation analyses, including road pricing, infrastructure investment/financing, land-use impacts, cross-border trade, and Intelligent Transportation Systems (ITS).

CGE models are an attractive tool for modeling economic and transportation interactions because they address several shortfalls of their predecessors and alternatives. Traditional benefit-cost analysis assumes markets are perfectly competitive, does not readily measure distributional impacts, and ignores externalities outside of the transportation sector (Hansen, 2010; Chen et al., 2016). IO analysis also suffers from several inherent limitations including fixed technical and trade coefficients, a lack of supply-side constraints (e.g., labor, capital), and no macroeconomic feedback (e.g., price signals) (Brocker, 1998b). Interested readers can see Wegener (2004) and Iacono, Levinson, and El-Geneidy (2008) for an overview of Land-Use and Transport Integrated (LUTI) modelling approaches, and Bachmann, Kennedy, and Roorda (2014) for a comparison between IO and CGE.

Naturally, CGE models also have their deficiencies and limitations, including the difficulty of estimating numerous elasticity parameters; the sensitivity of results to market conditions; the sensitivity of results to the format of the social accounting matrix (SAM) (e.g., location and distribution of taxes); and the overall intense data demands (Thissen, 1998; Ossterhaven and Tavasszy, 2001). Tavasszy et al. (2002) note "pitfalls" specific to transport applications of CGE models including interfacing problems between CGE and transport models, the modelling of the influence of transport costs on sectoral production, the interpretation of the conventional, micro-level specification of product variety in aggregate applications, and the problem of irrational agglomeration effects in economic activities.

2.1.3.Literature collection methodology

To identify literature for this chapter, previous reviews of CGE models for transportation applications provided a suitable starting point (Bröcker, 2004; Bröcker and Mercenier, 2011; Tavasszy and De Jong, 2013; Robson and Dixit, 2015). Snowball sampling techniques were applied to these previous reviews. Additionally, literature searches were conducted using a University of Waterloo online library catalogue, including TRELLIS (2017) and Primo Central index (2017). The search resulted in 103 journal articles, 11 conference papers, 21 book chapters and technical reports, for a total of 135 articles.

Papers were included or excluded primarily based on the focus of their application. The scope of this review is on *transportation* applications and excludes CGE models developed and applied to related areas such as tourism. Interested readers can refer to Hosny (2013), Van Truong and Shimizu (2017), and Economics Frontier (2008), which focus on CGE models applications in trade, tourism, and environmental analysis, respectively.

2.1.4.CGE model Applications in Transportation

This section reviews the transportation applications of CGE models. The applications are categorized by three major characteristics: 1) the actual or intended application; 2) how transportation costs were specified (Table 2.1); and 3) whether or not the model considers a time dimension – i.e., static or dynamic model (Table 2.2).

With regards to model applications, the following categories are identified: road pricing, disaster evaluation/management, transportation network changes (e.g., expansion, removal, and speed change), infrastructure investment/financing, land-use impacts, cross-border trade, transport cost change (e.g., ITS, fuel cost change), infrastructure interdependencies, and trade agreements. Note that there may be overlap between some of the categories and thus some studies fall in multiple bins, which are highlighted with an asterisk (*) in Tables 2.1 and 2.2. For example, the transportation network change category deals with applications related to network expansion, removal or change in a transport network attribute (e.g., speed), but studies in this category may overlap with the transportation infrastructure investments category.

2.1.4.1.Transportation Costs

Representation of transportation costs is one of the major modeling choices that is important for transportation applications. The earliest representation of transportation came in the form of iceberg theory and its variant, modified iceberg, which are based on the work of Samuelson (1952). Inspired by the notion that an iceberg melts as it moves from one location to another, this concept has been adopted to commodity transportation, where a transport cost is simulated as a reduction in the amount of commodity arriving at its destination. If x is the amount of commodity produced at the origin, and λ is the transport cost factor, the amount that arrives at the destination is equal to x / λ. If p is the price to the manufacturer, by imposing the conservation of value, the price at the destination is $p \times \lambda$, where $\lambda \geq 1$. The transport cost factor λ increases with the distance between origin and destination and can have a variable rate of increase. For example, a conventional functional form to represent λ is: $\lambda = \gamma d^{\eta}$, where γ and η are the scaling and power parameters, and *d* is the distance between transporting regions (Bröcker 2000). Further details on the iceberg approach and its modified version are provided in Chapter 3 as well as Bröcker (1998a; 1998b) and Bröcker et al. (2010).

A more realistic, but also more complicated, representation of transport costs is the marginal cost of transport in additive form, as opposed to the multiplicative type used with the iceberg approach. Some studies consider transport cost as a marginal cost added to the production cost of a commodity (e.g., Schafer and Jacoby, 2005; Buckley, 1992; Ueda et al., 2001). This marginal transport cost can depend on distance and travel time associated with the transport of a commodity, as well as other transaction costs such as bureaucracies, business trips, tariffs, cultural barriers, etc. Suppose that p_i^k is the production price of commodity *k* at origin *i*, and p_j^k is the price of commodity *k* to a consumer at destination *j*, then an additive form of introducing transport margins would be: $p_j^k = p_i^k + c_{ij}^k$ where c_{ij}^k is the cost of transporting commodity *k* from origin *i* to destination *j*. One formulation for c_{ij}^k used by Bröcker (2002) is presented in Equation 2.1:

$$c_{ij}^k = \varphi^k(\tau_i^k T_{ij}(\theta), ß_i^k B_{ij}(\theta)) \quad (2.1)$$

where c_{ij}^k is the cost of transporting commodity *k* from origin *i* to destination *j*, and φ^k is the trade cost function for commodity *k*. In this example, the trade cost function includes τ_i^k, the cost of transporting one unit of commodity *k* in region *i;* T_{ij}, the distance between origin *i* and destination *j*; $ß_i^k$, the cost of business travel in region *i* for commodity *k*; and B_{ij}, the business travel distance between *i* and *j*. The distances (T_{ij}, B_{ij}) are a function of transport infrastructure (θ).

Transportation costs can also be considered in the form of an accessibility index, which is defined as the ease of spatial interaction between economic activities (Kim et al., 2017; Kim and Hewings, 2003; Kim et al., 2004). The economic activities represent population, job opportunities, etc. The "ease of access" can be represented by travel time, travel distance, or a generalized cost function combining both the monetary and non-monetary costs of travel (Hansen, 1959). In a simple form, accessibility for a region *i* is defined as $\sum_j \frac{p_j}{d_{ij}^{ß}}$, where p_j is the population of region *j* and $d_{ij}^{ß}$ is the distance between regions *i* and *j* with distance decay parameter ß (Kim and Hewings, 2003). The accessibility index is then treated as an input into production and utility functions. A change in transport network or transport costs causes a change in the accessibility index, which in turn causes a change in the production cost of a commodity.

The aforementioned approaches for representing transportation in the CGE context focus on transportation costs. Notably, some studies introduce transportation as a stock of infrastructure input into production and utility functions (e.g., Gallen and Winston, 2016; and Seung and Kraybill, 2001). The pros and cons of each of these transportation representations are discussed in the next Chapter.

Table 2.1: Representation of transportation cost in CGE models

Application/ Transport cost	Iceberg	Modified iceberg	Explicit transport cost	Accessibility index	Transport capital
Road pricing			(Rutherford and van Nieuwkoop, 2011), (Mayeres and Proost, 2004), (Mayeres, 2000)*, (Steininger, Friedl, and Gebetsroither, 2007)*, (Van Dender, 2003)*, (Parry and Bento, 2001)*, (Van Steenbergen, Vandresse, and Mayeres, 2011), (Kalinowska and Steininger, 2009a, 2009b), (Mayeres, Proost, Dender, 2005), (Munk, 2006), (Steininger, Schmid, and Tobin, 2012), (Arnott and MacKinnon, 1977), (Steininger, 2002), (M. Thissen, Limtanakool, and Hilbers, 2011), (Vandyck and Rutherford, 2013), (Larsen, Madsen, and Jensen-Butler, 2005), (Proost and Van Dender, 1999)		
Disaster evaluation and management	(Tatano and Tsuchiya, 2008),		(Ueda, Koike, and Iwakami, 2001), (Kato, Fujiwara, and Ieda, n.d.), (Thissen, 2004)		

Transportation network changes (expansion, removal, speed change)	(Bröcker, 2004), (Oosterhaven, Knaap, Rijgrok, and Tavasszy, 2001), (Knaap and Oosterhaven, 2011), (Oosterhaven and Knaap, 2003), (Caspersen, Eriksen, and Larsen, 2000), (Sundberg, 2010b),	(Bröcker, 1998a), (Bröcker et al., 2010)	(Robson and Dixit, 2016), (Elshahawany, Haddad, and Lahr, 2016), (Nitzsche and Tscharaktschiew, 2013) , (Miyagi, 2001), (Tsuchiya, Tatano, and Okada, 2007), (Koike, Tavasszy, and Sato, 2009), (Tirasirichai and Enke, 2007), (Ueda, Koike, Yamaguchi, & Tsuchiya, 2005)	(Kim and Hewings, 2003, 2009), (Kim, Hewings, and Hong, 2004), (Haddad, Hewings, Porsse, Van Leeuwen, and Vieira, 2015)	
Infrastructure investment/financing	(Bröcker, 1998b)	(Bröcker, 1998b), (Bröcker, 2000),	(Li, 2015),(Conrad and Heng, 2002)*, (Conrad, 1997)*, (Mayeres, 2000)* , (Mayeres and Proost, 2001), (Kim, 1998), (Hadj-Salem et al., 2016), (Gallen and Winston, 2016), (Mayeres, 2001)*, (Steininger et al., 2007)*, (Van Dender, 2003)*, (Parry and Bento, 2001)*, (Siegesmund, Luskin, Fujiwara, and Tsigas, 2008), (Tscharaktschiew and Hirte, 2012), (Rioja, 1999)*, (Imdad and Westin, 1998), (Nordman, 1998), (Chen, Xue, Rose, and Haynes, 2016), (Chen and Haynes, 2015)*,	(Bröcker et al., 2001),(Kim, Kim, and Hewings, 2011), (Kim, Hewings, & Amir, 2017)	(Conrad and Heng, 2002)*, (Conrad, 1997)*, (Seung and Kraybill, 2001), (Rioja, 1999)*, , (Chen and Haynes, 2015)*, (Berrittella, 2010)*, (Kim and Kim, 2002), (Duffy-Deno and Eberts, 1991), (Chen and Haynes, 2013),

			(Berrittella, 2010)*, (Deloitte, 2014) , (Roson and Dell'Agata, 1996), (Hensher, Truong, Mulley, and Ellison, 2012), (Duffy-Deno and Eberts, 1991)*		
Land-use impacts			(Anas and Kim, 1996), (Anas and Rhee, 2006), (Anas and Xu, 1999), (Anas and Liu, 2007), (Horridge, 1994), (Venables, 1996), (Anas and Hiramatsu, 2012), (Doi, Itoh, Tiwari, and Doi, 2006), (Jin, Echenique, & Hargreaves, 2013)	(Lennox and Adams, 2016), (Lowty, 1964)	
Cross-border trade			(Shunsuke, , P. Anderson, and Maureen, 2015), (Roberts et al., 2014), (Nguyen and Wigle, 2011), (Haddad, Hewings, Perobelli, and Santos, 2010), (Doi et al., 2006), (Avetisyan, Heatwole, Rose, and Roberts, 2015)		
Transport cost change (ITS, cost change, fuel cost change)		(Bröcker and Korzhenevych, 2013) (Sakamoto, 2011)	(Lahr, Haddad, Elshahawany, and Vassallo, 2016), (Kawakami, Tiwari, and Doi, 2004), (Buckley, 1992), (Lofgren, Robinson, 1999), (Haddad and Hewings, 2001), (Anas, 2015), (Verikios and Zhang, 2015), (Ishiguro and Inamura, 2005),	(Mittal, Dai, Fujimori, Hanaoka, and Zhang, 2016),	

		(Aydın, 2016), (Konan and Kim, 2003), (Ando and Meng, 2009), (Karplus, Paltsev, Babiker, and Reilly, 2013), (Roson, 1996), (Lofgren et al., 1999), (Chen, Rose, Prager, Chatterjee, 2017), (Schäfer& Jacoby, 2005) (Johansen & Hansen, 2016)
Infrastructure interdependencies		(Zhang and Peeta, 2011, 2014)
Trade Agreement	(Bröcker, 1998a)	(Itakura and Lee, 2015), (Takeda, 2010), (Bröcker et al., 2001), (Higgs, Parmenter, and Rimmer, 1988), (Bachmann, 2017)

* Studies that fall under two application categories

2.1.4.2. Static and Dynamic Models

With regards to the representation of time, models are categorized as static or dynamic, where the dynamic approach can take two forms: recursive and forward-looking. Static models do not have an explicit time dimension. In essence, they compare two snapshots of an economy: the base case for which the model is calibrated to reproduce, and a new counterfactual scenario due to an exogenous shock. On the other hand, dynamic models include the evolution of the economy under study over multiple time periods.

In recursive-dynamic models, the dynamics are actually static solutions, recalculated repeatedly. In other words, the outputs of solving a static model for time period n (t_n) are then fed into the CGE model again for the next time period (t_{n+1}), which again is solved as a static model, and so on. Series of equilibriums from one period to the next are linked through saving decisions, such that the capital stock in each period is impacted by investment decisions in previous periods. Saving decisions, in their simplest form, follow myopic expectations, which means that the rates of return in future periods are assumed to be the same as the current period (Shoven and Whalley, 1984).

Alternatively, in forward-looking dynamic models, consideration of consumers' perfect foresights lead them to react to both announcement and implementation of a transport policy as in the model by Sundberg (2010a). Table 2.2 categorizes the transport applications of CGE models under the static and dynamic categories. Further details on the static and dynamic settings, and identified trends and insights with regard to suitable transportation applications are presented in Chapter 3.

Other than the two modeling characteristics discussed above (space, time), some of the other more general choices when designing a traditional CGE model are discussed in Chapter 3.

Table 2.2: Static vs. Dynamic modeling for CGE applications in transportation

Application/Modelling Attributes	**Static model**	**Dynamic model**
Road pricing	• (Steininger et al., 2007) • (Mayeres and Proost, 2004) • (Mayeres, 2001)* • (Steininger et al., 2007)* • (Van Dender, 2003) • (Parry and Bento, 2001)* • (Kalinowska and Steininger, 2009b) • (Mayeres et al., 2005) • (Vandyck and Rutherford, 2013) • (Larsen et al., 2005) • (Munk, 2006) • (Steininger et al., 2012) • (Arnott and MacKinnon, 1977) • (Kalinowska and Steininger, 2009a) • (Steininger, 2002) • (Johnsson, 2005) • (Thissen et al., 2011)	
Disaster evaluation and management	• (Ueda et al., 2001) • (Kato et al., n.d.) • (Tatano and Tsuchiya, 2008)	

Transportation network changes (expansion, removal, speed change)	• (Robson and Dixit, 2016) • (Elshahawany et al., 2016) • (Nitzsche and Tscharaktschiew, 2013) • (Bröcker, 2004) • (Bröcker, 1998a) • (Bröcker et al., 2010) • (Miyagi 2001) • (Oosterhaven et al., 2001) • (Knaap and Oosterhaven, 2011)* • (Oosterhaven and Knaap, 2003)* • (Caspersen et al., 2000) • (Chen et al., 2017) • (Haddad et al., 2015) • (Tsuchiya et al., 2007) • (Sundberg, 2010b) • (Koike et al., 2009) • (Tirasirichai and Enke, 2007) • (Ueda et al., 2005)	• (Kim and Hewings, 2003)† • (Kim et al., 2004)† • (Kim and Hewings, 2009)†

Infrastructure investment/financing	• (Conrad and Heng, 2002) • (Conrad, 1997) • (Mayeres, 2000) • (Mayeres and Proost, 2001) • (Bröcker, 1998a, 1998b)* • (Hadj-Salem et al., 2016) • (Gallen and Winston, 2016) • (Mayeres, 2001)* • (Bröcker et al., 2001)* • (Steininger et al., 2007)* • (Parry and Bento, 2001)* • (Siegesmund et al., 2008) • (Tscharaktschiew and Hirte, 2012) • (Truong and Hensher, 2012) • (Imdad and Westin, 1998) • (Nordman, 1998) • (Van Steenbergen et al., 2011) • (Hensher et al., 2012) • (Duffy-Deno and Eberts, 1991) • (Chen and Haynes, 2013) • (Chen and Haynes, 2015) • (Berrittella, 2010) • (Bröcker et al., 2001) • (Deloitte, 2014)	• (Li, 2015)† • (Kim, 1998)† • (Seung and Kraybill, 2001)† • (Rioja, 1999)† • (Kim et al., 2011)† • (Chen et al., 2016) • (Kim and Kim, 2002)† • (Kim, Hewings, & Amir, 2017)†

Land-use impacts	• (Rutherford and van Nieuwkoop, 2011) • (Anas and Kim, 1996) • (Anas and Rhee, 2006) • (Anas and Xu, 1999) • (Horridge, 1994) • (Venables, 1996) • (Anas and Hiramatsu, 2012) • (Doi et al., 2006) • (Lowty, 1964) • (Miyagi, 1998)	• (Lennox and Adams, 2016)[†] • (Anas and Liu, 2007)[†,‡] • (Anas, 2015)[*,†,‡] • (Adams et al., 2000)[†,‡] • (Jin, et al., 2013)[†]
Cross-border trade	• (Shunsuke et al., 2015) • (Roberts et al., 2014) • (Nguyen and Wigle, 2011) • (Haddad et al., 2010) • (Doi et al., 2006) • (Avetisyan et al., 2015)	

Transport cost change (ITS, cost change, fuel cost change)	• (Lahr et al., 2016) • (Kawakami et al., 2004) • (Buckley, 1992) • (Bröcker, 1998a, 1998b)* • (Bröcker, 2002) • (Bröcker et al., 2001) • (Knaap and Oosterhaven, 2003, 2011)* • (Lofgren et al., 1999) • (Haddad and Hewings, 2001) • (Verikios and Zhang, 2015) • (Ishiguro and Inamura, 2005) • (Roson, 1996) • (Aydın, 2016) • (Konan and Kim, 2003) • (Ando and Meng, 2009) • (Roson and Dell'Agata, 1996) • (Sakamoto, 2011) • (Johansen & Hansen, 2016)	• (Bröcker and Korzhenevych, 2013)[‡] • (Anas, 2015)[*,†,‡] • (Mittal et al., 2016)[†] • (Karplus et al., 2013)[†] • (Schäfer & Jacoby, 2005)[†]
Infrastructure interdependencies	• (Zhang and Peeta, 2011)	• (Zhang and Peeta, 2014)[†]
Trade agreement	• (Bröcker, 1998a) • (Higgs et al., 1988) • (Takeda, 2010) • (Bachmann, 2017)	• (Itakura and Lee, 2015)[†]

† Recursive dynamic model
‡ Forward-looking dynamic model
*Studies that fall under two application categories

This chapter reviewed transport applications of CGE models to develop an understanding of CGE models applications in transportation. The reviewed applications are summarized in Tables 2.1 and 2.2, which researchers can use as look-up tables to find previous CGE models developed for a given application of interest.

2.2. Literature on CGE models applications in border crossing investment analysis

Studies that have investigated the impacts of tariffs on international trade are numerous, however non-tariff trade barriers have received little attention – partly due to the complexity involved in quantifying the impacts of such barriers. This section focuses on studies that used CGE models for quantifying economic impacts of border crossing investment. Table 2.3 summarizes the studies with respect to their geographical location – North America vs. other countries; with respect to used CGE model – Global Trade Analysis Project (GTAP) vs. other CGE models; their approach to modelling border crossing investment; number of borders investigated; horizon year; and presence of mode choice analysis.

Table 2.3: Literature review summary

Title	Author (Year)	Geographical location	CGE model	Number of BCs	Modelling approach	Horizon (short-term/long-term)	Mode choice investigation
Optimizing Canada–U.S. Border Crossing Investments for Export Competitiveness	Shahrokhi Shahraki, H. and Bachmann, C. (2019)	North America	GTAP	72	Individual BCs are investigated. Delay changes at individual BC are translated into transport cost change	Short term	No
Competitiveness and Macroeconomic Impacts of Reduced Wait Times at US Land Freight Border Crossings	Avetisyan, M., Heatwole, N., Rose, A., and Roberts, B. (2015)	North America	GTAP	12	Focused on macroeconomics (e.g., employment) Increased staffing were translated into freight cost change	Not mentioned	No
Measuring Border Crossing Costs and Their Impact on Trade Flows: The United States-Mexican Trucking Case	Francois, J. F., A. K. Fox, and M. Londoño-Kent (2003)	North America	GTAP	Not border specific	Constant change of transport cost across all BCs and sectors	Not mentioned	No
Trade Impacts of Increased Border Security Concerns	Walkenhorst, P., and N. Dihel (2006)	North America	GTAP	Not border specific	Constant change of transport cost across BCs and sectors	Long/Short	No

The Impact on the US Economy of Changes in Wait Times at Ports of Entry	Roberts, B., Rose, A. , Heatwole, N., Wei, D., Avetisyan, M., Chan, O., and Maya, I. (2014)	North America	GTAP	17 land crossing, and 4 airports	Focused on macroeconomic impacts of staffing. Assumed that commercial vehicles do not change if BC improved	Long/Short	No
Welfare Costs of Border Delays: Numerical Calculations From a Canadian Regional Trade Model	Nguyen, T., and Wigle, M. (2009)	North America	Non-GTAP CGE model (BMRT model)	Not border specific	Constant change of transport cost across all sectors and BCs	Long	No
Border Delays Re-Emerging Priority: Within-Country Dimensions for Canada	Nguyen, T., and Wigle, M. (2011)	North America	Non-GTAP CGE model (BMRT model)	Not border specific	Constant change of transport cost across all sectors and BCs	Not mentioned	No
Assessing the Cost of Post-9/11 Security Measures and the Impact of a North American Security Perimeter–A Computable General Equilibrium Analysis	Georges, P., Mérette, M., and Zhang, Q. (2011)	North America	Non-GTAP CGE model (FDI model)	Not border specific	Constant change of transport cost across all BCs but different across sectors	Short	No

Toward a North American Security Perimeter? Assessing the Trade, FDI, and Welfare Impacts of Liberalizing 9/11 Security Measures	Georges, P., and Mérette, M. (2012)	North America	Non-GTAP CGE model (CGE-FDI)	Not border specific	Constant reduction of transport cost across BCs and sectors	Short	No
Economy-Wide Impacts of Reduced Wait Times at U.S. International Airports	Prager, F., Rose, A. , Wei, D. , Roberts, B., and Baschnagel , C. (2015)	North America	Non-GTAP CGE model (USCGE)	4 international airports	Change in staffing for passport inspection, not freight	Short	No
Impact Assessment Model of International Transportation Infrastructure Development: Focusing on Trade and Freight Traffic in Central Asia	Tanabe, S., R. Shibasaki, and H. Kato (2016)	Other countries	GTAP	Not border specific	Constant change in border crossing wait times	Long and Short	Yes
Trade and Investment among BRICS: Analysis of Impact of Tariff Reduction and Trade Facilitation Based on Dynamic Global CGE Model	Wu, L., X. Yin, C. Li, H. Qian, T. Chen, and W. Tang (2013)	Other countries	GTAP	Not border specific	Constant change in transport sector efficiency	Not mentioned	No

The Impact Of Regional Trade Agreements And Trade Facilitation In The Middle East And North Africa Region	Dennis, A. (2006)	Other countries	GTAP	Not border specific	Constant change in transport cost	Not mentioned	No
An Ex-Ante General Equilibrium Analysis of the COMESA-EAC-SADC Tripartite Free Trade Agreement	Willenbockel, D. (2014)	Other countries	Non-GTAP CGE model (Globe Model)	Not border specific	Constant reduction of transport cost across all sectors and BCs	Short	No
Geographical Simulation Analysis for Logistics Enhancement in Asia	Kumagai, S., Hayakawa,K., Isono, I., Keola, S., and Tsubota, K. (2013)	Other countries	Non-GTAP CGE model (Not specified)	1 port and 1 highway corridor	Constant change of wait times across BCs and sectors	Short	Yes
Socioeconomic Impacts of Cross-Border Transport Infrastructure Development in South Asia	Gilbert, J., and Banik, N. (2010)	Other countries	Non-GTAP CGE model (Not specified)	Not border specific	Constant change in transport cost across all BCs and sectors	Short	No
Towards an Explicit Modeling of Trade Facilitation in CGE Models: Evidence from Egypt	Zaki, C. (2010)	Other countries	Non-GTAP CGE model (Not specified)	Not border specific	Constant changes in transport cost across BCs	Short/Long	No

The Economic Cost of Rolling Back Schengen	Aussilloux, V., and Le Hir, B. (2016)	Other countries	Non-GTAP CGE model (MIRAGE model)	Not border specific	Focused on tourism, BC restriction is assumed to reduce the number of tourist by a constant percentage	Short/Long	No
Modeling Services Liberalization: The Case of Kenya	Balistreri, E. J., Rutherford, T. F., and Tarr, D. G. (2009)	Other countries	Non-GTAP CGE model (Not specified)	Not border specific	Constant changes in commodities' prices in form of ad-valorem equivalent of effects of barriers; constant across BCs	Long	No

Previous CGE application in BC studies suffer from notable limitations: first, often a stylized CGE modelling approach is taken to investigate the economic impacts of BC investments, with an abstract representation of transportation and trade, commodity, and truck flows, which lacks realism and empirical evidence. Second, the studies often simulate the impacts of border crossing investment by a constant relative or absolute reduction of delays at border crossings; this approach results in incomparable investments on border crossings - i.e., equal investments on border crossings results in different delay reductions for different border crossings. Third, in a stylized manner, a constant change in transport cost for all commodities and across all BCs is often used to simulate BC investments rather than investigating changes in individual BCs performance and their impacts on individual industries, which is not realistic. For example, the effects of an improvement to Ambassador Bridge, which is located in the Eastern Canada, would be felt more by the automobile industry located mostly in the Eastern Canada, compared to that of the Oil and Gas industries, which are mostly located in the Western Canada.

Lastly, the scope and scale of previous studies are limited in many ways. First, very few studies have attempted to comprehensively prioritize BCs for investment - often the economic impacts of investment on a few BCs are investigated. Second, although it is expected that investment in one mode may trigger a mode shift, the analysis is often disregarded in previous studies. Third, despite the importance of disaggregated macroeconomic measures such as industry-level trade change resulting from infrastructure investment, other studies have focused only on aggregated macroeconomic measures (e.g., GDP, welfare, overall trade change). Fourth, previous studies have mostly focused on either long- or short-term effects of BC investment as opposed to simultaneously considering both horizons and discussing their implications.

2.3.Brief review of border crossing delay modelling approaches

Since border crossing delay modelling is a component of the proposed framework in this research, a brief overview of the literature in border crossing delay modelling is presented. Three different approaches have been used in other studies for modelling border crossing delays. Moniruzzaman, Maoh, and Anderson (2016) and Lin et al. (2018) used machine learning techniques to estimate waiting times at Canada-US-Mexico borders. Khan (2010) used traffic microsimulation to estimate delays at the Ambassador Bridge. Lin, Wang, and Sadek (2014) used queuing models to estimate delay times at Canada-US border crossings.

Each of these approaches have their strengths and weaknesses. Traffic simulation models are capable of explicitly capturing a high level of detail, such as geometric layout of a queuing area and vehicular interactions. However, development and calibration of these models is resource intensive: the development of these models requires geometric layouts and field observation traffic data as their inputs; the calibration of these models requires searching through numerous calibration parameters. Artificial Intelligence-based methods are simpler to implement due to the availability of data-driven self-learning algorithms in commercial software packages. However, these methods behave as a “black-box” and lack traceability. On the other hand, analytical queuing models have theoretical foundations and hence produce results which are traceable. These models, however, represent a stylized system and lack some real-world details.

The choice of the modelling approach for border crossing delay analysis is driven by project scope, data availability, and formulation and computational complexity. In this thesis, given the scope and the available data, queuing models are used to model border crossing delays.

3. Chapter 3

A CGE Modelling Design Guideline for Transportation Applications

3.1.CGE Modelling Attributes Choices

An unexplored aspect of CGE model applications is the influence of model design choices on the functioning and results of CGE models. As noted by Mitra-Kahn (2008), the literature to date has focused too little on the choices of CGE model builder. For example, how does a modeller choose the functional forms and behavioural equations? How is a model closure (i.e., choice of exogenous versus endogenous variables) determined? Particularly important for transportation applications is the question: how are the representations of space and time selected? Although not always clearly discussed or justified, these and other design choices influence the workings, and subsequently the results, of CGE models applications. Relatively little research has focused on the influence of model design choices on the functioning and the results of CGE models, providing the motivation for this section.

This section discusses CGE modelling choices, trends in the reviewed model applications, and advantages and disadvantages associated with CGE modelling choices. Where possible, a recommendation is made on the modeling attribute choice. However, these recommendations are drawn taking into consideration individual modeling attributes and not from a holistic perspective. This single attribute perspective means that considering all the recommended options may result in an “expensive” model development process (i.e., high data requirements, and increased modeling and computational complexity); practical limitations may not warrant the inclusion of all recommendations.

3.1.1.Representation of transportation

This section examines the CGE modelling applications in transportation with respect to their representation of transportation including the presentations of transportation cost, transportation network, feedback effects, travel demand modelling, and transportation infrastructure financing.

3.1.1.1.Transportation costs

A variety of methods are used to represent transportation costs in CGE models, namely: quantity-based approaches (iceberg/modified iceberg), price-based approach (explicit transport costs), accessibility indices, and transportation capital stocks.

The iceberg approach has frequently been used in the CGE modeling of transport applications. As mentioned by Bröcker (1995; 2002), the popularity of the approach stems from its computational (and theoretical) simplicity and its accuracy in simulating single-sector models, which were dominant in seminal applications. On the other hand, in multi-sectoral models, the use of the iceberg approach raises some theoretical concerns. As mentioned by Bröcker (2000) and Tavasszy et al. (2011), the implicit assumption of the iceberg approach is that the transport sector has the same production technology as the transported commodity. This assumption becomes problematic in a multi-sectoral context because transport technology should not vary across industries. A change in the transport sector should be consistently applied across all industries.

Another drawback of the iceberg approach is that changes in transport costs are independent of the economic activities in the transport sector. For example, a reduction in transport costs does not change the input factors into the transport sector. This inability to reflect changes in transport sectors skews the consumption and production of non-transport commodities and can lead to anomalies such as less production to meet consumer demand (Oosterhaven et al., 2001). Lastly, the iceberg approach fails to fully capture the negative relationship of transport costs with distance because transport cost depends on various factors, only one of which is transport distance (Li, 2015). Hence, the iceberg approach is suggested only for applications with one commodity (i.e., single-sector models) or when only the high-level impacts of a project/policy are investigated (e.g., a preliminary feasibility analysis).

Because of the intuitive drawbacks of the iceberg approach, Bröcker (2004) suggests representing transportation as a sector that offers transportation services to both consumers and firms. This approach takes into account the economic activities within the transport sector, which is not taken into consideration in the iceberg approach. However, the inclusion of "margin industries" makes the model more complex (Bröcker and Mercenier, 2011).

To tackle the production issue created by the iceberg approach, Bröcker (1998a) developed a modified version of iceberg, where instead of individual commodities, a composite commodity of all the tradeable commodities is consumed to cover transport costs. This approach leads to a consistent transport service production function across all industries. The transition from iceberg to the modified iceberg (and more advanced representations) over time is apparent in applications of transportation infrastructure investment and financing (Table 2.1 in Chapter 2). This trend is less apparent in transportation network change applications (Table 2.1 in Chapter 2) because recent studies such as Knaap and Oosterhaven (2011) continued to use the iceberg approach. However, they come to the conclusion that some inconsistencies in their results are in fact because of the drawbacks of the iceberg approach.

A more realistic representation of transport costs is the explicit approach that enters into the price mechanisms of the model (Equation 2.1 in Chapter 2). As mentioned earlier, this approach treats transportation services as a commodity to be consumed by producers and consumers or by driving a wedge in the prices of commodities. By virtue of having a wider scope, this approach forms the majority of transport cost representations in CGE applications

(Table 2.1 in Chapter 2). Although no theoretical deficiencies are noted in the literature, there have been some technical difficulties associated with the use of the wedge cost method. As mentioned by Bröcker (2002), the use of additive transport costs, as a type of explicit approach, raises a technical difficulty in the standard Dixit-Stiglitz approach of monopolistic competition, since the producers do not face constant price elasticities of demand. Bröcker (2002) also mentions that this is not the case with the iceberg approach, explaining its earlier applications. Commercial models that represent transport cost using explicit approach include PINGO (Vold and Jean-Hansen, 2007); MONASH (Dixon and Rimmer, 2001); and RAEM (Oosterhaven et al., 2001). The explicit representation of transport costs has been widely used and is recommended by other studies (e.g., Knaap and Oosterhaven, 2011).

To the authors' knowledge, there has been no criticism directed at the use of an accessibility index to represent transport costs in the reviewed literature. In the reviewed applications (e.g., Kim et al., 2017; and Kim et al, 2004), the accessibility index usually depends on geographical distance, which is a deficiency considering that congestion is one of the most important externalities of transportation investments. Hence, the distance-based accessibility index approach may not be useful in the presence of congestion or in justifying infrastructure projects that improve travel time rather than shorten distances. In this light, accessibility indices may instead use travel time as opposed to distance.

Regarding the use of infrastructure capital, the only concern raised in the literature is that a monetary representation of transportation stock may lead to a misinterpretation of the physical infrastructure endowment because of the variability of infrastructure construction and maintenance fees from one geographic region to another. Additionally, a monetary representation of transportation infrastructure is incapable of capturing the spatial effects of infrastructure investments (Kim et al., 2004; Kim and Hewings, 2009).

The representation of transport costs with respect to applications is summarized in Table 2.1.

Earlier studies consistently used the iceberg approach because of its reduced complexity. Due to the drawbacks of iceberg approach explained above, a modified version was developed and used in more recent studies. The latest studies take advantage of advancements in theory and computation technologies and were able to include explicit additive transport costs, resulting in the most realistic representation of transport costs. The choice of transportation costs is partly driven by data availability and computational limitations. As explained above, the choice also depends on the scope and objective of the study.

3.1.1.2.Transportation network

The specification of a transportation network varies across studies. Some studies use an explicit and separate transportation network model as shown in Figure 3.1 (e.g., Haddad et al., 2015; Anas and Liu, 2007; Schäfer and Jacoby, 2005; Kim et al., 2017; Rutherford and van Nieuwkoop, 2011; Kim and Hewings, 2003; RAEM model (Knaap et al., 2001); PINGO model (Vold and Jean-Hansen, 2007)), while others have represented the transportation system within the CGE model by a set of simpler equations (e.g., GTAP (2017); Seung and Kraybill, 2001; Conrad and Heng, 2001; Conrad, 1997; MONASH model (Adams et al., 2000); CGEurope (Bröcker, 1998c)). The complete representation of the transportation network comes at the cost of computational complexity and the additional efforts required for linking it to the CGE model. However, a complete specification increases the flexibility to modify transport network attributes. On the other hand, the representation of a transport network within the CGE model makes the computations less complex compared to an explicit transportation model, since linking the two models is not required.

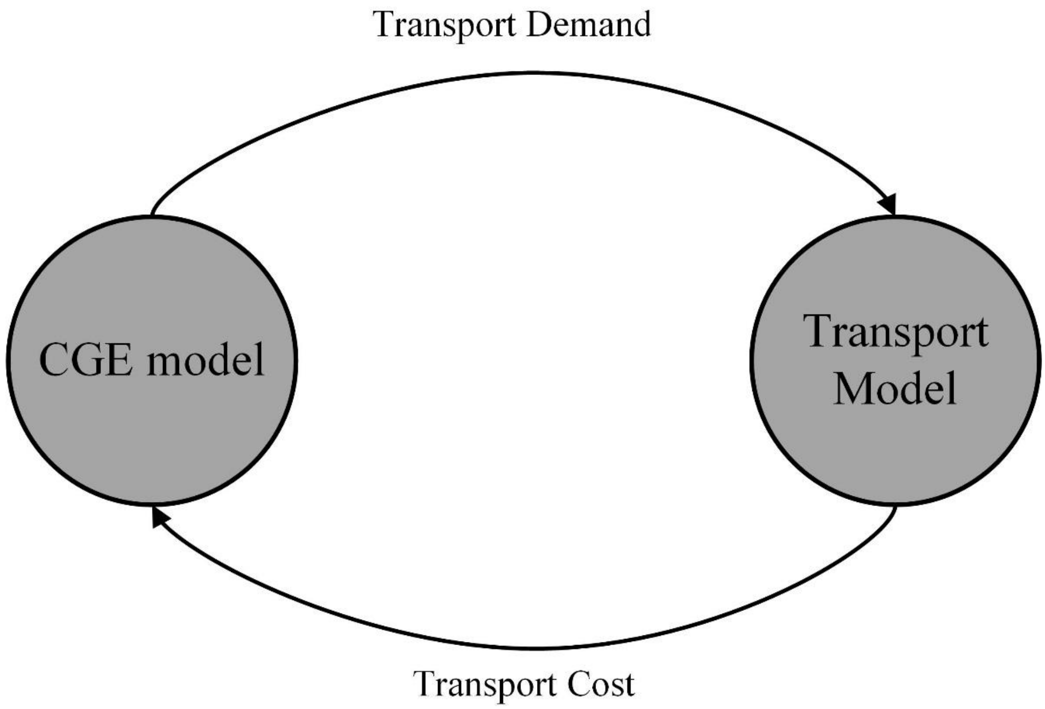

Figure 3.1: CGE-transport model

Another important aspect of the transportation network is the aggregation level. Ideally, the transport network model will have the same level of zonal aggregation as the CGE model. In general, the aggregation of regions in a CGE model is only appropriate if the merged regions have similar demand patterns and technology (Higgs et al., 1988). However, the disaggregation of infrastructure, particularly roads, should also consider the availability of data and purpose of the study. The state-of-practice is to aggregate roads to represent major connections between regions (e.g., Vandyck and Rutherford, 2013). However, if not limited by computational complexity or data, a more detailed model is preferred to improve accuracy (Caspersen et al., 2000). The caveat is that by highly disaggregating a model (i.e., greater level of detail), the modeler risks reducing the traceability of the model (Caspersen et al., 2000; Lennox and Adams, 2016). Naturally, the objective/scope of a study also impacts the level of aggregation. For example, if the objective of a study is to investigate infrastructure investment in a particular corridor (e.g., rail corridor), then aggregating road and rail alternatives within the corridor is obviously prohibited (e.g., Kim, 1998).

3.1.1.3.Sequential vs. non- sequential (feedback effect)

In transportation applications of CGE models, the model often comprises sub-models that interact with one another. For example, the sub-models can include CGE, land-use, and transport sub-models (e.g., Anas and Liu, 2007). Feedbacks can exist internally, within a sub-model, or externally, between sub-models. If the external feedback from one sub-model to another is a one-time event, the model is categorized as sequential. In this context, each sub-model reaches its own equilibrium and there is no overall equilibrium. On the contrary, in the non-sequential or feedback setting, the output of a sub-model is iteratively fed back into the other sub-models until the system reaches an equilibrium. In this setting, not only does each sub-model reach an internal equilibrium, but also the entire system reaches an equilibrium.

To contrast these approaches, consider an integrated CGE-transport system, where CGE and transport sub-models provide one another with transport demand and transport impedance (e.g., a function of transport distances or times), respectively. In the sequential setting, as opposed to non-sequential setting, the evaluated transport demand after a policy change is not fed-back into the transport model for re-evaluation, which means that the transport impedance used in the CGE models for analysis does not reflect the transport demand generated by the CGE model.

There are many studies that use or suggest the use of a feedback setting because of its more realistic representation of reality (e.g., Kim and Hewings, 2009). Tavasszy et al. (2002) explains that the use of the feedback approach solves the inconsistency and transferability issue between the two sub-models (transport and CGE), which arises due to the endogeneity of production and attraction rates in the CGE model. However, there have also been other studies that did not consider feedbacks (e.g., Berg, 2007; Kim and Hewings (2003; 2009); Kim et al., 2004; Kim et al., 2011). Choosing a sequential setting can be due to the complexity of modeling feedbacks, computational limitations, or due to lack of data (Kim and Hewings, 2009).

Feedbacks are most important in the context of externalities, of which congestion is recognized as paramount with regards to transport infrastructure. In the reviewed applications (Mayeres and Proost, 2001; Parry and Bento, 2001), congestion is considered as part of economic agents decisions, while other externalities (e.g., environmental) are introduced as a disutility that does not affect their decision behavior. Consideration of congestion is recommended, as mentioned by Parry and Bento (2001), but it is mandatory for policies where time-savings plays a major role, and less important for policies that negatively influence transport demand such as a fuel tax or scenarios where the network does not suffer from considerable bottlenecks.

3.1.1.4.Travel demand modeling

Various characteristics of transport demands can be included in the CGE model. These can include the level of transport demand (e.g., number of trips), trip types (e.g. freight, shopping, commuting, etc.), and transport modes.

Transport demands in CGE models are typically determined by demands for commodities (goods and services) as well as demand for factors. Producers require production factors and intermediate commodities in their production processes. They also need to get their outputs to retailers in each region for final sale. On the other hand, households produce travel demands in the form of work, shopping, and other leisure trips. The demand for each commodity/factor is determined through optimization behavior of the agents (e.g., utility maximization for consumers and profit maximization for firms) and then converted to transport demand by an exogenous conversion factor (e.g., every thousand units of agricultural products requires one trip).

The demand for each trip type is also impacted by modeling assumptions on the mobility of goods and factors, model details, and underlying data availability. For example, the labor mobility assumption can impact the number of commuting trips, by restricting labors to their origin zone (creating intra-zonal trips).

In addition to freight and individual trips, depending on the scope of the project, a more disaggregated representation of individual transport modes can be incorporated into the model. Examples include public transit, rail transit, air transport, marine transport, etc. An example is a study by Chen et al., (2016) where investment in a specific transport sector (rail), mandated the distinction among different transport services.

3.1.1.5.Transportation infrastructure financing

Transportation infrastructure is financed through different channels including user fees, government investment, foreign investment, etc. (Kim, 1998). The modelled financing strategy has a significant impact on the economic impact of infrastructure investment as indicated by various studies (e.g., Anas and Rhee, 2006; Caspersen et al., 2000; Parry and Bento, 2001; Mayeres and Proost (2001; 2004)). Despite the importance of financing strategy on the results, some studies have disregarded it: for example, Caspersen et al., (2000) disregarded maintenance costs in their model and Van Steenbergen et al. (2011) disregarded financing strategies altogether to avoid model complication.

As stated by Mayeres et al. (2005), consideration of the financing strategy is critical to welfare analysis. This is particularly important when distributional welfare impacts are to be evaluated. A clear example is the different impacts that financing through labor tax and fuel tax can have on an economy. Fuel tax impacts all road users regardless of time, income category, trip purpose, etc. Users of other modes of transportation are not impacted by fuel taxes (e.g. public transit users). On the other hand, a labor tax can target consumers within certain income bracket or a specific occupation and does not impact the unemployed although they may be road users. Therefore, the financing strategy should be determined prior to the analysis, or a sensitivity analysis should be conducted on the model results with respect to various financing strategies, as in the study of Van Steenbergen et al. (2011).

3.1.2.Dynamic vs. Static

The application of a CGE model and scope of analysis influences the choice of a static or dynamic formulation. As can be seen from Table 2.2 in Chapter 2, most applications use a static model. However, dynamic models have been used for many applications: disaster evaluation and management, transportation network changes, infrastructure investment/financing, land-use, transport cost change, infrastructure interdependencies, and trade agreements. Static models have been used to sufficiently analyse policies over the long-term (e.g., road pricing (Mayeres, 2001); trade agreements and trade related policies (Takeda, 2010); network expansion (Bröcker, 2004)), whereas dynamic modelling has been used to capture short-term policy impacts or where the evolution to equilibrium was of interest (e.g., construction policy (Kim and Hewings, 2009); and infrastructure resiliency (Zhang and Peeta, 2014)). Hence, the prominent driver of the choice between dynamic and static modeling is the model application and scope of analysis. This recommendation is consistent with Kim (1998) and Kim and Hewings (2009). In the study of Kim (1998) as an example, the consideration of operation and services brought about by infrastructure investment, as well as consideration of financing strategy, mandated the use of a dynamic model because they both have a temporal component and take place in stages.

Compared to static models, dynamic models require more data to capture the temporal aspect and the associated variable dependencies. The extensive adoption of the static setting in the literature, compared to dynamic setting, can be partly attributed to their higher scalability potentials (both at the region and technological level), lower computational complexity, and easier convergence.

3.1.3.Functional form of utility and production functions

As per McKitrick (1998) and Bröcker and Mercenier (2011), different functional forms lead to different results since they represent different theoretical foundations of behavior. Thus, it is necessary to choose a well-justified functional form or conduct a sensitivity analysis. According to Shoven and Whalley (1984) and Bröcker (2004), there are four criteria for selecting functional forms: (1) Computational simplicity; (2) Theoretical consistency; (3) Flexibility; and (4) Parsimony. In addition to these criteria, knowledge about the real-world economic environment is important. For example, if production factors are known to be not substitutable, a Leontief production function is appropriate. An example of a sensitivity analysis on functional forms can be found in the study by Berg (2007).

The various functional forms used in the transportation literature, their level of usage, and limitations are presented in Table 3.1. Constant Elasticity of Substitution (CES) and its variations (Leontief and Cobb-Douglas) have extensively been used in the reviewed literature both individually and in nested forms. The popularity seems to stem from the convenience they bring about by less complexity and required calibration data compared to a more general form (e.g., translog). However, the CES functional form imposes limits on the determination of cross and own price elasticities. For example, if individual expenditure shares are small, each commodities compensated own-price elasticity equals the elasticity of substitution (Shoven and Whalley, 1992). In the real-world, own-price elasticities vary based on many factors such as the availability of substitute goods, degree of necessity, and proportion of the purchaser’s budget consumed by the commodity. In CGE modelling, more aggregated sectors would also be expected to have lower elasticities of substitution because fewer substitutes exist (e.g., “food”, for which no substitute exists, would have a lower elasticity of substitution than “tomatoes”, which could be substituted by other vegetables). These limitations can be addressed by the common practice of nesting CES functions (Shoven and Whalley, 1984), or through the use of a more flexible functional form such as translog or normalized quadratic that do not suffer from the aforementioned limitations, as suggested by McKitrick (1998).

Table 3.1: Functional Forms

Functional form	Level of usage (%)	Equation	Stated pros and cons
Cobb-Douglas (CD)	27%	$Y = AL^{\alpha}K^{ß}$ • Y: amount of output • L amount of capital • A: scale parameter • α and ß: calibration parameters-cost share parameters of labor and capital respectively.	• Imposes restriction of unitary income and uncompensated own-price elasticities, and zero cross-price elasticities. This restrictions can be relaxed by employing CES (McKitrick, 1998; Shoven and Whalley, 1984). • Calibration is possible by simple point observation; less complexity compared to CES (Shoven and Whalley, 1984). • Unitary income can also be solved by employing Linear Expenditure System (LES) function with displaced origin (Shoven and Whalley, 1984).
Leontief	20%	$Y = Min(\frac{L}{\alpha}, \frac{K}{ß})$ • Same as above.	• Does not allow substitution among factors (Leontief, 1951)
Constant Elasticity of Substitution (CES)	46%	$Y = \varphi(\alpha K^{\frac{\sigma-1}{\sigma}} + (1-\alpha)L^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$ • Same as above for Y, K, L • φ, α, and σ: calibration parameters-scale parameter, cost share parameter of capital, and elasticity of substitution respectively.	• Unlike CD, unitary income and own-price elasticity limitations do not apply (Shoven and Whalley, 1984). • Can be used in nested format which prevents having the same compensated own-price elasticities (Shoven and Whalley, 1984). • Imposes restriction of constant ES across all industries (McKitrick, 1998).

Stone-Geary/Linear Expenditure System (LES)	5%	$U = \prod_i (q_i - \alpha_i)^{ß_i}$ • U: utility function • q_i: consumption level of commodities/services • α_i and $ß_i$: calibration parameter	• Unitary income of CD can be solved by employing LES with displaced origin; otherwise, same limitations as for CD (Shoven and Whalley, 1984).
Constant Ratios of Elasticities of Substitution-Homothetic (CRESH)/ Constant Ratios of Elasticities of Transformation-Homothetic (CRETH)	1%	$F(Y, \underline{x}) = \sum_{i=1}^{n} D_i [x_i / h(Y)]^{d_i} - 1 \equiv 0$ • Y: level of production • $\underline{x}$ and x_i: production input vector and production inputs respectively • F(): inverse function of production function • h(Y):a function of output, differentiable, used to reflect non-constant return to scale • D_i and d_i: calibration parameters	• The general form of CD, Leontief, and CES (Hanoch, 1971).
Translog	1%	$ln\, Y = \ln \alpha_0 + \alpha_A \ln A + \sum_{i=1}^{n} \alpha_i \ln X_i + 0.5\gamma_{AA} (\ln A)^2 + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln X_i \ln X_j + \sum_{i=1}^{n} \gamma_{iA} \ln X_i \ln A$ • Y: level of output • A: production technology index • X_i: quantity of production inputs • α_A, γ_{ij}: calibration parameters	• Suggested as the preferred functional form because of its flexibility; does not have limitations of CES (McKitrick, 1998). • More parameters to be calibrated/determined compared to CES (McKitrick, 1998).

Normalized Quadratic	<1%	$C(p) = ß^T p + 0.5 p^T B p / (\alpha^T p)$ • C(p): unit cost function • p: market price of commodities • B, ß, and α: calibration parameters vectors and matrices.	• Suggested as the preferred functional form because of its flexibility; does not have limitations of CES (McKitrick, 1998). • More parameters to be calibrated/determined compared to CES (McKitrick, 1998).

3.1.4.Mobility of factors

The assumed mobility of factors is an important aspect of CGE modeling as it directly impacts the structure of the model. The real-world economic environment and scope of the analysis are the drivers of the assumed factor mobility. Naturally, land is immobile, but land-use composition may change depending on the scope of the analysis. As another example, consider gas and municipal services as inputs to the production process. Based on real-world observation, the former can be considered mobile while the latter is bounded by location and cannot be transferred (Tavasszy et al., 2002).

Mobility is also impacted by the scope of the study. Factor mobility is often considered where the focus is to capture the long-term effect of a policy change. Factor mobility may not be a realistic assumption for short-term study horizon as the movement of factors across industries/regions requires time (Lahr et al., 2016). Under an imperfect competition market structure, mobility of factors is an alternative that allows for capturing agglomeration effects (Bröcker et al., 2010). However, Bröcker et al. (2010) note that assuming perfect mobility of factors made their models sensitive to changes in transport costs and generated unrealistic results. Hence, it is recommended to conduct a sensitivity analysis with respect to the level of mobility (immobile, imperfect mobility, and mobile), as is done in Bröcker et al. (2010).

3.1.5.Closure

Closure is the process of choosing endogenous and exogenous variables in the model, which is also proven to be influential on the model results. For example, Bachmann's (2017) study of the transportation impacts of a free trade agreements found that fixed endowments of labor and capital led to higher factor prices once industries expanded, which resulted in increased prices and damped demand effects. On the other hand, fixed factor prices created a limitless pool of factors, which promoted industry expansion. Ultimately, the closure should reflect the real-world economic environment. For example, if the unemployment rate is variable in the Canadian economy, it may be more sensible to consider the wage rate as fixed and let the endowment of labor change to determine the equilibrium. If Canada had a low or relatively constant unemployment rate, fixing the labor supply would be more reflective of reality.

The scope of study should also be considered in determining model closures. For example, Siegesmund et al., (2008) considered the capital rate of return constant and capital supply is allowed to vary to impose a long-run equilibrium. In the short-run, the supply is assumed constant and the price changes to impose a short-run equilibrium.

3.1.6.Market Structure/competition

The impact of market structure on model performance has received little attention in transportation applications of CGE models. Although proven to be substantially influential on the outcome of CGE modeling (Takeda, 2010), only the study of Bröcker (1998d) seems to have attempted to address the impact of market structure specifically in CGE-transport modeling.

Market structure has a diverse range, from perfect competition (e.g., Kim and Hewings, 2003) to monopolistic competition (e.g., Oosterhaven et al., 2001). When modeling imperfect competition, a number of alternatives may be implemented which differ in terms of the level of competition (e.g., monopoly and oligopoly), economies of scale (e.g., internal and external), assumptions on market entry and exit, etc. The decision of the market structure is driven by the scope of the analysis and the real-world observation of markets. Capturing economies of scale and economies of agglomeration requires imperfect competition market structure and is, therefore, a mandate if the focus is on economies of scale and agglomeration (e.g., Bröcker, 1998d). Market structure choice must also be consistent with the real-world economic environment. For example, capturing cross-hauling trade pattern between regions requires product differentiation, which involves monopolistic competition behavior modeling (Oosterhaven and Knaap, 2003). Information on market operation and structure, however, are not always available. Thus, a potential workaround is to again conduct a sensitivity analysis to investigate the changes in the results with respect to various market structures. From the literature reviewed, attention to market structure is a notable gap in transportation applications of CGE models, which would benefit from additional attention.

3.1.7.Scope of Analysis

One of the prominent drivers of the structure of the model, as seen in the preceding sub-sections, is the scope of the analysis. Although it is not a modelling attribute itself, this section elaborates on the scope of the analysis because of its significant impact on other modelling attributes. As described in detail below, the impacts of transportation shocks can be categorized as permanent or temporary, direct or indirect, and internal or external.

As mentioned by Seung and Kraybill (2001), there are two channels through which infrastructure can impact the economy: first, if the infrastructure is treated as an input into production, then a change in the infrastructure supply causes a change in the price of the manufactured commodity; second, if infrastructure causes a change in supply or productivity of inputs to a sector, then the same amount of inputs results in a different amount of outputs. The former brings about direct impact while the latter causes indirect effects.

Short (temporary) and long (permanent) effects are concerned with the life span of the impacts. Temporary effects are not expected to last long, whereas long-term impacts are to be in effect indefinitely, at least up to the horizon year. Examples of short and long-term effects are job creation in the construction industry and travel time savings, respectively (Kim and Hewings, 2009).

Effects can also be categorized as external and internal. External effects deal with externalities caused by infrastructure investment (environmental externalities such as accidents, noise, and air pollution) while internal effects are brought about by the market linkages (supply and demand). For more on internal and external effects, refer to Oosterhaven and Knaap (2003).

Figure 3.2 summarizes the discussion of modeling choices, highlighting the advantages, disadvantages, and recommendations made throughout this section.

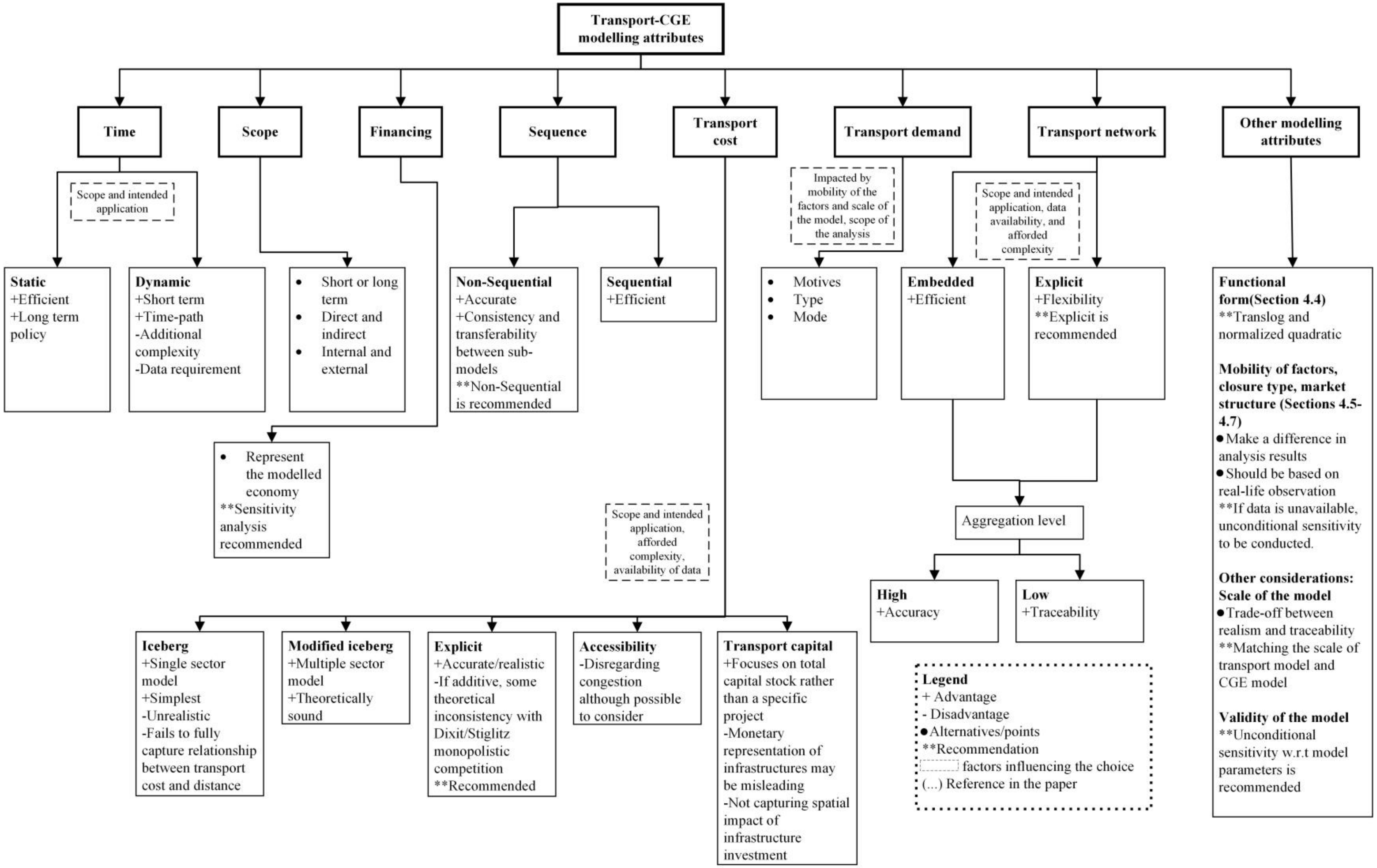

Figure 3.2: CGE-transport modelling attributes, pros and cons, and recommendations

3.2. Recommendations

In totality, this chapter resulted in a road map (Figure 3.2) of the most influential choices that a transport modeler confronts, while also providing a discussion on the advantages, disadvantages, and impacts of these choices on the model behavior and results. Where possible, recommendations on best practices were made. Here some of the key findings of the study and where possible, the prominent reason for the recommended choice is re-stated. The scope of the analysis is of significant importance to many modelling choices including transportation cost, aggregation level of transportation network, inclusion of modes of transportation, dynamic/static, mobility of factors, model closure, and types of impacts to be investigated. Regarding transportation related modeling choices, the explicit representation of transport costs, an explicit transport network model, non-sequential feedbacks, and the inclusion of representative financing strategies, are recommended for all studies as they better reflect real-world environments and behaviors. In choosing between dynamic and static formulations, it is recommended to consider the scope of the analysis, data requirements, and whether an increased level of complexity is warranted. A recommendation cannot be made on the choices of factor mobility. Factor mobility is driven by the scope of the analysis and real-world observation if possible. With regard to model closure, real-world observation and scope of the analysis (e.g., short or long run analysis) are the determining factors. As for the market structure, a sensitivity analysis is recommended. Above all, sensitivity analyses were often overlooked or conducted in a restricted manner in previous studies particularly with respect to mobility of factors, model closure, market structure, as well as key modeling parameters (e.g., elasticities). It is highly recommended that an unconditional sensitivity analysis with respect to aforementioned modeling components be conducted in future studies.

As cautioned previously, these recommendations are drawn taking into consideration individual modeling attributes and not from a holistic or practical modelling perspective. This single attribute perspective means that considering all the recommended options may result in an “expensive” model development process (i.e., high data requirements, and increased modeling and computational complexity). In this light, the choices and prioritization of trade-offs should reflect the specific application of interest.

As this chapter illustrates, different model design choices can lead to different behavior and results. Thus, transport modelers should make choices based on real-world observations, where possible, and justifiable assumptions otherwise. The author hopes that in the light of this research, transport modelers have a clearer understanding of the choices and alternatives in CGE model development, as well as the impacts that those choices can have on model results. For those not developing their own transport CGE model, it is hoped that a clear understanding of influential model choices has nonetheless been developed, to aid in the interpretation and assessment of other CGE model results.

4. Chapter 4
A Conceptual Framework for BC Investment Analysis

As the previous chapter concluded, explicit representation of transportation activities and transportation costs are necessary for CGE applications in transportation. This chapter develops a framework that explicitly links transportation models and databases to a CGE model of the economy aimed at analysing border crossing infrastructure investments. Transportation costs and activities are determined using transportation models and empirical transportation databases. Economic interactions in the CGE model drive the transportation demand for transportation models, while the transportation models determine the transportation costs input to the CGE model. The framework consists of four stages, which are illustrated in Figure 4.1.

The first stage deals with calculation of supply-chain characteristics including Border Crossing Shares (BCS), Value to Weight (VW) ratios, and Payload Factors (PF) using trade databases. In the second stage, using the supply-chain parameters calculated in the first stage, the number of trucks for each commodity crossing each Border Crossing (BC) are calculated. In the second step, the trade value between trading partners are extracted from CGE models or trade databases at the sectoral level. The trade values of each commodity are distributed among BCs using the share of each BC, BCS. Next, the trade values of each commodity crossing each BC are converted to weights using a commodity- and BC-specific VW ratios. Finally, the weights are converted to the number of trucks using PFs, which is again calculated specifically for each commodity and each BC. The output of the second stage of the framework is the number of trucks for each industry crossing the BC being investigated.

The third stage focuses on logistic modelling and scenario design and consists of three sub-components: a mode choice model, a BC delay model, and scenario design. For mode choice modelling, using a trade database, mode-specific attributes for Origin and Destination (OD) pairs are extracted. A mode choice model is then developed and calibrated to link the mode choices to the modelling attributes. The model is used to estimate the mode shift resulting from changes in BC delay. For BC delay modelling, transportation and trade databases are used to extract BC attributes, BC delay, and observed truck volumes crossing the border. Next, a delay model for each border crossing is developed and calibrated and then is used to estimate changes in delay because of changes in BC attributes – i.e., changes in BC delays resulting from an addition of one lane. The scenarios are designed based on changing the BC attributes and calculating the impacts on BC delays. Using the delay model, the changes in delay resulting from changes in a BC attribute of interest are estimated. The changes in delay are then translated into changes in mode choice model variables. For example, changes in the delay of a BC are translated into changes in OD-level travel time in the mode choice model. The changes in mode choice model variables triggers a mode shift, which results in changes in truck volumes, which is again fed back into the delay model. The interaction between the three components - the mode choice model, the delay model, and the scenario design forms a loop, which is highlighted by red arrows in Figure 4.1. The loop can stop upon reaching some stopping criteria such as a threshold for changes in BC delays or the resulting mode shift. The output of stage three are changes in delay for each border crossing due to the changes in BC attributes of interest.

The fourth and final stage focuses on economic analysis and BC prioritization. The changes in delay for each BC along with the number of trucks calculated in stage one are used to calculate the monetary changes in shipment cost for each commodity and each BC. The monetary changes in shipping cost are translated into changes in the CGE model parameter – i.e., shocking the CGE model parameter to reflect changes in shipping/transport costs. Numerous measures such as welfare, change in trade levels of industries, GDP, etc. can be extracted from the shocked CGE model for each scenario. BCs are then ranked based on the extracted aggregate and disaggregate macroeconomic measures.

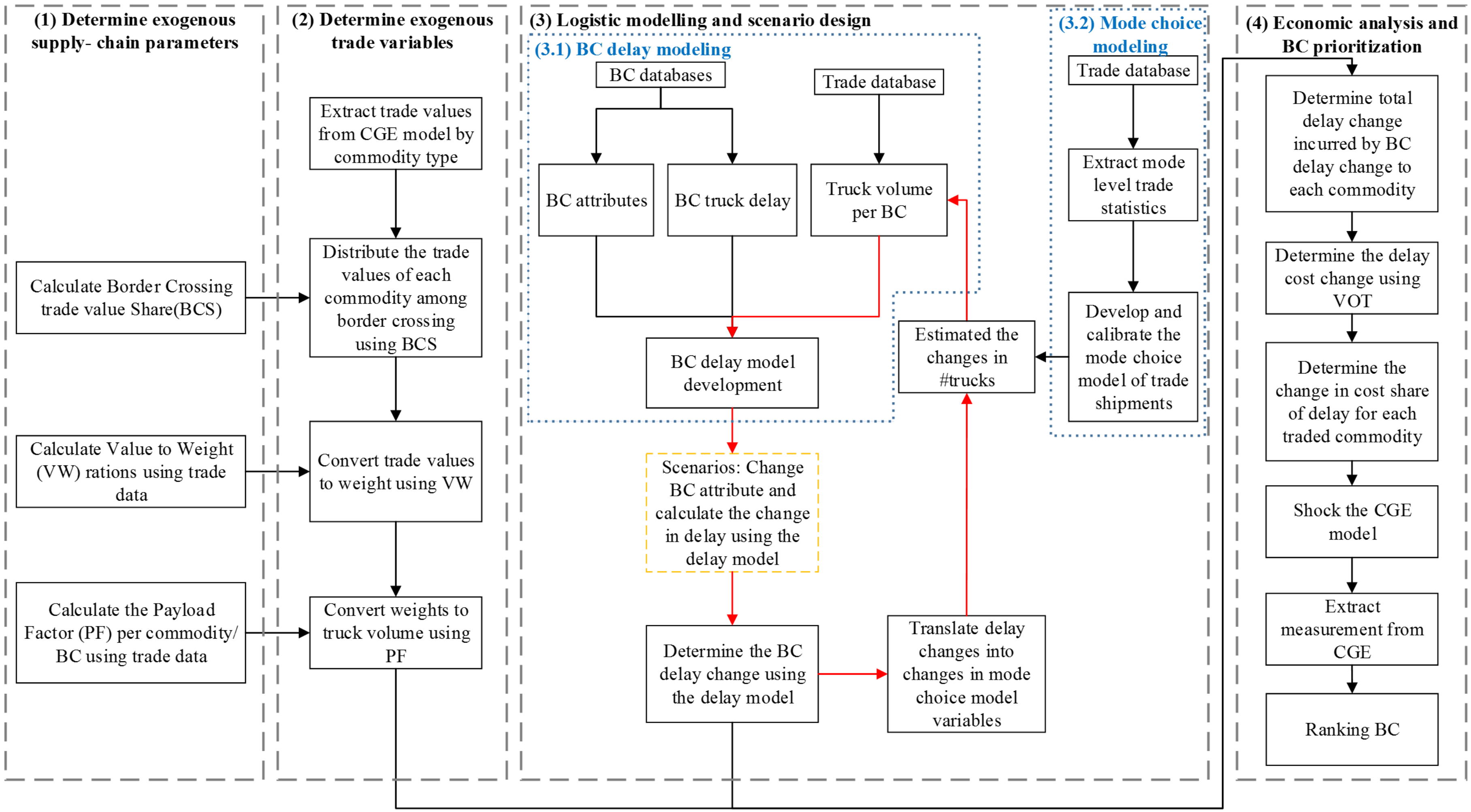

Figure 4.1: Border crossing investment prioritization framework

4.1.Preliminary application

To assess the feasibility of the proposed framework, it is applied to Canada-US BC infrastructure investments. This application is limited in scope: it uses a simplistic BC delay model and does not investigate shippers' mode choice; moreover, the application is focused on short-term analysis. These limitations are later addressed in Chapter 5.

4.1.1.CGE Modelling

The CGE analysis in this thesis uses the standard Global Trade Analysis Project (GTAP) Model and the current release of the GTAP Data Base (version 9, reference year 2011). The standard GTAP Model is a multi-region, multi-sector, CGE model, with perfect competition and constant returns to scale. Bilateral trade is handled via the Armington assumption, which states that consumers differentiate commodities based on their country of origin (allowing for the replication of real-world trade patterns, in which countries often simultaneously import and export the same commodity). The 140 regions in the GTAP 9 Data Base were aggregated into 20 geographically differentiated global regions including individual representations of Canada and the United States to identify directional movements for the resulting trade flows. Goods were left completely disaggregated into the base 57 GTAP sectors. The factors of production classification also remained unchanged. Delay cost savings were translated into changes in the model's iceberg trade cost (*ams*), the calculation of which is explained in the next sub-section.

4.1.1.1.Iceberg trade costs in GTAP

The iceberg trade cost, *ams*, is defined as an import augmenting technological change variable, which is introduced to facilitate the handling of service liberalization as well as efficiencyenhancing measures. This parameter impacts the effective price and quantity of a traded commodity (GTAP Data Bases, 2018). As mentioned in the literature review, it has been used to simulate the impacts of changes in non-tariff barriers to trade (Walkenhorst and Dihel, 2006).

As described by Hertel et al. (2001), representation of non-tariff trade barriers is done by introducing an "effective price" of the traded commodity, PMS^*_{irs}, which is the price of commodity *i* at market price adjusted to reflect unobserved trade barriers:

$$PMS^*_{irs} = PMS_{irs}/AMS_{irs} \tag{4.1}$$

where AMS_{irs} is the iceberg trade cost of commodity *i* exported from country *r* to country *s* and PMS_{irs} is the market price of commodity *i* exported from country *r* to country *s*.

To maintain consistent trade values in the model, an "effective quantity", QSX^*_{irs}, associated with the effective price is also introduced:

$$QXS^*_{irs} = QXS_{irs} \times AMS_{irs} \tag{4.2}$$

where QSX_{irs} is the quantity of commodity *i* exported from country *r* to country *s*. Note that effective quantities are needed, or else the trade value (multiplication of price and quantity) would not be consistent between the importer and exporter. From Equations 4.1 and 4.2, an increase in AMS_{irs} will result in a decrease in the effective price and an increase in the associated effective quantity of the traded commodity. The increase and decrease of AMS_{irs} are measured relative to the base scenario value of 1 for all traded commodities and trading regions.

This is the iceberg representation of transportation/trade cost, which was introduced by Samuleson (1952) and is inspired by the notion that an iceberg melts as it moves.

In the GTAP CGE model, percentage change forms of Equations 4.1 and 4.2 are used, which also include substitution effects due to price changes:

$$qxs_{irs} = -ams_{irs} + qim_{is} - \sigma_m^i[pms_{irs} - ams_{irs} - pim_{is}] \tag{4.3}$$

$$pim_{is} = \sum_k \theta_{iks}.[pms_{iks} - ams_{iks}] \tag{4.4}$$

where: qxs_{irs} represents percentage change in bilateral imports of *i* of *s* from *r*; qim_{is} represents percentage change in total imports of *i* into *s*; σ_m^i represents the elasticity of substitution among imports of *i*; pms_{irs} represents percentage change in price of imports of *i* from *r* in *s*; ams_{irs} represents percentage change in effective price of *i* from *r* in *s* due to change in unobserved trade costs; pim_{is} represents percentage change in average import price of *i* in *s*; and θ_{iks} represents the share of imports of *i* from *k* in total imports of *s*. See Hertel et al. (2001) for further interpretation of Equations 4.3 and 4.4.

4.1.1.2.“ams” shock calculation

Trade of commodity *i* from country *r* to *s* is represented by t_i^{rs}. The trade value is then distributed among borders connecting country *r* to *s* using the BCS. Let $BCS_i^{rs,x}$ represent the value share of commodity *i* transported through border *x* connecting country *r* to *s* (unitless), then the value of traded commodity *i* through border *x* is calculated as:

$$t_i^{rs,x} = t_i^{rs} \times BCS_i^{rs,x} \tag{4.5}$$

$t_i^{rs,x}$ is converted to number of trucks using VW ratios and PFs. Let $VW_i^{rs,x}$ and $PF_i^{rs,x}$represent the VW ratio (dollar/kilogram) and PF (kilogram/truck) of commodity *i* traded through border *x* from country *r* to *s*, then the number of trucks ($q_i^{rs,x}$) are calculated as:

$$q_i^{rs,x} = \frac{t_i^{rs,x}}{PF_i^{rs,x} \times VW_i^{rs,x}} \tag{4.6}$$

Note that summing $q_i^{rs,x}$ across *i* results in the total number of commodity-carrying trucks crossing the border *x*, $q^{rs,x}$.

As mentioned previously, the delay at a BC is defined as a function of transportation demand and BC attributes – e.g., number of lanes/inspection booths, number of employees, etc. Let d^x represent the delay (hours) of border *x* as follows:

$$d^x = f(q^{rs,x}, \underline{x}) \tag{4.7}$$

where $\underline{x}$ represents a vector of border *x*'s attributes. Function *f* is calibrated to available border crossing delay data. Given function *f*, one can calculate the changes in a BC delay for a change in $q^{rs,x}$ or $\underline{x}$. Let d_0^x and d_1^x represent delays before and after the improvement, the difference in the delays (δd^x) can be calculated as follows:

$$\delta d^x = d_1^x - d_0^x \tag{4.8}$$

Delay time savings for a given commodity that uses border *x* is then translated to monetary cost saving of commodity *i* from *r* to *s*, δc_i^{rs}(dollar), using the Value of Time (VOT) [dollar/hour] as follows:

$$\delta c_i^{rs} = \delta d^x \times q_i^{rs,x} \times VOT^r \tag{4.9}$$

Division of δc_i^{rs} by the trade value of commodity *i* results in changes in the effective price of commodity *i* from region *r* to *s*, which is also the shock to $ams_i^{rs,x}$ (unitless):

$$ams_i^{rs,x} = \frac{\delta c_i^{rs}}{t_i^{rs}} = \frac{\delta d^x \times q_i^{rs,x} \times VOT^r}{t_i^{rs}} = \frac{\delta d^x \times t_i^{rs,x} \times VOT^r}{t_i^{rs} \times PF_i^{rs,x} \times VW_i^{rs,x}} = \frac{\delta d^x \times BCS_i^{rs,x} \times VOT^r}{PF_i^{rs,x} \times VW_i^{rs,x}} \tag{4.10}$$

For the application in this thesis, only the number of lanes and the delay information for 15 BCs were available. For this chapter, delay is assumed to be a function of initial delay – based on observations of existing conditions – and the number of lanes as follows:

$$d_1^x = (\frac{NL_0^x}{NL_1^x})d_0^x \tag{4.11}$$

where NL_0^x and NL_1^x are the initial and scenario specific number of lanes of border *x*, respectively. This model of delay is used to calculate the new delays of each BC after adding one lane/inspection booth. This functional form is inspired by the notion that an increase in the number of lanes/inspection booth will reduce the delay relative to its initial level. A limitation of this formulation is its lack of truck volume consideration. An example for the calculation of the ams variable is presented in Appendix A. The ams variables for all the scenarios in Chapter 4 and Chapter 5 are presented in Appendix B.

4.1.2.Data

Border crossing shares for trade flows were determined from export data derived from the Canada Border Service Agency (CBSA), obtained from Transport Canada. The data included the Harmonized Systems code (HS), Standard Classification of Transported Good (SCTG) code, Canadian province of origin, Canadian province of exit, country of destination, international mode of transport, and port of clearance. The year 2011 “road” shipment shares in these data were used to disaggregate Canada-US trade flows to road BCs. The commodities from the GTAP Model use the GTAP Sector Classification (GSC2), which includes both commodities and industries, and thus has concordances with both the Central Product Classification (CPC) and International Standard Industrial Classification (ISIC) (Table C.1 and Table C.2 in Appendix C). The United States Statistical Division provides a number of correspondence tables, including HS-CPC and CPC-ISIC (United Nations’ Statistics Division, 2018). Hence, records from the CBSA data (HS) were given a GSC2 sector by either assigning it according to its CPC commodity code, or if the CPC code is not uniquely identified in the GSC2 sector correspondence, according to the ISIC industry which produces the commodity. For example, Table C.3 in Appendix C shows an example of the developed correspondence for GSC2 Sector 38, Motor vehicles and parts. In this way, each record in the CBSA data was assigned a GSC2 code, and the aggregation of records by GSC2 code provides the required BC shares (BCS).

To validate this harmonization scheme, trade flows as calculated by the CBSA data aggregated by GSC2 sectors were compared with the base GTAP Data Base. For example,

Figure 4.2 shows a comparison of Canada's exports to the US, as measured by the CBSA data aggregated by GSC2 sector, and the GTAP Data Base. The resulting correlation coefficients ranged from 0.89 (exports to Middle East and North Africa) to 0.99 (exports to the Rest of Europe), averaging 0.96 for all regions in the model (0.95 for the US, 0.97 for the EU, and 0.93 for Korea), indicating excellent consistency between the GTAP Data Base and the CBSA data aggregated by their assigned GSC2 sectors.

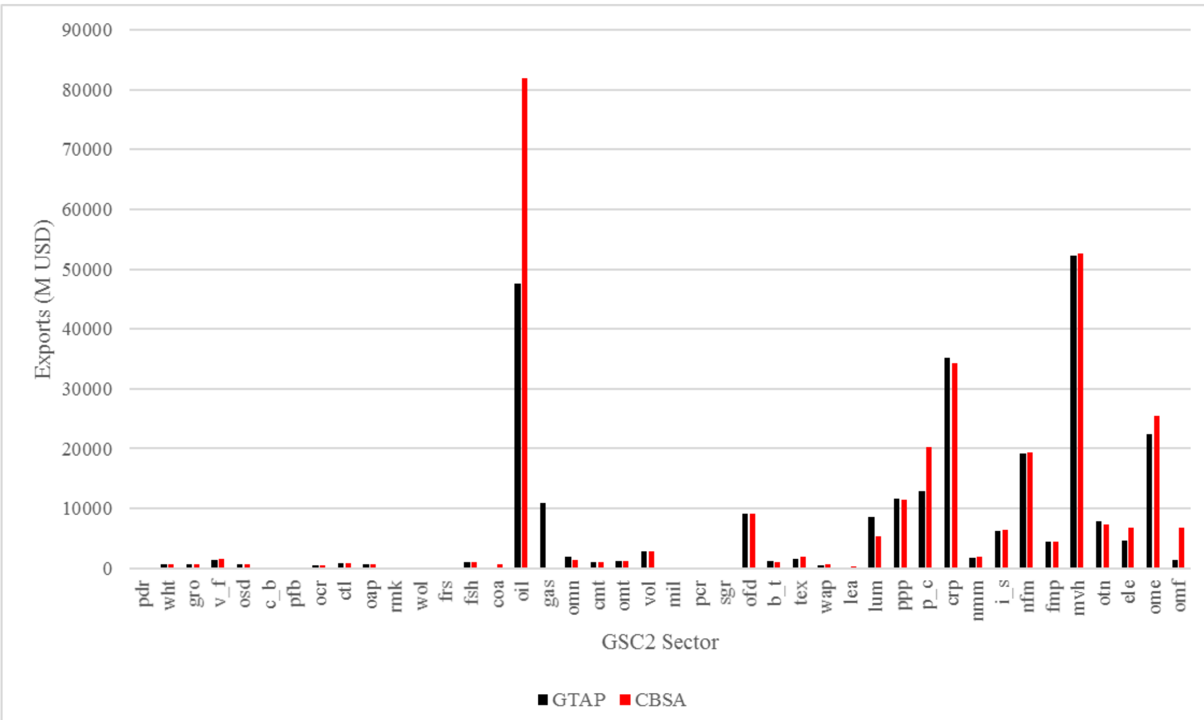

Figure 4.2: Canada to US export: CBSA vs. GSC2

VWs were determined using trade weight data from the International Trade Division of Statistics Canada. For the year 2008, the data include the total value ($) and weight (kg) of exports and imports by SCTG commodity code. These data were used to compute value-weight ratios ($/kg) for each SCTG code, and then linked to the CBSA export records described previously, to determine unique value-weight ratios for each BC. Since trade flow data from the GTAP 9 Data Base are measured in 2011 US dollars, and the value-weight factors were developed from 2008 records in Canadian dollars, the trade flows were converted to Canadian dollars and adjusted for inflation before conversion to quantities. In 2011, 1 US dollar equaled approximately 0.99 Canadian dollars. Canada's Consumer Price Index (CPI) was 119.9 in 2011 and 114.1 in 2008 (base year 2002=100). Therefore, a Canadian dollar in the year 2011 had the equivalent average purchasing power as approximately 95 cents in the year 2008. After these adjustments, trade flows measured in tonnage were determined.

Truck payload factors, PF, were estimated using the 2012 Ministry of Transportation of Ontario (MTO) Commercial Vehicle Survey (CVS). The MTO CVS is a roadside intercept survey that records truck and company information, commodity carried, route information, and trip frequency, for each truck surveyed. Of particular interest to this study is the commodity weight (kg) and commodity code (SCTG) recorded for each vehicle. Using the records on external trips (i.e., those trucks crossing the border in either direction), an average payload for each SCTG group was determined from the cargo-carrying trucks surveyed. These payloads by SCTG group were then linked to the CBSA records described previously, to determine unique payloads for each GSC2 group and BC. Table D.1 in Appendix D shows the average payload for each industry for Can-US and US-Can. The mean average payload (across all commodity types) is 17,116 kg for Canada to US trade, 16,923 kg for US to Canada trade. The average payloads are comparable to 17142.6 kg used in the study of Transport Canada (2008).

In summary, each trade flow ($) from the GTAP CGE model can be allocated to road BCs using the CBSA data, converted to weight (kg) using trade weight data from the International Trade Division of Statistics Canada, and converted to cargo-carrying truck trips using the Ministry of Transportation of Ontario (MTO) Commercial Vehicle Survey (CVS).

Lastly, delay data were obtained from a Transport Canada database for 15 BC (for both Canada and US bound trips). The dataset recorded the monthly median delay from 2013 to 2018. Canada bound has a maximum delay of 24 minutes for Ambassador Bridge and a minimum delay of 4.4 minutes for Woodstock Road. US bound has a maximum delay of 22.2 minutes for Fort Erie and a minimum delay of 5.2 minutes for St Stephen BC. Canada bound delays average 6.2 minutes, while US bound delays average 6.6 minutes. The minimum value of BC delays is used for BCs where delay data were not available. Figure 4.3 presents the averages of monthly medians and an average of all years for each BC. Figure 4.4 shows the Box and Whisker plot of delay data for each BC.

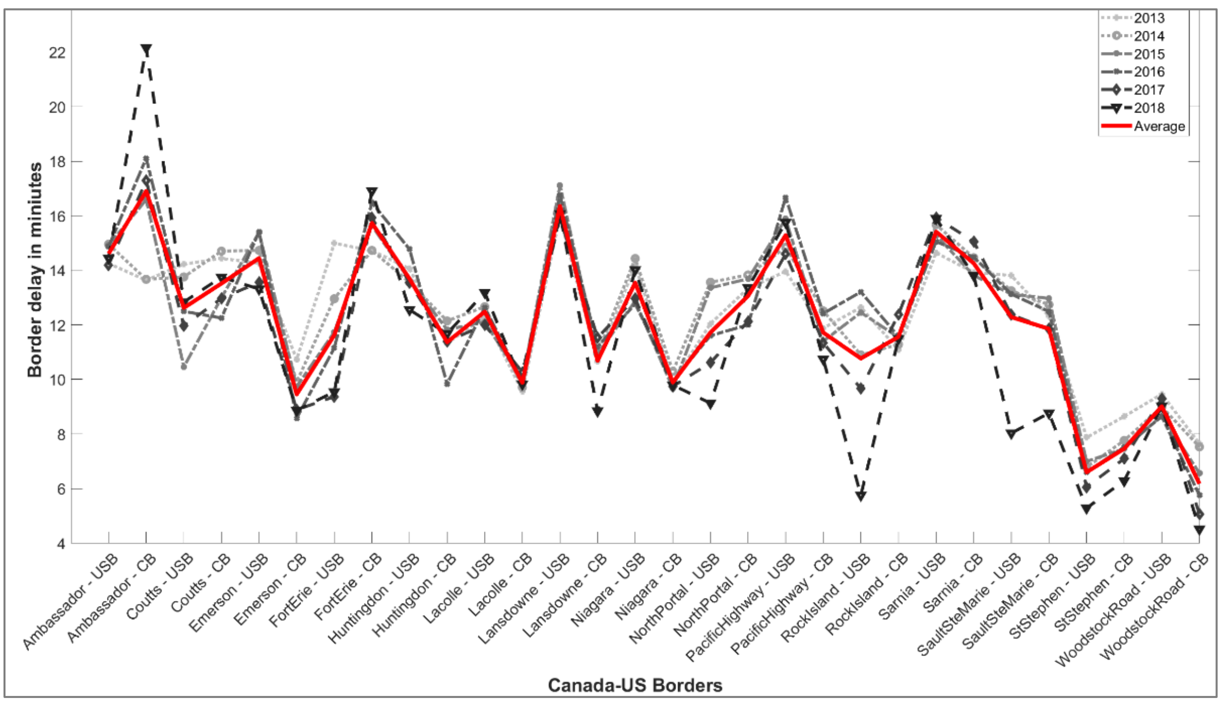

Figure 4.3: Average Annual delay for Canada-US BCs

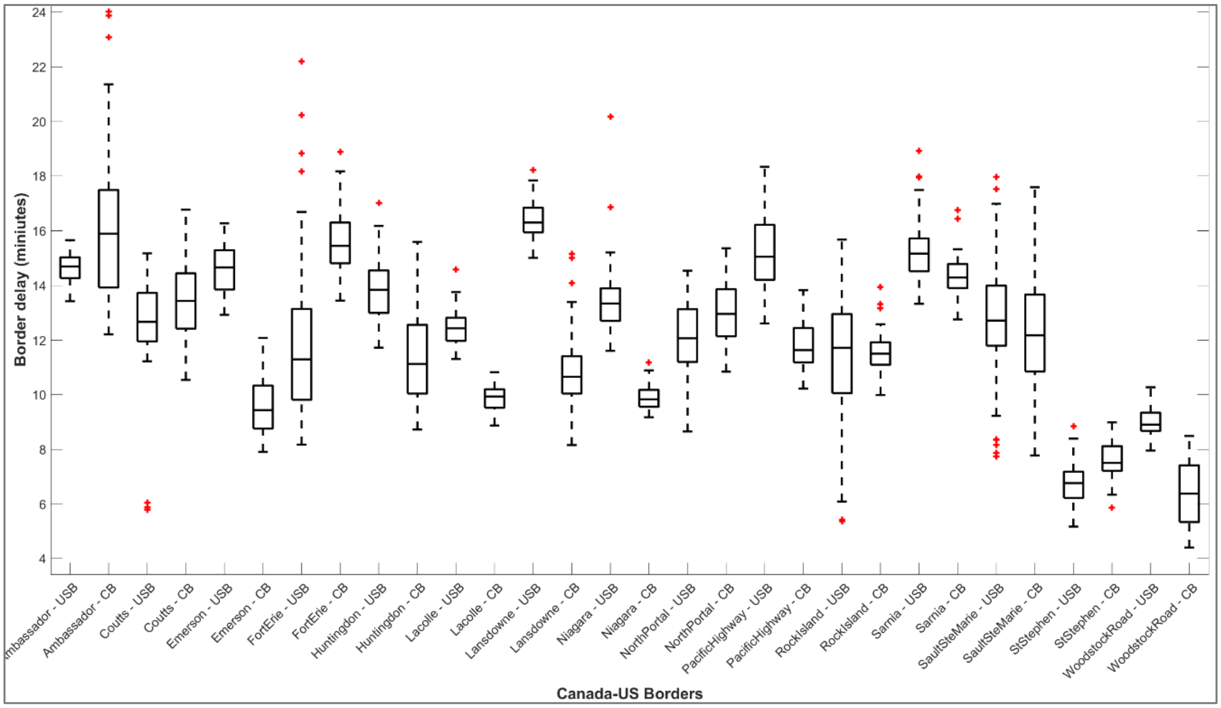

Figure 4.4: Whisker box plot of BC delay

4.1.3.Results

The addition of one lane to the existing number of lanes/inspection booths are examined for all Canada-US BCs using part of the proposed framework. This section presents the results of changes in trade value and quantity, changes in each country's GDP, and changes in their levels of welfare – measured by Hicks Equivalent Variation (EV). As mentioned previously, mode choice analysis, delay modeling, and consideration of long-term effects are absent in the preliminary application. All figures in this section are annual unless indicated otherwise.

Figure 4.5 presents the changes in trade value for Canada as a result of individual BC improvements in the direction of Canada to the US (US bound). The intensity of colors in Figure 4.5 shows the magnitude of the change; the darker red color means larger increases in trade value while the darker grey color means larger decreases in trade value, relative to other measurements. The analysis enables investigating the impact of individual BC improvement on each industry. The average increase in Canadian export value across all industries and across all BCs is 0.004M USD, while US export value is increased by 0.008M USD. The average increase in Canadian export value to the US is 0.03M USD, while US export value to Canada is increased by 0.03M USD. Overall, Canada and US trade values are increased on average by 0.005M USD (including industries that experience decreases).

An improvement in Fort Erie BC (Canada bound) resulted in the maximum change in trade value of 2.09 M USD, which is for the US's metal products export to Canada. However, the machinery and equipment industry in the US faces a reduction in export value to the European Union (EU) of 0.22 M USD as a results of this improvement in Fort Erie BC (Canada bound). This *reduction* in trade, which results from a border crossing *improvement*, is explained in the discussion section. For Canadian industries, the maximum increase in trade *value* (including price and quantity effects) occurs in the wood products industry, which benefits from a 1.45M USD increase in exports to US as a result of an improvement in Huntingdon BC (US bound). Meanwhile, the maximum reduction in trade value occurs to Canada's metal industry, which suffers from reduction of -0.14M USD in exports to the UK as a result of an improvement in Lansdowne BC (US bound). In terms of trade *volume* (including only quantity effects), the wool industry in Canada incurs the maximum change of 0.10% in exports volume to the US as a result of an improvement in Prescott BC (US bound). The maximum reduction in Canadian exports volume is faced by the gas industry, which incurs a 0.01% reduction in exports to Africa as a result of the improvement in Coutts BC (US bound).

Figure 4.5: Changes in Canada to US trade values as a result of BC improvements in the direction of Canada to US

Figure 4.6 shows the changes in Canada and US GDP for each BC improvement. For the Canadian economy, GDP changes range from 0 to 4.75M USD, while for US the changes range from 0 to 11.50M USD. In terms of percentages, an improvement can increase Canadian GDP by 0.0003%, or improve the US's GDP by 0.0001%. The most critical BC to Canada's GDP is Lansdowne BC (US bound), while for the US's GDP it is Fort Erie BC (Canada bound). Note that although the overall result is that improving a BCs outbound performance is more beneficial to a country than improving a BC's inbound performance, there are some exceptions (shown on Figure 4.6), such as the finding that an improvement in Salut Ste. Marie BC (US bound) is more beneficial to US GDP than an improvement in the Canada bound direction to US GDP. Overall, the distribution of Canada and US GDP changes from BC improvements follows an exponential distribution, where around 90% of the time the impacts are 1M USD or less for both countries. Hence, there is a small subset of BCs that should be the focus of BC investments.

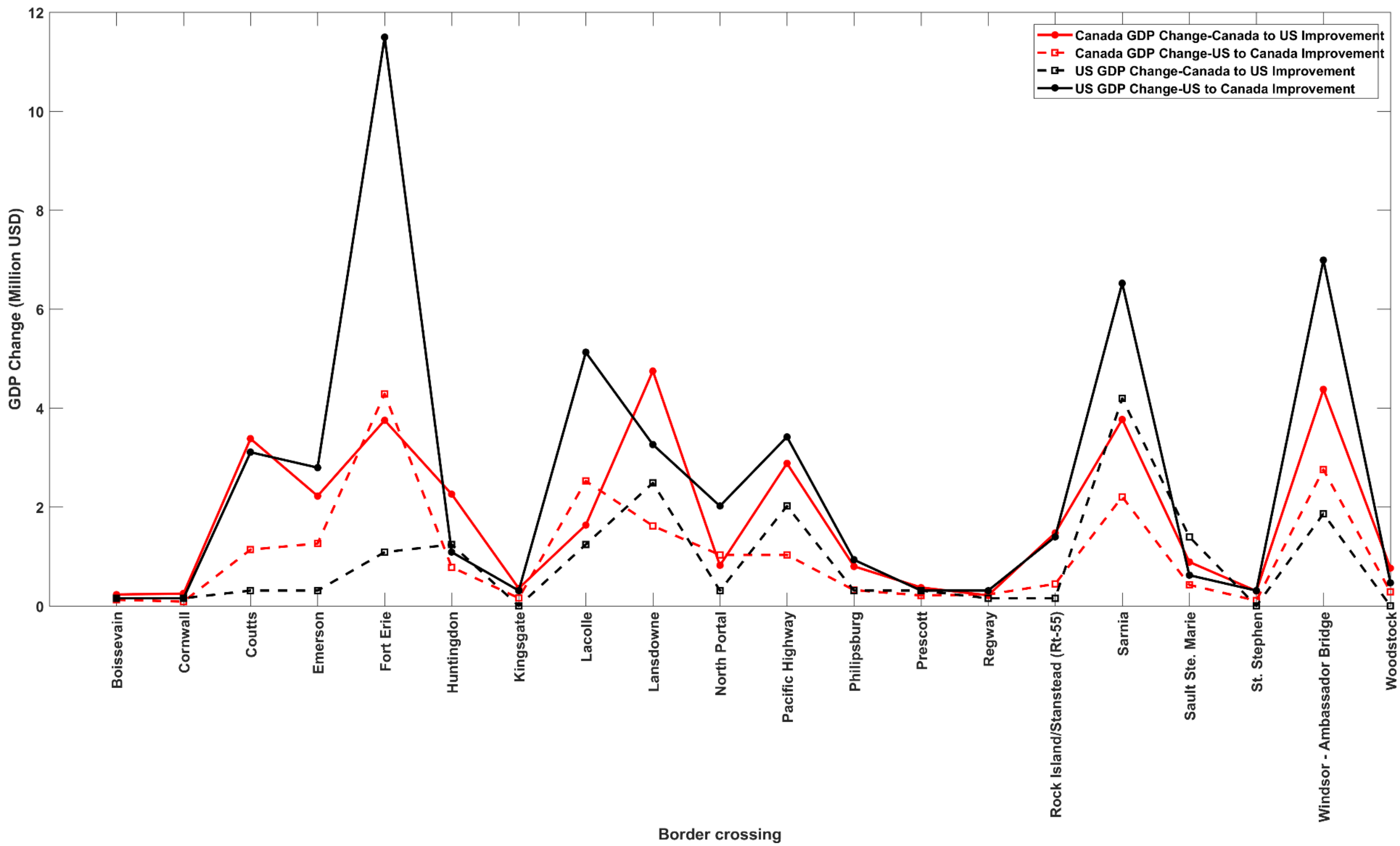

Figure 4.6: GDP change for Canada and US per BC improvement

Figure 4.7 presents the changes in welfare measured by Hick's Equivalent Variation (EV) as a result of individual BC improvements. The maximum welfare benefit amounts to 3.15M USD for Canada, which results from an improvement in Fort Erie BC (Canada bound). The maximum welfare loss amounts to -0.39M USD for Latin America (trade diversion), which results from the improvement in Fort Erie BC (Canada bound). The most influential BC to Canada's and US's welfare is Fort Erie BC (Canada bound). The 85th percentile welfare changes are 0.30M USD and 0.22M USD, for Canada and the US respectively. As can be seen in Figure 4.7, Canada-US BC improvements could have ripple effects on other economies world-wide. These effects vary depending on the direct and indirect trade relationships of other countries with the US and Canada. For example, Russia's welfare is not as sensitive to Canada-US trade facilitation as the European Union countries since Russia's overall trade level with the two countries is approximately one eighth that of the European Union.

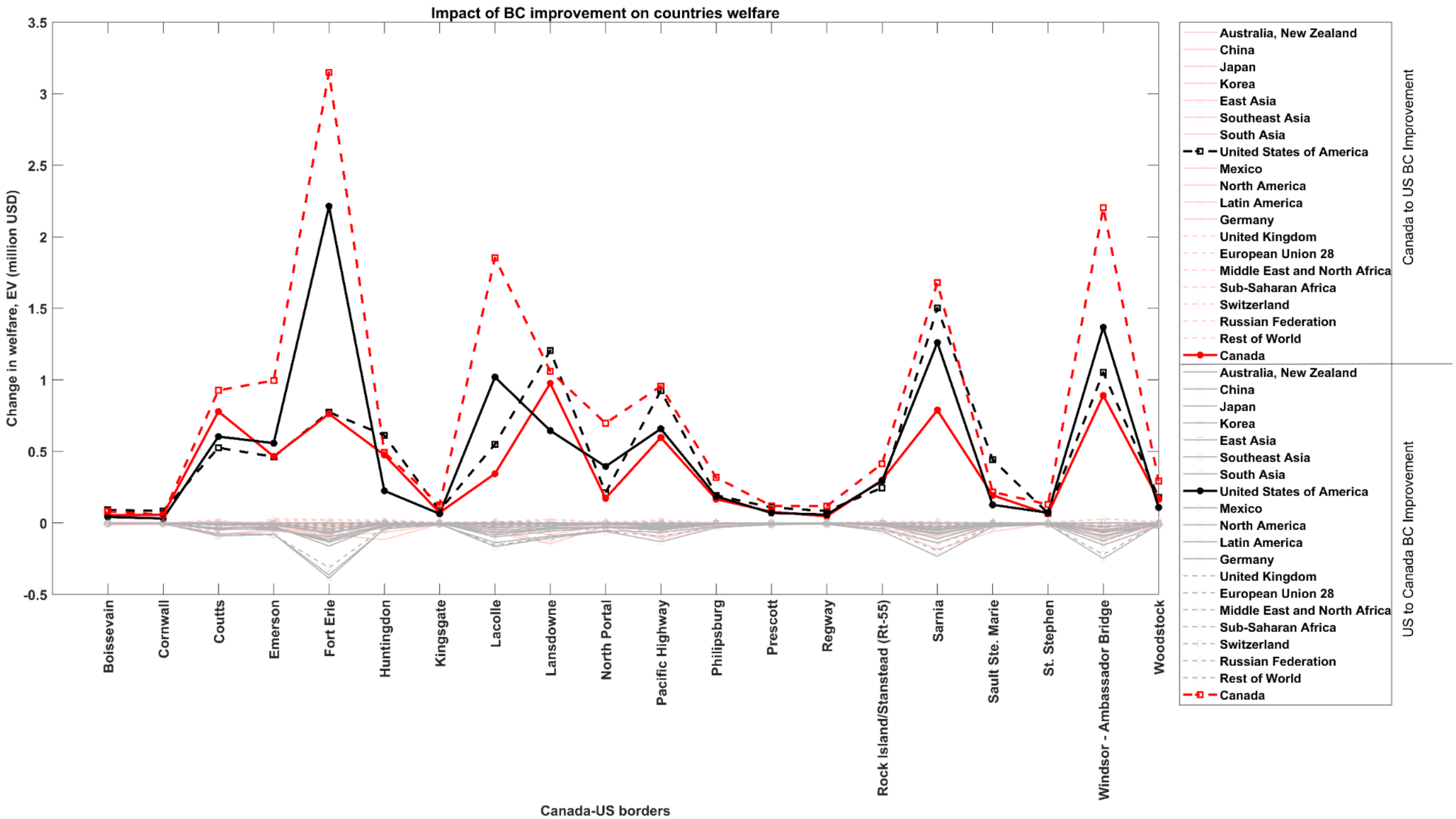

Figure 4.7: EV welfare change per BC improvement

4.1.4.Discussion

As shown in Figures 4.6 and 4.7, investment in BCs will generally have sizeable positive impacts on the level of welfare and GDP of both Canada and the US. From Figure 4.5, it can be concluded that different BC improvements will impact industries differently.

The impacts of BC infrastructure investment on Canada's overall trade are always positive. However, there are occasionally negative consequences for trade in some industries according to the CGE model – for example, the reduction in the motor vehicle and parts exports of 0.08M USD or 0.0003% from Canada to US as a result of an improvement in Huntingdon BC (US bound). This decrease in trade value can be explained by following the underlying theory of the CGE model. A reduction in transport/trade cost will make Canadian products more competitive in the US market, which leads to additional demand for Canadian products. This increase in the demand for Canadian products also increases the demand for production inputs including production factors (capital, labor, and land) in Canada. An increase in the demand for a production factor results in an increase in its price (since the quantity is fixed in the neoclassical model closure), which in turn makes Canadian goods slightly more expensive. The trade can then decrease if the reduction in transport costs does not offset the increase in the production price brought about by increased demand for production factors. Note that an unrelated industry may be driving up the factors of production (e.g., demanding more labor), thereby impacting other industries that require those same factors. In the case of Huntingdon BC (US bound) improvement, the reduction in transport costs offsets the increase in the production price of the wood products and thus its trade value increases (1.45M USD). However, this does not occur for motor vehicle and parts exports, hence their slight decrease in trade value (0.08M USD).

Figure 4.7 implies that other countries – for example, in Latin America – may face a welfare loss as a result of Canada-US BC improvements. This is due to the fact that optimizing trade between US and Canada will make other countries less competitive for the markets in these two countries. This change in the level of attractiveness/competitiveness will divert trade away from other countries as it creates new trade for Canada and the US.

Table 4.1 presents the 15 most important borders to maximize Canada and US welfare, GDP, and change in export value to one another. Table 4.1 also ranks the BCs with respect to export values for the benchmark year between the two countries. Referring to Table 4.1, it is clear that different objectives lead to different investment priorities. As an example, if the objective is to maximize US exports to Canada, then Fort Erie BC (Canada bound) in Ontario is the optimal investment, whereas if the objective is to maximize Canadian exports to US, Lansdowne BC (US bound) is best. In other words, the true driver of BC investment choice is the investment objective. Hence, investment priorities based on value of trade (seventh and eighth columns of Table 4.1) are different from those based on changes in trade values (fifth and sixth columns of Table 4.1). Focusing on Canada to US BCs, the Windsor-Ambassador Bridge is the BC that carries the most trade from Canada to US. Intuitively, this would be the most important BC when considering changes in exports from Canada to the US – in fact, this is suggested by the study from the Ontario Chamber of Commerce (Transport Canada, 2018), where the Ambassador Bridge is identified as the most critical BC. However, these results indicate the Lansdowne BC is instead the highest priority BC that maximizes Canada's exports to the US. This stems from two reasons: 1) the BCs are improved equally in this study (i.e., one lane/inspection booth is added to each BC to enable carrying out a reasonable comparison of scenarios; and 2) the translation of delay savings is dependent on the delay function formulation.

In this case, an addition of one lane to Lansdowne does not lead to the same delay saving percentage (33.3%) as an addition of a lane to Windsor-Ambassador Bridge (7.1%) because of the difference in the initial number of lanes (2 and 13, respectively).

The correlation between measure in Table 4.1 was also calculated. There is a high correlation between Canada's welfare, US's welfare, US's GDP, and change of export from US to Canada. The high level of correlation means that the improvements to borders that would lead to an increase in US's export to Canada would most likely improve the US's welfare, Canada's welfare, and US's GDP.

Figure 4.8 illustrates the eight most important BCs for Canada and US trade changes based on Table 4.1. As can be seen in Figure 4.8, the investment priorities to maximize export competitiveness vary from one country to another, and span the entire Intercontinental Boundary. This highlights the need to examine all BCs when taking a global approach to competitiveness. Results of this analysis enable qualitative trade policy planning. For example, if Canada decides to improve its GDP through BC improvements or plans to increase its dairy product exports to the US, a set of BC improvement that satisfies the policy goal can be extracted from these results. The results also enable policy assessment at the industrial sector level. An example is that if the US plans to maximize its export of metal products to Canada, improvements to Fort Erie BC would be most beneficial. This improvement, however, comes at the expense of the reduction of the oil and gas industries export to Canada. Exports of the dairy industry from Canada to US would be maximized by investment in the Huntingdon BC, which results in a reduction in Canada's export of motor vehicle and parts to the US. Hence, the combination of a theory driven economic model (CGE) with empirical datasets allows for industry-specific and globally focused policy analysis.

Table 4.1: Most Important BC

Priority	Canada's EV gain	US's EV gain	Canada's GDP gain	US's GDP gain	Canada's Export gain to US	US's Export gain to Canada	Initial Value of Trade-Canada to US	Initial Value of Trade-US to Canada
1	Fort Erie-CB	Fort Erie-CB	Lansdowne-USB	Fort Erie-CB	Lansdowne-USB	Fort Erie-CB	Ambassador-USB	Ambassador-CB
2	Ambassador-CB	Sarnia-USB	Ambassador-USB	Ambassador-CB	Ambassador-USB	Ambassador-CB	Fort Erie-USB	Fort Erie-CB
3	Lacolle-CB	Ambassador-CB	Fort Erie-CB	Sarnia-CB	Sarnia-USB	Sarnia-CB	Sarnia-USB	Sarnia-CB
4	Sarnia-CB	Sarnia-CB	Sarnia-USB	Lacolle-CB	Fort Erie-USB	Lacolle-CB	Lacolle-USB	Lacolle-CB
5	Lansdowne-CB	Lansdowne-USB	Fort Erie-USB	Sarnia-USB	Coutts-USB	Lansdowne-CB	Lansdowne-USB	Coutts-CB
6	Emerson-CB	Ambassador-USB	Coutts-USB	Pacific Highway-CB	Pacific Highway-USB	Pacific Highway-CB	Pacific Highway-USB	Pacific Highway-CB
7	Lansdowne-USB	Lacolle-CB	Pacific Highway-USB	Lansdowne-CB	Huntingdon-USB	Coutts-CB	Coutts-USB	Lansdowne-CB
8	Pacific Highway-CB	Pacific Highway-USB	Ambassador-CB	Coutts-CB	Emerson-USB	Emerson-CB	Emerson-USB	Emerson-CB

9	Coutts-CB	Fort Erie-USB	Lacolle-CB	Emerson-CB	Fort Erie-CB	North Portal-CB	Philipsburg-USB	Philipsburg-CB
10	Ambassador-USB	Pacific Highway-CB	Huntingdon-USB	Lansdowne-USB	Lacolle-USB	Rock Island-CB	Woodstock-USB	North Portal-CB
11	Sarnia-USB	Lansdowne-CB	Emerson-USB	Pacific Highway-USB	Rock Island-USB	Huntingdon-CB	North Portal-USB	Woodstock-CB
12	Coutts-USB	Huntingdon-USB	Sarnia-CB	North Portal-CB	Sarnia-CB	Lansdowne-USB	St. Stephen-USB	Huntingdon-CB
13	Fort Erie-USB	Coutts-CB	Lacolle-USB	Ambassador-USB	Ambassador-CB	Ambassador-USB	Rock Island-USB	Rock Island-CB
14	North Portal-CB	Emerson-CB	Lansdowne-CB	Sault Ste. Marie-USB	Sault Ste. Marie-USB	Sarnia-USB	Huntingdon-USB	St. Stephen-CB
15	Pacific Highway-USB	Lacolle-USB	Rock Island-USB	Rock Island-CB	North Portal-USB	Philipsburg-CB	Prescott-USB	Prescott-CB

USB: US bound
CB: Canada bound

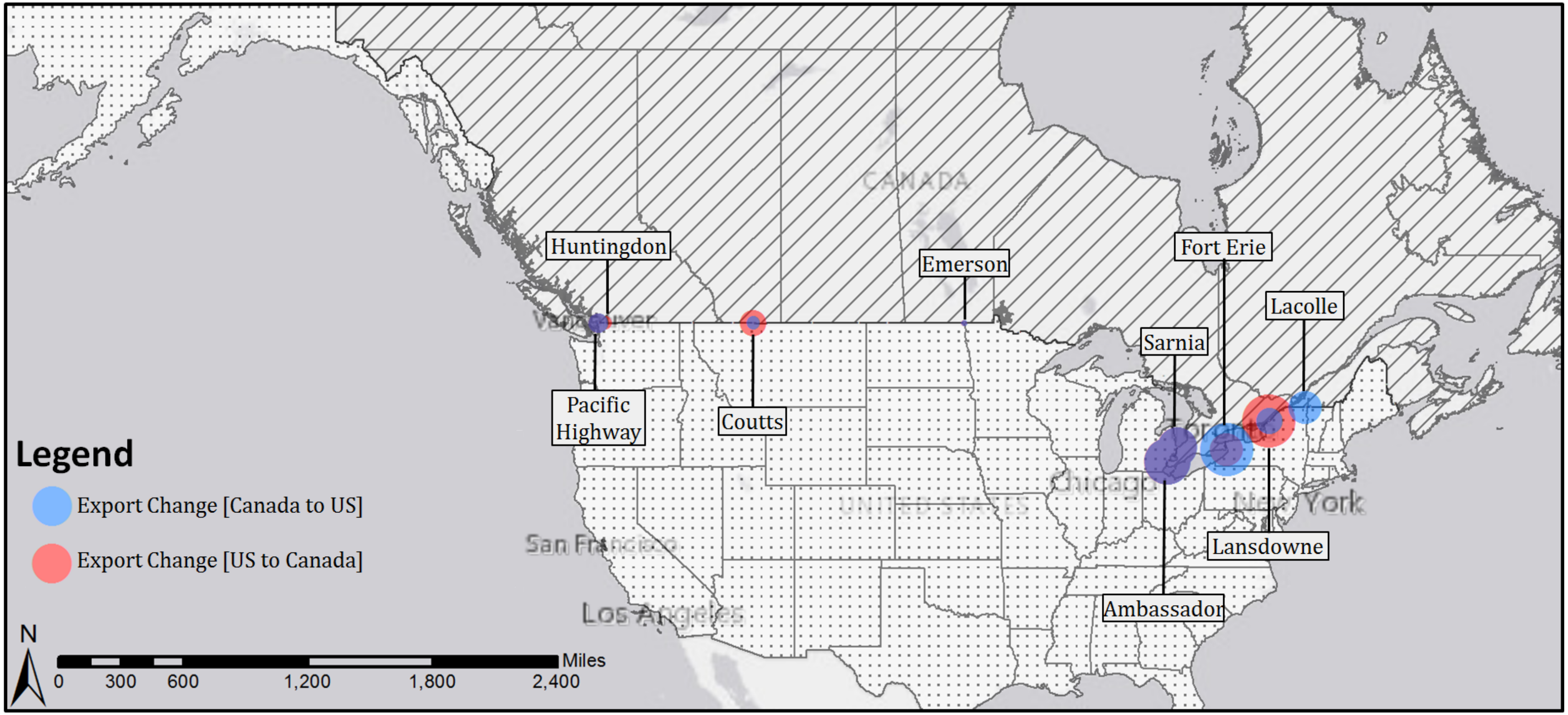

Figure 4.8: BC investment priority

4.1.5.Sensitivity analysis

A counter factual scenario, where BC delays are reduced by 46% instead of adding a lane to each BC was tested to provide a sensitivity analysis of the results with respect to delay modelling approach. Table 4.2 below presents the most important BCs with respect to Canada and US welfares under the two scenarios: adding a lane to each BC (using the simplified delay model specified by equation 4.11) and reducing BC delays by 46%. Table 4.2 shows that investment priorities are highly sensitive to the chosen BC delay model since the two different approaches of delay modelling lead to different BC priorities for maximizing Canada and US welfare. Therefore, modelling of BC delays to represent real-life operation conditions at BCs is a necessary step in determining BC priorities for real-world investments. The sensitivity analysis also shows that results from non-systematic/non-comparable scenarios (i.e., reducing BC delay by the same percentage for all BCs) are different from the results from systematic/comparable scenarios (i.e., reducing BC delay by an addition of one lane to each BC).

Table 4.2: Canada and US welfare gains - sensitivity analysis

Canada's welfare gain by addition of a lane to BCs	**Canada's welfare gain by reducing BC delays by 46%**	**US's welfare gain by addition of a lane to BCs**	**US's welfare gain by reducing BC delays by 46%**
Fort Erie-CB	Ambassador Bridge-CB	Fort Erie-CB	Ambassador Bridge-CB
Ambassador Bridge-CB	Fort Erie-CB	Sarnia-USB	Ambassador Bridge-USB
Lacolle-CB	Sarnia-CB	Ambassador Bridge-CB	Fort Erie-CB
Sarnia-CB	Ambassador Bridge-USB	Sarnia-CB	Sarnia-USB
Lansdowne-CB	Sarnia-USB	Lansdowne-USB	Sarnia-CB
Emerson-CB	Fort Erie-USB	Ambassador Bridge-USB	Fort Erie-USB
Lansdowne-USB	Lacolle-CB	Lacolle-CB	Lacolle-USB
Pacific Highway-CB	Pacific Highway-CB	Pacific Highway-USB	Pacific Highway-USB
Coutts-CB	Lacolle-USB	Fort Erie-USB	Lansdowne-USB
Ambassador Bridge-USB	Lansdowne-CB	Pacific Highway-CB	Lacolle-CB
Sarnia-USB	Lansdowne-USB	Lansdowne-CB	Pacific Highway-CB

Coutts-USB	Coutts-CB	Huntingdon-USB	Lansdowne-CB
Fort Erie-USB	Pacific Highway-USB	Coutts-CB	Emerson-USB
North Portal-CB	Coutts-USB	Emerson-CB	Huntingdon-USB
Pacific Highway-USB	Emerson-CB	Lacolle-USB	Coutts-CB
Huntingdon-CB	Emerson-USB	Coutts-USB	Coutts-USB
Huntingdon-USB	Huntingdon-CB	Emerson-USB	Sault Ste. Marie-USB
Emerson-USB	Huntingdon-USB	Sault Ste. Marie-USB	Emerson-CB
Rock Island-CB	North Portal-CB	North Portal-CB	Rock Island-CB
Lacolle-USB	Rock Island-CB	Rock Island-CB	North Portal-USB

USB: US bound
CB: Canada bound

4.1.6.Preliminary conclusions

Simulation results suggest that BC investment priorities vary given the investment objective. For example, if the objective is to maximize US exports to Canada, then Fort Erie BC is the top priority; on the other hand, if the objective is to maximize Canada's exports to the US, then the Lansdowne BC should be considered for investment purposes. It was also found that BC investments are expected to have small international ramifications for other countries. The magnitude of these effects are impacted by direct and indirect trade interdependencies of other countries with the US and Canada. The simulation results also suggest that there is correlation between some measures – e.g., there is a high correlation between US to Canada exports and US level of welfare. This correlation means that investment in BCs that maximize this objective would most likely improve the other objective to some extent.

The results of the analysis provide several policy insights for the countries and industries. An investment in a BC will always have positive impacts on the two countries' welfare and GDP. The positive impact of BC investments on both countries' economy contradict the typical political reality that investment in border crossing infrastructure are perceived to disproportionately benefit non-tax payers. The study suggests that BC investments increase the overall trade values and volumes. However, a general recommendation cannot be drawn at the industry/commodity level since BC improvements were shown to have differing impacts.

The preliminary application in this chapter proves the feasibility and benefits of the proposed framework. However, the simplications made in the preliminary application may compromise the realism of the model: first, the delay model is simplistic and does not reflect real-world observations - i.e., the delay model is not calibrated to replicate delay observations; second, mode choice analysis is absent in the preliminary application; third, the preliminary application focuses on a single time horizon (short-term effects of infrastructure investment) as opposed to considering both long- and short- term effects.

The next chapter addresses the limitations of the preliminary application by calibrating a delay model using empirical delay data to accurately estimate impacts of an addition of a lane to BC delays; calibrating a shippers' mode choice model using a shipment database; and by altering CGE model closures to investigate both long- and short- term effects of BC investments.

5. Chapter 5

Extended Application of the Framework: Logistics Modelling and Calibration

The identified limitations in the preliminary application - presented in Chapter 4- are addressed in Chapter 5. The analysis includes development and calibration of BC delay models for individual BC using empirical data to allow designing *comparable* investment scenarios, i.e., addition of one lane to each border crossing. Using empirical shipment data, a mode choice model is developed and calibrated to investigate the mode shifts that may result from investment in only road infrastructure. In the analysis, both short and long term BC priorities are determined to simultaneously include both time horizons.

The remainder of the chapter is as follows. First, border crossing delay modelling and mode choice modelling concepts are explained, which is followed by the calibration of the two models. The analysis results for three scenarios - addition of one lane to each BC, reducing BC delays by 35%, and reducing BC delays by 4 minutes - are presented. This is followed by a validation of the modelling results by comparing estimated and observed total number of trucks (loaded and empty), which is followed by a detailed discussion of the analysis results. The chapter concludes with key finding and policy insights.

5.1.Border Crossing Delay Modelling

Border crossings are modelled as an M/M/N queuing system, where *N* represents number of servers, and vehicle arrivals and service rates are governed by Markovian processes (Poisson and negative exponential, respectively). The average waiting time in an M/M/N queuing system is:

$$\bar{W} = \frac{\rho + \bar{Q}}{\lambda} \qquad (5.1)$$

where ρ is the traffic intensity [unitless], $\bar{Q}$ is the average number of vehicles in the system, and λ is the arrival rate [veh/h]. The traffic intensity, ρ, is calculated as follows:

$$\rho = \frac{\lambda}{\mu} \qquad (5.2)$$

where μ is the average service rate [veh/h] and $\bar{Q}$ is the average number of vehicles in the system, calculated as follows:

$$\bar{Q} = \frac{P_0 \rho^{N+1}}{N!N} \left[\frac{1}{(1-\frac{\rho}{N})^2}\right] \qquad (5.3)$$

where *N* is the number of servers [unitless], and P_0 is the probability of presence of no vehicle in the system. P_0 is calculated as follows:

$$P_0 = \frac{1}{\sum_{n_c=0}^{N-1}\left(\frac{\rho^{n_c}}{n_c!}\right) + \frac{\rho^N}{N!(1-\frac{\rho}{N})}} \qquad (5.4)$$

See Shortle et al. (2008) for derivations of these formulas.

Truck delay data for the 15 most important border crossings for both Canada and US bound were provided by Transport Canada. The dataset reports the monthly median delay for the years 2013 to 2018. The monthly delay medians are averaged to represent the delay for each direction for a given year. Canada bound has a maximum delay of 24 minutes for Ambassador Bridge and a minimum delay of 4.4 minutes for Woodstock Road. US bound has a maximum delay of 22.2 minutes for Fort Erie and a minimum delay of 5.2 minutes for St Stephen BC. Canada bound delays average is 6.2 minutes, while US bound delays average is 6.6 minutes. Refer to Figure 4.3 for the averages of monthly medians and an average of all years for each BC. Refer to Figure 4.4 for the Box and Whisker plot of delay data for each BC.

The Canada-US Border Infrastructure Plan (BIIP) provides periodic reports for the years 2011, 2012, and 2014, on BC infrastructure (Canada-US Border Infrastructure Plan, 2013; 2014; 2016). The report includes a survey of BC attributes such as truck volumes; passenger vehicle volumes; number of inspection lanes for trucks and passenger vehicles; and availability of FAST and NEXUS, which are express lanes for trucks and passenger vehicles, respectively. The year 2014 is used as the basis for analysis in this research since both delay data and BC attributes data are available for 2014. BC characteristics are presented in Table 5.1.

Table 5.1: BC characteristics

Name of Border	Commercial vehicles [veh/year]	Passenger vehicles [veh/year]	# of Commercial lanes	# of Passenger lanes	NEXUS lane	FAST lane
Ambassador	1473820	2107430	13	19	1	1
Coutts	147617	305735	2	3	1	0
Emerson	230487	370502	4	4	1	0
FortErie	619028	2220985	7	11	1	1
Huntingdon	148047	1170667	2	4	1	0
Lacolle	282742	1154058	9	10	1	1
Lansdowne	189229	653319	3	7	1	0
Niagara	342859	1253227	4	6	0.5*	1
NorthPortal	99071	109215	3	3	0	0
PacificHighway	362034	1856891	3	6	1	1
RockIsland	96782	717591	2	4	0	1
Sarnia	754053	2005415	9	9	1	1
SaultSteMarie	44088	976167	2	4	1	0
StStephen	61437	206429	3	6	0.5*	0
WoodstockRoad	84187	332901	2	6	1	0

* 0.5 indicates limited operation hours of NEXUS and FAST lanes

5.1.1.Delay modelling

To calculate the changes in delay resulting from an addition of an inspection lane to a

BC using the queuing model, the arrival rate (λ), service rate (μ), and number of lanes (N) are required. Substituting P_0, $\bar{Q}$, ρ from Equations 5.4, 5.3 and 5.2 in $\bar{W}$ in Equation 5.1, makes $\bar{W}$ a complex summation function of μ:

$$\bar{W} = \frac{\frac{\lambda}{\mu} + \frac{1}{\sum_{n_c=0}^{N-1}\left(\frac{\lambda^{n_c}}{\mu^{n_c} n_c!}\right) + \frac{\lambda^N}{\mu^N N!(1-\frac{\lambda}{\mu N})}} \cdot \frac{\lambda^{N+1}}{\mu^{N+1} N! N} \cdot \left[\frac{1}{(1-\frac{\lambda}{\mu N})^2}\right]}{\lambda} \tag{5.5}$$

As shown by equation 5.5, μ cannot be determined analytically given $\bar{W}$ because of the embedded summation form leading to variability of the order of the problem. Thus, for each BC, an exhaustive search method was used to find μ, given an average waiting time, $\bar{W}$. The lower-bound for the exhaustive search is set to $\frac{\lambda}{N}$ to ensure $\frac{\rho}{N} < 1$, which is a condition under which the queuing formulations are valid (Stability condition: $\frac{\rho}{N} < 1 \rightarrow \frac{\lambda}{\mu N} < 1 \rightarrow \frac{\lambda}{N} < \mu$). If this condition is violated, the queue would grow infinitely. The service rate (μ) was increased until the search stopping criterion, $| \bar{W}_{estimated} - \bar{W}_{observed} | < \varepsilon$, was met, where ε is an error threshold set to 0.68 minutes, or 10% of the minimum of annual delays. In other words, a small arbitrary increment is added to μ of the previous step in each iteration, and the search stops when the stopping criterion is met. Figure 5.1 shows the search results for Ambassador Bridge.

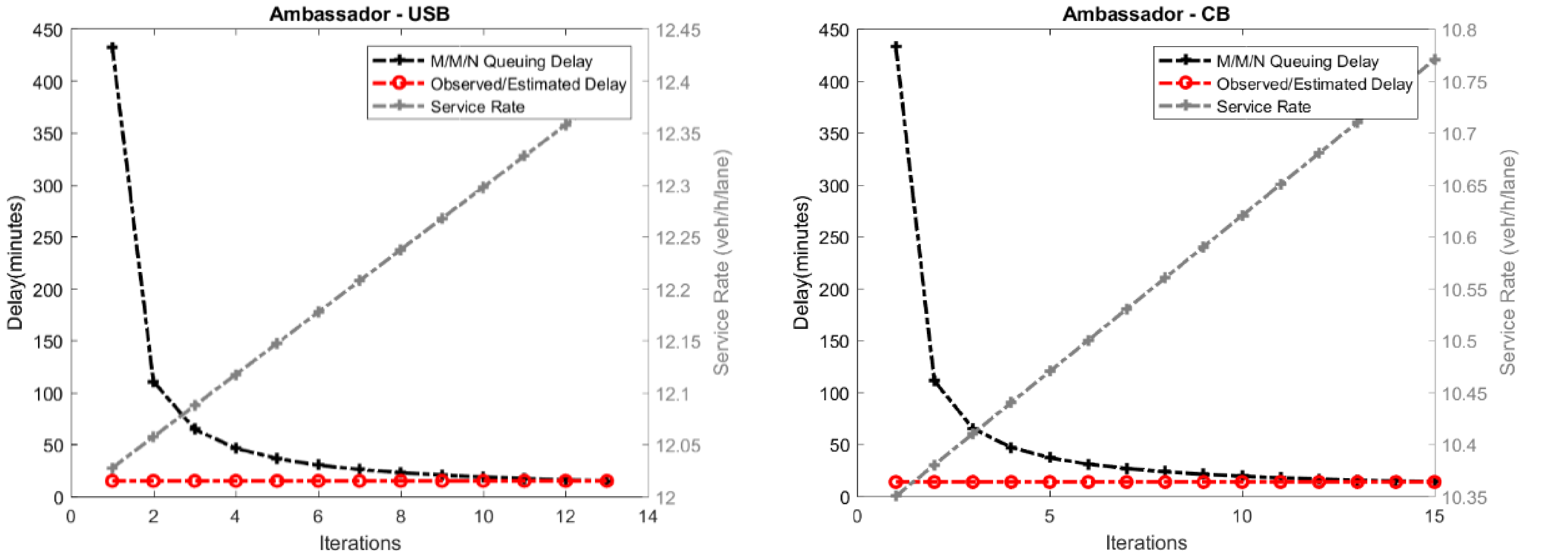

Figure 5.1: BC service rate calibration-Observed delay vs. simulated delay

Table 5.2 summarizes the BC attributes, including the estimated service rates, and the difference between observed and predicted wait times. Upon finding μ for each BC, Equation 5.1 is used to calculate the changes in delay as a result of adding an inspection lane to each BC (last column of Table 5.2).

Table 5.2: Border crossing attributes

Name of Border	Arrival rate (λ) [veh/h]	# of commercial lane(s)	# of FAST lane(s)	Estimated service rate (μ) [veh/h/lane]	Total service rate ($N.\mu$) [veh/h]	Observed wait time [min/veh]	Wait time estimation error (observed-estimated)	Change in delay resulting from addition of one inspection lane
Ambassador	168.24	13	1	12.38	173.32	14.95	-0.3418	54%
Coutts	16.85	2	0	10.77	21.54	13.75	-0.6379	54%
Emerson	26.31	4	0	7.87	31.48	14.72	-0.6123	40%
FortErie	70.67	7	1	9.60	76.8	12.95	-0.6688	41%
Huntingdon	16.90	2	0	10.82	21.64	13.55	-0.6609	54%
Lacolle	32.28	9	1	4.77	47.7	12.66	-0.6633	3%
Lansdowne	21.60	3	0	8.62	25.86	16.30	-0.5996	50%
Niagara	39.14	4	1	8.88	44.4	14.42	-0.5894	44%
NorthPortal	11.31	3	0	5.86	17.58	13.55	-0.6286	22%
PacificHighway	41.33	3	1	11.48	45.92	14.83	-0.6645	56%
RockIsland	11.05	2	1	6.46	19.38	10.89	-0.6771	16%
Sarnia	86.08	9	1	9.11	91.1	15.66	-0.6384	46%
SaultSteMarie	5.03	2	0	5.48	10.96	13.24	-0.6482	18%
StStephen	7.01	3	0	8.28	24.84	6.77	-0.6773	2%
WoodstockRoad	9.61	2	0	8.84	17.68	8.99	-0.6574	25%

The relatively high percentage change for BCs resulting from the addition of an inspection lane indicates that the BCs are operating near capacity, where small changes in capacity can substantially decrease delays. This is also evident from the decreasing rate of delay change with respect to μ in Figure 5.1.

5.2.Mode choice modelling

The mode choice analysis takes advantage of the recently released Canadian Freight Analysis Framework (CFAF) database, which captures intra- and inter- national Canadian trade flows at an aggregated level. The database consists of aggregated trade flows between Canadian Census Metropolitan Areas (CMA) and provinces, classified according to the 2-digit Standard Classification of Transported Goods (SCTG). International trade is highly aggregated into two origins/destinations: one representing the US and Mexico; and the second representing other countries. For each CMA and each commodity class, the database includes the mode of transport, number of shipments, aggregated weight, aggregated revenue, aggregated distance travelled, aggregated Tonne-Km, and aggregated value of trade.

From the database, the average weight, average value, average distance, and average shipper revenue (i.e., transportation cost) were calculated for each mode and Origin-Destination (OD) pair. It was found that air transport is associated with lower weights, higher transportation costs, and higher values of transported goods. Therefore, investments in road infrastructure are not expected to trigger a mode shift for high-value commodities transported by air. Hence, the analysis focuses on the two most common modes of land transportation: truck and rail. Records with only one mode are considered mode captive and are not included in the mode choice analysis.

An aggregate Multinomial Logit (MNL) model is used to analyze shippers' mode choices. The dependent variable is the ratio of shipment weights by truck to that of rail. Independent variables include relative differences or relative advantages of truck mode over rail mode in terms of number of shipments, aggregated weight, aggregated revenue, aggregated distance-travelled, aggregated TonneKm, aggregated value of trade, average weight, average value, average distance, and average shippers' revenue. The aggregate logit model is found by dividing two logit probabilities by each other and taking the natural logarithm, which gives a log-linear regression in the form:

$$Ln\left(\frac{P(truck)}{P(rail)}\right) = \boldsymbol{\beta}\mathbf{X} \tag{5.6}$$

where **X** is a vector of independent variables (differences) including dummy variable for each commodity class, and **β** is the vector of coefficients corresponding to each independent variable. *P(a)* is the probability of choosing mode "*a*", which is equivalent to the percentage of shipment weight transported by mode *a* in the base year dataset. This technique is well-known as the Berkson-Theil transformation (see 6.5.4 in Ortúzar and Willumsen, 2011), and has been widely used in freight demand modelling when only aggregate mode share data are available (Tavasszy & de Jong, 2013). The aggregate MNL model can be estimated using Ordinary Least Square (OLS) regression. The correlation coefficient matrix between explanatory variables is presented in Table E.1 in Appendix E.

All possible model specifications (i.e., combinations of independent variables) were tested and the resulting model performances (R^2) are illustrated in Figure 5.2, where the horizontal axis represents the scenario number, which increases with the number of variables included in the model.

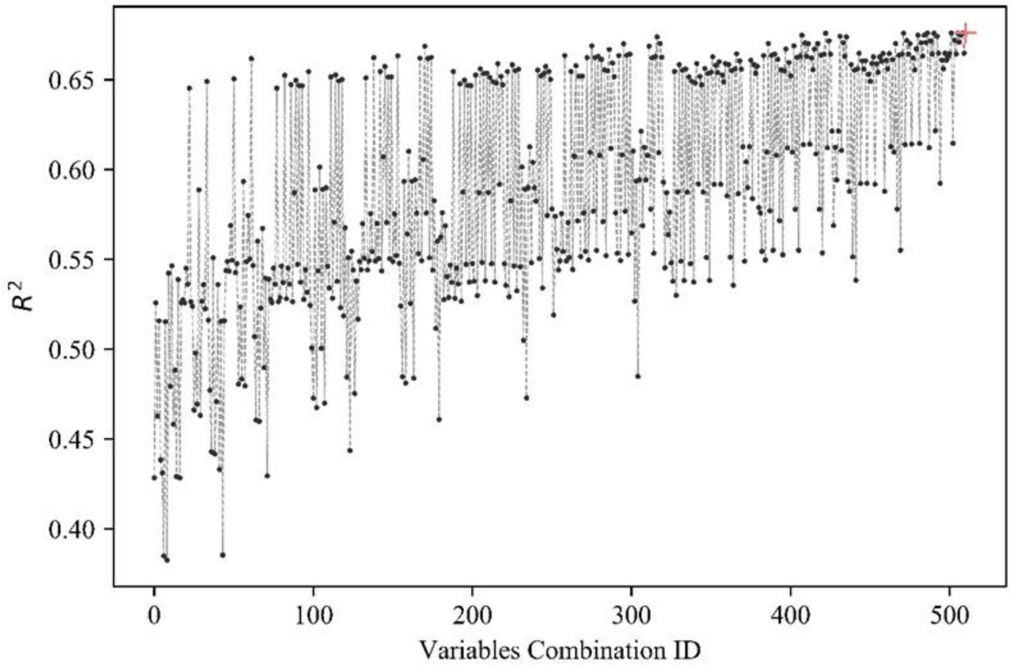

Figure 5.2: Logit models' performances

Naturally, including all variables in the model results in the highest R^2. However, this model was not considered for two reasons: first, there is a high level of correlation between some variables (e.g., 92% of correlation between revenue and TonneKm), so they should not be included simultaneously in the model; and second, there is no logical justification to include variables such as number of shipments in the model. Instead, a parsimonious model consisting of three variables was specified and benchmarked against the possibilities shown in Figure 5.2: it includes average revenue, average distance, average weight, and dummy variables for each commodity class. The model resulted in an R^2 of 0.54, which is acceptable considering that the highest attainable R^2 is 0.68. The model resulted in an adjusted R^2 of 0.51, which is comparable to the maximum attainable adjusted R^2 of 0.65. All variables are significant at the 90% level of significance (i.e., p-values of less than 10%). The logit model statistics are presented in Table 5.3.

The corresponding MNL model systematic utility functions are:

$V_{truck} = 0.75765 + 0.00003\ Average\ Weight_{truck} -$

$0.00010\ Average\ Revenue_{truck} - 0.00116\ Average\ Distance_{trcuk}\ + \beta_{COM} X_{COM}$

(5.7)

$V_{rail} = 0.00003\ Average\ Weight_{rail} - 0.00010\ Average\ Revenue_{rail} -$

$0.00116\ Average\ Distance_{rail}\ + \beta_{COM} X_{COM}$

(5.8)

Table 5.3: Logit model statistics summary

R^2 : 0.54 Adjusted R^2: 0.51 Number of observations: 204				
Variable	**Coefficients**	**t-statistics**	**p-value**	**Confidence Interval (95%)**
Constant	0.75760	2.06	0.041	[0.031, 1.484]
Average Weight [kg]	0.00003	3.44	0.001	[0.00001, 0.00005]
Average Revenue [C$]	-0.00010	-1.83	0.069	[0, 0.0000079]
Average Distance [km]	-0.00120	-5.51	0.000	[-0.002, -0.001]
Sector Dummy Variables				
Other Manufactured goods	3.60210	5.64	0.000	[2.341, 4.863]
Miscellaneous products	1.61270	2.52	0.013	[0.35, 2.876]
Minerals	0.26630	0.50	0.621	[-0.795, 1.328]
Plastic and Chemical products	-0.50580	-0.96	0.341	[-1.55, 0.539]
Food	2.08370	3.92	0.000	[1.034, 3.133]
Agricultural products	1.25320	2.33	0.021	[0.192, 2.314]
Base metals and Articles of Base metals	1.66270	3.14	0.002	[0.617, 2.708]
Forest products	0.24670	0.47	0.639	[-0.79, 1.283]
Fuel Oils and crude petroleum	-4.03530	-7.44	0.000	[-5.105, -2.966]
Automobiles and other Transportation Equipment	0.54000	0.98	0.330	[-0.551, 1.631]
Waste and Scrap	-0.35210	-0.67	0.505	[-1.393, 0.689]
Coal	-5.61630	-4.45	0.000	[-8.106, -3.127]

Average shipment revenue, average shipment weight, and average shipment distance represent mode specific variable; X_{COM} and β_{COM} represent commodities dummy variables and their associated coefficients, respectively. Average distance has a negative coefficient, which means that with a decrease in average distance of truck relative to rail, the truck mode becomes more attractive and thus triggers a mode shift from rail to truck. Similarly, average revenue has a negative coefficient, which means that with a decrease in average revenue (cost) of truck relative to rail, the truck mode becomes more attractive and thus triggers a mode shift from rail to truck. On the other hand, average weight has a positive coefficient, which means that with an increase in the average shipping weight of truck relative to rail, i.e., use of trucks with higher carrying capacity, the truck mode becomes more attractive and thus triggers a mode shift from rail to truck.

Using equation 5.9 (Train, 2009), the elasticities of truck mode with respect to average distance and average cost are calculated:

$$E_{i,X_{ni}} = \frac{\partial V_{ni}}{\partial X_{ni}} X_{ni}(1 - P_{ni}) \tag{5.9}$$

where $E_{i,X_{ni}}$ is the elasticity of probability of choosing mode *i* by decision maker *n*, P_{ni}, with respect to modelling variable X_{ni}. V_{ni} is the deterministic part of utility function of decision maker *n* for mode *i*.

The 85th percentile of elasticities for average distance and average cost are -0.19 and -0.02, respectively. The elasticities represent the percentage change in truck mode share resulting from a one percent change in the model variables. The calculated elasticities are relatively small; given the expected magnitude of change in the three variables, the mode shift is not expected to be substantial.

5.2.1.Mode shift calculation

Of interest to this study is the potential mode shift resulting from adding an inspection lane to a border crossing. First, using the BC delay model, the changes in delay as a result of adding an inspection lane are calculated. Savings in delay time are translated to savings in average distances using an average truck speed. The savings in travel distances are then used to calculate mode shifts resulting from the travel distance savings.

The average travel distance for commodity *c* is calculated as follows:

$$d^c = \frac{\sum_i \sum_j \sum_b d^c_{ij,b} . s^c_{ij,b}}{\sum_i \sum_j \sum_b s^c_{ij,b}} \tag{5.10}$$

where $d^c_{ij,b}$ is average distance that commodity *c* is transported from origin *i* to destination *j*, and through border crossing *b*. $s^c_{ij,b}$ represents the number of shipments of commodity *c* from origin *i* to destination *j*, and through border crossing *b.*

Decoupling the numerator to separate the border of interest, b^*, from the other borders, results in:

$$d^c = \frac{\sum_i \sum_j \sum_b d^c_{ij,b} . s^c_{ij,b} + \sum_i \sum_j d^c_{ij,b^*} . s^c_{ij,b^*}}{\sum_i \sum_j \sum_b s^c_{ij,b}} \tag{5.11}$$

The changes in d^c resulting from changes in b^* is calculated as follows:

$$\Delta d^c_{b^*} = \frac{\Delta d^c_{ij,b^*} \sum_i \sum_j s^c_{ij,b^*}}{\sum_i \sum_j \sum_b s^c_{ij,b}} = \Delta d^c_{ij,b^*} \times BCTS_{b^*} \tag{5.12}$$

where $\frac{\sum_i \sum_j s^c_{ij,b^*}}{\sum_i \sum_j \sum_b s^c_{ij,b}}$ is the share of number of shipments through border crossing b^*, which can be approximated by the Border Crossing Trucks Share (BCTS). $\Delta d^c_{ij,b^*}$ is the change in average transport distance of commodity *c*, transported through border crossing b^*, which is calculated as follows:

$$\Delta d^c_{ij,b^*} = s \times \Delta t^c_{ij,b^*} \tag{5.13}$$

where s is the average trucking speed of 5 mph at border crossings(Roberts et al., 2014), and $\Delta t^{c}_{ij,b^*}$ is the change in travel time of transporting commodity *c* from region *i* to region *j* through border crossing b^*, which is calculated from the border crossing queueing model.

The $\Delta d^{c}_{b^*}$ ranges from 0 km to 0.47 km, with an 85th percentile of 0.09 km. Changes in a probability of choosing a mode with respect to changes in modelling variable can be calculated as follows (Train, 2009):

$$\frac{\partial P_i}{\partial X_j} = \frac{\partial V_i}{\partial X_j} P_i(1 - P_i) = \beta_{X_j} P_i(1 - P_i) \tag{5.14}$$

where V_i is the linear form of perceived utility from using mode *i*; P_i is the probability of choosing mode *i*; X_j and β_{X_j} are the modelling variable and its corresponding coefficient in the utility function V_i. From Equation 5.14, the changes in the probability of choosing a mode with respect to changes in a modelling variable is $-\beta_{X_j} P_i(1 - P_i)\, \partial X_j$. The coefficients of Average Distance variable in the modes' utilities is -0.00116; given that the maximum change in Average Distance variable is 0.47 and that $P_{truck}(1 - P_{truck})$ is maximized when $P_{truck} = 0.5$, the maximum expected change in choosing truck mode resulting from adding a lane to a BC is 0.00014, which is negligible. Therefore, this analysis suggests that addition of an inspection lane to a BC would have little to no effect on shippers' mode choice behavior. Although mode shifts were not substantial in this study, it should not be concluded that mode choice analysis should be disregarded in BC infrastructure investment studies, since the impacts of mode choice may be different in other cases.

5.3.Simulation results

This section presents the analysis results of examined scenarios, which includes addition of one inspection lane/booth to each BC, a reduction of 35% reduction in BC delays, and a 4 minutes reduction in BC delays under long and short term closures. The 35% is calculated based on the averages of percentage reductions in BC delays resulting from an addition of one lane to each BC; the 4-minute reduction is calculated to allow a 50% reduction in the minimum BC delay. The scenarios are compared with respect to changes in industry-level trade value, GDP, and welfare – measured in Hick's Equivalent Variation (EV) – from Canadian perspective. All the figures in this section are annual and in 2011 USD unless indicated otherwise. The results for an addition of a lane to each BC are discussed in this section, unless explicitly indicated otherwise.

Figure 5.3 presents the long- and short- term changes of Canada's export resulting from BC improvements. The changes consist of both positive and negative export change. The BC improvements always lead to an increase in Canada's export for all the scenarios. The long term changes of exports (red lines) are more than two times larger than the short term changes (black lines). Ambassador Bridge is the most important BC for Canada's export, followed by Sarnia and Fort Erie. The long-term changes range from 0.02M USD to 27.77M USD, while the short-term export changes can range from 0.02M USD to 10.72M USD. In average Canada's export increases by 0.002M USD and 0.005M USD in short and long term, respectively.

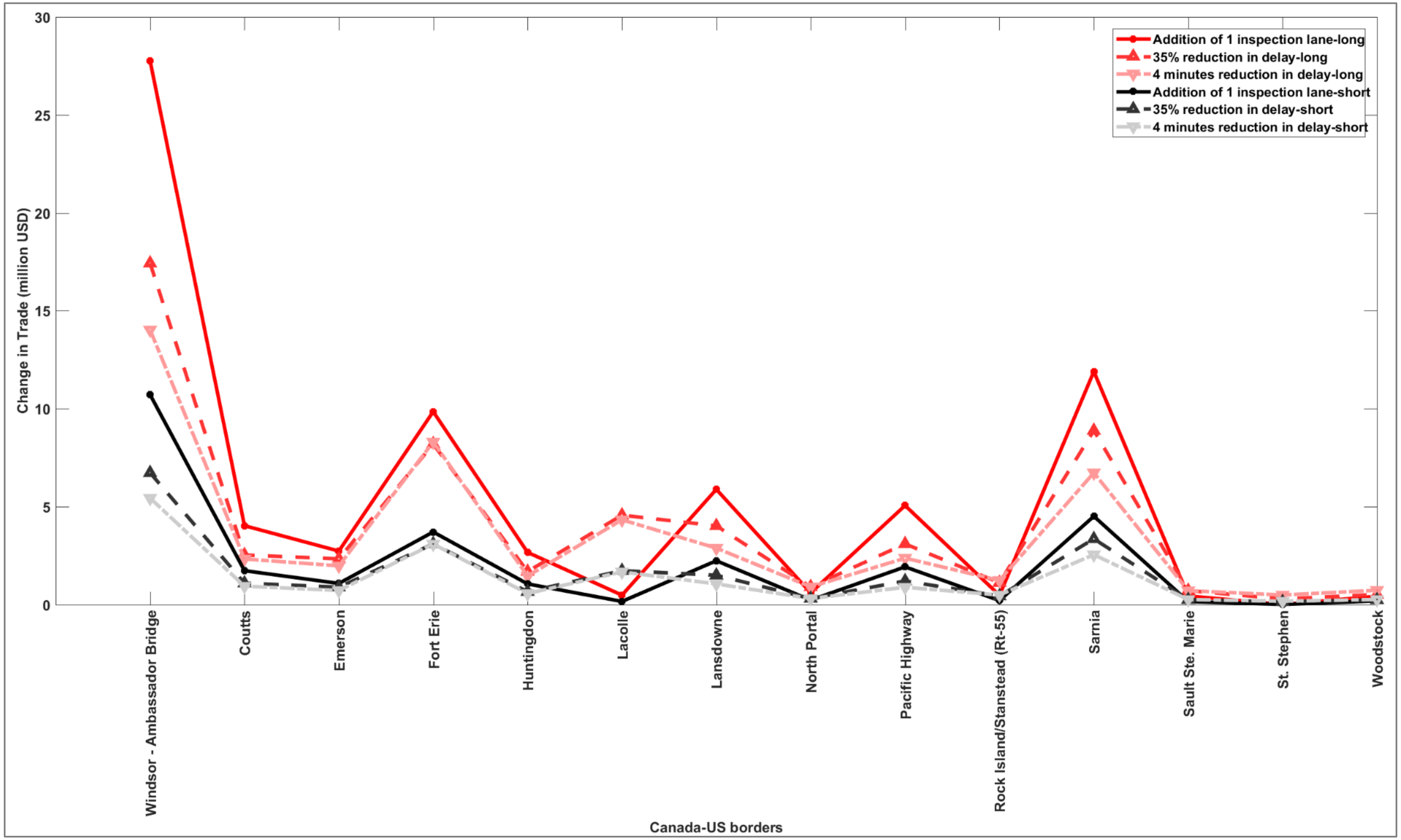

Figure 5.3: Canada's international export change

Recall that this framework determines how each border crossing improvement uniquely impacts each industry through the empirical datasets described previously. Therefore, each industry benefits differently from a BC improvement. Figure 5.4 and Figure 5.5 present the long- and short- term changes in Canada's export to the US resulting from an addition of one lane to each BC. Canada's chemical, rubber and plastic industry exhibits the maximum export change of 8.47M USD and 6.30M USD to the US in long and short term, respectively, as a result on investment in Ambassador Bridge. In the long term, the oil industry in Canada faces the maximum reduction of 0.86M USD in trade with the US as a result of the investment in Ambassador Bridge. In the short term, however, investment in Ambassador Bridge results in the maximum reduction of 0.85M USD in the metal industry's export to the UK. The average increase in Canada's export internationally is 0.12 M USD and 0.084M USD for long and short terms respectively, while increases in Canada's export to the US are 0.20M USD and 0.18M USD in the long and short terms, respectively. For Canada's export to the US, Ambassador Bridge is the most critical BC, followed by Sarnia and Fort Erie.

In comparing Figure 5.4 and Figure 5.5, note that Figure 5.4 is filled with more red cells compared to Figure 5.5, which means that the positive impacts of BC investments are felt more in the long term. Figure 5.6 and Figure 5.7 illustrate short and long term changes of Canada's export to the US in 3-dimensions (3D). The bars in the long term are larger than that of short term, which again means that the magnitude of the BC infrastructure investments are felt more in the long term than in short term. Note that although the overall impacts of BC improvement are positive on the overall trade (Figure 5.3), the impacts of BC improvement varies across industries and is not necessarly positive (grey cells in Figure 5.4 and Figure 5.5).

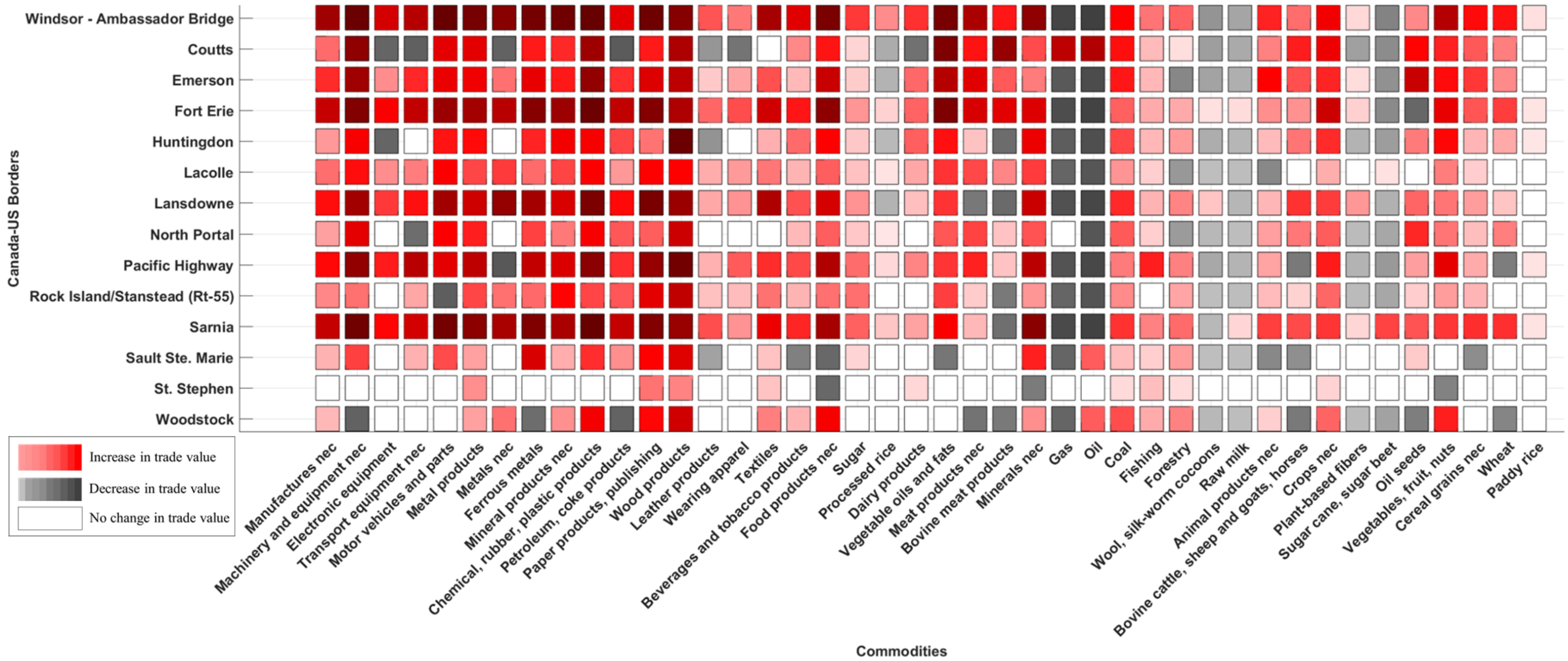

Figure 5.4:Long-term changes in Canada's export to the US

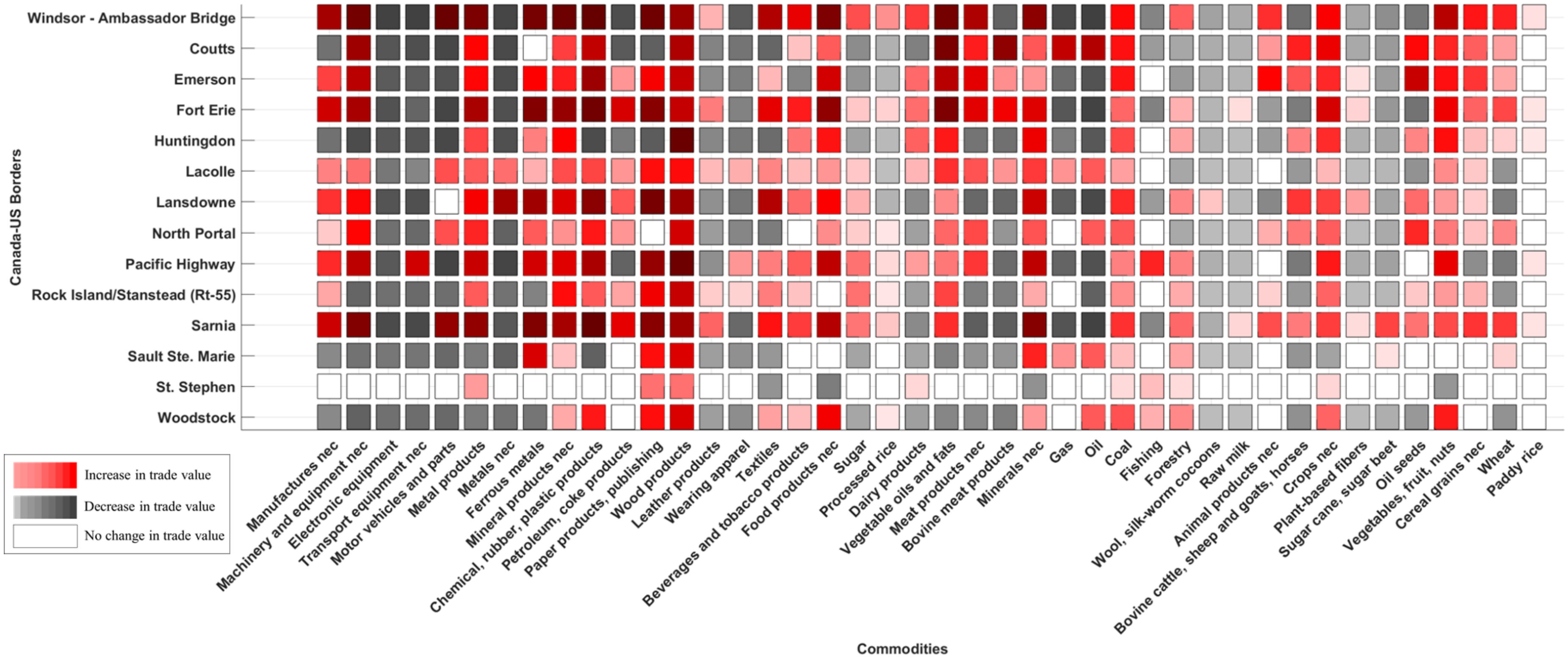

Figure 5.5: Short-term changes in Canada's export to the US

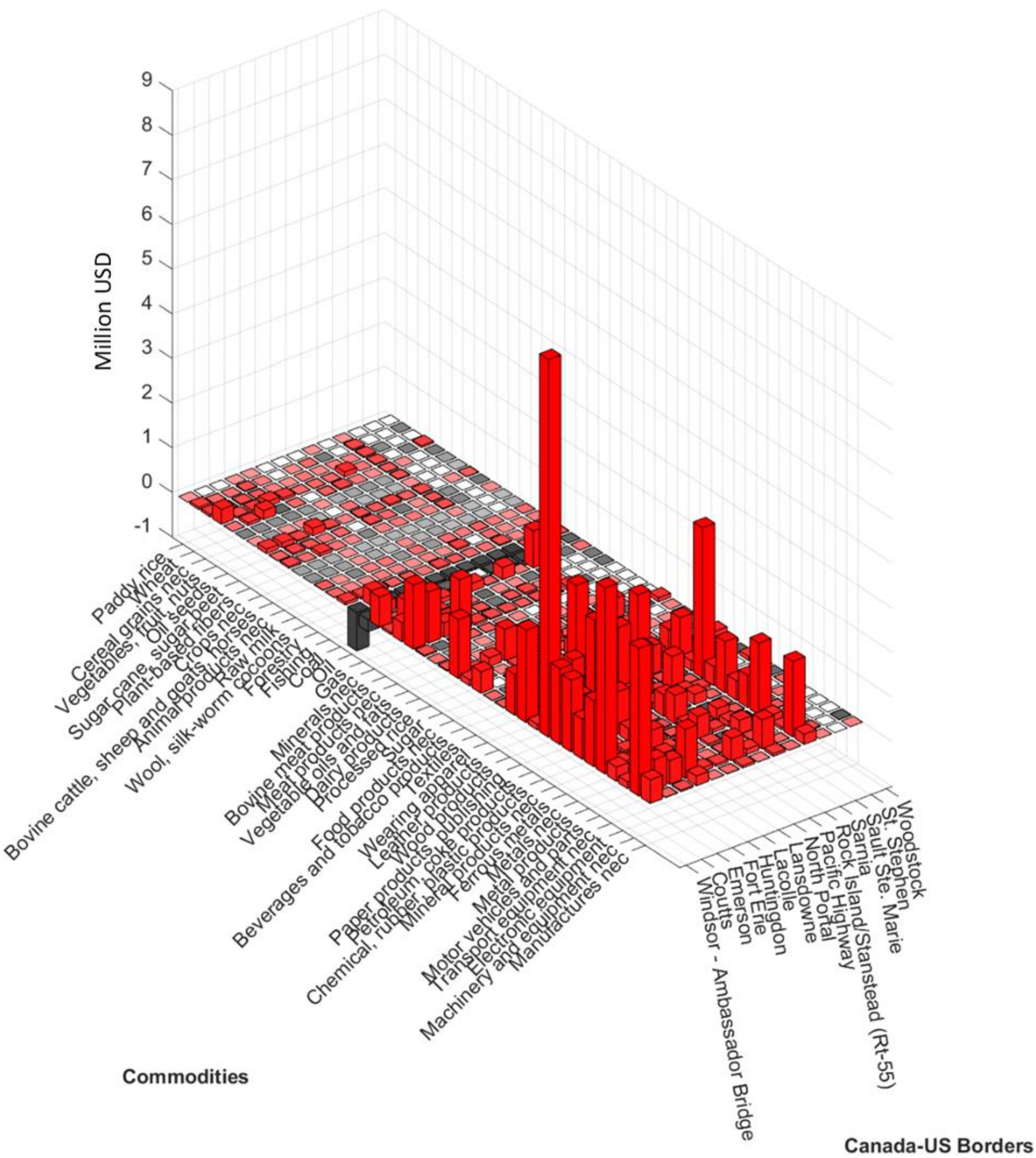

Figure 5.6: Long-term changes in Canada's export to the US-3D

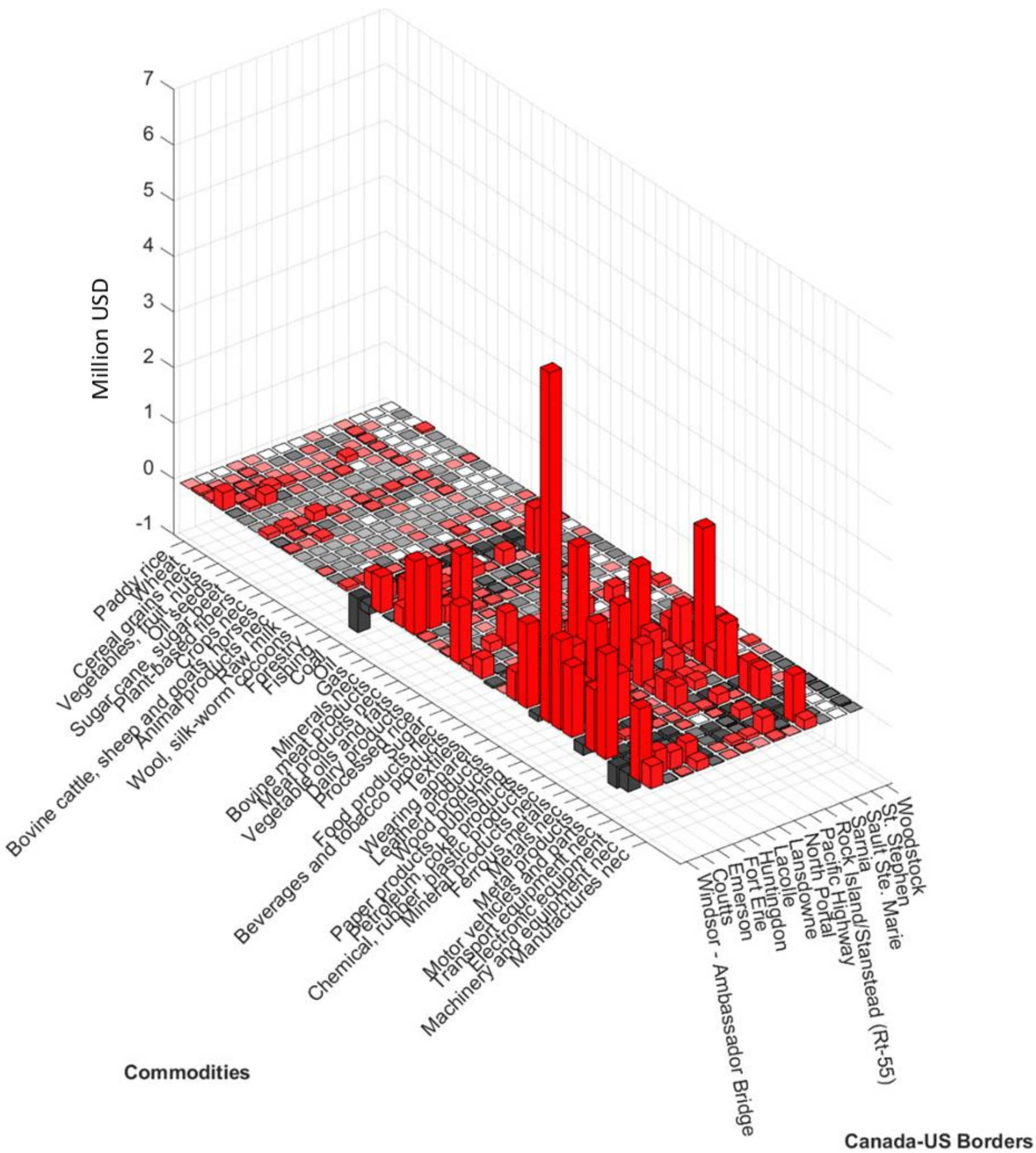

Figure 5.7: Short-term changes in Canada's export to the US-3D

Figure 5.8 presents the long and short term changes in Canada's GDP resulting from BC infrastructure investment. Investment in BCs always have positive impact in Canada's GDP. Long-term impacts of BC investment – shown in red lines – are three times larger than that of short-term impacts-shown in black lines. Canada's GDP change ranges from 0.07M USD to 92.44M USD in the long term and ranges between 0.04M USD and 33.28M USD in short term. The averages of Canada's GDP change are 5.19M USD and 14.29M USD for short and long terms across all scenarios – addition of one lane, a 35% reduction in BC delays, and reduction of BC delays by 4 minutes. Ambassador Bridge is the most critical BC for Canada's GDP across all the scenarios, followed by Sarnia and Fort Erie BCs.

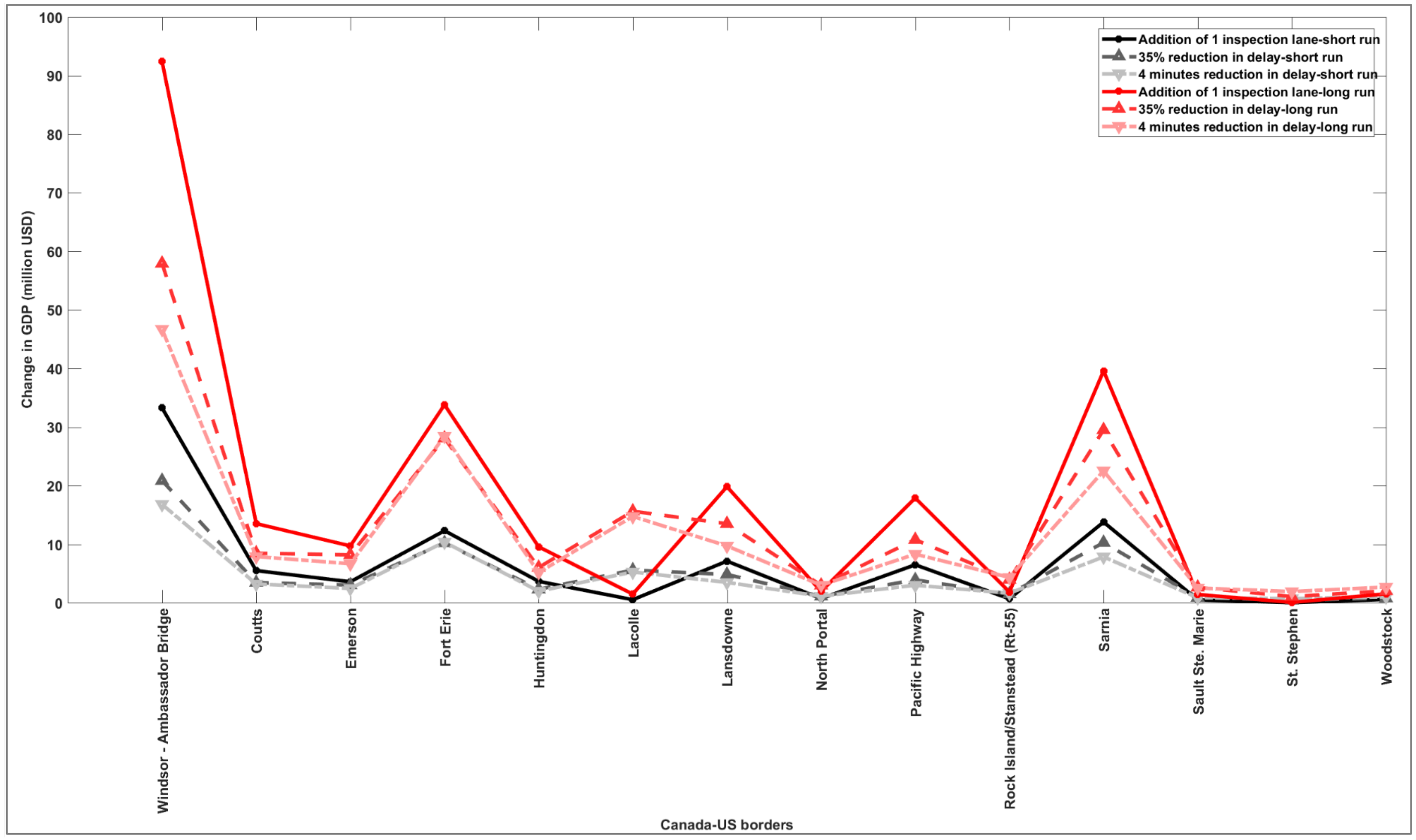

Figure 5.8: Canada GDP change

Figure 5.9 presents the changes in Canada’s welfare change resulting from Canada-US BC investment. BC infrastructure improvement always have a positive impacts on Canada’s welfare. Long-term impacts of BC investment – shown in red lines – are more than ten times larger than that of short-term impacts-shown in black lines. In long term, Canada’s welfare change range from 0.06M USD to 79.83M USD, while in the short term, the changes range from 0.01M USD to 6.76M USD. In average and across all scenarios, Canada’s welfare changes by 12.26M USD and 1.07M USD in the long and short term, respectively. Ambassador Bridge is the most critical BC to Canada’s welfare, followed by Sarnia and Fort Erie. Internationally, countries other than Canada and the US may face a welfare reduction as a result of improvement in Canada-US BCs. For example, adding a lane to Ambassador Bridge results in a welfare loss of 34.78M USD to European Union (EU). The welfare changes for countries other than the US and Canada range from -34.78M USD to 0.89M USD in long term and -0.98M USD to 0.22M USD in the short term. It is evident that the impacts of BC investments on other countries’ welfares are larger in the long term than in short term.

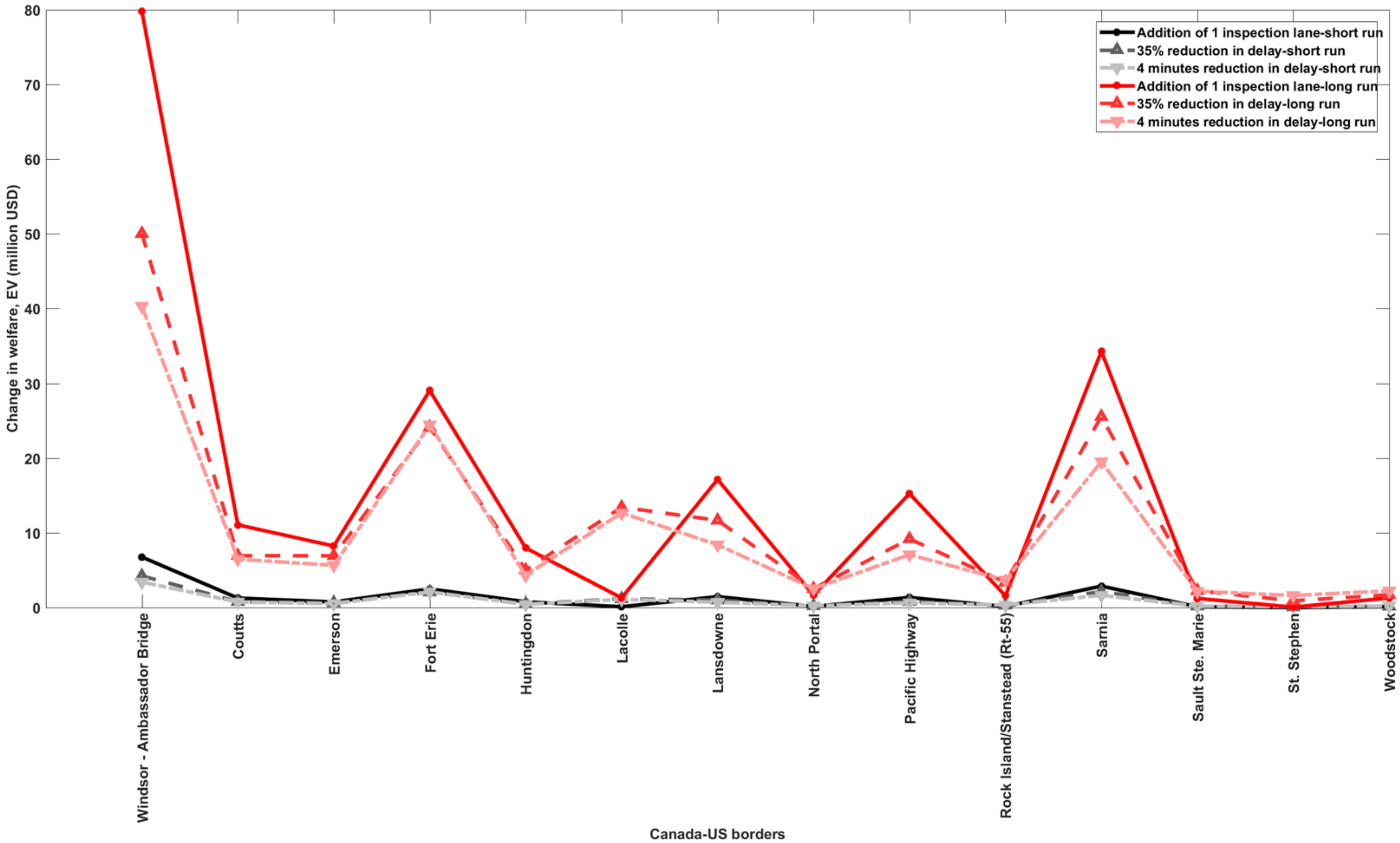

Figure 5.9: Canada's welfare change

5.4.Validation

To validate the modelling results, the estimated number of trucks are compared to observed number of trucks for each BC. The observed number of trucks were obtained from the BIIP report (BIIP, 2016). The estimated number of trucks were calculated using the number of trucks generated by trade flows (i.e., converted from trade flows to commodity weights to truck volumes) and were scaled up based on empty truck estimates from two different sources: the Eastern Border Transportation Coalition (EBTC) report by Donnelly (2002), which is produced as a subcomponent of the National Roadside Survey (NRS) study of Transport Canada; and the Ministry of Transportation of Ontario (MTO) Commercial Vehicle Survey (CVS) 2012 database.

The relative errors between the observed and estimated number of trucks are illustrated in Figure 5.10. The average relative error is 29% and the maximum is 70%, which is associated with a relatively low truck volume (5 veh/h). The average absolute error is 13.57 [veh/h], while the maximum of absolute errors is 56.32 [veh/h], which is associated with Ambassador Bridge, which has highest truck volume of 168.24[veh/h]. On average, and for most of the border crossings, the model generates a reasonable number of trucks. The errors are associated with different benchmark years and seasonality of the databases used for validation. The number of trucks are estimated using the GTAP model trade values for year 2011, while the EBTC and MTO CVS databases use 1999 and 2012 data. The BIIP reports uses 2014 observations for the reported truck volumes. MTO CVS data was collected for 7 days of 2012, while other databases used annual data. Additionally, the simulated truck volumes generated by the GTAP database are compared to the observed truck volume reported in BIIP reports. For Salute Ste Marie BC, the simulated truck volumes exceed the observed volume, which further highlights the differences in the databases.

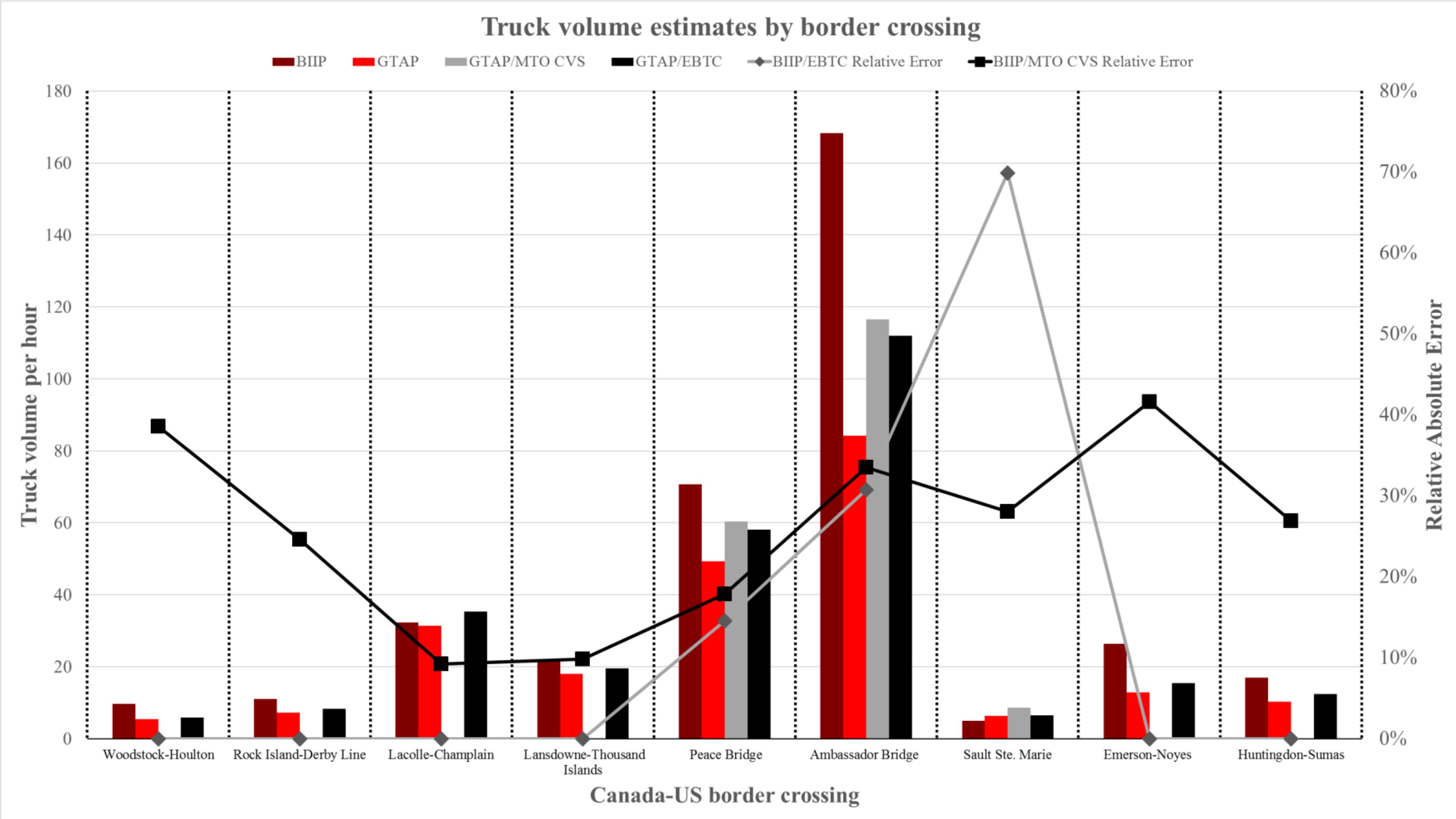

Figure 5.10: Truck volume estimates by border crossing

5.5.Discussion of results

As shown in Figure 5.3, improving Canada-US BCs are expected to always have positive impacts on Canada's total exports internationally across all tested scenarios: addition of one lane to each BC, reducing BC delays by 35%, and reducing BC delays by 4-minutes. Although the overall impacts on trade are positive, some Canadian industries may face a reduction in trade resulting from a BCs improvement. For example, Canada's oil industry faces a reduction of 0.86M USD in its long-term export to the US resulting from an addition of one inspection lane to Ambassador Bridge. Similarly, the electronic equipment industry in Canada faces a reduction of 0.084M USD in its short-term exports to the US due to an improvement in the Fort Erie BC.

In both the short and long terms, the reduction in trade can be traced back to the underlying theoretical assumptions of the CGE model. An investment in Canada to US BCs results in lower transportation costs, which makes Canadian commodities cheaper in the US market and thus more competitive. This competitiveness – lower prices – leads to increase in demands for Canadian products in US markets, which drives up the production of Canadian products. With an increase in the production of Canadian products, the demand for factors of production (land, labour, capital) also increases. In both short and long term analyses, the increased demand for production factors, drives up the price of factors of production with fixed quantity. In the short term, all factors of production – land, labour, capital, and natural resources- are assumed to have fixed quantities, while in the long-term, only land and natural resources are assumed to have fixed quantities. The increase in the prices of factors of production results in an increase in production price of Canadian commodities. If the decrease in transportation costs – resulting from the BC infrastructure investment – does not offset the increase in the production prices in Canada – resulting from increased demand for the factors of production – trade values decrease, as is the case of the oil and gas industries under both short and long term improvements of Ambassador Bridge. Note that an increase in demand of factors of production increases the prices of factors of production for all industries, thus, an increase in demand of one industry can impact the production prices of others. In the case of Fort Erie improvement and under long term, the decreased transportation cost does not offset the increased production cost for oil industry, resulting in a decrease of 0.38M USD in exports to the US.

As shown in Figures 5.3-5.9, the long-term effects of BC improvements are always larger than the effects in the short term across all scenarios. This is again rooted in the structure of the CGE model, particularly the difference of microeconomic closure in the short and long terms. The long term microeconomic closure assumes that the rate of return on capital and wages of labour are fixed exogenously and the supply quantities of the two are allowed to change. Thus, an expanding industry can use the "unlimited" supply pool of the factors of production to increase their level of production. On the other hand, the short term microeconomic closure assumes a fixed supply quantity of all factors of production, allowing the rate of return on capital and the wage rate to vary. In the short term, expanding industries are faced with a limited supply pool of factors of production. The more accessible supply pool of factors of production in the long run results in industries expanding more in the long term. In other words, the long-term closure imposes a less restrictive assumptions on the supply of factors of production than short-term closure, and thus allowing expanding industries to expand more compared to short term; this causes the benefits of BC infrastructure investment to Canada's trade, GDP, and welfare to be larger in the long term than in the short term.

As mentioned before, BC investments have international ramifications. As simulation results suggest, improving Canada-US BCs results in decreases to other countries welfares. For example, improving Ambassador Bridge results in -34.78M USD of welfare loss to the European Union (EU) in the long term. The reason is that the improvements of BCs between Canada and the US makes other countries less competitive in the two countries markets and thus results in trade diversion between the two countries and the rest of the world, and trade creation between Canada and the US. The trade diversion with other countries results in lower production levels by other countries, which in turn results in welfare losses due to lower income. The magnitude of the impacts of Canada-US BC investments on other countries welfare is influenced by the countries trade level with Canada and the US. For example, the EU that has six times as much trade with Canada and the US compared to Switzerland, and hence is impacted more severely (-34.78M USD vs. -2.11M USD), by Canada-US trade creation. Note that there are countries other than Canada and the US that benefit from the Canada-US BCs improvements, which is due supply-chain dependencies of countries on one another. For example, improving Canada-US BCs results in a small welfare increase in Russia, since the overall trade between Russia, Canada and the US is increased due to supply-chain dependencies. These results indicate that the complexity of global supply chains needs to be considered when evaluating changes in BC improvements, if all direct, indirect, and induced effects are to be accounted for.

Table 5.4 presents the rankings of all investigated BCs with respect to Canada’s welfare change, GDP change, trade change with the US, and level of trade with the US. From Table 5.4, it is evident that investment priorities change with investment objectives. For example, if the objective is to maximize Canada’s welfare, then Ambassador Bridge, Sarnia, and Fort Erie are most important (in descending order);

which is different from BC priorities with respect to the existing export from Canada to US: Ambassador Bridge, Fort Erie, and Sarnia (in descending order). Referring to Table 5.4, Ambassador Bridge, Sarnia, and Fort Erie BCs are the three most important BCs for Canadian economy across all measures. Other priorities – e.g., seventh and eighth, etc.– vary given the objective. For example, Huntingdon is the seventh most important BC for maximizing Canada's GDP in short term, while Huntingdon is the eighth BC priority for maximizing Canada's export to the US under short term.

Table 5.4: Border crossing rankings

Canada's EV Change_Short	Canada's EV Change_Long	Canada's GDP Change_Short	Canada's GDP Change_Long	Canada's International Export Change_Short	Canada's International Export Change_Long	Canada to US Export Change_Short	Canada to US Export Change_Long	Canada to US Export
Ambassador Bridge	Ambassador Bridge	Ambassador Bridge	Ambassador Bridge	Ambassador Bridge	Ambassador Bridge	Ambassador Bridge	Ambassador Bridge	Ambassador Bridge
Sarnia	Sarnia	Sarnia	Sarnia	Sarnia	Sarnia	Sarnia	Sarnia	Fort Erie
Fort Erie	Fort Erie	Fort Erie	Fort Erie	Fort Erie	Fort Erie	Fort Erie	Fort Erie	Sarnia
Lansdowne	Lansdowne	Lansdowne	Lansdowne	Lansdowne	Lansdowne	Lansdowne	Lansdowne	Lacolle
Pacific Highway	Pacific Highway	Pacific Highway	Pacific Highway	Pacific Highway	Pacific Highway	Pacific Highway	Pacific Highway	Lansdowne
Coutts	Coutts	Coutts	Coutts	Coutts	Coutts	Coutts	Coutts	Pacific Highway
Huntingdon	Emerson	Huntingdon	Emerson	Emerson	Emerson	Emerson	Emerson	Coutts
Emerson	Huntingdon	Emerson	Huntingdon	Huntingdon	Huntingdon	Huntingdon	Huntingdon	Emerson
North Portal	North Portal	North Portal	North Portal	North Portal	North Portal	North Portal	North Portal	Woodstock
Rock Island	Rock Island	Rock Island	Rock Island	Rock Island	Lacolle	Rock Island	Rock Island	North Portal
Woodstock	Lacolle	Woodstock	Woodstock	Woodstock	Rock Island	Woodstock	Lacolle	St. Stephen
Lacolle	Woodstock	Lacolle	Lacolle	Lacolle	Sault Ste. Marie	Lacolle	Woodstock	Rock Island
Sault Ste. Marie	Sault Ste. Marie	Sault Ste. Marie	Sault Ste. Marie	Sault Ste. Marie	Woodstock	Sault Ste. Marie	Sault Ste. Marie	Huntingdon
St. Stephen	St. Stephen	St. Stephen	St. Stephen	St. Stephen	St. Stephen	St. Stephen	St. Stephen	Sault Ste. Marie

Another observation in Table 5.4 is that BC investment priorities are different from the intuition that the most important borders are those that carry the most truck traffic. For example, Fort Erie is the second most important BC in terms of carrying trade with the US, but it is the third BC priority for maximizing Canada's export to the US. The main driver of BC investment priorities is in fact the investment objective. For export competitiveness, Ambassador Bridge is by far the most important BC, followed by Sarnia and Fort Erie across all scenarios and time horizons. Adding an inspection lane to Ambassador Bridge results in about 60% of the trade change resulting from adding a lane to all other BCs combined in the long term. This also holds true for changes in welfare as well GDP; Canada's GDP and welfare benefit from improving Ambassador Bridge alone weights 60% of the impacts of improving all other BCs combined in the long term.

Investment priorities also vary with time horizon – short and long terms. For example, adding a lane to Emerson BC is seventh and eighth investment priority with respect to GDP under long and short terms, respectively. This indicates that in addition to the investment objective, the investment horizon also impacts BC investment priorities.

In this study two counterfactual scenarios– a reduction of BC delays by 35% and a reduction of BC delays by 4 minutes – were tested. This analysis reveals that results are sensitive to the delay model, both in magnitudes and priorities. For example, adding a lane to Lansdowne would result in an increase of 6.37M USD of Canada's export to the US under long term, while reducing Lansdowne's delay by 4 minutes and 35% results in 3.13M USD and 4.36M USD of increase in Canada's export to the US. For maximizing Canada's export to the US, Lansdowne BC is the fourth priority when adding a lane to BCs, while the same BC is the fifth priority when BC delays are reduced by 35% and 4 minutes.

The results of these scenarios can be compared to those of Chapter 4. Chapter 4 identified Lansdowne, Ambassador Bridge, and Sarnia as BC investment priorities that maximized Canada's export to the US, while this analysis suggests Ambassador Bridge, Sarnia, and Fort Erie for the same objective. The difference in the results of two analyses is rooted in the different delay models. The sensitivity analysis in this Chapter and the comparison of the results with those of Chapter 4 highlights the importance of BC delay modelling in BC infrastructure investment optimization. Investment priorities change with the changes in BC delay modelling. Hence, BC investment studies must consider delay reductions carefully if the results are to have real world project or policy implications.

There is a high correlation between all measures of Table 5.4 except for Canada to US existing export level, which has less correlation with other variables. The high correlation between other measures implies that BC investments that improve Canada's GDP, would likely results in improvement in Canada's welfare and Canada's export competitiveness. The low correlation between the Canada to US export level and other measures in Table 5.4 contradicts the intuition that the most important borders are those that carry the most trade - which can be true for some BCs, such as Ambassador, but not for other BCs, such as Fort Erie (which carries more trade than Sarnia but is less important with respect to all measures in Table 5.4).

Figure 5.11 illustrates the most important BCs for Canada's international export competitiveness. The larger the circle around a BC, the more important that BC is for Canada's international export competiveness. It is shown that Ambassador, Sarnia, Fort Erie and Lansdowne are the most important BCs in both the short and long terms. It is also shown that St Stephen is the least important BC among all investigated BCs. The most important BCs for Canada's export competiveness are located in Eastern Canada, particularly in the province of Ontario, which highlights the critical role that Ontario plays in Canada's international export competitiveness.

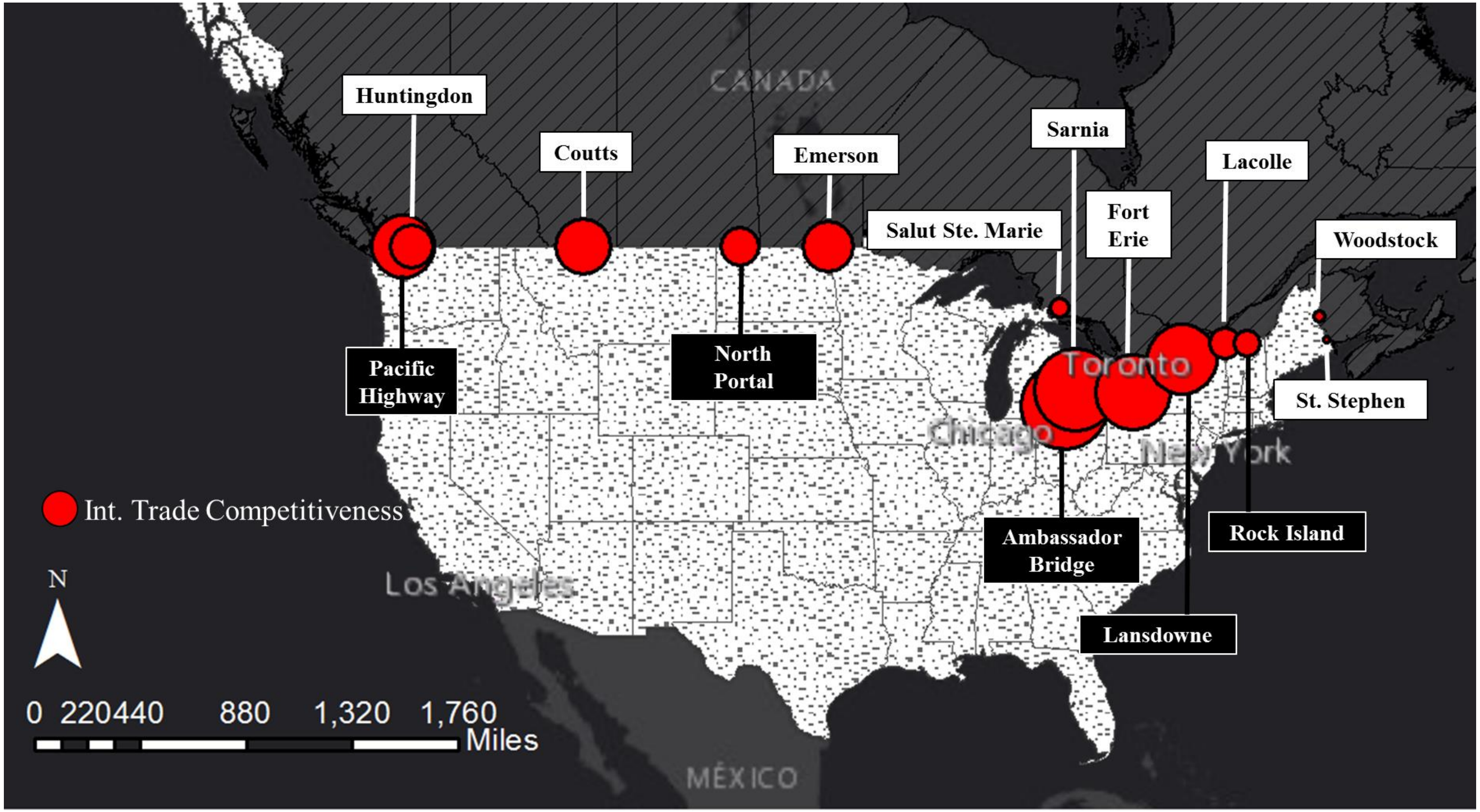

Figure 5.11: International Trade Competitiveness

Numerous trade policy planning insights can be extracted from these results. For example, if Canada plans to maximize its export of machinery and equipment to the US and internationally, a set of BCs that meet the policy criteria can be extracted from the analysis results. The analysis results also enables quantitative policy planning at the industry level. For example investment in Ambassador Bridge maximizes the export of chemical products to the US. The investment also results in an increase of export of other industries such as minerals and metal products, while, it simultaneously brings about a reduction in Canada's oil export to the US. This highlights the fact that for BC investment analysis, a theory-driven economic model – such as a CGE model – combined with transportation models and datasets are required to determine economic impacts of an investment strategy.

5.6.Application analysis conclusion

The application in this Chapter features innovation in spatial optimization of border crossing infrastructure investment by migrating from a stylized CGE modelling approach to a joint transport-economic modelling framework, where transportation activities at border crossings are explicitly linked to a CGE model of the global economy. The application of the framework to Canada-US border crossings identifies short and long term border crossing investment priorities and quantifies the distributional impacts of border crossing investments on economies and industries internationally. Simulation results suggest that border crossing investment priorities and the magnitude of their economic impacts are highly sensitive to border crossing delay modelling and less sensitive to mode shifts resulting from investments in one mode of transportation.

It is concluded that border crossing investments always have a positive total impact on Canada's export competitiveness, GDP, and welfare. Although the investments result in an overall export increase, a general conclusion could not be drawn from simulation results at the industrial level. It is concluded that border crossing investment priorities change with investment objective and horizon. Ambassador Bridge is the most critical BC for Canada's export competitiveness, welfare, and GDP in long and short terms. There are correlation between priorities determined by different measures – i.e., export competitiveness, welfare, and GDP. This correlation means that investment in border crossings that improves Canada's export competitiveness will most likely improve Canada's GDP and welfare as well. Considering all measures - export competitiveness, GDP, and welfare- Ambassador Bridge, Sarnia, and Fort Erie are the three most important border crossings for Canadian economy.

6. Chapter 6
Conclusion

Border crossings are vital to a nation's safety and security as well as its economic competitiveness. On one hand, borders are intended to ensure the safety of a nation against external threats; on the other, they are needed to ensure the efficient crossing of legitimate people and goods. Inefficient operation of border crossings are often estimated to cost economies billions of dollars.

Despite their importance, border crossing investments have received little attention; previous studies suffer from notable limitations including limited representation of transportation (abstract representation of transportation network and transportation activities, simplistic representation of transportation costs, and abstract mode splits and mode choice analysis), as well as limited analysis scope (limited horizon year, use of aggregated trade measures, etc.).

This thesis develops a framework that migrates from the stylistic representation of transportation in the literature and explicitly links models of transportation activities at border crossings to a CGE model of the economy to comprehensively investigate the economic impacts of border crossing investments. The use of queuing theory combined with numerous transportation and trade databases enables the framework to determine the unique impacts of an investment in a border crossing on each industry.

As the analysis in this thesis concluded, border crossing investment priorities and the magnitude of their effects are sensitive to accurate modelling of delays at border crossings and freight mode splits. Therefore, to draw a reliable conclusion on the impacts of border crossing investments, explicit linkage of transportation activities to CGE models are necessary. A summary of key findings of the thesis follows.

6.1. Summary of Key Findings

Chapter 2 develops an understanding of CGE models applications in transportation through a comprehensive literature review. It is found that static modelling and iceberg representation of transport cost dominate CGE applications in transportation. CGE-transport modelers can use Tables 2.1 and 2.2 to find trends in previous CGE models developed for a given application of interest.

The close examination of CGE modelling applications in transportation in Chapter 3 reveals that a variety of CGE model specifications are used in the literature. Choices are made with respect to representation of time, representation of transportation activities and transportation cost, model closure, utility and production functions, factors mobility, and market structure, which impact modelling results. Regarding transportation related modeling choices, the explicit representation of transport costs, an explicit transport network model, and non-sequential feedbacks are recommended.

The feasibility of the proposed framework is assessed through a preliminary application to Canada-US border crossings in Chapter 4. It is found that using the proposed framework, it is possible to determine the unique impact of a border crossing improvement on each industry. It is concluded that the impacts at the industrial level are not necessarily positive and that the results are sensitive to the delay modelling – suggesting an accurate empirical modelling of delays at border crossing.

Chapter 5 addresses the limitation of the preliminary application in Chapter 4 by incorporating logistic modelling and extending the scope of the analysis. It is concluded that border crossing investment impacts are highly sensitive to delay modeling and mode splits and less sensitive to mode shifts. The validation of the modelling results concludes that the model generates a reasonable number of trucks matching the real-world observations.

6.2.Contributions

This thesis makes three major contributions to transport-economic modelling: The first contribution is a comprehensive literature review and CGE design guideline presented in Chapters 2 and Chapter 3, respectively. A total of 135 articles (103 journal articles, 11 conference papers, 21 book chapters and technical reports) that applied CGE modelling to various transportation applications were examined with respect to CGE modelling attributes choices. The reviewed applications are summarized in Tables 2.1 and 2.2, which researchers can use as look-up tables to find previous CGE models developed for their application of interest. In total, the literature review resulted in a road map of the most influential choices that a transport modeller confronts, while also providing a discussion on the advantages, disadvantages, and impacts of these choices on the model behavior and results. Where possible, recommendations on best practices were made. The design guideline itself and the scale and scope of the study is the first of its kind known to the author.

The second contribution of this thesis is the development and application of an analysis framework that migrates from stylized CGE modelling approach by explicitly linking transportation models of border crossing activities to a CGE model of the global economy. This framework contrast previous studies that often simulated the impacts of infrastructure investment by a simplistic and stylized shocking of CGE models (e.g., a constant change in transport cost or delay times), which is unrealistic on at least two grounds: first, as the results of this study showed, improving a border crossing has varying effects on different industries; second, as shown by the analysis results, equal and comparable investments (e.g., one additional lane at each border crossing) would results in different change in border crossing delays for each border crossing. Thus, reducing border crossing delays in absolute or relative terms across all border crossings does not reflect comparable investments on all border crossings.

The third contribution of this thesis is that unlike prior studies that only focused on the economic impacts of one or more border crossings within a local area and with limited scope (i.e., use of only aggregate macroeconomic measures and investigating either short or long term effects of border crossing investment and disregarding mode splits and mode choice), the proposed framework enables prioritizing border crossings along an entire border with consideration of their *global*, rather than just *local*, impacts (Chapter 4). The framework enables measuring both aggregate and disaggregate macroeconomic measures to determine border crossing investment priorities and takes into account freight mode splits and modal shifts that may result from an investment in one mode of transportation. The framework also expands the horizon consideration of previous studies by simultaneously investigating long- and short- term effects of border crossing infrastructure investments.

6.3.Future work

This study's framework enlightens a few avenues for future work. In the current study, only road BCs are considered. A straightforward extension to this study could analyze investment priorities for all Ports of Entries (POEs) including airports and marine ports in addition to border crossings. A necessary step for this extension would be to translate an investment in POEs' infrastructure into POEs' efficiency changes and finally to shipping cost changes, similar to the translation of infrastructure investment on border crossing into shippers' cost savings in the application presented in this thesis.

The proposed framework was applied to investigate individual border crossing investments. A straightforward application of the framework would be to investigate economic impacts of simultaneous investment in more than one border crossing and prioritize groupings of border crossings for investment, rather than investigating individual border crossings.

The framework and the application are tailored toward infrastructure investment. However, the framework can also be used to assess economic criticality of border crossing closures. The closure would trigger a route shift by vehicles diverting from the closed border crossing, which adds additional trucks and passenger vehicles to other border crossings. The rerouting increases the shipping cost in two ways: first, through the additional time that will have to be spent by diverting vehicles to find their next border crossing of interest and second, by the additional border crossing wait times resulting from the additional diverting truck and passenger car volumes.

A valuable extension would include developing a route choice modelling component for the proposed framework. Modelling route choice in a CGE context is a data-intensive process in the sense that it requires information and modelling of firms and shippers locations, routing preferences, and shipping frequencies by destination, which due to confidentiality concerns, is not readily available or shared. Upon the availability of these data, a calibrated regional transportation model reflecting real-life shippers routing choice linked to a CGE model of the economy would be used to comprehensively investigate the economic impacts of border crossing investments, taking into account the routing pattern changes resulting from an investment in a particular border crossing.

Lastly, this thesis identifies the long and short term priorities for border crossing infrastructure investment. Future research should include financing mechanisms -e.g., user fees, taxes, foreign investment, etc.- to complete the picture of infrastructure investment optimization. In other words, an appropriate inclusion of the costs associated with each scenario and the necessary financing impacts, would provide an even more holistic perspective on BC investments.

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Appendix A: Sample "ams" and output calculations

This section provides an example for the calculation of the ams variable of the GTAP model. The example focuses on the calculation of ams for wood industry when Huntingdon is improved in the preliminary application in Chapter 4.

The trade value from Canada to the US for the wood industry is 8578.44M USD. The BCS of Huntingdon for the wood industry is 0.0687. Using equation 4.5, the value of wood products that Huntingdon BC carries is calculated as follows:

$$t_i^{rs,x} = t_i^{rs} \times BCS_i^{rs,x} \rightarrow t_{wood}^{Canada\ to\ US,Huntingdon} = t_{wood}^{Canada\ to\ US} \times$$

$$BCS_{wood}^{Canada\ to\ US,Huntingdon} = 8578.44\text{M USD} \times 0.0687 = 590\text{M USD}$$

Using equation 4.6 and the VW and PF, the number of trucks of wood products crossing Huntingdon BC is calculated. $PF_{wood}^{Canada\ to\ US,Huntingdon}$ is 24114.93[kg/truck] and $VW_{wood}^{Canada\ to\ US,Huntingdon}$ is 0.4933[USD/kilogram], hence:

$$q_i^{rs,x} = \frac{t_i^{rs,x}}{PF_i^{rs,x} \times VW_i^{rs,x}} \rightarrow q_{wood}^{Canada\ to\ US,Huntingdon} =$$

$$\frac{t_{wood}^{Canada\ to\ US,Huntingdon}}{VW_{wood}^{Canada\ to\ US,Huntingdon} \times PF_{wood}^{Canada\ to\ US,Huntingdon}} = \frac{590\text{M USD}}{0.4933[\text{USD/kilogram}] \times 24114.93[\text{kg/truck}]} =$$

$$49599.14[trucks]$$

The average delay for Huntingdon is 13.68 [minute/vehicle]. Considering that the number of inspection lanes at Huntingdon is 2, equation 4.11 is applied to calculate the new delay resulting from an addition of one lane:

$$d_1^x = \left(\frac{NL_0^x}{NL_1^x}\right) d_0^x \rightarrow d_1^{Huntingdon} = \left(\frac{2}{3}\right) 13.68 \left[\frac{\text{minute}}{\text{vehicle}}\right] = 9.12 \left[\frac{\text{minute}}{\text{vehicle}}\right]$$

Using equation 4.8, the difference in delay per vehicle is calculated as follows:

$$\delta d^x = d_1^x - d_0^x \rightarrow \delta d^x = 9.12 - 13.68 = -4.56 \left[\frac{\text{minute}}{\text{vehicle}}\right]$$

Using equation 4.9 and a VOT of 83.68[USD/hour], monetary delay savings for the wood industry resulting from improving Huntingdon BC is calculated as follows:

$$\delta c_i^{rs} = \delta d^x \times q_i^{rs,x} \times VOT^r \rightarrow \delta c_{wood}^{Canada\ to\ US} = \delta d^{Huntingdon} \times q_{wood}^{Canada\ to\ US,Huntingdon} \times VOT^{Canada} \rightarrow \delta c_{wood}^{Canada\ to\ US} = 4.56 \left[\frac{\text{minute}}{\text{vehicle}}\right] \times 49599.14[trucks] \times 83.68 \left[\frac{\text{USD}}{\text{hour}}\right] \times \frac{1}{60} \left[\frac{\text{hour}}{\text{miniute}}\right] = 315426.08\ USD$$

Equation 4.10 is used to calculate the ams variable of the GTAP model:

$$ams_i^{rs,x} = \frac{\delta c_i^{rs}}{t_i^{rs}} \rightarrow ams_{wood}^{Canada\ to\ US,Huntingdon} = \frac{\delta c_{wood}^{Canda\ to\ US}}{t_{wood}^{canda\ to\ US}} = \frac{315426.08\ USD}{8578.44M\ USD} = 0.00367\%$$

Appendix B: ams variable values for all scenarios

Table B.1: ams for Canada to US trades - addition of a lane to each BC

	Ambassador Bridge	Coutts	Emerson	Fort Erie	Huntingdon	Lacolle	Lansdowne	North Portal	Pacific Highway	Rock Island	Sarnia	Sault Ste. Marie	St. Stephen	Woodstock
Paddy rice	0.021712	0.000000	0.000000	0.001869	0.000186	0.000011	0.000000	0.000000	0.002585	0.000000	0.002678	0.000000	0.000000	0.000000
Wheat	0.002873	0.000517	0.000367	0.001406	0.000119	0.000004	0.000015	0.000284	0.000002	0.000002	0.001456	0.000000	0.000000	0.000000
Cereal grains nec	0.011530	0.002935	0.005697	0.002892	0.000260	0.000073	0.000298	0.000185	0.000079	0.000310	0.006015	0.000000	0.000000	0.000033
Vegetables, fruit, nuts	0.010262	0.001416	0.001828	0.003530	0.001838	0.000174	0.000241	0.000232	0.003381	0.000097	0.000805	0.000001	0.000010	0.001248
Oil seeds	0.001536	0.005810	0.015480	0.000771	0.000516	0.000018	0.000746	0.002670	0.000198	0.000050	0.000936	0.000007	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.049070	0.000000	0.000000	0.000000
Plant-based fibers	0.000957	0.000000	0.000277	0.001942	0.000000	0.000000	0.023639	0.000000	0.000000	0.000000	0.000752	0.000000	0.000000	0.000000
Crops nec	0.005082	0.004938	0.001802	0.007532	0.001439	0.000084	0.001120	0.000528	0.002048	0.000447	0.001333	0.000002	0.000006	0.000459
Bovine cattle, sheep and goats, horses	0.000779	0.003011	0.001062	0.000519	0.000445	0.000001	0.001680	0.000437	0.000000	0.000002	0.000783	0.000000	0.000000	0.000003
Animal products nec	0.005103	0.000960	0.009972	0.000660	0.000108	0.000016	0.000052	0.000343	0.000241	0.000077	0.002877	0.000003	0.000001	0.000044
Raw milk	0.000134	0.000000	0.000000	0.001851	0.000000	0.000002	0.000000	0.000000	0.000000	0.000000	0.005051	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000038	0.000000	0.000355	0.000000	0.000000	0.003630	0.000000	0.000000	0.000000	0.000134	0.000000	0.000000	0.000000
Forestry	0.003894	0.000324	0.000155	0.000954	0.002263	0.000046	0.001788	0.000109	0.002483	0.000721	0.002958	0.000783	0.000019	0.001344
Fishing	0.000376	0.000000	0.000077	0.000026	0.000051	0.000005	0.000001	0.000000	0.006140	0.000002	0.000021	0.000012	0.000095	0.000312
Coal	0.007410	0.006414	0.005955	0.001204	0.002256	0.000372	0.004072	0.001432	0.000677	0.000474	0.003390	0.000075	0.000012	0.001835
Oil	0.000000	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000
Gas	0.000000	0.000601	0.000000	0.000000	0.000000	0.000000	0.000000	0.000007	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000
Minerals nec	0.064602	0.001249	0.000403	0.012997	0.010481	0.002395	0.017856	0.001420	0.026983	0.000243	0.081178	0.003958	0.000026	0.000375
Bovine meat products	0.001068	0.010398	0.000303	0.002249	0.000001	0.000079	0.000000	0.000024	0.000060	0.000000	0.000002	0.000000	0.000000	0.000000

Meat products nec	0.006701	0.000936	0.002038	0.002433	0.000045	0.000252	0.000002	0.000314	0.000630	0.000000	0.000021	0.000000	0.000002	0.000002
Vegetable oils and fats	0.013714	0.011056	0.003314	0.011064	0.000538	0.000278	0.000274	0.000142	0.000293	0.000224	0.000726	0.000001	0.000000	0.000012
Dairy products	0.004990	0.000000	0.001593	0.001781	0.001721	0.000275	0.000144	0.000017	0.000752	0.000010	0.000397	0.000000	0.000013	0.000013
Processed rice	0.023159	0.000000	0.000000	0.001311	0.000000	0.000013	0.000000	0.000000	0.000491	0.000000	0.002735	0.000000	0.000000	0.000000
Sugar	0.003272	0.000033	0.000032	0.000384	0.000063	0.000076	0.000414	0.000059	0.001185	0.001045	0.001341	0.000004	0.000001	0.000000
Food products nec	0.005718	0.000303	0.000905	0.003115	0.000324	0.000056	0.000625	0.000059	0.001520	0.000025	0.001854	0.000007	0.000012	0.000423
Beverages and tobacco products	0.009393	0.000301	0.000036	0.003527	0.000656	0.000103	0.000950	0.000038	0.001119	0.000109	0.002147	0.000008	0.000006	0.000077
Textiles	0.004638	0.000024	0.000149	0.001580	0.000028	0.000068	0.003453	0.000002	0.000302	0.000083	0.001005	0.000008	0.000004	0.000053
Wearing apparel	0.000193	0.000013	0.000070	0.000472	0.000008	0.000086	0.000106	0.000001	0.000369	0.000025	0.000074	0.000000	0.000000	0.000000
Leather products	0.001513	0.000025	0.000061	0.001158	0.000006	0.000188	0.000203	0.000000	0.000176	0.000063	0.001669	0.000002	0.000000	0.000001
Wood products	0.002483	0.001047	0.000718	0.001042	0.005951	0.000168	0.001498	0.000452	0.004132	0.000629	0.001533	0.000333	0.000016	0.000400
Paper products, publishing	0.005122	0.000146	0.000379	0.002499	0.000088	0.000154	0.003347	0.000034	0.001602	0.000297	0.002480	0.000166	0.000013	0.000152
Petroleum, coke products	0.000132	0.000068	0.000052	0.000567	0.000047	0.000018	0.000111	0.000022	0.000011	0.000031	0.000480	0.000002	0.000001	0.000002
Chemical, rubber, plastic products	0.004743	0.000337	0.000384	0.001259	0.000063	0.000035	0.000668	0.000054	0.000418	0.000018	0.001870	0.000010	0.000002	0.000051
Mineral products nec	0.021992	0.000469	0.000644	0.007101	0.001251	0.000260	0.001961	0.000088	0.001915	0.000793	0.005589	0.000020	0.000002	0.000051
Ferrous metals	0.005982	0.000194	0.000408	0.003521	0.000160	0.000035	0.001832	0.000074	0.000897	0.000029	0.004330	0.000576	0.000000	0.000004
Metals nec	0.000964	0.000009	0.000009	0.000299	0.000019	0.000028	0.000649	0.000000	0.000017	0.000013	0.000549	0.000005	0.000000	0.000010
Metal products	0.005483	0.000465	0.000384	0.001855	0.000223	0.000061	0.000622	0.000153	0.000925	0.000069	0.002660	0.000015	0.000008	0.000016
Motor vehicles and parts	0.001955	0.000053	0.000050	0.000239	0.000015	0.000027	0.000206	0.000029	0.000036	0.000003	0.000679	0.000003	0.000000	0.000001
Transport equipment nec	0.000560	0.000009	0.000067	0.000439	0.000008	0.000012	0.000087	0.000002	0.000575	0.000007	0.000245	0.000006	0.000000	0.000001
Electronic equipment	0.000385	0.000018	0.000018	0.000236	0.000002	0.000007	0.000066	0.000000	0.000123	0.000000	0.000128	0.000000	0.000000	0.000000
Machinery and equipment nec	0.002162	0.000487	0.000351	0.000732	0.000060	0.000027	0.000322	0.000075	0.000437	0.000008	0.001085	0.000012	0.000000	0.000005
Manufactures nec	0.005714	0.000127	0.000369	0.002382	0.000070	0.000088	0.000589	0.000027	0.000651	0.000057	0.002438	0.000013	0.000001	0.000011

Table B.2: ams for Canada to US trades - reducing BC delays by 4 minutes

	Ambassador Bridge	Coutts	Emerson	Fort Erie	Huntingdon	Lacolle	Lansdowne	North Portal	Pacific Highway	Rock Island	Sarnia	Sault Ste. Marie	St. Stephen	Woodstock
Paddy rice	0.010970	0.000000	0.000000	0.001573	0.000101	0.000103	0.000000	0.000000	0.001200	0.000000	0.001525	0.000000	0.000000	0.000000
Wheat	0.001452	0.000303	0.000252	0.001183	0.000064	0.000035	0.000008	0.000435	0.000001	0.000004	0.000829	0.000000	0.000000	0.000000
Cereal grains nec	0.005826	0.001717	0.003912	0.002434	0.000141	0.000714	0.000146	0.000282	0.000036	0.000727	0.003424	0.000000	0.000003	0.000058
Vegetables, fruit, nuts	0.005185	0.000828	0.001255	0.002971	0.000996	0.001710	0.000118	0.000354	0.001569	0.000227	0.000458	0.000001	0.000262	0.002177
Oil seeds	0.000776	0.003399	0.010629	0.000649	0.000279	0.000179	0.000366	0.004087	0.000092	0.000117	0.000533	0.000012	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.027936	0.000000	0.000000	0.000000
Plant-based fibers	0.000483	0.000000	0.000191	0.001634	0.000000	0.000000	0.011583	0.000000	0.000000	0.000000	0.000428	0.000000	0.000000	0.000000
Crops nec	0.002568	0.002888	0.001237	0.006339	0.000780	0.000826	0.000549	0.000809	0.000951	0.001048	0.000759	0.000004	0.000154	0.000800
Bovine cattle, sheep and goats, horses	0.000393	0.001761	0.000729	0.000437	0.000241	0.000013	0.000823	0.000669	0.000000	0.000004	0.000446	0.000000	0.000000	0.000005
Animal products nec	0.002578	0.000562	0.006847	0.000556	0.000059	0.000153	0.000025	0.000525	0.000112	0.000181	0.001638	0.000006	0.000025	0.000077
Raw milk	0.000068	0.000000	0.000000	0.001558	0.000000	0.000017	0.000000	0.000000	0.000000	0.000000	0.002876	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000022	0.000000	0.000298	0.000000	0.000000	0.001779	0.000000	0.000000	0.000000	0.000077	0.000000	0.000000	0.000000
Forestry	0.001968	0.000190	0.000107	0.000803	0.001227	0.000448	0.000876	0.000166	0.001153	0.001691	0.001684	0.001392	0.000495	0.002343
Fishing	0.000190	0.000000	0.000053	0.000022	0.000028	0.000047	0.000000	0.000000	0.002851	0.000005	0.000012	0.000021	0.002444	0.000545
Coal	0.003744	0.003752	0.004089	0.001013	0.001223	0.003651	0.001995	0.002191	0.000314	0.001111	0.001930	0.000133	0.000309	0.003200
Oil	0.000000	0.000201	0.000000	0.000000	0.000000	0.000000	0.000000	0.000006	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000
Gas	0.000000	0.000351	0.000000	0.000000	0.000000	0.000000	0.000000	0.000011	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000
Minerals nec	0.032641	0.000730	0.000277	0.010939	0.005681	0.023504	0.008749	0.002174	0.012527	0.000569	0.046215	0.007041	0.000673	0.000654
Bovine meat products	0.000539	0.006082	0.000208	0.001893	0.000000	0.000774	0.000000	0.000037	0.000028	0.000000	0.000001	0.000000	0.000000	0.000000
Meat products nec	0.003386	0.000548	0.001399	0.002047	0.000024	0.002470	0.000001	0.000481	0.000292	0.000000	0.000012	0.000001	0.000044	0.000003
Vegetable oils and fats	0.006929	0.006467	0.002275	0.009311	0.000291	0.002724	0.000134	0.000217	0.000136	0.000526	0.000413	0.000002	0.000000	0.000021

Dairy products	0.002521	0.000000	0.001094	0.001499	0.000932	0.002696	0.000071	0.000025	0.000349	0.000023	0.000226	0.000000	0.000329	0.000022
Processed rice	0.011701	0.000000	0.000000	0.001103	0.000000	0.000128	0.000000	0.000000	0.000228	0.000000	0.001557	0.000000	0.000000	0.000000
Sugar	0.001653	0.000019	0.000022	0.000324	0.000034	0.000743	0.000203	0.000090	0.000550	0.002451	0.000763	0.000007	0.000028	0.000000
Food products nec	0.002889	0.000177	0.000621	0.002622	0.000175	0.000549	0.000306	0.000091	0.000705	0.000058	0.001055	0.000013	0.000320	0.000739
Beverages and tobacco products	0.004746	0.000176	0.000025	0.002969	0.000356	0.001011	0.000465	0.000058	0.000520	0.000255	0.001222	0.000014	0.000148	0.000134
Textiles	0.002344	0.000014	0.000102	0.001330	0.000015	0.000670	0.001692	0.000002	0.000140	0.000194	0.000572	0.000013	0.000099	0.000092
Wearing apparel	0.000097	0.000007	0.000048	0.000397	0.000004	0.000848	0.000052	0.000001	0.000171	0.000058	0.000042	0.000000	0.000006	0.000001
Leather products	0.000764	0.000015	0.000042	0.000975	0.000003	0.001840	0.000099	0.000000	0.000082	0.000148	0.000950	0.000003	0.000002	0.000001
Wood products	0.001255	0.000613	0.000493	0.000877	0.003225	0.001646	0.000734	0.000692	0.001918	0.001475	0.000873	0.000593	0.000402	0.000697
Paper products, publishing	0.002588	0.000085	0.000260	0.002103	0.000048	0.001509	0.001640	0.000053	0.000744	0.000697	0.001412	0.000296	0.000345	0.000265
Petroleum, coke products	0.000067	0.000040	0.000036	0.000478	0.000025	0.000177	0.000055	0.000034	0.000005	0.000072	0.000273	0.000003	0.000035	0.000003
Chemical, rubber, plastic products	0.002397	0.000197	0.000264	0.001060	0.000034	0.000344	0.000327	0.000083	0.000194	0.000042	0.001065	0.000018	0.000060	0.000088
Mineral products nec	0.011112	0.000274	0.000442	0.005976	0.000678	0.002556	0.000961	0.000134	0.000889	0.001860	0.003182	0.000036	0.000060	0.000090
Ferrous metals	0.003022	0.000113	0.000280	0.002963	0.000087	0.000344	0.000898	0.000113	0.000416	0.000069	0.002465	0.001025	0.000001	0.000006
Metals nec	0.000487	0.000005	0.000006	0.000251	0.000010	0.000270	0.000318	0.000000	0.000008	0.000031	0.000312	0.000009	0.000002	0.000018
Metal products	0.002770	0.000272	0.000264	0.001562	0.000121	0.000602	0.000305	0.000235	0.000430	0.000162	0.001514	0.000026	0.000193	0.000028
Motor vehicles and parts	0.000988	0.000031	0.000034	0.000201	0.000008	0.000265	0.000101	0.000044	0.000017	0.000007	0.000387	0.000006	0.000001	0.000002
Transport equipment nec	0.000283	0.000005	0.000046	0.000370	0.000004	0.000123	0.000043	0.000004	0.000267	0.000017	0.000139	0.000011	0.000006	0.000002
Electronic equipment	0.000195	0.000010	0.000012	0.000198	0.000001	0.000070	0.000032	0.000001	0.000057	0.000001	0.000073	0.000000	0.000001	0.000000
Machinery and equipment nec	0.001092	0.000285	0.000241	0.000616	0.000033	0.000267	0.000158	0.000115	0.000203	0.000019	0.000618	0.000022	0.000008	0.000008
Manufactures nec	0.002887	0.000074	0.000253	0.002005	0.000038	0.000867	0.000289	0.000041	0.000302	0.000133	0.001388	0.000023	0.000029	0.000020

Table B.3: ams for Canada to US trades - reducing BC delays by 35%

	Ambassador Bridge	Coutts	Emerson	Fort Erie	Huntingdon	Lacolle	Lansdowne	North Portal	Pacific Highway	Rock Island	Sarnia	Sault Ste. Marie	St. Stephen	Woodstock
Paddy rice	0.013612	0.000000	0.000000	0.001553	0.000117	0.000110	0.000000	0.000000	0.001558	0.000000	0.001996	0.000000	0.000000	0.000000
Wheat	0.001801	0.000324	0.000309	0.001168	0.000075	0.000037	0.000011	0.000433	0.000001	0.000004	0.001085	0.000000	0.000000	0.000000
Cereal grains nec	0.007229	0.001841	0.004800	0.002403	0.000164	0.000757	0.000203	0.000281	0.000047	0.000665	0.004484	0.000000	0.000002	0.000044
Vegetables, fruit, nuts	0.006433	0.000888	0.001540	0.002933	0.001158	0.001813	0.000164	0.000353	0.002038	0.000208	0.000600	0.000001	0.000147	0.001666
Oil seeds	0.000963	0.003644	0.013042	0.000641	0.000325	0.000189	0.000508	0.004067	0.000119	0.000107	0.000698	0.000012	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.036578	0.000000	0.000000	0.000000
Plant-based fibers	0.000600	0.000000	0.000234	0.001613	0.000000	0.000000	0.016095	0.000000	0.000000	0.000000	0.000561	0.000000	0.000000	0.000000
Crops nec	0.003186	0.003097	0.001518	0.006259	0.000907	0.000875	0.000763	0.000805	0.001235	0.000958	0.000994	0.000004	0.000086	0.000613
Bovine cattle, sheep and goats, horses	0.000488	0.001888	0.000895	0.000431	0.000280	0.000014	0.001144	0.000666	0.000000	0.000004	0.000583	0.000000	0.000000	0.000004
Animal products nec	0.003199	0.000602	0.008402	0.000549	0.000068	0.000163	0.000035	0.000523	0.000146	0.000166	0.002145	0.000006	0.000014	0.000059
Raw milk	0.000084	0.000000	0.000000	0.001538	0.000000	0.000018	0.000000	0.000000	0.000000	0.000000	0.003766	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000024	0.000000	0.000295	0.000000	0.000000	0.002472	0.000000	0.000000	0.000000	0.000100	0.000000	0.000000	0.000000
Forestry	0.002441	0.000203	0.000131	0.000792	0.001426	0.000475	0.001218	0.000165	0.001496	0.001547	0.002205	0.001453	0.000277	0.001794
Fishing	0.000235	0.000000	0.000065	0.000021	0.000032	0.000050	0.000001	0.000000	0.003701	0.000004	0.000016	0.000022	0.001369	0.000417
Coal	0.004646	0.004023	0.005017	0.001001	0.001422	0.003871	0.002772	0.002181	0.000408	0.001016	0.002527	0.000139	0.000173	0.002449
Oil	0.000000	0.000215	0.000000	0.000000	0.000000	0.000000	0.000000	0.000006	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000
Gas	0.000000	0.000377	0.000000	0.000000	0.000000	0.000000	0.000000	0.000011	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000
Minerals nec	0.040500	0.000783	0.000339	0.010799	0.006605	0.024920	0.012158	0.002163	0.016266	0.000520	0.060513	0.007346	0.000377	0.000500
Bovine meat products	0.000669	0.006521	0.000255	0.001869	0.000000	0.000821	0.000000	0.000037	0.000036	0.000000	0.000001	0.000000	0.000000	0.000000
Meat products nec	0.004201	0.000587	0.001717	0.002021	0.000028	0.002619	0.000001	0.000479	0.000380	0.000000	0.000016	0.000001	0.000025	0.000002

Vegetable oils and fats	0.008597	0.006934	0.002792	0.009193	0.000339	0.002888	0.000187	0.000216	0.000177	0.000481	0.000541	0.000002	0.000000	0.000016
Dairy products	0.003128	0.000000	0.001342	0.001480	0.001084	0.002858	0.000098	0.000025	0.000453	0.000021	0.000296	0.000000	0.000184	0.000017
Processed rice	0.014519	0.000000	0.000000	0.001089	0.000000	0.000135	0.000000	0.000000	0.000296	0.000000	0.002039	0.000000	0.000000	0.000000
Sugar	0.002051	0.000021	0.000027	0.000319	0.000040	0.000787	0.000282	0.000090	0.000714	0.002242	0.001000	0.000007	0.000016	0.000000
Food products nec	0.003585	0.000190	0.000762	0.002588	0.000204	0.000582	0.000425	0.000090	0.000916	0.000053	0.001382	0.000013	0.000179	0.000565
Beverages and tobacco products	0.005888	0.000189	0.000031	0.002931	0.000414	0.001071	0.000647	0.000057	0.000675	0.000233	0.001600	0.000014	0.000083	0.000102
Textiles	0.002908	0.000015	0.000125	0.001313	0.000018	0.000710	0.002351	0.000002	0.000182	0.000178	0.000749	0.000014	0.000056	0.000070
Wearing apparel	0.000121	0.000008	0.000059	0.000392	0.000005	0.000899	0.000072	0.000001	0.000223	0.000053	0.000055	0.000000	0.000003	0.000000
Leather products	0.000948	0.000016	0.000051	0.000963	0.000004	0.001951	0.000138	0.000000	0.000106	0.000136	0.001244	0.000003	0.000001	0.000001
Wood products	0.001557	0.000657	0.000605	0.000866	0.003751	0.001745	0.001020	0.000689	0.002491	0.001349	0.001143	0.000619	0.000225	0.000533
Paper products, publishing	0.003211	0.000092	0.000319	0.002077	0.000055	0.001600	0.002279	0.000052	0.000966	0.000637	0.001848	0.000309	0.000193	0.000203
Petroleum, coke products	0.000083	0.000043	0.000044	0.000471	0.000029	0.000188	0.000076	0.000034	0.000007	0.000066	0.000358	0.000003	0.000019	0.000002
Chemical, rubber, plastic products	0.002974	0.000211	0.000324	0.001046	0.000040	0.000365	0.000455	0.000083	0.000252	0.000038	0.001394	0.000019	0.000033	0.000068
Mineral products nec	0.013787	0.000294	0.000542	0.005900	0.000789	0.002710	0.001335	0.000134	0.001154	0.001701	0.004166	0.000037	0.000034	0.000069
Ferrous metals	0.003750	0.000121	0.000344	0.002926	0.000101	0.000364	0.001247	0.000112	0.000541	0.000063	0.003228	0.001069	0.000001	0.000005
Metals nec	0.000604	0.000006	0.000008	0.000248	0.000012	0.000286	0.000442	0.000000	0.000010	0.000028	0.000409	0.000010	0.000001	0.000014
Metal products	0.003437	0.000292	0.000323	0.001542	0.000140	0.000638	0.000423	0.000233	0.000558	0.000148	0.001983	0.000027	0.000108	0.000021
Motor vehicles and parts	0.001225	0.000033	0.000042	0.000199	0.000010	0.000281	0.000140	0.000043	0.000022	0.000006	0.000506	0.000006	0.000001	0.000002
Transport equipment nec	0.000351	0.000006	0.000057	0.000365	0.000005	0.000130	0.000059	0.000004	0.000346	0.000015	0.000182	0.000011	0.000003	0.000001
Electronic equipment	0.000242	0.000011	0.000015	0.000196	0.000001	0.000074	0.000045	0.000001	0.000074	0.000001	0.000095	0.000000	0.000000	0.000000
Machinery and equipment nec	0.001355	0.000306	0.000296	0.000608	0.000038	0.000283	0.000219	0.000114	0.000264	0.000018	0.000809	0.000023	0.000004	0.000006
Manufactures nec	0.003582	0.000080	0.000311	0.001979	0.000044	0.000919	0.000401	0.000041	0.000392	0.000121	0.001818	0.000024	0.000016	0.000015

Table B.4: ams for Canada to US trades - addition of a lane to each BC - Preliminary scenario

	Abercorn	Aden	Aldergrove	Andover	Armstrong	Boissevain	Boundary Bay	Campobello	Carievale	Carson	Cartwright	Carway	Cascade	Centreville
Paddy rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wheat	0.000008	0.000000	0.000000	0.000000	0.000000	0.000042	0.000000	0.000000	0.000004	0.000000	0.000000	0.000000	0.000000	0.000000
Cereal grains nec	0.000496	0.000000	0.000003	0.000003	0.000005	0.000486	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000
Vegetables, fruit, nuts	0.000000	0.000000	0.000078	0.000004	0.000002	0.000380	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000051
Oil seeds	0.000000	0.000000	0.000000	0.000000	0.000001	0.005566	0.000000	0.000000	0.000243	0.000000	0.000236	0.000000	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Crops nec	0.000001	0.000000	0.000016	0.000000	0.000016	0.000153	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000000	0.000000	0.000000	0.000559	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Animal products nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000946	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Forestry	0.000000	0.000000	0.000000	0.000124	0.001461	0.000017	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Fishing	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000	0.000000	0.000012	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Coal	0.000000	0.000000	0.000000	0.000000	0.000149	0.000042	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Oil	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000005	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000000	0.000000	0.000000	0.000000	0.000170	0.000301	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001

Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Meat products nec	0.000003	0.000000	0.000000	0.000000	0.000000	0.000010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Vegetable oils and fats	0.000037	0.000000	0.000000	0.000000	0.000227	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sugar	0.000000	0.000000	0.000000	0.000000	0.000017	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Food products nec	0.000016	0.000000	0.000001	0.000021	0.000009	0.000007	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000008
Beverages and tobacco products	0.000000	0.000000	0.000001	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Textiles	0.000000	0.000000	0.000000	0.000000	0.000055	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000000	0.000007	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wood products	0.000000	0.000000	0.000007	0.000000	0.000403	0.000020	0.000001	0.000000	0.000000	0.000002	0.000000	0.000000	0.000012	0.000000
Paper products, publishing	0.000003	0.000000	0.000000	0.000001	0.000084	0.000002	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Petroleum, coke products	0.000000	0.000000	0.000004	0.000000	0.000007	0.000006	0.000000	0.000000	0.000000	0.000000	0.000000	0.000016	0.000000	0.000000
Chemical, rubber, plastic products	0.000000	0.000000	0.000000	0.000000	0.000034	0.000047	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000002

Mineral products nec	0.000000	0.000000	0.000020	0.000002	0.001194	0.000037	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Ferrous metals	0.000000	0.000000	0.000000	0.000000	0.000006	0.000004	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Metals nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Metal products	0.000001	0.000000	0.000002	0.000000	0.000026	0.000050	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000
Motor vehicles and parts	0.000000	0.000000	0.000000	0.000000	0.000002	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Transport equipment nec	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000000	0.000000	0.000000	0.000003	0.000007	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Manufactures nec	0.000000	0.000000	0.000000	0.000000	0.000004	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	Clair	Climax	Cornwall	Coronach	Coulter	Coutts	Crystal City	Dawson City	Del Bonita	Edmundston	Emerson	Fort Erie	Fort Frances	Fraser
Paddy rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000571	0.000000	0.000000
Wheat	0.000000	0.000002	0.000000	0.000000	0.000000	0.000318	0.000000	0.000000	0.000000	0.000000	0.000227	0.000429	0.000000	0.000000
Cereal grains nec	0.000000	0.000000	0.000054	0.000000	0.000006	0.001805	0.000000	0.000000	0.000000	0.000000	0.003529	0.000884	0.000013	0.000000
Vegetables, fruit, nuts	0.000000	0.000000	0.000003	0.000000	0.000001	0.000870	0.000000	0.000000	0.000000	0.000000	0.001132	0.001078	0.000001	0.000000
Oil seeds	0.000000	0.000000	0.000027	0.000000	0.000221	0.003572	0.000000	0.000000	0.000000	0.000000	0.009590	0.000236	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000172	0.000593	0.000000	0.000000
Crops nec	0.000000	0.000000	0.000032	0.000000	0.000000	0.003036	0.000000	0.000011	0.000000	0.000001	0.001116	0.002301	0.000029	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000000	0.000000	0.000000	0.001851	0.000000	0.000000	0.000000	0.000000	0.000658	0.000159	0.000000	0.000000

Animal products nec	0.000000	0.000000	0.000004	0.000000	0.000000	0.000590	0.000000	0.000002	0.000000	0.000000	0.006178	0.000202	0.000014	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000566	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000024	0.000000	0.000000	0.000000	0.000000	0.000000	0.000108	0.000000	0.000000
Forestry	0.000062	0.000000	0.000040	0.000000	0.000000	0.000199	0.000000	0.000000	0.000000	0.000005	0.000096	0.000291	0.000000	0.000000
Fishing	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000047	0.000008	0.000000	0.000000
Coal	0.000001	0.000000	0.000012	0.000000	0.000000	0.003944	0.000000	0.000000	0.000000	0.000000	0.003689	0.000368	0.000062	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000211	0.000000	0.000000	0.000011	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000346	0.000000	0.000000	0.000018	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000001	0.000000	0.000248	0.000000	0.000136	0.000768	0.000000	0.000002	0.000000	0.000000	0.000249	0.003970	0.000127	0.000864
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000000	0.006393	0.000000	0.000000	0.000000	0.000000	0.000188	0.000687	0.000000	0.000000
Meat products nec	0.000000	0.000000	0.000002	0.000000	0.000000	0.000576	0.000000	0.000000	0.000000	0.000000	0.001262	0.000743	0.000000	0.000000
Vegetable oils and fats	0.000000	0.000000	0.000583	0.000000	0.000000	0.006798	0.000000	0.000000	0.000000	0.000000	0.002053	0.003380	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000987	0.000544	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000400	0.000015	0.000000
Sugar	0.000000	0.000000	0.000002	0.000000	0.000000	0.000020	0.000000	0.000000	0.000000	0.000000	0.000020	0.000117	0.000000	0.000000
Food products nec	0.000000	0.000000	0.000019	0.000000	0.000000	0.000186	0.000000	0.000000	0.000000	0.000000	0.000561	0.000952	0.000000	0.000000
Beverages and tobacco products	0.000000	0.000000	0.000061	0.000000	0.000000	0.000185	0.000000	0.000000	0.000000	0.000000	0.000022	0.001077	0.000007	0.000000
Textiles	0.000000	0.000000	0.000009	0.000000	0.000000	0.000015	0.000000	0.000001	0.000000	0.000000	0.000092	0.000483	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000000	0.000000	0.000008	0.000000	0.000003	0.000000	0.000000	0.000043	0.000144	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000016	0.000000	0.000000	0.000000	0.000000	0.000037	0.000354	0.000000	0.000000
Wood products	0.000009	0.000000	0.000033	0.000000	0.000014	0.000644	0.000000	0.000012	0.000000	0.000005	0.000445	0.000318	0.000138	0.000000
Paper products, publishing	0.000000	0.000000	0.000080	0.000000	0.000000	0.000090	0.000000	0.000000	0.000000	0.000071	0.000235	0.000763	0.000241	0.000000

Petroleum, coke products	0.000010	0.000000	0.000202	0.000000	0.000000	0.000042	0.000000	0.000000	0.000000	0.000020	0.000032	0.000173	0.000000	0.000000
Chemical, rubber, plastic products	0.000001	0.000004	0.000007	0.000003	0.000002	0.000207	0.000000	0.000001	0.000000	0.000000	0.000238	0.000385	0.000001	0.000000
Mineral products nec	0.000000	0.000000	0.000078	0.000000	0.000000	0.000288	0.000000	0.000005	0.000000	0.000002	0.000399	0.002169	0.000059	0.000000
Ferrous metals	0.000000	0.000000	0.000008	0.000000	0.000000	0.000119	0.000000	0.000007	0.000000	0.000000	0.000253	0.001076	0.000002	0.000000
Metals nec	0.000000	0.000000	0.000052	0.000000	0.000000	0.000006	0.000000	0.000000	0.000000	0.000000	0.000006	0.000091	0.000000	0.000000
Metal products	0.000000	0.000000	0.000007	0.000000	0.000000	0.000286	0.000000	0.000016	0.000003	0.000000	0.000238	0.000567	0.000004	0.000000
Motor vehicles and parts	0.000000	0.000000	0.000000	0.000000	0.000000	0.000033	0.000000	0.000001	0.000000	0.000000	0.000031	0.000073	0.000000	0.000000
Transport equipment nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000005	0.000000	0.000006	0.000000	0.000000	0.000042	0.000134	0.000001	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000000	0.000000	0.000011	0.000000	0.000000	0.000000	0.000000	0.000011	0.000072	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000001	0.000003	0.000000	0.000000	0.000300	0.000000	0.000006	0.000000	0.000000	0.000217	0.000224	0.000002	0.000000
Manufactures nec	0.000000	0.000000	0.000008	0.000000	0.000000	0.000078	0.000000	0.000002	0.000000	0.000000	0.000229	0.000728	0.000001	0.000000
	Gillespie Portage	Goodlands	Gretna	Huntingdon	Kingsgate	Lacolle	Lansdowne	Lena	Lyleton	Nelway	North Portal	Northgate	Osoyoos	Oungre
Paddy rice	0.000000	0.000000	0.000000	0.000115	0.000000	0.000032	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wheat	0.000000	0.000000	0.000000	0.000073	0.000003	0.000011	0.000010	0.000000	0.000016	0.000000	0.000318	0.000003	0.000000	0.000000
Cereal grains nec	0.000062	0.000000	0.000013	0.000161	0.000130	0.000223	0.000199	0.000000	0.000000	0.000000	0.000207	0.001059	0.000010	0.000000
Vegetables, fruit, nuts	0.000000	0.000000	0.000000	0.001136	0.000242	0.000533	0.000161	0.000000	0.000000	0.000000	0.000259	0.000000	0.000129	0.000000
Oil seeds	0.000000	0.000068	0.000190	0.000319	0.000145	0.000056	0.000498	0.000168	0.000066	0.000000	0.002991	0.000240	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.015780	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Crops nec	0.000000	0.000000	0.000000	0.000889	0.001180	0.000257	0.000748	0.000000	0.000000	0.000000	0.000592	0.000000	0.000050	0.000000

Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000000	0.000275	0.002554	0.000004	0.001121	0.000000	0.000000	0.000000	0.000490	0.000000	0.000253	0.000000
Animal products nec	0.000000	0.000000	0.000000	0.000067	0.000638	0.000048	0.000035	0.000000	0.000000	0.000000	0.000384	0.000000	0.000000	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000005	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002423	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Forestry	0.000000	0.000000	0.000000	0.001398	0.000177	0.000140	0.001194	0.000000	0.000000	0.000006	0.000122	0.000000	0.000470	0.000000
Fishing	0.000000	0.000000	0.000000	0.000032	0.000000	0.000015	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Coal	0.000000	0.000000	0.000000	0.001394	0.001289	0.001139	0.002718	0.000000	0.000000	0.000000	0.001603	0.000061	0.000059	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000005	0.000000	0.000000	0.000002
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000008	0.000000	0.000000	0.000003
Minerals nec	0.000000	0.000000	0.000000	0.006476	0.000176	0.007329	0.011919	0.000000	0.000000	0.000000	0.001591	0.000071	0.000010	0.000000
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000135	0.000241	0.000000	0.000000	0.000000	0.000000	0.000027	0.000000	0.000000	0.000000
Meat products nec	0.000000	0.000000	0.000000	0.000028	0.000101	0.000770	0.000001	0.000000	0.000000	0.000000	0.000352	0.000000	0.000000	0.000000
Vegetable oils and fats	0.000000	0.000000	0.000000	0.000332	0.000066	0.000849	0.000183	0.000000	0.000000	0.000000	0.000159	0.000002	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000000	0.001063	0.000000	0.000841	0.000096	0.000000	0.000000	0.000000	0.000019	0.000000	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000040	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sugar	0.000000	0.000000	0.000000	0.000039	0.000288	0.000232	0.000276	0.000000	0.000000	0.000000	0.000066	0.000000	0.000000	0.000000
Food products nec	0.000000	0.000000	0.000000	0.000200	0.000075	0.000171	0.000417	0.000000	0.000000	0.000000	0.000067	0.000000	0.000022	0.000000
Beverages and tobacco products	0.000000	0.000000	0.000000	0.000405	0.000109	0.000315	0.000634	0.000000	0.000000	0.000000	0.000042	0.000000	0.000102	0.000000
Textiles	0.000000	0.000000	0.000000	0.000017	0.000002	0.000209	0.002305	0.000000	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000005	0.000000	0.000265	0.000071	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000004	0.000001	0.000574	0.000135	0.000000	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000

Wood products	0.000000	0.000000	0.000000	0.003677	0.000198	0.000513	0.001000	0.000000	0.000000	0.000043	0.000506	0.000001	0.000424	0.000000
Paper products, publishing	0.000000	0.000000	0.000000	0.000054	0.000019	0.000471	0.002234	0.000000	0.000000	0.000000	0.000038	0.000000	0.000003	0.000000
Petroleum, coke products	0.000000	0.000000	0.000008	0.000029	0.000023	0.000055	0.000074	0.000000	0.000000	0.000000	0.000025	0.000001	0.000000	0.000000
Chemical, rubber, plastic products	0.000001	0.000000	0.000007	0.000039	0.000019	0.000107	0.000446	0.000000	0.000000	0.000001	0.000061	0.000000	0.000005	0.000003
Mineral products nec	0.000000	0.000000	0.000004	0.000773	0.000211	0.000797	0.001309	0.000000	0.000000	0.000000	0.000098	0.000000	0.000193	0.000000
Ferrous metals	0.000000	0.000000	0.000000	0.000099	0.000022	0.000107	0.001223	0.000000	0.000000	0.000000	0.000082	0.000000	0.000001	0.000000
Metals nec	0.000000	0.000000	0.000000	0.000012	0.000002	0.000084	0.000433	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Metal products	0.000000	0.000000	0.000006	0.000138	0.000024	0.000188	0.000415	0.000000	0.000000	0.000000	0.000172	0.000003	0.000015	0.000000
Motor vehicles and parts	0.000000	0.000000	0.000000	0.000009	0.000005	0.000083	0.000138	0.000000	0.000000	0.000000	0.000032	0.000000	0.000004	0.000000
Transport equipment nec	0.000000	0.000000	0.000000	0.000005	0.000006	0.000038	0.000058	0.000000	0.000000	0.000000	0.000003	0.000000	0.000002	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000001	0.000000	0.000022	0.000044	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000000	0.000000	0.000037	0.000014	0.000083	0.000215	0.000000	0.000000	0.000000	0.000084	0.000000	0.000004	0.000000
Manufactures nec	0.000000	0.000000	0.000000	0.000043	0.000009	0.000270	0.000393	0.000000	0.000000	0.000000	0.000030	0.000000	0.000005	0.000000
	Pacific Highway	Paterson	Philipsburg	Pigeon River	Pleasant Camp	Prescott	Prince Rupert	Rainy River	Regway	Rock Island	Roosville	Rykerts	Sarnia	Sault Ste. Marie
Paddy rice	0.001146	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000734	0.000000
Wheat	0.000001	0.000000	0.000004	0.000000	0.000000	0.000000	0.000000	0.000000	0.000121	0.000004	0.000000	0.000002	0.000399	0.000000
Cereal grains nec	0.000035	0.000000	0.001165	0.000000	0.000000	0.000254	0.000000	0.000000	0.000066	0.000652	0.000000	0.000002	0.001648	0.000000
Vegetables, fruit, nuts	0.001498	0.000000	0.000038	0.000000	0.000000	0.000000	0.000000	0.000000	0.000092	0.000204	0.000000	0.000000	0.000221	0.000001
Oil seeds	0.000088	0.000000	0.000035	0.000000	0.000000	0.000019	0.000000	0.000000	0.000184	0.000105	0.000000	0.000000	0.000257	0.000012
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.013448	0.000000

Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000494	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000206	0.000000
Crops nec	0.000908	0.000000	0.000992	0.000001	0.000000	0.000071	0.000000	0.000000	0.000171	0.000939	0.000010	0.000019	0.000365	0.000004
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000099	0.000000	0.000000	0.000000	0.000000	0.000000	0.000153	0.000004	0.000000	0.000000	0.000214	0.000000
Animal products nec	0.000107	0.000000	0.000024	0.000000	0.000000	0.000000	0.000000	0.000000	0.000031	0.000162	0.000000	0.000000	0.000789	0.000006
Raw milk	0.000000	0.000000	0.000046	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001384	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.008638	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000037	0.000000
Forestry	0.001100	0.000000	0.000049	0.000002	0.000004	0.000282	0.000000	0.000000	0.000195	0.001517	0.000098	0.000056	0.000811	0.001424
Fishing	0.002722	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000	0.000000	0.000006	0.000021
Coal	0.000300	0.000000	0.000241	0.000000	0.000000	0.000035	0.000000	0.000000	0.000072	0.000997	0.000011	0.000000	0.000929	0.000136
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000
Minerals nec	0.011960	0.000000	0.000773	0.000001	0.000000	0.000643	0.000000	0.000000	0.001113	0.000510	0.000002	0.001035	0.022248	0.007202
Bovine meat products	0.000027	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Meat products nec	0.000279	0.000000	0.000009	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000006	0.000001
Vegetable oils and fats	0.000130	0.000000	0.001436	0.000000	0.000000	0.000100	0.000000	0.000000	0.000011	0.000472	0.000000	0.000000	0.000199	0.000002
Dairy products	0.000333	0.000000	0.000707	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000021	0.000000	0.000000	0.000109	0.000000
Processed rice	0.000218	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000750	0.000000
Sugar	0.000525	0.000000	0.000429	0.000000	0.000000	0.000007	0.000000	0.000000	0.000000	0.002198	0.000000	0.000000	0.000367	0.000007
Food products nec	0.000674	0.000000	0.000286	0.000000	0.000000	0.000042	0.000000	0.000000	0.000007	0.000052	0.000000	0.000000	0.000508	0.000013
Beverages and tobacco products	0.000496	0.000000	0.000276	0.000005	0.000000	0.000019	0.000000	0.000001	0.000005	0.000229	0.000000	0.000126	0.000588	0.000014
Textiles	0.000134	0.000000	0.000042	0.000000	0.000000	0.000053	0.000000	0.000000	0.000000	0.000174	0.000000	0.000000	0.000275	0.000014

Wearing apparel	0.000164	0.000000	0.000074	0.000000	0.000000	0.000013	0.000000	0.000000	0.000000	0.000052	0.000000	0.000000	0.000020	0.000000
Leather products	0.000078	0.000000	0.000264	0.000000	0.000000	0.000006	0.000000	0.000000	0.000000	0.000133	0.000000	0.000000	0.000457	0.000003
Wood products	0.001832	0.000008	0.000176	0.000067	0.000000	0.000078	0.000000	0.000000	0.000068	0.001323	0.000334	0.000024	0.000420	0.000606
Paper products, publishing	0.000710	0.000000	0.000167	0.000235	0.000000	0.000066	0.000000	0.000000	0.000004	0.000625	0.000008	0.000000	0.000680	0.000303
Petroleum, coke products	0.000005	0.000000	0.000174	0.000002	0.000000	0.000142	0.000000	0.000000	0.000009	0.000065	0.000018	0.000000	0.000131	0.000003
Chemical, rubber, plastic products	0.000185	0.000020	0.000030	0.000002	0.000000	0.000033	0.000000	0.000000	0.000034	0.000037	0.000001	0.000000	0.000513	0.000019
Mineral products nec	0.000849	0.000000	0.000902	0.000001	0.000000	0.000033	0.000000	0.000000	0.000016	0.001667	0.000012	0.000000	0.001532	0.000036
Ferrous metals	0.000397	0.000000	0.000132	0.000000	0.000000	0.000240	0.000000	0.000000	0.000038	0.000062	0.000000	0.000000	0.001187	0.001048
Metals nec	0.000008	0.000004	0.000008	0.000000	0.000000	0.000026	0.000000	0.000000	0.000000	0.000028	0.000000	0.000000	0.000150	0.000009
Metal products	0.000410	0.000000	0.000071	0.000024	0.000000	0.000031	0.000000	0.000000	0.000052	0.000145	0.000000	0.000000	0.000729	0.000027
Motor vehicles and parts	0.000016	0.000000	0.000002	0.000000	0.000000	0.000002	0.000000	0.000000	0.000017	0.000006	0.000000	0.000000	0.000186	0.000006
Transport equipment nec	0.000255	0.000000	0.000015	0.000000	0.000000	0.000001	0.000000	0.000000	0.000002	0.000015	0.000000	0.000000	0.000067	0.000011
Electronic equipment	0.000055	0.000000	0.000021	0.000000	0.000000	0.000020	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000035	0.000000
Machinery and equipment nec	0.000194	0.000000	0.000023	0.000003	0.000000	0.000034	0.000000	0.000000	0.000022	0.000017	0.000000	0.000000	0.000297	0.000022
Manufactures nec	0.000289	0.000000	0.000274	0.000000	0.000000	0.000063	0.000000	0.000000	0.000000	0.000119	0.000000	0.000000	0.000668	0.000024
	Sidney	South Junction	Sprague	St. Croix	St. Johns	St. Leonard	St. Stephen	Stanhope	Trout River	Victoria	West Poplar River	Ambassador Bridge	Windygates	Winkler
Paddy rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002860	0.000000	0.000000
Wheat	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000007	0.000378	0.000000	0.000000
Cereal grains nec	0.000000	0.000013	0.000004	0.000000	0.000000	0.000026	0.000001	0.000000	0.000102	0.000000	0.000000	0.001519	0.000000	0.000067
Vegetables, fruit, nuts	0.000000	0.000035	0.000000	0.000000	0.000000	0.000034	0.000108	0.000000	0.000000	0.000000	0.000000	0.001352	0.000000	0.000102
Oil seeds	0.000000	0.000021	0.000012	0.000000	0.000000	0.000000	0.000000	0.000000	0.000265	0.000000	0.000000	0.000202	0.000000	0.000806

Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000126	0.000000	0.000000
Crops nec	0.000000	0.000015	0.000008	0.000000	0.000000	0.000001	0.000063	0.000154	0.000000	0.000000	0.000000	0.000669	0.000000	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000103	0.000000	0.000000
Animal products nec	0.000000	0.000006	0.000037	0.000000	0.000000	0.000000	0.000010	0.000000	0.000000	0.000000	0.000000	0.000672	0.000000	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000018	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Forestry	0.000152	0.000000	0.000000	0.000000	0.000000	0.000119	0.000204	0.000222	0.000000	0.000000	0.000000	0.000513	0.000000	0.000000
Fishing	0.000000	0.000000	0.000004	0.000000	0.000000	0.000000	0.001006	0.000000	0.000000	0.000000	0.000000	0.000049	0.000000	0.000000
Coal	0.000000	0.000197	0.000144	0.000000	0.000000	0.000001	0.000127	0.000069	0.000000	0.000000	0.000000	0.000976	0.000000	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000000	0.000009	0.000001	0.000000	0.000000	0.000014	0.000277	0.000206	0.000000	0.000000	0.000000	0.008508	0.000000	0.000000
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000141	0.000000	0.000000
Meat products nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000213	0.000018	0.000000	0.000000	0.000000	0.000000	0.000883	0.000000	0.000000
Vegetable oils and fats	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000045	0.000000	0.000000	0.001806	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000136	0.000000	0.000000	0.000000	0.000000	0.000657	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003050	0.000000	0.000000
Sugar	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000012	0.000000	0.000000	0.000000	0.000000	0.000431	0.000000	0.000000
Food products nec	0.000000	0.000008	0.000002	0.000000	0.000000	0.000000	0.000132	0.000003	0.000038	0.000000	0.000000	0.000753	0.000001	0.000000
Beverages and tobacco products	0.000000	0.000000	0.000000	0.000000	0.000007	0.000000	0.000061	0.000002	0.000000	0.000000	0.000000	0.001237	0.000000	0.000000

Textiles	0.000000	0.000000	0.000004	0.000000	0.000000	0.000000	0.000041	0.000012	0.000000	0.000000	0.000000	0.000611	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000002	0.000015	0.000000	0.000000	0.000000	0.000025	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000010	0.000022	0.000000	0.000000	0.000199	0.000000	0.000000
Wood products	0.000000	0.000009	0.000029	0.000001	0.000000	0.000142	0.000166	0.000049	0.000009	0.000003	0.000000	0.000327	0.000000	0.000000
Paper products, publishing	0.000000	0.000001	0.000002	0.000000	0.000000	0.000001	0.000142	0.000033	0.000001	0.000001	0.000000	0.000675	0.000000	0.000000
Petroleum, coke products	0.000000	0.000002	0.000010	0.000000	0.000000	0.000004	0.000014	0.000007	0.000018	0.000000	0.000000	0.000017	0.000000	0.000000
Chemical, rubber, plastic products	0.000000	0.000019	0.000002	0.000000	0.000000	0.000002	0.000025	0.000012	0.000000	0.000000	0.000002	0.000625	0.000005	0.000013
Mineral products nec	0.000000	0.000004	0.000006	0.000001	0.000000	0.000029	0.000025	0.000028	0.000006	0.000000	0.000000	0.002896	0.000000	0.000000
Ferrous metals	0.000000	0.000000	0.000013	0.000000	0.000000	0.000000	0.000000	0.000025	0.000000	0.000000	0.000000	0.000788	0.000000	0.000000
Metals nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000127	0.000000	0.000000
Metal products	0.000000	0.000002	0.000007	0.000000	0.000000	0.000001	0.000080	0.000012	0.000000	0.000000	0.000000	0.000722	0.000000	0.000031
Motor vehicles and parts	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000	0.000000	0.000257	0.000000	0.000001
Transport equipment nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000002	0.000001	0.000000	0.000000	0.000000	0.000074	0.000000	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000051	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000001	0.000001	0.000000	0.000000	0.000000	0.000003	0.000004	0.000000	0.000000	0.000000	0.000285	0.000000	0.000002
Manufactures nec	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000	0.000012	0.000013	0.000000	0.000000	0.000000	0.000753	0.000000	0.000000
	Woodstock	Yarmouth												
Paddy rice	0.000000	0.000000												
Wheat	0.000000	0.000000												
Cereal grains nec	0.000043	0.000000												
Vegetables, fruit, nuts	0.001633	0.000000												
Oil seeds	0.000000	0.000000												

Sugar cane, sugar beet	0.000000	0.000000													
Plant-based fibers	0.000000	0.000000													
Crops nec	0.000601	0.000000													
Bovine cattle, sheep and goats, horses	0.000004	0.000000													
Animal products nec	0.000058	0.000002													
Raw milk	0.000000	0.000000													
Wool, silk-worm cocoons	0.000000	0.000000													
Forestry	0.001758	0.000000													
Fishing	0.000409	0.000000													
Coal	0.002401	0.000000													
Oil	0.000000	0.000000													
Gas	0.000000	0.000000													
Minerals nec	0.000491	0.000000													
Bovine meat products	0.000000	0.000000													
Meat products nec	0.000002	0.000000													
Vegetable oils and fats	0.000016	0.000000													
Dairy products	0.000016	0.000000													
Processed rice	0.000000	0.000000													
Sugar	0.000000	0.000000													
Food products nec	0.000554	0.000000													
Beverages and tobacco products	0.000100	0.000000													

Textiles	0.000069	0.000000													
Wearing apparel	0.000000	0.000000													
Leather products	0.000001	0.000000													
Wood products	0.000523	0.000000													
Paper products, publishing	0.000199	0.000000													
Petroleum, coke products	0.000002	0.000000													
Chemical, rubber, plastic products	0.000066	0.000000													
Mineral products nec	0.000067	0.000000													
Ferrous metals	0.000005	0.000000													
Metals nec	0.000013	0.000000													
Metal products	0.000021	0.000000													
Motor vehicles and parts	0.000002	0.000000													
Transport equipment nec	0.000001	0.000002													
Electronic equipment	0.000000	0.000000													
Machinery and equipment nec	0.000006	0.000000													
Manufactures nec	0.000015	0.000000													

Table B.5: ams for US Canada trades - addition of a lane to each BC - Preliminary scenario

	Abercorn	Aden	Aldergrove	Andover	Armstrong	Boissevain	Boundary Bay	Campobello	Carievale	Carson	Cartwright	Carway	Cascade	Centreville
Paddy rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wheat	0.000006	0.000000	0.000000	0.000000	0.000000	0.000032	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000
Cereal grains nec	0.000464	0.000000	0.000004	0.000001	0.000004	0.000450	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Vegetables, fruit, nuts	0.000000	0.000000	0.000099	0.000005	0.000003	0.000343	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000	0.000000	0.000056
Oil seeds	0.000000	0.000000	0.000000	0.000000	0.000001	0.004074	0.000000	0.000000	0.000179	0.000000	0.000174	0.000000	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Crops nec	0.000002	0.000000	0.000034	0.000000	0.000029	0.000240	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000000	0.000000	0.000000	0.002007	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Animal products nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000208	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Forestry	0.000000	0.000000	0.000000	0.000468	0.014303	0.000177	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Fishing	0.000000	0.000000	0.000000	0.000000	0.000005	0.000000	0.000000	0.000015	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Coal	0.000000	0.000000	0.000000	0.000000	0.000204	0.000066	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000000	0.000000	0.000000	0.000000	0.000119	0.000074	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Meat products nec	0.000002	0.000000	0.000000	0.000000	0.000000	0.000006	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Vegetable oils and fats	0.000022	0.000000	0.000000	0.000000	0.000139	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sugar	0.000000	0.000000	0.000000	0.000000	0.000147	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Food products nec	0.000017	0.000000	0.000001	0.000024	0.000014	0.000008	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000010
Beverages and tobacco products	0.000000	0.000000	0.000001	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Textiles	0.000000	0.000000	0.000000	0.000000	0.000033	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000000	0.000007	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wood products	0.000000	0.000000	0.000002	0.000000	0.000171	0.000016	0.000001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000003	0.000000
Paper products, publishing	0.000004	0.000000	0.000000	0.000001	0.000068	0.000002	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Petroleum, coke products	0.000000	0.000000	0.000005	0.000000	0.000004	0.000005	0.000000	0.000000	0.000000	0.000000	0.000000	0.000019	0.000000	0.000000
Chemical, rubber, plastic products	0.000001	0.000000	0.000000	0.000000	0.000030	0.000055	0.000000	0.000000	0.000000	0.000000	0.000002	0.000000	0.000000	0.000003
Mineral products nec	0.000000	0.000000	0.000041	0.000003	0.002316	0.000065	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Ferrous metals	0.000000	0.000000	0.000000	0.000000	0.000004	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Metals nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Metal products	0.000002	0.000000	0.000013	0.000000	0.000070	0.000086	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000001

Motor vehicles and parts	0.000000	0.000000	0.000000	0.000000	0.000005	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Transport equipment nec	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000000	0.000000	0.000000	0.000005	0.000011	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Manufactures nec	0.000000	0.000000	0.000000	0.000000	0.000004	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	Clair	Climax	Cornwall	Coronach	Coulter	Coutts	Crystal City	Dawson City	Del Bonita	Edmundston	Emerson	Fort Erie	Fort Frances	Fraser
Paddy rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002130	0.000000	0.000000
Wheat	0.000000	0.000002	0.000000	0.000000	0.000000	0.000279	0.000000	0.000000	0.000000	0.000000	0.000244	0.000635	0.000000	0.000000
Cereal grains nec	0.000000	0.000000	0.000031	0.000000	0.000006	0.001965	0.000000	0.000000	0.000000	0.000000	0.005703	0.001558	0.000011	0.000000
Vegetables, fruit, nuts	0.000000	0.000000	0.000002	0.000000	0.000001	0.000558	0.000000	0.000000	0.000000	0.000000	0.001095	0.002515	0.000001	0.000000
Oil seeds	0.000000	0.000000	0.000019	0.000000	0.000164	0.003202	0.000000	0.000000	0.000000	0.000000	0.010602	0.000335	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000182	0.000867	0.000000	0.000000
Crops nec	0.000000	0.000000	0.000056	0.000000	0.000000	0.005698	0.000000	0.000020	0.000000	0.000003	0.001971	0.006891	0.000056	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000000	0.000000	0.000000	0.007596	0.000000	0.000001	0.000000	0.000000	0.002816	0.001085	0.000000	0.000001
Animal products nec	0.000000	0.000000	0.000010	0.000000	0.000000	0.000805	0.000000	0.000000	0.000000	0.000000	0.003614	0.000770	0.000003	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008569	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000009	0.000000	0.000000	0.000000	0.000000	0.000000	0.000066	0.000000	0.000000
Forestry	0.000449	0.000000	0.000181	0.000000	0.000000	0.002104	0.000000	0.000000	0.000000	0.000033	0.000501	0.001779	0.000000	0.000000
Fishing	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000056	0.000013	0.000000	0.000000

Coal	0.000001	0.000000	0.000016	0.000000	0.000000	0.006209	0.000000	0.000000	0.000000	0.000000	0.007076	0.000972	0.000085	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000083	0.000000	0.000000	0.000004	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000136	0.000000	0.000000	0.000006	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000000	0.000000	0.000053	0.000000	0.000033	0.000120	0.000000	0.000000	0.000000	0.000000	0.000133	0.003157	0.000071	0.000669
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000000	0.004205	0.000000	0.000000	0.000000	0.000000	0.000161	0.000760	0.000000	0.000000
Meat products nec	0.000000	0.000000	0.000001	0.000000	0.000000	0.000377	0.000000	0.000000	0.000000	0.000000	0.001024	0.000828	0.000000	0.000000
Vegetable oils and fats	0.000000	0.000000	0.000378	0.000000	0.000000	0.004787	0.000000	0.000000	0.000000	0.000000	0.001830	0.004033	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000004	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001940	0.001117	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001494	0.000029	0.000000
Sugar	0.000000	0.000000	0.000011	0.000000	0.000000	0.000106	0.000000	0.000000	0.000000	0.000000	0.000127	0.001062	0.000001	0.000000
Food products nec	0.000000	0.000000	0.000029	0.000000	0.000000	0.000268	0.000000	0.000000	0.000000	0.000000	0.000940	0.002282	0.000000	0.000000
Beverages and tobacco products	0.000000	0.000000	0.000058	0.000000	0.000000	0.000172	0.000000	0.000000	0.000000	0.000000	0.000028	0.001847	0.000007	0.000000
Textiles	0.000000	0.000000	0.000012	0.000000	0.000000	0.000023	0.000000	0.000002	0.000000	0.000000	0.000141	0.001125	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000000	0.000000	0.000019	0.000000	0.000007	0.000000	0.000000	0.000120	0.000600	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000030	0.000000	0.000000	0.000000	0.000000	0.000079	0.001033	0.000000	0.000000
Wood products	0.000006	0.000000	0.000042	0.000000	0.000019	0.000426	0.000000	0.000016	0.000000	0.000003	0.000594	0.000686	0.000141	0.000000
Paper products, publishing	0.000000	0.000000	0.000077	0.000000	0.000000	0.000103	0.000000	0.000000	0.000000	0.000068	0.000298	0.001399	0.000208	0.000000
Petroleum, coke products	0.000006	0.000000	0.000105	0.000000	0.000000	0.000065	0.000000	0.000000	0.000000	0.000014	0.000040	0.000278	0.000000	0.000000
Chemical, rubber, plastic products	0.000001	0.000006	0.000011	0.000004	0.000002	0.000289	0.000001	0.000002	0.000001	0.000000	0.000376	0.000884	0.000002	0.000000
Mineral products nec	0.000000	0.000000	0.000160	0.000000	0.000000	0.000460	0.000000	0.000008	0.000000	0.000003	0.000709	0.006030	0.000089	0.000000

Ferrous metals	0.000000	0.000000	0.000007	0.000000	0.000000	0.000135	0.000000	0.000007	0.000000	0.000000	0.000236	0.001554	0.000001	0.000000
Metals nec	0.000000	0.000000	0.000048	0.000000	0.000000	0.000044	0.000000	0.000000	0.000000	0.000000	0.000104	0.002753	0.000000	0.000000
Metal products	0.000001	0.000000	0.000013	0.000000	0.000000	0.001060	0.000000	0.000069	0.000004	0.000000	0.000791	0.008525	0.000006	0.000000
Motor vehicles and parts	0.000000	0.000000	0.000001	0.000000	0.000000	0.000099	0.000000	0.000001	0.000000	0.000000	0.000085	0.000257	0.000000	0.000000
Transport equipment nec	0.000000	0.000000	0.000001	0.000000	0.000000	0.000009	0.000000	0.000075	0.000000	0.000000	0.000049	0.000141	0.000001	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000000	0.000000	0.000015	0.000000	0.000000	0.000000	0.000000	0.000015	0.000158	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000001	0.000007	0.000000	0.000000	0.000697	0.000000	0.000012	0.000000	0.000000	0.000496	0.000976	0.000003	0.000000
Manufactures nec	0.000000	0.000000	0.000010	0.000000	0.000000	0.000107	0.000000	0.000002	0.000000	0.000000	0.000396	0.001795	0.000001	0.000000
	Gillespie Portage	Goodlands	Gretna	Huntingdon	Kingsgate	Lacolle	Lansdowne	Lena	Lyleton	Nelway	North Portal	Northgate	Osoyoos	Oungre
Paddy rice	0.000000	0.000000	0.000000	0.000197	0.000000	0.000176	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wheat	0.000000	0.000000	0.000000	0.000050	0.000002	0.000023	0.000006	0.000000	0.000012	0.000000	0.000581	0.000002	0.000000	0.000000
Cereal grains nec	0.000032	0.000000	0.000018	0.000112	0.000108	0.000752	0.000156	0.000000	0.000000	0.000000	0.000403	0.001480	0.000012	0.000000
Vegetables, fruit, nuts	0.000000	0.000000	0.000000	0.001655	0.000235	0.001926	0.000135	0.000000	0.000000	0.000000	0.000339	0.000000	0.000158	0.000000
Oil seeds	0.000000	0.000050	0.000136	0.000250	0.000121	0.000114	0.000250	0.000123	0.000049	0.000000	0.005326	0.000177	0.000000	0.000000
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008341	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Crops nec	0.000000	0.000000	0.000000	0.001375	0.001977	0.001193	0.000905	0.000000	0.000000	0.000000	0.002360	0.000000	0.000074	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000000	0.000876	0.009180	0.000041	0.002808	0.000000	0.000000	0.000000	0.004190	0.000000	0.000910	0.000000
Animal products nec	0.000000	0.000000	0.000000	0.000116	0.000433	0.000355	0.000016	0.000000	0.000000	0.000000	0.000597	0.000000	0.000000	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000538	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Forestry	0.000000	0.000000	0.000000	0.007367	0.001136	0.001528	0.004250	0.000000	0.000000	0.000010	0.002744	0.000000	0.003963	0.000000
Fishing	0.000000	0.000000	0.000000	0.000026	0.000000	0.000034	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Coal	0.000000	0.000000	0.000000	0.001695	0.001773	0.004397	0.002599	0.000000	0.000000	0.000000	0.006537	0.000106	0.000081	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000	0.000000	0.000001
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000006	0.000000	0.000000	0.000001
Minerals nec	0.000000	0.000000	0.000000	0.002199	0.000058	0.005309	0.003319	0.000000	0.000000	0.000000	0.000720	0.000017	0.000035	0.000000
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000076	0.000403	0.000000	0.000000	0.000000	0.000000	0.000041	0.000000	0.000000	0.000000
Meat products nec	0.000000	0.000000	0.000000	0.000016	0.000057	0.001389	0.000001	0.000000	0.000000	0.000000	0.000476	0.000000	0.000000	0.000000
Vegetable oils and fats	0.000000	0.000000	0.000000	0.000183	0.000059	0.001504	0.000091	0.000000	0.000000	0.000000	0.000282	0.000002	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000000	0.001326	0.000000	0.003276	0.000073	0.000000	0.000000	0.000000	0.000062	0.000000	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000217	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sugar	0.000000	0.000000	0.000000	0.000183	0.001318	0.004586	0.001483	0.000000	0.000000	0.000000	0.000721	0.000000	0.000000	0.000000
Food products nec	0.000000	0.000000	0.000000	0.000262	0.000085	0.000570	0.000332	0.000000	0.000000	0.000000	0.000177	0.000000	0.000024	0.000000
Beverages and tobacco products	0.000000	0.000000	0.000000	0.000312	0.000099	0.000775	0.000407	0.000000	0.000000	0.000000	0.000095	0.000000	0.000097	0.000000
Textiles	0.000000	0.000000	0.000000	0.000018	0.000003	0.000838	0.001547	0.000000	0.000000	0.000000	0.000007	0.000000	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000010	0.000000	0.001607	0.000110	0.000000	0.000000	0.000000	0.000006	0.000000	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000005	0.000001	0.001997	0.000151	0.000000	0.000000	0.000000	0.000001	0.000000	0.000007	0.000000
Wood products	0.000000	0.000000	0.000000	0.001645	0.000135	0.001413	0.000613	0.000000	0.000000	0.000013	0.000755	0.000001	0.000146	0.000000
Paper products, publishing	0.000000	0.000000	0.000000	0.000044	0.000018	0.001214	0.001477	0.000000	0.000000	0.000000	0.000091	0.000000	0.000002	0.000000
Petroleum, coke products	0.000000	0.000000	0.000006	0.000022	0.000026	0.000106	0.000046	0.000000	0.000000	0.000000	0.000059	0.000001	0.000000	0.000000
Chemical, rubber, plastic products	0.000003	0.000000	0.000009	0.000038	0.000027	0.000344	0.000350	0.000000	0.000000	0.000002	0.000147	0.000000	0.000007	0.000004

Mineral products nec	0.000000	0.000000	0.000006	0.000904	0.000362	0.003504	0.001376	0.000000	0.000000	0.000000	0.000345	0.000001	0.000262	0.000000
Ferrous metals	0.000000	0.000000	0.000000	0.000064	0.000021	0.000224	0.000689	0.000000	0.000000	0.000000	0.000169	0.000000	0.000000	0.000000
Metals nec	0.000000	0.000000	0.000000	0.000013	0.000002	0.000224	0.000300	0.000000	0.000000	0.000000	0.000007	0.000000	0.000000	0.000000
Metal products	0.000000	0.000000	0.000009	0.000291	0.000057	0.002118	0.001133	0.000000	0.000000	0.000000	0.000831	0.000005	0.000019	0.000000
Motor vehicles and parts	0.000001	0.000000	0.000000	0.000022	0.000018	0.000792	0.000339	0.000000	0.000000	0.000000	0.000268	0.000000	0.000007	0.000000
Transport equipment nec	0.000000	0.000000	0.000000	0.000008	0.000002	0.000156	0.000099	0.000000	0.000000	0.000000	0.000035	0.000000	0.000022	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000002	0.000000	0.000065	0.000029	0.000000	0.000000	0.000000	0.000002	0.000000	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000000	0.000000	0.000079	0.000021	0.000410	0.000230	0.000000	0.000000	0.000000	0.000358	0.000000	0.000008	0.000000
Manufactures nec	0.000000	0.000000	0.000000	0.000047	0.000011	0.000916	0.000328	0.000000	0.000000	0.000000	0.000091	0.000000	0.000006	0.000000

	Pacific Highway	Paterson	Philipsburg	Pigeon River	Pleasant Camp	Prescott	Prince Rupert	Rainy River	Regway	Rock Island	Roosville	Rykerts	Sarnia	Sault Ste. Marie
Paddy rice	0.001815	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001403	0.000000
Wheat	0.000001	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000093	0.000003	0.000000	0.000002	0.000302	0.000000
Cereal grains nec	0.000035	0.000000	0.001082	0.000000	0.000000	0.000221	0.000000	0.000000	0.000042	0.000827	0.000000	0.000003	0.001512	0.000000
Vegetables, fruit, nuts	0.002102	0.000000	0.000026	0.000000	0.000000	0.000000	0.000000	0.000000	0.000053	0.000302	0.000000	0.000000	0.000256	0.000002
Oil seeds	0.000049	0.000000	0.000027	0.000000	0.000000	0.000014	0.000000	0.000000	0.000157	0.000101	0.000000	0.000000	0.000177	0.000009
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009011	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000375	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000154	0.000000
Crops nec	0.001231	0.000000	0.001730	0.000003	0.000000	0.000125	0.000000	0.000000	0.000288	0.001888	0.000017	0.000010	0.000599	0.000007
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000349	0.000000	0.000000	0.000000	0.000000	0.000000	0.000551	0.000014	0.000000	0.000000	0.000574	0.000000
Animal products nec	0.000044	0.000000	0.000137	0.000000	0.000000	0.000000	0.000000	0.000000	0.000084	0.000080	0.000000	0.000000	0.000696	0.000009
Raw milk	0.000000	0.000000	0.000362	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.010746	0.000000

Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.002748	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000012	0.000000
Forestry	0.004124	0.000000	0.000167	0.000003	0.000027	0.001186	0.000000	0.000000	0.002228	0.003629	0.000884	0.000239	0.002726	0.006172
Fishing	0.001920	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000	0.000000	0.000004	0.000018
Coal	0.000340	0.000000	0.000330	0.000000	0.000000	0.000048	0.000000	0.000000	0.000099	0.001567	0.000015	0.000000	0.001258	0.000193
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000483	0.000000	0.000574	0.000001	0.000000	0.000236	0.000000	0.000000	0.000450	0.000314	0.000001	0.000012	0.001238	0.000738
Bovine meat products	0.000014	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Meat products nec	0.000142	0.000000	0.000006	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000004	0.000000
Vegetable oils and fats	0.000075	0.000000	0.000884	0.000000	0.000000	0.000063	0.000000	0.000000	0.000007	0.000336	0.000000	0.000000	0.000129	0.000002
Dairy products	0.000241	0.000000	0.002980	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000036	0.000000	0.000000	0.000146	0.000000
Processed rice	0.000345	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001433	0.000000
Sugar	0.001977	0.000000	0.003612	0.000000	0.000000	0.000063	0.000000	0.000000	0.000000	0.021208	0.000000	0.000000	0.002811	0.000061
Food products nec	0.000656	0.000000	0.000278	0.000000	0.000000	0.000039	0.000000	0.000000	0.000009	0.000076	0.000000	0.000000	0.000601	0.000019
Beverages and tobacco products	0.000353	0.000000	0.000393	0.000005	0.000000	0.000018	0.000000	0.000001	0.000005	0.000251	0.000000	0.000122	0.000505	0.000013
Textiles	0.000172	0.000000	0.000052	0.000000	0.000000	0.000049	0.000000	0.000000	0.000001	0.000142	0.000000	0.000000	0.000306	0.000019
Wearing apparel	0.000298	0.000000	0.000163	0.000000	0.000000	0.000027	0.000000	0.000000	0.000000	0.000134	0.000000	0.000000	0.000043	0.000001
Leather products	0.000097	0.000000	0.000298	0.000000	0.000000	0.000008	0.000000	0.000000	0.000000	0.000177	0.000000	0.000000	0.000547	0.000004
Wood products	0.001013	0.000002	0.000210	0.000024	0.000000	0.000130	0.000000	0.000000	0.000055	0.001124	0.000126	0.000008	0.000519	0.000662
Paper products, publishing	0.000479	0.000000	0.000169	0.000228	0.000000	0.000055	0.000000	0.000000	0.000002	0.000644	0.000008	0.000000	0.000582	0.000270
Petroleum, coke products	0.000004	0.000000	0.000116	0.000002	0.000000	0.000099	0.000000	0.000000	0.000007	0.000056	0.000021	0.000000	0.000177	0.000008

Chemical, rubber, plastic products	0.000172	0.000049	0.000037	0.000003	0.000000	0.000028	0.000000	0.000000	0.000038	0.000061	0.000001	0.000000	0.000636	0.000022
Mineral products nec	0.001098	0.000000	0.001628	0.000001	0.000000	0.000064	0.000000	0.000000	0.000027	0.002834	0.000018	0.000000	0.002155	0.000050
Ferrous metals	0.000216	0.000000	0.000087	0.000000	0.000000	0.000194	0.000000	0.000000	0.000034	0.000058	0.000000	0.000000	0.000817	0.000656
Metals nec	0.000009	0.000003	0.000011	0.000000	0.000000	0.000045	0.000000	0.000000	0.000000	0.000028	0.000000	0.000000	0.000447	0.000027
Metal products	0.003840	0.000000	0.000352	0.000074	0.000000	0.000090	0.000000	0.000000	0.000077	0.000643	0.000000	0.000000	0.007205	0.000098
Motor vehicles and parts	0.000019	0.000000	0.000003	0.000000	0.000000	0.000006	0.000000	0.000000	0.000064	0.000015	0.000000	0.000000	0.000219	0.000011
Transport equipment nec	0.000239	0.000000	0.000035	0.000001	0.000000	0.000002	0.000000	0.000000	0.000004	0.000040	0.000000	0.000000	0.000132	0.000018
Electronic equipment	0.000060	0.000000	0.000038	0.000000	0.000000	0.000017	0.000000	0.000000	0.000000	0.000003	0.000000	0.000000	0.000047	0.000000
Machinery and equipment nec	0.000338	0.000000	0.000040	0.000006	0.000000	0.000047	0.000000	0.000000	0.000041	0.000043	0.000000	0.000000	0.000605	0.000052
Manufactures nec	0.000275	0.000000	0.000540	0.000000	0.000000	0.000088	0.000000	0.000000	0.000000	0.000160	0.000000	0.000000	0.000809	0.000029
	Sidney	South Junction	Sprague	St. Croix	St. Johns	St. Leonard	St. Stephen	Stanhope	Trout River	Victoria	West Poplar River	Ambassador Bridge	Windygates	Winkler
Paddy rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006841	0.000000	0.000000
Wheat	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000005	0.000359	0.000000	0.000000
Cereal grains nec	0.000000	0.000004	0.000001	0.000000	0.000000	0.000022	0.000001	0.000000	0.000095	0.000000	0.000000	0.001760	0.000000	0.000068
Vegetables, fruit, nuts	0.000000	0.000015	0.000000	0.000000	0.000000	0.000037	0.000198	0.000001	0.000000	0.000000	0.000000	0.002945	0.000000	0.000045
Oil seeds	0.000000	0.000017	0.000011	0.000000	0.000000	0.000000	0.000000	0.000000	0.000190	0.000000	0.000000	0.000180	0.000000	0.000587
Sugar cane, sugar beet	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Plant-based fibers	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000118	0.000000	0.000000
Crops nec	0.000000	0.000017	0.000012	0.000000	0.000000	0.000001	0.000194	0.000256	0.000000	0.000000	0.000000	0.001387	0.000000	0.000000
Bovine cattle, sheep and goats, horses	0.000000	0.000000	0.000008	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000449	0.000000	0.000000

Animal products nec	0.000000	0.000015	0.000012	0.000000	0.000000	0.000000	0.000007	0.000000	0.000000	0.000000	0.000000	0.000392	0.000000	0.000000
Raw milk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000172	0.000000	0.000000
Wool, silk-worm cocoons	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Forestry	0.000653	0.000000	0.000000	0.000000	0.000000	0.000513	0.000508	0.000211	0.000000	0.000000	0.000000	0.000940	0.000000	0.000000
Fishing	0.000000	0.000000	0.000004	0.000000	0.000000	0.000000	0.001687	0.000000	0.000000	0.000000	0.000000	0.000052	0.000000	0.000000
Coal	0.000000	0.000270	0.000198	0.000000	0.000000	0.000001	0.000281	0.000094	0.000000	0.000000	0.000000	0.001654	0.000000	0.000000
Oil	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Gas	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Minerals nec	0.000000	0.000005	0.000000	0.000000	0.000000	0.000003	0.000114	0.000020	0.000000	0.000000	0.000000	0.002450	0.000000	0.000000
Bovine meat products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000101	0.000000	0.000000
Meat products nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000122	0.000018	0.000000	0.000000	0.000000	0.000000	0.000743	0.000000	0.000000
Vegetable oils and fats	0.000000	0.000002	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000028	0.000000	0.000000	0.001401	0.000000	0.000000
Dairy products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000344	0.000000	0.000000	0.000000	0.000000	0.001061	0.000000	0.000000
Processed rice	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007297	0.000000	0.000000
Sugar	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000157	0.000000	0.000000	0.000000	0.000000	0.003866	0.000000	0.000000
Food products nec	0.000000	0.000009	0.000002	0.000000	0.000000	0.000000	0.000244	0.000003	0.000050	0.000000	0.000000	0.001165	0.000001	0.000000
Beverages and tobacco products	0.000000	0.000000	0.000000	0.000000	0.000006	0.000000	0.000087	0.000002	0.000000	0.000000	0.000000	0.001208	0.000000	0.000000
Textiles	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000085	0.000015	0.000000	0.000000	0.000000	0.000790	0.000000	0.000000
Wearing apparel	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000009	0.000034	0.000000	0.000000	0.000000	0.000064	0.000000	0.000000
Leather products	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000002	0.000011	0.000043	0.000000	0.000000	0.000380	0.000000	0.000000
Wood products	0.000000	0.000017	0.000037	0.000000	0.000000	0.000032	0.000190	0.000056	0.000011	0.000001	0.000000	0.000455	0.000000	0.000000
Paper products, publishing	0.000000	0.000001	0.000003	0.000000	0.000000	0.000001	0.000224	0.000034	0.000001	0.000001	0.000000	0.000799	0.000000	0.000000

Petroleum, coke products	0.000000	0.000002	0.000010	0.000000	0.000000	0.000002	0.000018	0.000005	0.000012	0.000000	0.000000	0.000014	0.000000	0.000000
Chemical, rubber, plastic products	0.000000	0.000014	0.000003	0.000000	0.000000	0.000004	0.000038	0.000014	0.000001	0.000000	0.000003	0.000680	0.000008	0.000021
Mineral products nec	0.000000	0.000005	0.000007	0.000003	0.000000	0.000031	0.000098	0.000048	0.000010	0.000000	0.000000	0.004304	0.000000	0.000000
Ferrous metals	0.000000	0.000000	0.000008	0.000000	0.000000	0.000000	0.000001	0.000022	0.000000	0.000000	0.000000	0.000863	0.000000	0.000000
Metals nec	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000	0.000000	0.000230	0.000000	0.000000
Metal products	0.000000	0.000003	0.000009	0.000000	0.000000	0.000004	0.000165	0.000028	0.000000	0.000000	0.000000	0.004861	0.000000	0.000047
Motor vehicles and parts	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	0.000002	0.000001	0.000000	0.000000	0.000000	0.000415	0.000000	0.000003
Transport equipment nec	0.000002	0.000000	0.000001	0.000000	0.000000	0.000000	0.000016	0.000001	0.000000	0.000003	0.000000	0.000127	0.000000	0.000000
Electronic equipment	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000	0.000000	0.000073	0.000000	0.000000
Machinery and equipment nec	0.000000	0.000002	0.000002	0.000000	0.000000	0.000000	0.000012	0.000008	0.000000	0.000000	0.000000	0.000888	0.000000	0.000003
Manufactures nec	0.000000	0.000000	0.000003	0.000000	0.000000	0.000000	0.000025	0.000014	0.000000	0.000000	0.000000	0.001008	0.000000	0.000000
	Woodstock	Yarmouth												
Paddy rice	0.000000	0.000000												
Wheat	0.000000	0.000000												
Cereal grains nec	0.000023	0.000000												
Vegetables, fruit, nuts	0.001968	0.000000												
Oil seeds	0.000000	0.000000												
Sugar cane, sugar beet	0.000000	0.000000												
Plant-based fibers	0.000000	0.000000												
Crops nec	0.001277	0.000000												

Bovine cattle, sheep and goats, horses	0.000014	0.000000													
Animal products nec	0.000013	0.000000													
Raw milk	0.000000	0.000000													
Wool, silk-worm cocoons	0.000000	0.000000													
Forestry	0.003247	0.000000													
Fishing	0.000453	0.000000													
Coal	0.003613	0.000000													
Oil	0.000000	0.000000													
Gas	0.000000	0.000000													
Minerals nec	0.000054	0.000000													
Bovine meat products	0.000000	0.000000													
Meat products nec	0.000002	0.000000													
Vegetable oils and fats	0.000015	0.000000													
Dairy products	0.000025	0.000000													
Processed rice	0.000000	0.000000													
Sugar	0.000003	0.000000													
Food products nec	0.000740	0.000000													
Beverages and tobacco products	0.000107	0.000000													
Textiles	0.000081	0.000000													
Wearing apparel	0.000001	0.000000													
Leather products	0.000002	0.000000													

Wood products	0.000211	0.000000												
Paper products, publishing	0.000199	0.000000												
Petroleum, coke products	0.000002	0.000000												
Chemical, rubber, plastic products	0.000061	0.000000												
Mineral products nec	0.000079	0.000000												
Ferrous metals	0.000005	0.000000												
Metals nec	0.000013	0.000000												
Metal products	0.000046	0.000001												
Motor vehicles and parts	0.000004	0.000000												
Transport equipment nec	0.000004	0.000000												
Electronic equipment	0.000000	0.000000												
Machinery and equipment nec	0.000014	0.000000												
Manufactures nec	0.000027	0.000000												

Appendix C: Correspondence tables

Table C.1: GSC2-CPC correspondence table

GSC2 code	Sector Abbreviation	CPC code	Sector Description
1	pdr	113	Rice, not husked
		114	Husked rice
2	wht	111	Wheat and meslin
3	gro	112	Maize (corn)
		115	Barley
		116	Rye, oats
		119	Other cereals
4	v_f	12	Vegetables
		13	Fruit and nuts
5	osd	14	Oil seeds and oleaginous fruit
6	c_b	18	Plants used for sugar manufacturing
7	pfb	192	Raw vegetable materials used in textiles
8	ocr	15	Live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds
		16	Beverage and spice crops
		17	Unmanufactured tobacco
		191	Cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets
		193	Plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes
		194	Sugar beet seed and seeds of forage plants
		199	Other raw vegetable materials
9	ctl	211	Bovine cattle, sheep and goats, horses, asses, mules, and hinnies, live
		299	Bovine semen
10	oap	212	Swine, poultry and other animals, live
		292	Eggs, in shell, fresh, preserved or cooked

		293	Natural honey
		294	Snails, live, fresh, chilled, frozen, dried, salted or in brine, except sea snails; frogs' legs, fresh, chilled or frozen
		295	Edible products of animal origin n.e.c.
		297	Hides, skins and furskins, raw
		298	Insect waxes and spermaceti, whether or not refined or coloured
11	rmk	291	Raw milk
12	wol	296	Raw animal materials used in textile
13	for	3	Forestry, logging and related service activities
19	cmt	21111	Meat of bovine animals, fresh or chilled
		21112	Meat of bovine animals, frozen
		21115	Meat of sheep, fresh or chilled
		21116	Meat of sheep, frozen
		21117	Meat of goats, fresh, chilled or frozen
		21118	Meat of horses, asses, mules or hinnies, fresh, chilled or frozen
		21119	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen
		2161	Fats of bovine animals, sheep, goats, pigs and poultry, raw or rendered; wool grease
20	omt	21113	Meat of swine, fresh or chilled
		21114	Meat of swine, frozen
		2112	Meat and edible offal, fresh, chilled or frozen, n.e.c.
		2113	Preserves and preparations of meat, meat offal or blood
		2114	Flours, meals and pellets of meat or meat offal, inedible; greaves
		2162	Animal oils and fats, crude and refined, except fats of bovine animals, sheep, goats, pigs and poultry
21	vol	2163	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed rape, colza and mustard oil, crude
		2164	Palm, coconut, palm kernel, babassu and linseed oil, crude

		2165	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil and their fractions, refined but not chemically modified; other oils obtained solely from olives and sesame oil, and their fractions, whether or not refined, but not chemically modified
		2166	Maize (corn) oil and its fractions, not chemically modified
		2167	Palm, coconut, palm kernel, babassu and linseed oil and their fractions, refined but not chemically modified; castor, tung and jojoba oil and fixed vegetable fats and oils (except maize oil) and their fractions n.e.c., whether or not refined, but not chemically modified
		2168	Margarine and similar preparations
		2169	Animal or vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised, whether or not refined, but not further prepared
		217	Cotton linters
		218	Oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes
22	mil	22	Dairy products
23	pcr	2316	Rice, semi- or wholly milled
24	sgr	235	Sugar
25	ofd	212	Prepared and preserved fish
		213	Prepared and preserved vegetables
		214	Fruit juices and vegetable juices
		215	Prepared and preserved fruit and nuts
		2311	Wheat or meslin flour
		2312	Cereal flours other than of wheat or meslin
		2313	Groats, meal and pellets of wheat

		2314	Cereal groats, meal and pellets n.e.c.
		2315	Other cereal grain products (including corn flakes)
		2317	Other vegetable flours and meals
		2318	Mixes and doughs for the preparation of bakers' wares
		232	Starches and starch products; sugars and sugar syrups n.e.c.
		233	Preparations used in animal feeding
		234	Bakery products
		236	Cocoa, chocolate and sugar confectionery
		237	Macaroni, noodles, couscous and similar farinaceous products
		239	Food products n.e.c.
26	b_t	24	Beverages
		25	Tobacco products

Table C.2: GSC2-ISIC correspondence table

GSC2 code	Sector Abbreviation	ISIC code	Sector Description
14	fsh	15	Hunting, trapping and game propagation including related service activities
		5	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
15	col	101	Mining and agglomeration of hard coal
		102	Mining and agglomeration of lignite
		103	Mining and agglomeration of peat
16	oil	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	12	Mining of uranium and thorium ores
		13	Mining of metal ores
		14	Other mining and quarrying
27	tex	17	Manufacture of textiles
		243	Manufacture of man-made fibres

28	wap	18	Manufacture of wearing apparel; dressing and dyeing of fur
29	lea	19	Tan and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
30	lum	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	21	Manufacture of paper and paper products
		22	Publishing, printing and reproduction of record media
32	p_c	231	Manufacture of coke oven products
		232	Manufacture of refined petroleum products
		233	Processing of nuclear fuel
33	crp	241	Manufacture of basic chemicals
		242	Manufacture of other chemical products
		25	Manufacture of rubber and plastics products
34	nmm	26	Manufacture of other non-metallic mineral products
35	i_s	271	Manufacture of basic iron and steel
		2731	Casting of iron and steel
36	nfm	272	Manufacture of basic precious and non-ferrous metals
		2732	Casting of non-ferrous metals
37	fmp	28	Manufacture of fabricated metal products, except machinery and equipment
38	mvh	34	Manufacture of motor vehicles, trailers and semi-trailers
39	otn	35	Manufacture of other transport equipment
40	ele	30	Manufacture of office, accounting and computing machinery
		32	Manufacture of radio, television and communication equipment and apparatus
41	ome	29	Manufacture of machinery and equipment n.e.c.
		31	Manufacture of electrical machinery and apparatus n.e.c.
		33	Manufacture of medical, precision and optical instruments, watches and clocks
42	omf	36	Manufacturing n.e.c.
		37	Recycling
43	ely	401	Production, collection and distribution of electricity
44	gdt	402	Manufacture of gas; distribution of gaseous fuels through mains

		403	Steam and hot water supply
45	wtr	41	Collection, purification and distribution of water
46	cns	45	Construction
47	trd	50	Sales, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
		51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
		521	Non-specialized retail trade in stores
		522	Retail sale of food, beverages and tobacco in specialized stores
		523	Other retail trade of new goods in specialized stores
		524	Retail sale of second-hand goods in stores
		525	Retail trade not in stores
		526	Repair of personal and household goods
		55	Hotels and restaurants
48	otp	60	Land transport; transport via pipelines
		63	Supporting and auxiliary transport activities; activities of travel agencies
49	wtp	61	Water transport
50	atp	62	Air transport
51	cmn	64	Post and telecommunications
52	ofi	65	Financial intermediation, except insurance and pension funding
		67	Activities auxiliary to financial intermediation
53	isr	66	Insurance and pension funding, except compulsory social security
54	obs	K	Real estate, renting and business activities
55	ros	92	Recreational, cultural and sporting activities
		93	Other service activities
		95	Private households with employed persons
56	osg	75	Public administration and defense; compulsory social security
		80	Education
		85	Health and social work
		90	Sewage and refuse disposal, sanitation and similar activities
		91	Activities of membership organizations n.e.c.
		99	Extra-territorial organizations and bodies
57	dwe	n.a.	n.a.

Table C.3: HS codes and descriptions corresponding to sector 38 (Motor vehicle and parts) in GSC2

HS 2007	Description
840731	Engines; reciprocating piston engines, of a kind used for the propulsion of vehicles of chapter 87, of a cylinder capacity not exceeding 50cc
840732	Engines; reciprocating piston engines, of a kind used for the propulsion of vehicles of chapter 87, of a cylinder capacity exceeding 50cc but not exceeding 250cc
840733	Engines; reciprocating piston engines, of a kind used for the propulsion of vehicles of chapter 87, of a cylinder capacity exceeding 250cc but not exceeding 1000cc
840734	Engines; reciprocating piston engines, of a kind used for the propulsion of vehicles of chapter 87, of a cylinder capacity exceeding 1000cc
840820	Engines; compression-ignition internal combustion piston engines (diesel or semi-diesel engines), of a kind used for the propulsion of vehicles of chapter 87
840991	Engines; parts, suitable for use solely or principally with spark-ignition internal combustion piston engines (for other than aircraft)
840999	Engines; parts for internal combustion piston engines (excluding spark-ignition)
860900	Containers; (including containers for transport of fluids) specially designed and equipped for carriage by one or more modes of transport
870120	Tractors; road, for semi-trailers
870210	Vehicles; public transport type (carries 10 or more persons, including driver), with only compression-ignition internal combustion piston engine (diesel or semi-diesel), new or used
870290	Vehicles; public transport type (carries 10 or more persons, including driver), n.e.c. in heading 8702, new or used
870310	Vehicles; specially designed for travelling on snow, golf cars and similar vehicles
870321	Vehicles; with only spark-ignition internal combustion reciprocating piston engine, cylinder capacity not over 1000cc
870322	Vehicles; with only spark-ignition internal combustion reciprocating piston engine, cylinder capacity over 1000 but not over 1500cc
870323	Vehicles; with only spark-ignition internal combustion reciprocating piston engine, cylinder capacity over 1500 but not over 3000cc
870324	Vehicles; with only spark-ignition internal combustion reciprocating piston engine, cylinder capacity over 3000cc
870331	Vehicles; with only compression-ignition internal combustion piston engine (diesel or semi-diesel), cylinder capacity not over 1500cc
870332	Vehicles; with only compression-ignition internal combustion piston engine (diesel or semi-diesel), cylinder capacity over 1500 but not over 2500cc
870333	Vehicles; with only compression-ignition internal combustion piston engine (diesel or semi-diesel), cylinder capacity over 2500cc
870390	Vehicles; for transport of persons (other than those of heading no. 8702) n.e.c. in heading no. 8703
870421	Vehicles; compression-ignition internal combustion piston engine (diesel or semi-diesel), for transport of goods, (of a gvw not exceeding 5 tonnes), n.e.c. in item no 8704.1
870422	Vehicles; compression-ignition internal combustion piston engine (diesel or semi-diesel), for transport of goods, (of a g.v.w. exceeding 5 tonnes but not exceeding 20 tonnes), n.e.c. in item no 8704.1

870423	Vehicles; compression-ignition internal combustion piston engine (diesel or semi-diesel), for transport of goods, (of a g.v.w. exceeding 20 tonnes), n.e.c. in item no 8704.1
870431	Vehicles; spark-ignition internal combustion piston engine, for transport of goods, (of a g.v.w. not exceeding 5 tonnes), n.e.c. in item no 8704.1
870432	Vehicles; spark-ignition internal combustion piston engine, for transport of goods, (of a g.v.w. exceeding 5 tonnes), n.e.c. in item no 8704.1
870490	Vehicles; for transport of goods, n.e.c. in heading no. 8704
870510	Vehicles; crane lorries
870520	Vehicles; mobile drilling derricks
870530	Vehicles; fire fighting vehicles
870540	Vehicles; concrete-mixer lorries
870590	Vehicles; break-down lorries, road-sweepers, spraying lorries, mobile workshops, mobile radiological units, and other special purpose vehicles n.e.c. in heading no. 8705
870600	Chassis; fitted with engines, for the motor vehicles of heading no. 8701 to 8705
870710	Vehicles; bodies (including cabs) for the motor vehicles of heading no. 8703
870790	Vehicles; bodies (including cabs) for the motor vehicles of heading no. 8701, 8702, 8704 or 8705
870810	Vehicles; bumpers and parts thereof, for the vehicles of heading no. 8701 to 8705
870821	Vehicles; parts of bodies, safety seat belts
870829	Vehicles; parts and accessories, of bodies, other than safety seat belts
870830	Vehicle parts; brakes, servo-brakes and parts thereof
870840	Vehicle parts; gear boxes and parts thereof
870850	Vehicle parts; drive-axles with differential, whether or not provided with other transmission components, and non-driving axles; parts thereof
870870	Vehicle parts; road wheels and parts and accessories thereof
870880	Vehicle parts; suspension systems and parts thereof (including shock-absorbers)
870891	Vehicle parts; radiators and parts thereof
870892	Vehicle parts; silencers (mufflers) and exhaust pipes; parts thereof
870893	Vehicle parts; clutches and parts thereof
870894	Vehicle parts; steering wheels, steering columns and steering boxes; parts thereof
870895	Vehicle parts; safety airbags with inflater system; parts thereof
870899	Vehicle parts and accessories; n.e.c. in heading no. 8708
871610	Trailers and semi-trailers; of the caravan type, for housing or camping
871631	Tanker trailers and tanker semi-trailers
871639	Trailers and semi-trailers; (other than tanker type)
871640	Trailers and semi-trailers; n.e.c. in item no. 8716.3
871690	Trailers, semi-trailers and other vehicles not mechanically propelled; parts thereof for heading no. 8716

Appendix D: Sectoral average payload factor

Table D.1: Sectoral (CGS2) average payload factor

Sector name	Canada to US payload factor [Kg/truck]	US to Canada payload factor [Kg/truck]
Paddy rice	18397.58	18397.58
Wheat	31160	31160
Cereal grains nec	26022.9	25369.36
Vegetables, fruit, nuts	17796.14	17678.61
Oil seeds	19958.99	20033.24
Sugar cane, sugar beet	38680.33	38680.33
Plant-based fibers	10264.93	10264.93
Crops nec	13791.24	13666.09
Bovine cattle, sheep and goats, horses	21757.64	21868.34
Animal products nec	14054.31	13729.67
Raw milk	20416.5	20416.5
Wool, silk-worm cocoons	22552	22552
Forestry	25474.92	27931.67
Fishing	12181.57	12225.79
Coal	19895.18	19911.43
Oil	20848.3	20927.95
Gas	12181.57	12225.79
Minerals nec	24653.79	22701.34
Bovine meat products	18754.44	18765.88
Meat products nec	17791.11	17807.77
Vegetable oils and fats	9946.301	10354.67
Dairy products	16517.09	16878.27
Processed rice	18397.58	18397.58
Sugar	21564.13	23227.19
Food products nec	16846.69	16834.25
Beverages and tobacco products	20141.04	20102.76
Textiles	9097.192	9378.24
Wearing apparel	7429.36	7484.788
Leather products	6817.743	6955.787
Wood products	22673.77	20859.85
Paper products, publishing	16566.18	16600.15
Petroleum, coke products	29851.75	29023.87
Chemical, rubber, plastic products	18046.91	18367.35
Mineral products nec	20222.14	20402.44
Ferrous metals	22094.53	21643.24
Metals nec	18542.62	19315.99
Metal products	10402.89	9578.931
Motor vehicles and parts	7153.723	6607.547
Transport equipment nec	6848.262	6941.068

Electronic equipment	6474.687	6672.588
Machinery and equipment nec	10549.92	10173.69
Manufactures nec	6644.2	6573.599

Appendix E: Correlation coefficient matrix of mode choice modelling variables

The correlation coefficient matrix between the modelling variables are presented in Table E.1:

Table E.1: Correlation Coefficient Matrix

Variables/Variables	origins	commodities	shipment diffrence	weight diffrence	revenue difference	distance diffrence	tonnekm diffrence	value diffenrece	average weight diffrence	average revenue difference	average distance diffrence	average value diffenrece
origins	1.00	-0.01	-0.03	-0.11	-0.16	-0.17	-0.09	-0.24	0.08	0.03	0.01	0.05
commodities	-0.01	1.00	-0.18	-0.37	-0.14	-0.16	-0.04	-0.19	-0.09	0.04	0.05	0.06
shipment diffrence	-0.03	-0.18	1.00	0.31	0.28	0.35	0.13	0.40	0.03	-0.08	-0.18	-0.07
weight diffrence	-0.11	-0.37	0.31	1.00	0.53	0.42	0.48	0.38	0.33	-0.05	-0.32	-0.12
revenue difference	-0.16	-0.14	0.28	0.53	1.00	0.76	0.92	0.64	0.29	0.16	-0.01	-0.02
distance diffrence	-0.17	-0.16	0.35	0.42	0.76	1.00	0.58	0.68	0.15	0.07	0.00	-0.04
tonnekm diffrence	-0.09	-0.04	0.13	0.48	0.92	0.58	1.00	0.39	0.25	0.11	0.03	-0.03
value diffenrece	-0.24	-0.19	0.40	0.38	0.64	0.68	0.39	1.00	0.27	0.11	-0.09	0.13
average weight diffrence	0.08	-0.09	0.03	0.33	0.29	0.15	0.25	0.27	1.00	0.52	-0.16	0.11
average revenue difference	0.03	0.04	-0.08	-0.05	0.16	0.07	0.11	0.11	0.52	1.00	0.16	0.54
average distance diffrence	0.01	0.05	-0.18	-0.32	-0.01	0.00	0.03	-0.09	-0.16	0.16	1.00	-0.06
average value diffenrece	0.05	0.06	-0.07	-0.12	-0.02	-0.04	-0.03	0.13	0.11	0.54	-0.06	1.00

There is a high correlation (0.92) between TonneKm and Revenue, which make sense considering that shippers' pricing is sensitive to distances that weights are carried; higher TonneKm must result in higher Revenues, which is what this high positive correlation means. Total distance traveled is moderately correlated (0.76) with the Revenue, which makes sense given that shippers charge higher prices for shipments with longer distances. There exist moderate correlations of 0.68 and 0.64 between value and distance and value and revenue. The correlation between value and distance could be due to the fact that of shipments of higher value were shipped to longer distances. The moderate correlation between value and revenue may be due the fact that shippers charge higher prices for shipments of higher values. Other variable pairs are less correlated as the correlations are less than 0.60. Intuitively, revenue and weights should also be correlated since shippers would charge higher prices for shipments with higher weight, but the analysis results provided little evidence to support this hypothesis - a very low correlation level between the two variables.