Analyzing the Infrastructure Impacts of Free Trade Agreements

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Abstract

This paper presents a modelling framework to analyze the domestic transportation impacts of free trade agreements. In general, the analysis requires: 1) a model of the global economy that quantifies the impacts of a free trade agreement on international trade flows; 2) a multi-scale analysis that links changes in national production, consumption, and international imports and exports to subnational trade flows; and 3) a freight model that translates all trade flows into freight flows. Computable general equilibrium models are a suitable alternative for simulating complex economic policies such as free trade agreements because they comprehensively model the entire economy, the interdependency between all of its parts, and the microeconomic behavior within these parts. A multi-scale multi-regional input-output analysis then links global economic impacts to individual states, provinces, or regions using the interindustry and interregional structure of the national economy. Freight flow modeling can begin with a commodity-based approach in the initial implementation of the analysis, and once operational, models of logistics choices can be incorporated to upgrade the commodity-based model to an aggregate-disaggregate-aggregate freight model. A range of detail and theoretical consistencies in implementations is described in the paper, compromising data and labor requirements for the quantity and quality of the overall modelling framework's capabilities.

Introduction

Canada has recently progressed several Free Trade Agreements (FTAs). The country has recently brought the Canada Korea Free Trade Agreement (CKFTA) into force, and has concluded the Comprehensive Economic and Trade Agreement (CETA) between Canada and the European Union and the Trans-Pacific Partnership (TPP) involving the Pacific Rim countries. Previous FTAs suggest sizeable impacts on Canada's trade may be imminent. For example, the cross-border trade between the United States (US) and Canada increased rapidly following the implementation of the North America Free Trade Agreement (NAFTA). In approximately just the last decade, US freight exports to Canada have increased by 61% and US freight imports from Canada have risen by 36% (Chi, 2014). Moreover, CETA is "broader in scope and deeper in ambition than the historic North American Free Trade Agreement" according to the Government of Canada (Government of Canada, 2015a). Finally, Canada has ongoing negotiations with other trade partners such as India, Japan, and the Caribbean Community (CARICOM).

While the federal government, namely Global Affairs Canada (GAC), formerly the Department of Foreign Affairs, Trade and Development (DFATD), carries out considerable analysis of the potential impact of trade agreements on the Canadian economy, little to no work is done to assess the potential impact on Canada's transportation system. Trade patterns ultimately manifest themselves in freight flows on transportation systems, but the translation of economic flows into transportation patterns is not straightforward (e.g., consider the role of transhipment points and vehicle routing patterns). Changes to Canada's economy also impact firm and household behaviour through mechanisms such as employment and income, leading to changes in passenger flows as well (e.g., work trips and discretionary travel).

The objective of this research is to identify, describe and assess the analysis and related modeling techniques that can be used to analyze the infrastructure impacts of FTAs. The remainder of the paper is organized as follows. The literature review provides a review of research related to the transportation impacts of trade agreements. The methods section identifies potential analysis and related modeling that can be used to carry out this type of impact assessment, including a description of the pros, cons, risks and potential results. The framework section presents the proposed modeling framework and describes the requirements associated with implementing such analysis and modeling. The case study section then describes the work-in-progress aimed at quantifying the impacts of CKFTA and CETA on Canada's transportation infrastructure.

Literature Review

Few studies have focused on modeling the impact of trade agreements on transportation systems ex-ante. Cristea et al. (2013) developed one of the first simulations of global freight flows under different trade liberalization scenarios. They first employ a Computable General Equilibrium (CGE) model to simulate international trade flows. By using approximate weight to value ratios, fixed mode splits, bilateral great-circle distances between countries, and emission factors, they estimate the change in global emissions associated with international trade as a result of these trade liberalization schemes. More recently, Martinez et al. (2015) present a framework to predict the impacts of different global trade scenarios on international freight flows. Their framework also begins with a CGE model, but other components of their analysis are more detailed, including a mode choice model, a weight value model (to convert trade values into weight), and a global freight transport network model.

There are also very few studies investigating the impact of trade agreements on transportation systems after their implementation (ex-post). Slack (1993) provides a preliminary assessment of the impacts of Canada's first FTA, the Canada-U.S. Free Trade Agreement (CUSFTA), on Canadian transportation modes. Slack's (1993) qualitative analysis describes the impacts experienced by different transportation modes; for example, Canadian railways (primarily Canadian National and Canadian Pacific) were not initially well positioned to take advantage of any growth in north-south traffic, and the Canadian trucking industry claimed to face unfair competition from U.S. truckers. Woudsma (1999) uses the Trucking Commodity Origin Destination (TCOD) survey conducted annually by Statistics Canada to examine the influence of NAFTA on the Ontario-US cross-border trucking market. For the period 1987-1994, he found shipment levels on the whole were up substantially and the spatial pattern of shipments also indicated that Ontario-based carriers had moved further into the U.S, but a reliable explanation is complicated by the fact that the FTA, trucking deregulation, and a recession, occurred around the same time. In a later study, Bradbury (2002) discusses the challenges associated with planning and implementing a truly integrated continental transportation system to support NAFTA. She argues that the massive delays and congestion due to the significantly increased trade between the U.S., Canada, and Mexico, especially in trans-border corridors, were an inevitable result because NAFTA was simply written as a trade policy with no adjustment provisions for the resulting impacts on other related areas such as transportation.

Despite Bradbury's (2002) recommendations that accurate models are required to forecast and plan for future trade and transportation flows, no studies have specifically modelled the impacts of a potential FTA on a country's domestic infrastructure (e.g., highways, bridges, border crossings, railways, marine ports, and airports), to the best of the authors' knowledge.

Methods

As shown in Figure 1, modeling the impact of a FTA on domestic transportation infrastructure can be accomplished by integrating three models: 1) a model of the global economy that quantifies the impacts of the FTA on international trade flows; 2) a multi-scale model that links changes in national production, consumption, and international imports and exports to subnational trade flows; and 3) a freight model that translates subnational trade flows into freight flows. The remainder of the paper focuses specifically on freight flow impacts, but many passenger travel demand models (e.g., the four step model) could use the resulting population and employment forecasts and predictions to easily update passenger demands.

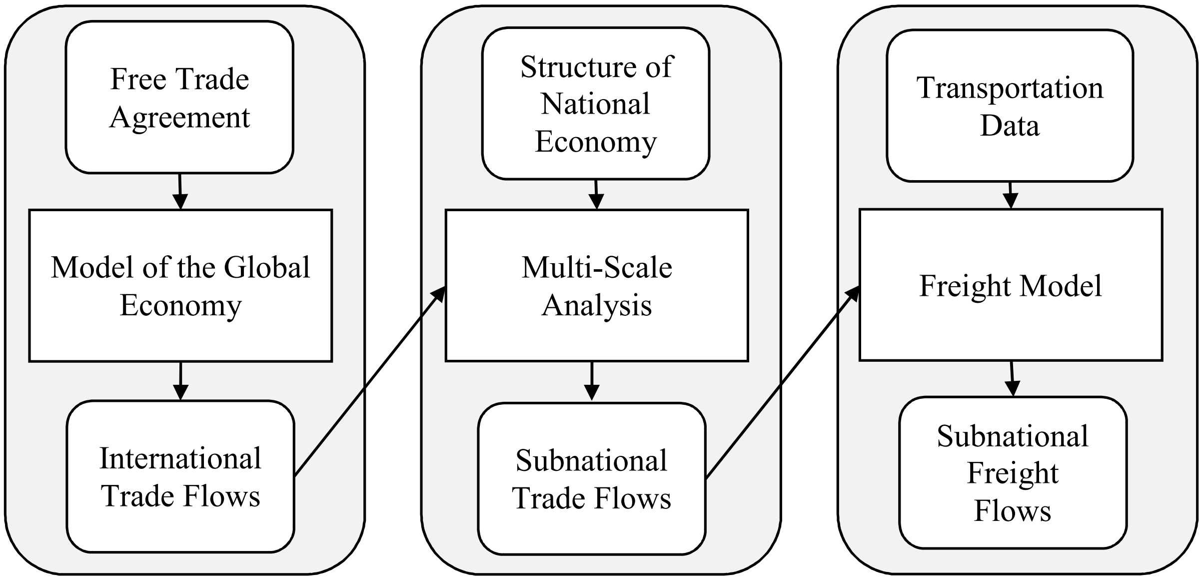

Figure 1: Conceptual Framework

Model of the Global Economy

CGE models may be the most suitable alternative for modelling the global economy to analyze FTAs. Indeed, multi-country CGE models have recently been used to study the impacts of numerous FTAs. Most previous FTA analyses rely on the GTAP model and/or database. Despite the availability of alternative approaches, their intended purposes make them less preferable. For example, gravity models are better suited for *ex-post* analysis of factors that affect trade flows (including FTAs). And Partial Equilibrium (PE) models are better suited for examining short-term effects, analyses of finely detailed sectors, analyses of sectors that represent a small proportion of the economy, or policy changes that are likely to change the price in only one market (while prices in other markets remain constant). The main benefit of CGE models is that they comprehensively model the entire economy, the interdependency between all of its parts, and the microeconomic behavior within these parts. However, given the complexity of CGE modelling and the opportunity for variability in the results due to the large number of assumptions, a sensitivity analysis is recommended at the conclusion of the analysis (i.e., for transportation impacts). For example, a distribution of traffic flow volumes at a particular border crossing could be determined based on varying assumptions about model closures and parameter values.

Multi-Scale Analysis

Multiregional models of production, consumption and trade, traditionally use a single spatial resolution (e.g., countries, states/provinces, or regions) but a few studies have undertaken multiscale analyses. Wittwer and Horridge (2010) estimate small-region shares of national activity (i.e., input-output [IO] tables) for Australia that can be aggregated for regions and sectors of interest for specific CGE simulations. Lenzen et al. (2014) advance this idea of "mother–daughter" database construction further in the Australian Industrial Ecology Virtual Laboratory (IELab) by enabling users to customize their Multi-Regional Input-Output (MRIO) model configuration and by allowing the derivation of new supplementary tables with the user's own data. Minx et al. (2014) assess the carbon footprints of settlements in the UK by linking global supply chains from a Global Multiregional Input-Output (GMRIO) model to local consumption activities by splitting national final demands with supplementary data. Meng et al. (2013) describe the construction of the transnational Interregional Input–Output (TIIO) table between China and Japan, which includes 3 regions (ASEAN5, East Asia, and the USA), 7 sub-regions of China, and 8 sub-regions of Japan. Bachmann et al. (2015) use import and export coefficients, sectors maps, and a mix of industry and commodity technology, to create a Multi-Scale Multi-Region Input-Output (MSMRIO) model, which includes representation of 47 countries and Canada's 10 provinces and 3 territories. All of these multi-scale analyses rely on subnational IO data to integrate spatial scales.

The MSMRIO approach can be applied to disaggregate the results of the GTAP model to the subnational scale. To make the CGE and IO results theoretically consistent, the elasticity of substitution between value added and intermediates in Canada's production functions should be set to zero (i.e., creating Leontief production functions) in the simulations. International exports by province can be determined for each commodity and province using export coefficients. The underlying assumption is that when Canada's exports increase, each Province contributes the same share as in the base case scenario (i.e., provincial exports have the same *growth rates*). Similarly, any changes in Canadian final demand are apportioned to individual provinces based on their share in the base case scenario, which is again equivalent to applying the percentage change in Canadian final demand from the FTA scenario to each province. The change in international exports and change in Canadian final demands are then combined into a demand shock for the MRIO model. Note that totals from the Canadian MRIO model (e.g., combined output from all provinces) will differ from the GTAP model due the sensitivity of MRIO models to sectoral and/or spatial aggregation. In other words, Canada is treated as a single region in the GTAP model, inducing some aggregation error; however, for many realistic situations the errors caused by spatial aggregation are small (Blair and Miller, 1983).

Changes in international imports must be considered in the MRIO model by changing the trade coefficients (i.e., the percentages of each commodity supplied to a province by itself, other provinces, and other countries). Since the GTAP model only provides changes in the domestic and imported use of a commodity at the level of each country, Canada's provinces are assumed to maintain their domestic trade *pattern*, but the overall *magnitude* of these interprovincial trade flows is adjusted to account for more or less imported supply (e.g., increased automobile imports displace an equal percentage of Ontario's supply of automobiles from all other provinces including itself). In other words, if firms in Ontario source more motor vehicle parts from Korea due to an FTA, these imports displace the firms previous provincial trade partners by the same proportion (e.g., Ontario provides 10% less, Quebec provides 10% less, etc.), which maintains the initial trade pattern (e.g., the size of Ontario's contribution relative to Quebec's) but decreases the overall level of provincial trade due to the increased Korean supply.

Freight Model

This discussion of freight models is limited to those that accept monetary trade flows as inputs for conversion into multi-modal vehicle flows. Recent comprehensive reviews of freight models are provided by de Jong et al. (2004) and de Jong et al. (2013), whereas Chow et al. (2010) review freight models with a greater emphasis on forecasting.

The simplest approach to convert trade flows into commodity flows is a commodity-based model, shown in Figure 2. Commodity-based models are commonly applied at the state-wide level in the US because of the availability of the US Commodity Flow Survey and the Freight Analysis Framework (FAF). Commodity-based freight models directly translate trade flows into freight flows using value/quantity (e.g., $/kg) transformation factors. These sector-specific factors are derived from data that have recorded both the values and weights of shipments. For example, the Bureau of Transportation Statistics Commodity Flow Survey from the US Department of Transportation provides the types, origins and destinations, values, weights, modes of transport, distance shipped, and ton-miles of commodities shipped, from which weight-value factors can be estimated. Alternatively, weight-value factors can also be modelled as a function of the origin and destination country attributes. For example, Martinez et al. (2015) estimate a Poisson regression model to estimate the conversion rate as a function of: travel time, distance, geographical and cultural variables (including trade agreements, land borders, common language), and economic profile variables (GPP percentile, GDP per capita percentile, and GDP per capita ratio between origin and destination countries). Using a regression model instead of fixed factors allows the analysis to capture some of the variance in weight-value ratios observed in real-world shipment data. For example, Martinez et al.'s (2015) marine-specific weight-value model suggests that more expensive goods are transported further away (less weight per value) and that exports to less developed countries are more weight intensive than those to more developed countries.

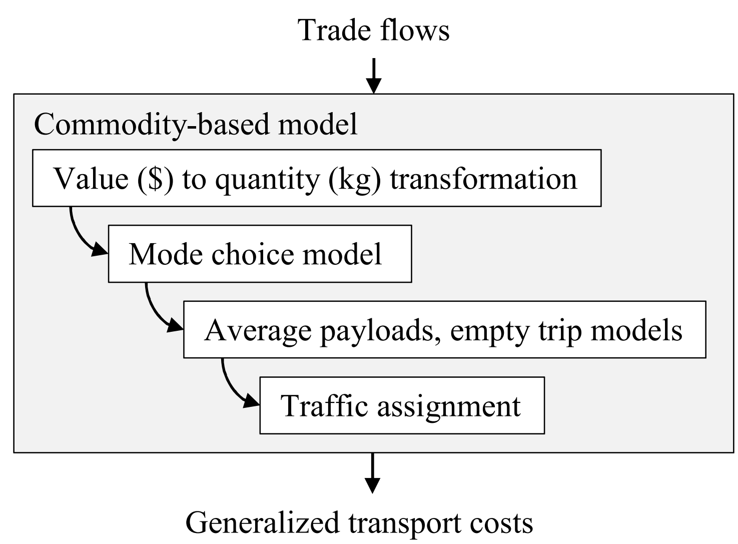

Figure 2: Commodity Based Freight Model

These freight flows are then usually split between modes by fixed factors or modelled as a function of transportation level of service attributes using a Random Utility Maximization (RUM) based mode choice model, resulting in a freight matrix by quantity and mode. For example, the study of greenhouse gas emissions from international freight transport by Cristea et al. (2013) uses fixed mode splits between origin and destination countries. The disadvantage of fixed mode shares is that the impacts of changes in the transportation system or in the level of congestion as a result of policy replacement scenarios cannot be assessed. A mode choice model can be estimated on disaggregate data that describes the choices made by individuals (e.g., the mode chosen for a particular shipment in the case of freight). A mode share model can be estimated on aggregate data that describes the total market share of a particular mode (e.g., the share of shipments between an origin and destination using a particular mode).

Quantities are then converted to trucks or other freight vehicle trips using average payloads or more elaborate empty trip models. Converting from quantities to shipments is only necessary for the trucking mode if the road transport network model includes congestion effects. The translation from quantities to shipments can be accomplished by fixed factors or by more advanced models. For example, Ruiz Juri & Kockelman (2006) use the (discontinued) US Census Bureau Vehicle Inventory and Use Survey to calculate average pay loads so that they can generate truck trips on a road network model. However, empty trips make up a substantial proportion of freight transportation, both in terms of miles traveled and trips made. Hence, empty trip models have been developed to estimate empty trips from a commodity flow matrix.

Rail and marine trade flows can be measured in quantities if fixed costs are assumed for rail and marine transport network models. For example, the recent freight demand model in Europe described by Cascetta et al. (2013) uses fixed costs for all modes including road, rail, sea and inland waterways. Fixed transport costs imply an all-or-nothing traffic assignment that is described in detail below. The resulting link flows would then be measured in tonnes rather than vehicles, but nonetheless suitable for calculating the relative changes between the base case and policy replacement scenario. Alternatively, tonnage can be converted to trains and ships if necessary using their respective capacities, as described above for converting road tonnage to truck trips.

Resulting demands can then be used for a macroscopic traffic assignment. Traffic assignment is a procedure that assigns transportation origin-destination demands to specific paths in a transportation network model. Once demands are assigned to paths, the flows on individual links (which carry demands from multiple paths) can be analyzed. If the transportation network model has fixed transportation costs (e.g., represented by distances or fixed travel times), traffic assignment can be done by calculating the shortest path between each origin and destination pair (also called an “all-or-nothing” assignment). Congestion effects are not captured if the transportation network model has fixed transportation costs. If the transportation network model includes congestion effects, traffic is usually assumed to achieve user equilibrium (i.e., all users act selfishly by attempting to minimize their own travel costs). Congestion effects are captured in network models by volume-delay functions (also called link-performance functions) which relate the travel costs on a particular link to its level of usage. Volume delay functions in road network models provide travel times (e.g., minutes) as a function of link flow (e.g., vehicles/hour) and hence, transportation demands must be specified in the same flow units (i.e., conversion to vehicle units is required).

A more sophisticated approach to freight modelling is the Aggregate-Disaggregate-Aggregate (ADA) freight model system, as shown in Figure 3. Aggregate trade flows enter the framework and are first disaggregated to individual firms in the regions containing the production and consumption activities. This can be done based on observed proportions of firms in local production and consumption data and/or from a registry of business establishments that includes a size metric (e.g., number of employees, square footage, etc.). Then, a model (e.g., de Jong and

Ben-Akiva, 2007) or series of models (e.g., Roorda et al., 2010) are used to simulate the logistics decisions of firms (e.g., shipment size, use of consolidation centers and distribution centers, modes, and loading units, such as containers). These logistics decisions are typically simulated with RUM based models because they are derived from behavioral choice theory. Finally, traffic assignment can be done by aggregating the shipments between firms to origin-destination flows between regions. The ADA freight model system was introduced by Ben-Akiva & de Jong (2013) and can be regarded as a compromise between agent-based models and commodity-based models, since it incorporates supply chain and logistics decisions like the former but is driven by commonly available aggregate trade flow data like the latter.

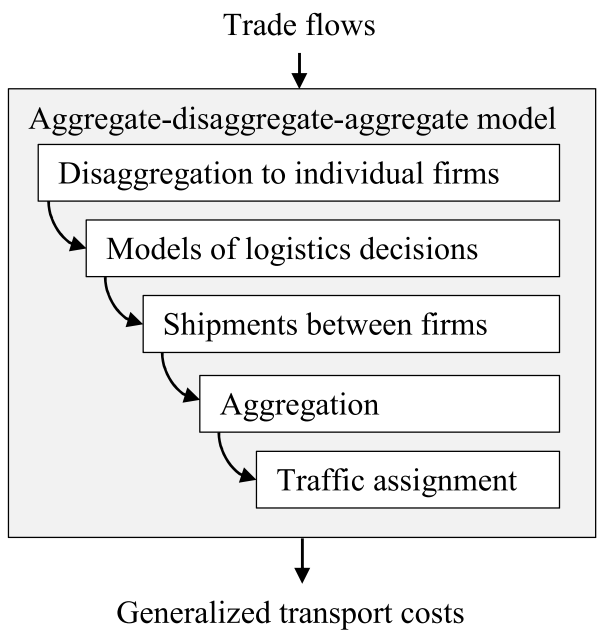

Figure 3: Aggregate-Disaggregate-Aggregate Model

The commodity-based freight model and the ADA freight model exist on a continuum of potential freight models. At one extreme, commodity-based models make direct translations between trade flows, commodity flows, and vehicle flows, completely ignoring any differences from supply chains and logistics. Commodity-based models also miss many local truck movements, including trips from service, utility, and construction trucks. At the other extreme, agent-based models simulate each individual in the freight system (e.g., shippers and carriers) and all of the logistics and supply chain complications observed in practice (e.g., vehicle routes and the use of distribution and consolidation centers). ADA models exist between these two extremes, as they take trade flows from more aggregate trade models as given, but introduce supply chains and logistics decisions by incorporating some agent-based models. Variations of ADA models can be closer to one extreme or the other as they include or omit more models from an agent-based framework.

The trade-off for the greater conceptual and theoretical detail included in agent-based models is their data and computing requirements. Implementation requirements are minimized with a simple commodity-based model. As further sub-models are added to a commodity-based model (e.g., empty-trip models), data and computing requirements increase. With further additions (e.g., logistics choice models), the commodity-based model enters into the domain of ADA models, where implementation requirements are higher but can still be feasible with specialized data. Moving further towards a complete agent-based model raises data and computing requirements significantly, and is often empirically infeasible due to current data limitations. Therefore, one can view the models as a progression moving toward more detailed (and hopefully more accurate) models with higher implementation requirements.

Based on these trade-offs, a commodity-based model is a suitable starting point for an initial analysis. Once experience is gained with the initial implementation, additional models of logistics choices can be incorporated to move the commodity-based model along the continuum of freight models toward the agent-based paradigm. This approach supports the notion that freight modeling should be considered evolutionary, moving from an operational but simplified approach, to more advanced models as new data and experience are acquired.

Proposed Modelling Framework

Figure 1 shows the proposed modelling framework, which includes three main components: a model of the global economy that quantifies the impacts of the FTA on international trade flows; a multi-scale analysis that links changes in national production, consumption, and international imports and exports to subnational trade flows; and a freight model that translates subnational trade flows into freight flows. The framework can also be divided into six major steps. The framework begins with a Computable General Equilibrium (CGE) model to simulate the changes in worldwide output and trade associated with the implementation of a potential FTA (e.g., by introducing tariff cuts, NTB reduction, etc.). Changes in national production, consumption, and trade are linked to provinces using a Multi-Scale Multi-Region Input-Output (MSMRIO) analysis. The resulting interprovincial and international trade flows are converted from monetary values to quantities using weight-value factors or a weight-value model. The trade flows measured in quantities are split among modes using the quantity shares of each mode or a mode share model. The total tonnage for each mode can be converted into shipments through fixed (exogenous) shipment dimensions (e.g., payloads); if this step is omitted, transportation flows are measured in tonnes instead of shipments. Finally, origin-destination matrices are assigned to a transport network model using standard traffic assignment techniques (e.g., shortest-path, user-equilibrium, etc.). Resulting transportation costs can be fed back to the CGE model (if possible) to consider the congestion impacts of the FTA, requiring all steps to be repeated until trade flows and trade costs stabilize.

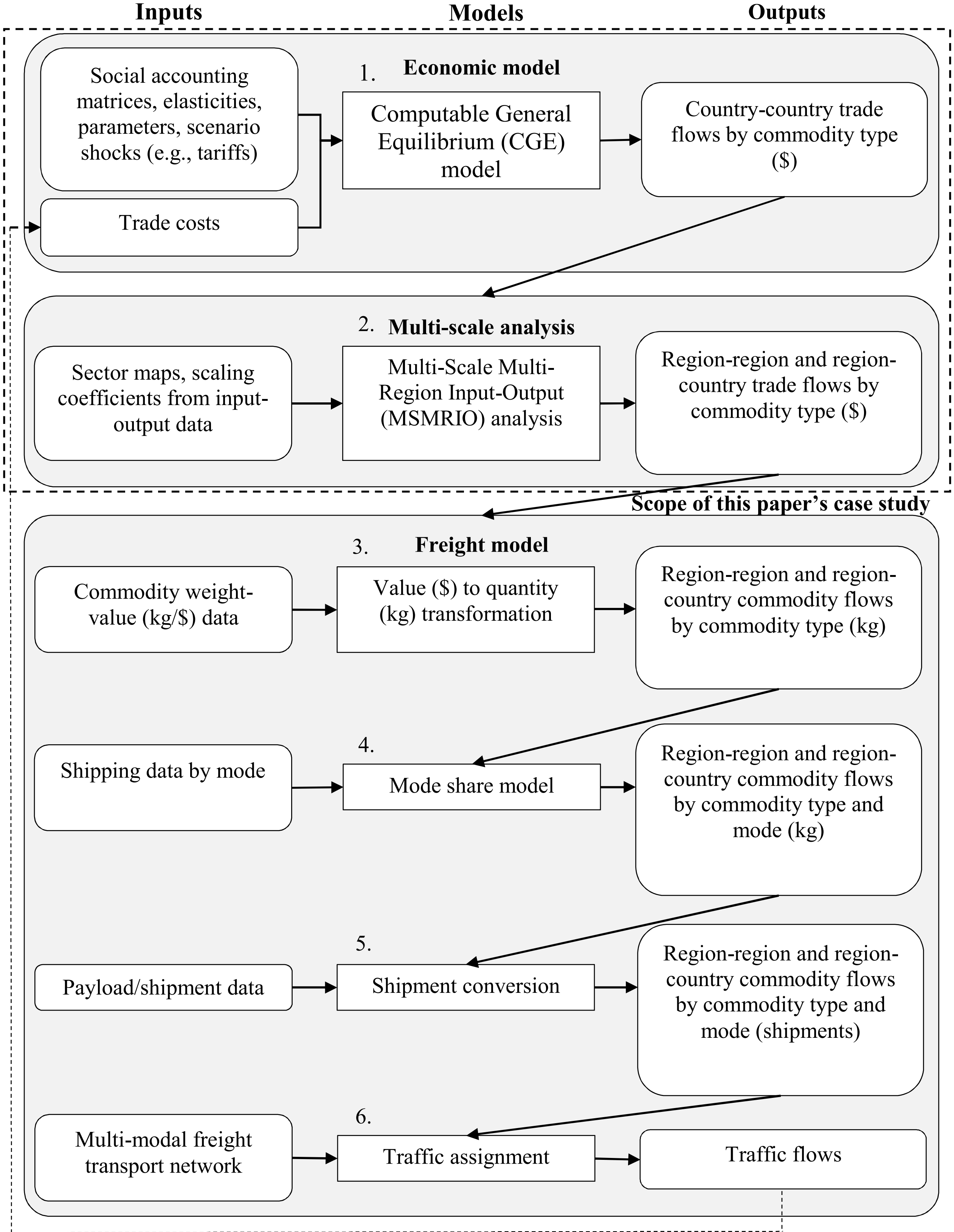

Figure 4: Modelling Framework

Case Study

This case study describes the implementation of the first two components of the modelling framework as highlighted in Figure 4 for CKFTA and CETA. The CGE analysis uses the standard Global Trade Analysis Project (GTAP) Model and the current release of the GTAP Data Base (version 9). The simulation of CETA follows the approach taken by the European Commission and Government of Canada (2008) and implements the same reductions in tariff barriers, non-tariff barriers (NTBs), and service trade barriers. For CKFTA, the ad-valorem tariff reductions at the 57 sector level estimated by Ciuriak and Xiao (2014) from the first formal analysis of the agreement as negotiated are adopted. Data for the MRIO analysis come from the Statistics Canada IO accounts. The linking of the CGE model and MRIO model is performed by apportioning the resulting international trade flows from the CGE simulations to individual provinces using Canada Border Services Agency (CBSA) trade flow data, allowing Canada's exports to be converted to provincial exports, and then applied as an exogenous demand shock to the MRIO model to determine interprovincial trade impacts. MRIO trade coefficients (i.e., the percentages of each commodity supplied to a province by itself, other provinces, and other countries) are adjusted to reflect changes in domestic versus imported sourcing by Canadian producers.

Table 1 highlights the top five export and import impacts due to CKFTA and CETA. Canada's largest change in exports to Korea due to CKFTA occurs in the meat products sector (#20). This is followed by increases in exports to Korea of food products (#25). The agreement also leads to an increase of Canadian exports to Korea in the manufacturing sectors including machinery and equipment (#41), chemical, rubber, and plastic products (#33), and metals (#36). Overall, Canada realizes a total export gain to Korea of approximately $1.631 billion. The growth in Canadian exports to Korea represent large relative increases. For example, the growth in meat products (#20) exports to Korea represents an increase of 353% and the growth in food products (#25) exports to Korea is 156%. In terms of imports from Korea, the largest change occurs in the motor vehicles sector (#38). This is followed by increases in imports from Korea of auto related sectors including transport equipment (#39) and machinery and equipment (#41). The agreement also leads to an increase of Korean exports to Canada in the manufacturing sectors: chemical, rubber, and plastic products (#33) and textiles (#27). Overall, Korea realizes a total export gain to Canada of approximately $852 million.

Table 1 indicates Canada's largest change in exports to the EU due to CETA occurs in metals (#36), which sees an increase of $2.450 billion. This is followed by increases in exports to the EU of other manufacturing sectors including: chemical, rubber, and plastic products (#33), transport equipment (#39), machinery and equipment (#41), and food products (#25). These top five commodity export increases are all within the modest range of 20% to 30% relative growth, except for food products (#25), which exhibits approximately 100% relative export growth. Overall, Canada realizes a total goods export gain to the EU of approximately $9.293 billion. Three of the EU's top five goods export increases to Canada are in the same sectors as the top five Canadian goods export increases to the EU: machinery and equipment (#41), chemical, rubber, and plastic products (#33), and food products (#25). The other two commodities in the top five are motor vehicles and parts (#38), and wearing apparel (#28). The three largest absolute increases (#38, 41, 33), are only small to modest relative gains (42%, 15%, and 15% respectively). On the other hand, the increases in food products (#25) and wearing apparel (#28) are relatively large gains (103% and 193% respectively). Overall, the EU realizes a total goods export gain to Canada of approximately $18.178 billion.

Table 1: Canadian Export and Import Impacts by Province (millions of 2011 US $)

		Province						
		NL, PE, NS, NB	QC	ON	MB, SK	AB	BC	Total
#	Description	Change in Exports from Canada to the EU due to CETA						
36	Metals nec	8	840	1040	33	521	8	2450
33	Chemical, rubber, plastic products	14	178	558	212	41	17	1020
39	Transport equipment nec	8	693	164	4	4	9	883
41	Machinery and equipment nec	17	289	403	31	48	50	837
25	Food products nec	88	313	88	35	131	20	675
		Change in Imports from the EU to Canada due to CETA						
38	Motor vehicles and parts	111	472	977	120	258	182	2125
41	Machinery and equipment nec	128	306	553	148	385	184	1713
33	Chemical, rubber, plastic products	76	308	645	102	143	138	1414
25	Food products nec	74	294	486	106	145	209	1318
28	Wearing apparel	49	185	305	49	106	97	793
		Change in Exports from Canada to Korea due to CKFTA						
20	Meat products nec	21	228	47	191	154	155	797
25	Food products nec	4	48	10	40	33	33	168
41	Machinery and equipment nec	1	18	72	2	29	6	127
33	Chemical, rubber, plastic products	1	14	42	20	5	8	89
36	Metals nec	0	4	14	4	5	28	56
		Change in Imports from Korea to Canada due to CKFTA						
38	Motor vehicles and parts	33	139	288	35	76	54	626
33	Chemical, rubber, plastic products	4	15	32	5	7	7	69
27	Textiles	2	7	12	2	4	4	32
39	Transport equipment nec	2	9	9	2	5	3	31
41	Machinery and equipment nec	2	5	9	2	6	3	28

FTAs have primary and secondary (or direct and indirect effects) on transportation demands. FTAs primarily impact trade flows between member countries (e.g., Canada and Korea with CKFTA, Canada and the EU with CETA). However, FTAs also create secondary effects through trade creation and diversion – trade flows that are redirected from one country (diversion) to another country (creation), specifically due to the formation of the FTA. For example, Table 2 shows the total trade created and diverted due to CETA. Europe's increase in exports to Canada ($21.116 billion) partly displaces exports from all other regions including $5.159 billion from the United States and Mexico and $2.567 billion from Asia. On the other hand, Canada's increase in exports to Europe of $11.513 billion mostly displaces trade from countries within Europe ($10.421 billion). Aside from the changes to trade flows involving Canada and the EU, the United States imports slightly less from all regions except Mexico. The remaining regions are affected little by

CETA. Overall, the net global trade created is $12.249 billion. Finally, to model the transportation impacts of CETA, the international export and import trade flows for Canada as shown in the Canada row and column of Table 2 respectively, can be disaggregated by commodity type and destination country (not shown for the sake of brevity) for subsequent conversion to quantities, mode-split, shipments, and so on. Transportation impacts are likely since these trade flows may use different infrastructure (e.g., highways, ports, rail, etc.) for the Canadian leg of the journey.

Table 2: CETA's Trade Creation and Diversion, Total Goods and Services (millions of 2011 US $)

Origin/ Destination	Australia, New Zealand	Asia	Canada	US, Mexico	Europe	South America	Africa	Total
Australia, New Zealand	14	62	-83	-11	31	1	5	19
Asia	30	1232	-2567	-1017	2311	-5	102	86
Canada	-3	-41	0	-403	11513	-8	0	11058
US, Mexico	149	2176	-5159	372	1784	400	134	-144
Europe	-321	-5146	21166	-2999	-10421	-643	-449	1187
South America	3	58	-121	-57	162	23	17	85
Africa	0	18	-59	-19	3	-2	17	-42
Canada	-128	-1641	13177	-4134	5383	-234	-174	12249

Another secondary impact of FTAs is a change in subnational trade flows as a result of multiplier effects. For example, increased food exports to Korea represents an increase in final demand for Canadian food (recall that exports are a form of final demand). Increases in the final demand for food triggers increases in the inputs required to produce food, including other commodities, as well as value added (i.e., factors of production such as land, labour and capital). Of course, these increased demands for inputs also trigger new inputs for their production, and so on. Inputs are often sourced locally, but also from neighbouring region and even more distant trade partners. Hence, FTAs impact international trade flows (through trade creation and diversion) as well as subnational trade flows (through interregional multiplier effects). Table 3 shows the total impact of CETA on Canada's interprovincial trade flows. The diagonal elements of Table 3 have the largest values in their columns, meaning that provinces generally supply themselves with their greatest share of total domestic inputs. The interprovincial trade changes are relatively small compared to international trade changes for 3 reasons: 1) international export demand growth is a direct demand change in commodity output, whereas these smaller trade changes are derived demands for commodity inputs used to make those exports; 2) provinces generally supply themselves with their greatest share of total domestic inputs; and 3) the net change in provincial trade flows is a result of the relatively small total changes in domestic consumption, in export demand (net of trade created and diverted due to the FTA), and in intermediate demands from other domestic industries. Overall, Quebec, Ontario, and Alberta have the largest intra-provincial trade increases, while the largest interprovincial trade growth occurs between Ontario and Quebec.

Table 3: CETA's Interprovincial Trade Impacts, Total Goods (millions of 2011 US $)

Origin/Destination	Newfoundland and	Prince Edward	Nova Scotia	New Brunswic	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia
Newfoundland and Labrador	-4	0	2.8	-0.5	16.7	5.2	0	0.1	0.1	0
Prince Edward Island	0	-0.1	0.8	-0.3	0.4	0.3	0	0.1	0	0
Nova Scotia	5.6	0.1	30.5	-2.4	4.9	0	-0.5	0.2	-1.1	-1.2
New Brunswick	9.2	0.6	6.4	-9.5	18.6	1.5	0	0.2	1	-0.1
Quebec	-0.9	-0.4	5.9	-4.9	472.4	30.9	-3	0.7	-2.1	-10.3
Ontario	0	-0.1	8	-5	81.9	314.8	-6.3	11.2	11.5	-13.7
Manitoba	-0.1	0	0.5	-0.2	3.2	7.2	-2.4	5.3	1.8	-2
Saskatchewan	0	0	0.4	-0.2	5.2	10.7	-0.4	83.5	9.5	-1.6
Alberta	1.5	0	1	-0.4	24.1	42.1	6.4	44.6	287.8	-3.2
British Columbia	-0.4	0	1.1	-0.6	5.1	1.8	-0.5	4.2	27.5	-57.8

Conclusion

Recent and forthcoming free trade agreements such as the TPP and CETA are likely to have sizeable impacts on economies and transportation systems. While the ex-ante analysis of FTAs on the global economy is typical, only recently have a few studies sought to understand the impacts of different trade liberalization scenarios on international freight flows. Moreover, to the best of the authors' knowledge, no studies have specifically identified the impacts of a potential free trade agreement on a country's domestic infrastructure, such as highways, bridges, border crossings, railways, marine ports, and airports. A joint spatial economic and transport modeling framework was developed to simulate the impact of a potential FTA on a domestic transportation system. Based on the models identified, described, and assessed in this study, a CGE model, a MSMRIO analysis, and a commodity-based freight model provide a suitable starting point for studying the impact of a FTA on a domestic transportation system.

Preliminary results from simulations of CKFTA and CETA indicate differing trade flow impacts. CKFTAs impacts are concentrated in fewer sectors and tend to have larger relative increases. On the other hand, CETAs impacts are larger and spread across several sectors, although these impacts are smaller in relative terms. From an economic view, simulations suggest CETA will have a larger impact. From a transportation view, the simulation results do not provide sufficient evidence to draw detailed conclusions for two reasons. First, while CETA's economic impacts are large in absolute terms, they tend to be smaller in relative terms. This might suggest CETA has existing supply chains which will be strengthened by the FTA. On the other hand, CKFTA's trade flow impacts are smaller in absolute terms, but higher in relative terms. This indicates CKFTA may result in the development of new supply chains that did not previously exist.

Second, without simultaneously modelling all of the changes in transportation flows (i.e., changes in imports and exports to all countries), it is not possible to determine transportation impacts because each trade flow uses a particular path or set of competitive paths in the network. Therefore, it is not possible to immediately deduce transportation impacts without further analysis, such as the remaining steps in the modelling framework. Future work will complete the remaining steps in the proposed framework to study the impact of CKFTA and CETA on Canada's domestic transportation system.

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