NBER WORKING PAPER SERIES

GENERAL EQUILIBRIUM TRADE MODELLING WITH CANADA-US TRANSPORTATION COSTS

Chuantian He
Chunding Li
John Whalley

Working Paper 23500
http://www.nber.org/papers/w23500

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 2017

We are grateful to the CN Fund (CN Post-doctoral Fellow in Canada-US Transportation Policy Research Grant) for financial support. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

General Equilibrium Trade Modelling with Canada-US Transportation Costs
Chuantian He, Chunding Li, and John Whalley
NBER Working Paper No. 23500
June 2017
JEL No. F10,F47,O51

ABSTRACT

Transportation costs are an important topic in international trade, but seldom have researches paid attention to general equilibrium trade modelling with transportation costs and explored their relevant effects. This paper uses different numerical general equilibrium trade model structures to simulate the impacts of transportation costs on both welfare and trade for a Canada-US country pair case. We compare two groups of model structure, Armington assumption models and homogeneous goods models. Within these two groups of models, we also compare balanced trade structures to trade imbalance structures, and production function transportation costs to iceberg transportation costs. Armington goods models generate absolute welfare gains from transportation cost elimination than homogeneous goods models. Welfare gains under balanced trade structures are larger in production function transportation cost scenarios, but are larger in iceberg transportation cost scenario under trade imbalance structures. Canada's welfare gains with iceberg transportation cost are significantly larger than gains with production function transportation cost. On trade effects, homogeneous goods models generate more export and import gains, balanced trade structures have more trade variations, and iceberg transportation cost generate more trade effects.

Chuantian He
School of Economics & Trade,
Guangdong University of Foreign Studies
No.2 Baiyun Avenue North
Baiyun District, Guangzhou Guangdong, PRC
Postcode: 510420
cthe@gdufs.edu.cn

Chunding Li
Institute of World Economics and Politics
Chinese Academy of Social Sciences
No.5 Jianguomenneidajie
Beijing, PRC
Postcode: 100732
chundingli@gmail.com

John Whalley
Department of Economics
Social Science Centre
Western University
London, ON N6A 5C2
CANADA
and NBER
jwhalley@uwo.ca

1. Introduction

Transportation costs (TC) are an important part of trade costs, and have begun to play a central role in theoretical and empirical analysis of international trade, but existing empirical literature on transportation cost and international trade is not rich and mainly focused on three fields.

The first is transportation cost estimation with trade data. Moneta (1959) is the first to estimate transportation costs in international trade, Hummels (1999) provides a detailed accounting of the time-series pattern of shipping costs, Hummels and Lugovskyy (2006) reviews the method of using matched partner trade statistics to measure transportation costs, Hummels (2007) systematically reviews transportation costs calculation methods and empirically computes different kinds of transport costs.

The second explores the relationship between transportation costs and international trade both theoretically and empirically. In the 1950s, Samuelson (1952, 1954) developed what has become known as the “iceberg” model of transport costs, in which transporting goods costs reduce some proportion of either the goods’ value or the physical quantity. After that, Mundell (1968) analyzed models in which transportation costs were included, both did so under the assumption that these costs were incurred in the form of sacrifices of the traded goods. Falvey (1976) included a transportation sector in the standard trade model to explore their potential effects. He treated transportation as services that need to be consumed in order for international trade to take place. Cassing (1978) attempted to integrate transport costs into the H.O.S model and then contrasts this model with a nontraded goods model incorporating elements of jointness in consumption. Hummels and Skiba (2002) argued that economies of scale in transport are important and in part, these scale economies may derive from large fixed costs of trade. Laussel and Riezman (2006) also explored a model in which there are economies of scale in transport. Hummels and Skiba (2004) provided strong evidences against the widely used assumption of “iceberg” form transportation costs. Ravn and Mazzenga (2004) evaluates the quantitative effects of introducing costs of transportation into an international trade model. Kleinert and Spies (2011) construct an international trade model with endogenous transport costs and study the influence of transport costs on international trade.

The third is to argue decline transportation cost to explain global trade growth. Baier and Bergstrand (2001) explores how decline tariffs, declining transport costs and income similarity have influenced world trade growth. Hummels (2007) also uses transportation costs to explain trade growth. In addition, some researches (Finger and Yeats, 1976) explore the effective protection of transportation costs and tariffs.

Among existing literature, little attention has been paid to general equilibrium modelling of transportation costs with both Armington and homogeneous goods assumptions, as well as both “iceberg” form and production function form transportation costs. Additionally, little of research on numerical general equilibrium models simulates the effects of transportation costs.

We build a classical two-country four-sector produced by two-factor general equilibrium structure, and introduce Armington goods and Homogeneous goods assumption in sequence and compare transportation cost effects. Within the two types of model structures, we compare the effects of “iceberg” and production function form of transportation costs, as well as the effects of balanced trade and trade imbalance structures.

We use Canada and the US data case to explore the effects of transportation costs with different model structures. The reason is that this two countries’ economic scales are far apart, and traded goods include both Armington type manufacturing goods and homogeneous resource goods. We use real data for 2015 to build a benchmark model dataset. Each country produces three goods, resource (tradable), manufacturing goods (tradable) and non-manufacturing goods (non-tradable), with two factors (labor and capital). Under the production function transportation cost structures, models have a fourth sector-transportation sector which determines transportation costs. In each model structure, we compare the equilibria of benchmark models with transportation costs to counterfactual models without transportation costs, so as to explore transportation cost effects. We pay attention to the effects on both welfare and trade.

We perform sensitivity analysis to both elasticities and ad valorem transportation costs to check simulation results. Elasticities in preference and production functions change from 1.5 to 4.5 in sensitivity analysis. Ad valorem transportation cost methodology is the main simulation analysis from Hummels (2007). We also use an indirect transportation cost calculation method following Anderson and Wincoop (2004) to explore simulation result sensitivity to transportation cost values.

The remaining parts of the paper are organized as follows: Part 2 calculates transportation costs between Canada and the US, Part 3 sets up general equilibrium models with transportation cost, Part 4 introduces data and parameters calibration, Part 5 gives simulation results, and last come the conclusions.

2. Transportation Costs between Canada-US

Transportation costs are a monetary measure of what the transport provider must pay to produce transportation services. They come as fixed (infrastructure) and variable (operating) costs, depending on a variety of conditions related to geography, infrastructure, administrative barriers, energy, and on how passengers and freight are carried. Three major components, related to transactions, shipments and the friction of distance, impact on transport costs (Rodrigue and Notteboom, 2013). We introduce transportation cost briefly and calculate transportation cost between Canada and the US in this part. The transportation cost between Canada and the US will be used in our numerical general equilibrium calibration and simulation.

2.1 Transportation Cost Components

According to different transport facilities, transportation can be divided into railway transport, road transport, inland waterway transport, pipeline transport, maritime transport, air transport and intermodal freight transport. Figure 1 shows the transportation freight of Canada and the US, and find that most types of freight are increasing steadily except coastal shipping of the US.

According to transportation cost contents, it may include transport facility ownership, transport facility operation, operating subsidies, travel time, internal crash, external crash, internal activity benefits, external activity benefits, internal parking, external parking, congestion, road facilities, land value, traffic services, transport diversity, air pollution, greenhouse gas pollution, noise, resource externalities, barrier effect, land use impacts, water pollution and waste. We compile these parts in Table 1.

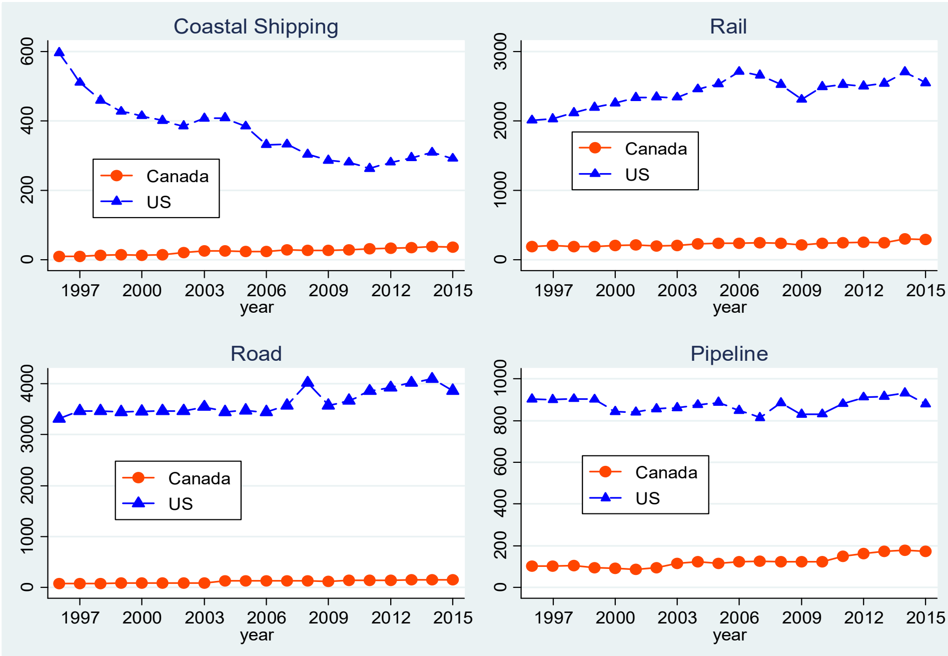


Figure 1: Freight in Million Tonne-Km of Canada and the US

Source: OECD International Transport Forum Statistics 2015.

Table 1: Main Transportation Cost Categories

Cost	Description
Transport Facility Ownership	Fixed costs of owning a transport facility
Transport Facility Operation	Variable transport facility costs, including fuel, oil, tires and tolls
Operating Subsidies	Financial subsidies for public transit services
Travel Time	The value of time used for travel
Internal Crash	Crash costs borne directly by travelers
External Crash	Crash costs a traveler imposes on others
Internal Activity Benefits	Health benefits of active transportation to travelers
External Activity Benefits	Health benefits of active transportation to society
Internal Parking	Off-street residential parking and long-term leased parking paid by users
External Parking	Off-street parking costs not borne directly by users
Congestion	Congestion costs imposed on other road users
Road Facilities	Roadway facility construction and operating expenses not paid by user fees
Land Value	The value of land used in public road rights-of-way
Traffic Services	Costs of providing traffic services such as emergency services
Transport Diversity	The value to society of a diverse transport system, particularly for non-drivers
Air Pollution	Costs of transport facility air pollution emissions
Greenhouse Gas Pollution	Lifecycle costs of greenhouse gases that contribute to climate change
Noise	Costs of transport facility noise pollution emissions
Resource Externalities	External costs of resource consumption, particularly petroleum
Barrier Effect	Delays that roads and traffic cause to non-motorized travel
Land Use Impacts	Increased costs of sprawled, automobile-oriented land use
Water Pollution	Water pollution and hydrologic impacts caused by transport facilities
Waste	External costs associated with disposal of transport facility wastes

Source: Litman and Doherty (2009).

2.2 Transportation Cost Calculation with a Direct Methodology

Trade related researches often express transportation cost in ad valorem terms, which equals the cost of shipping relative to the value of the good. This of equivalent to the percent change in the delivered price as a results of paying for transportation (Hummels, 2007).

Transportation costs drive a wedge between the price at the place of origin and the price at the destination. Denoting the origin price as p, destination price as p^*, and per unit shipping costs as f, so $p^* = p + f$. Then the ad valorem percent change in prices induced by transportation is $TC = p^* / p - 1 = f / p$. So our measure of transportation costs is

$$TC_i = \frac{imp_i^{cif}}{imp_i^{fob}} - 1 \qquad (1)$$

where imp_i^{cif} is the c.i.f. value of imports of good i, and imp_i^{fob} is the f.o.b. value of imports. Most trade research papers are using this equation to calculate transportation cost, like Moneta (1959), Geraci and Prewo (1977), Harrigam (1993), Baier and Bergstrand (2001), Limao and Venables (2001), Ravn and Mazzenga (2004), Hummels and Lugovskyy (2006), and Hummels (2007).

There are several available data to calculate transportation costs, the most comprehensive one is the IMF Direction of Trade Statistics (DOTS). The advantage of the IMF DOTS data is breadth of coverage: they are available for many years and include many countries (Hummels and Lugovskyy, 2006). Another available data is UN's COMTRADE database. But the best data for computing the ad valorem transportation cost comes from a few importers as the United States and New Zealand that collect freight expenditures as part of their import customs declarations. These data can examine ad valorem transportation costs for an individual good, or to calculate aggregate expenditures on transportation divided by aggregate import value. This aggregate measure is equivalent to an average of ad valorem transportation costs for each good, after weighting each good by its share of value in trade (Hummels, 2007). Fortunately, we can use the US Imports of Merchandise data to calculate transportation costs between Canada and the US.

Computation data are from the US Census Bureau website, we get US-Canada general imports by 3-digit NAICS (North American Industry Classification System) goods data from international trade statistics part. These data include customs value basis general imports and C.I.F. value basis general imports, so that we can calculate transportation costs of different goods and aggregate manufacturing goods. Calculation results are reported in Figure 2 and Table 2.

We find that ad valorem transportation costs of different goods and different years are different. Ad valorem transportation costs for a particular product depend on how far the good is shipped, the quality of the transport service, and the weight/value ratio of the good.

In the numerical GE calibration and simulation part, we use 2015 as the base year. Therefore transportation cost in 2015 between Canada and the US will be used in our numerical model, which is 2.3%.

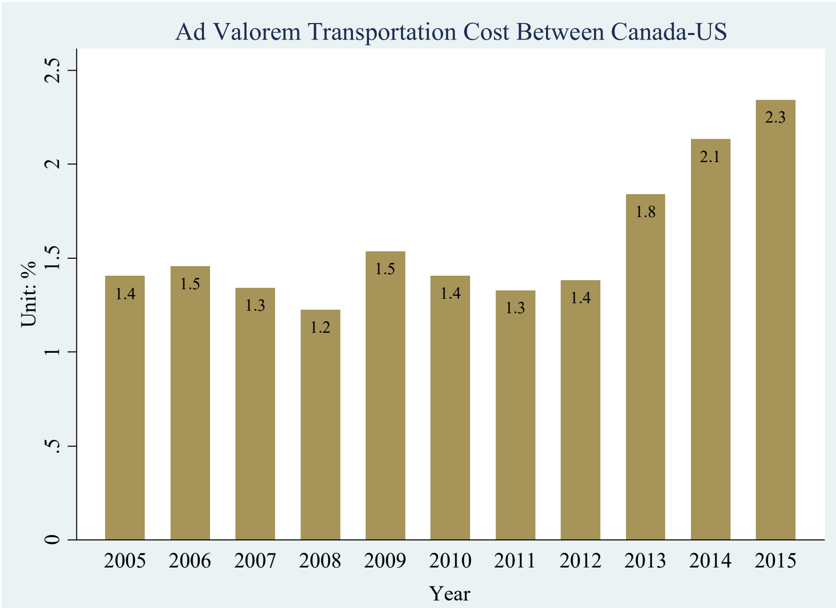


Figure 2: 2005-2015 Ad Valorem Transportation Cost between Canada-US

Source: Calculated with the data from the US Census Bureau.

Table 2: Ad Valorem Transportation Cost of 3-digit NAICS between Canada-US (Unit: %)

Products	2008	2009	2010	2011	2012	2013	2014	2015
Aggregate	1.224	1.535	1.405	1.328	1.381	1.839	2.132	2.051
Agricultural Products	2.390	2.772	2.749	2.712	2.438	1.990	1.995	0.465
Livestock & Livestock Products	0.906	0.851	0.770	0.832	0.707	0.593	0.382	3.451
Forestry Products	4.755	4.283	4.357	3.951	2.882	1.774	2.444	0.696
Marine Products	0.646	0.819	0.684	0.596	0.578	0.523	0.479	7.231
Oil & Gas	0.976	1.659	1.419	1.369	1.680	3.682	4.508	7.805
Minerals & Ores	8.092	9.244	8.374	6.698	7.670	7.859	6.971	1.274
Food & Kindred Products	1.711	1.802	1.715	1.598	1.542	1.317	1.203	4.639
Beverages & Tobacco Products	2.449	2.722	2.910	3.675	3.555	3.690	4.382	1.069
Textiles & Fabrics	1.291	1.288	1.263	1.127	1.156	1.011	1.054	1.212
Textile Mill Products	1.322	1.505	1.566	1.493	1.387	1.123	1.185	0.553
Apparel & Accessories	1.041	1.103	1.077	1.065	1.020	0.794	0.616	0.818
Leather & Allied Products	1.614	1.599	1.340	1.380	1.468	1.027	0.884	3.657
Wood Products	4.119	5.002	4.180	4.222	3.791	3.396	3.548	2.785
Paper	2.970	3.206	3.045	2.865	3.118	2.887	2.848	1.805
Printed Matter And Related Products	1.650	1.719	1.723	1.661	1.536	1.519	1.697	2.748
Petroleum & Coal Products	1.688	2.582	2.009	1.663	1.643	1.678	1.747	1.090
Chemicals	1.396	1.646	1.557	1.463	1.399	1.205	1.108	1.345
Plastics & Rubber Products	1.698	1.815	1.928	1.859	1.801	1.449	1.438	2.626
Nonmetallic Mineral Products	3.517	3.881	3.649	3.493	3.559	3.164	2.630	1.200
Primary Metal	1.011	1.213	1.104	0.994	1.149	0.991	1.270	1.182

Fabricated Metal Products	1.389	1.369	1.496	1.407	1.297	1.182	1.195	0.764
Machinery, Except Electrical	0.888	0.886	0.846	0.791	0.794	0.734	0.717	0.935
Computer & Electronic Products	1.102	0.973	1.104	1.019	0.990	0.990	0.947	1.046
Electrical Equipment & Components	1.231	1.236	1.305	1.335	1.275	1.069	1.096	0.469
Transportation Equipment	0.471	0.481	0.520	0.486	0.475	0.469	0.486	1.436
Furniture & Fixtures	1.529	1.583	1.932	1.815	1.788	1.413	1.393	2.507
Miscellaneous Manufactured Commodities	1.066	0.932	0.837	0.857	0.843	0.868	2.628	1.921
Waste And Scrap	2.283	1.858	1.495	1.720	2.649	1.814	1.573	1.040
Used Or Second-hand Merchandise	2.702	3.666	2.736	2.430	1.915	1.318	1.250	1.139
Goods Returned	1.224	1.238	1.793	1.408	1.183	1.203	1.171	0.002
Special Classification Provisions	0.031	0.039	0.067	0.083	0.006	0.003	0.004	2.341

Note: NAICS is North American Industry Classification System.

Source: Calculated with the data from the US Census Bureau.

2.3 Transportation Cost Calculation with an Indirect Methodology

Anderson and Wincoop (2004) is a famous trade cost paper, and it mentions that "a rough estimate of the tax equivalent of representative trade costs for industrialized countries can be broke down as 21 percent transportation costs, 44 percent border-related trade barriers and so one". Therefore, we can calculate trade cost firstly, and use the transportation cost share in the trade cost to indirectly compute transportation cost.

We calculate trade costs following the approaches in Novy (2013) and Wong (2012), which method had also been used in Li and Whalley (2014), and Li *et al.* (2016). Their method is to take the ratio of bilateral trade flows over local trade, scaled to some parameter values, and then use a measure that capture all barriers.

The measure of trade barrier used here is based on the gravity equation derived from Chaney (2008) model of heterogeneous firms with bilateral fixed costs of exporting. Trade barriers can take two forms in the model, a variable trade barrier τ_{ir} and a fixed cost of exporting F_{ir}. The variable trade barrier τ_{ir} is an iceberg cost. In order to deliver one unit of good to i from r, $\tau_{ir} > 1$ unit of good has to be delivered. Defining the geometric average of trade costs between the country pair i and r as

$$t_{ir} = (\frac{X_{ir}X_{ri}}{X_{ii}X_{rr}})^{-\frac{1}{2\gamma}} \tag{2}$$

Where X_{ir} is the import of country i from country r, γ is the Pareto parameter governs the distribution of firm productivities. We then get a measure of the average bilateral trade barrier between country i and r:

$$t_{ir} = (\frac{X_{ii}X_{rr}}{X_{ir}X_{ri}})^{\frac{1}{2\gamma}} = (\tau_{ir}\tau_{ri})^{\frac{1}{2}}(F_{ri}F_{ir})^{\frac{1}{2}(\frac{1}{\sigma-1}-\frac{1}{\gamma})} \tag{3}$$

Therefore, the ad valorem tariff-equivalent bilateral average trade cost between country i and r can be written as

$$\bar{t}_{ir} = t_{ir} - 1 = \left(\frac{X_{ii} X_{rr}}{X_{ir} X_{ri}}\right)^{\frac{1}{2\gamma}} - 1 \tag{4}$$

Using the above trade cost equation, we can calculate actual trade costs between bilateral country pairs in our general equilibrium model. In the calculation, X_{ir} and X_{ri} are separately exports and imports between countries i and r. Due to market clearing, intranational trade X_{ii} or X_{rr} can be rewritten as total income minus total exports,

$$X_{ii} = y_i - X_i \tag{5}$$

Where X_i are the total exports, defined as the sum of all exports from country i, which is

$$X_i \equiv \sum_{r, i \neq r} X_{ir} \tag{6}$$

In the trade cost calculation, all trade data are from the UN Comtrade database. For y_i, GDP data are not suitable because they are based on value added, whereas the trade data are reported as gross shipments. In addition, GDP data include services that are not covered by the trade data (Novy, 2013). It is hard to get this income data according to such a definition, so here we use GDP data minus total service value added. We get GDP data and the service share of GDP data from World Development Indicators (WDI) of World Bank database, we then calculate results for GDP minus services. We take the value of γ to be 8.3 as in Eaton and Kortum (2002).

Using this methodology, we can calculate trade costs between Canada and the US. As transportation cost (TC) shares 21% of the trade cost, so $TC_{ir} = 21\% \bar{t}_{ir}$, then we can get ad valorem transportation costs. Computation results are reported in Figure 3, so the transportation cost between Canada and the US in 2015 is 8.1% under this indirect calculation methodology, we will use this result to perform sensitivity analysis in the simulation part.

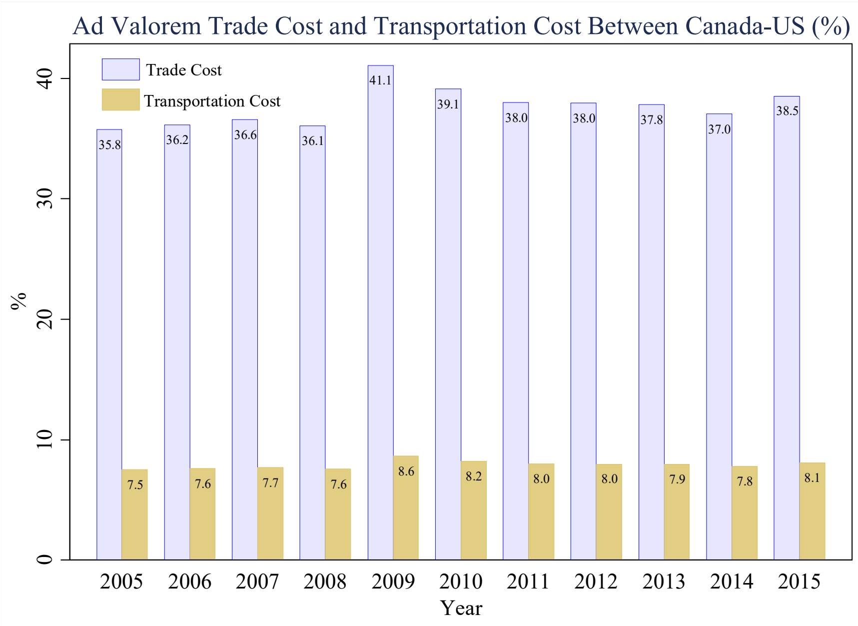


Figure 3: 2005-2015 Ad Valorem Trade Cost and Transportation Cost between Canada-US

Source: Calculated by authors.

3. General Equilibrium Trade Models with Transportation Cost

We use two different groups of general equilibrium model structures to explore the effects of transportation cost on welfare and trade. One is Armington assumption GE model which assume that the same goods from different countries are heterogeneous, Armington assumption is a normal and prevalent assumption in GE models. The other one is homogenous goods GE model which assume that the same goods produced in different countries are completely homogenous, and these goods are perfectly substitutable. The Armington assumption is a widespread assumption in literatures, the homogeneous goods structure can capture the characteristics of resource goods trade, like oil and electricity, which are completely substitutional.

We introduce both trade balance and fixed exogenous trade imbalance assumptions for each group of models. Trade balance structure is a traditional assumption that each country's total export should equals to its total import. Exogenous fixed trade imbalance general equilibrium structure assumes that trade imbalances for all countries are fixed all the time. We assume an exogenously determined fixed trade imbalance, denoted as S_i, which will be positive when in trade surplus and negative when in trade deficit. Trade equilibrium will influence individual country's budget constraint. In the equilibrium, we have

$$I_i = E_i + S_i \tag{7}$$

which means that one country's total income (I_i) equals its total consumption expenditure (E_i) plus its surplus (trade imbalance), if one country has trade surplus then its income will more than consumption expenditure, but if one country has trade deficit than its income will be less than consumption expenditure. We added these conditions in the global general equilibrium model yielding a fixed trade imbalance structure.

3.1 Two Forms of Transportation Cost and Modelling

We introduce two different forms of transportation cost into our general equilibrium models, which are iceberg transportation cost and production function transportation cost. The iceberg formulation of transport cost was first introduced by Samuelson (1952, 1954), in which part of the good to be delivered "melts" along the way by the very act of transportation. Far from realistic, but iceberg form is a tractable way of modelling transportation cost since it impacts no other market. We assume ad valorem transportation cost to be TC, so when the exporting country export $(1+TC)$ units of goods to the importing country, the importing country can only receive 1 unit of goods, TC units of goods are melted in the transportation.

Samuelson's iceberg function is explicitly defined as a continuous function of geographical distance, Krugman (1991) is one of many significant papers employing the assumption, and its formation of transportation cost is

$$TC(d) = e^{-\tau d} \tag{8}$$

Where $TC(d)$ is a transportation cost, τ is an iceberg decay parameter, d is a haulage distance. Long distance means high cost for transporting goods.

Under the iceberg transportation cost form, transportation costs are included in the melted exporting goods, which means exporting countries pay the transportation cost directly with a proportional share of exporting goods, so there are no transportation sectors in the model structure.

Production function transportation cost treat transportation process as a service provided by transportation sectors, so that transportation cost is the expense for transporting goods from export country to import country. We assume that transportation costs are paid by import countries with their transportation sector services. So that the transportation sector demand and supply in a specific country is endogenously determined by its import volume and ad valorem transportation cost. Under such assumption,

$$QTC_i = \sum_j \sum_r TC_{ijr} \times IM_{ijr}; \qquad i, j = countries, \quad r = sectors \tag{9}$$

Where QTC_i is the total production of transportation sector in country i, is the ad valorem transportation cost for country i to importing goods r from country j. IM_{ijr} denotes the import of goods r in country i from country j.

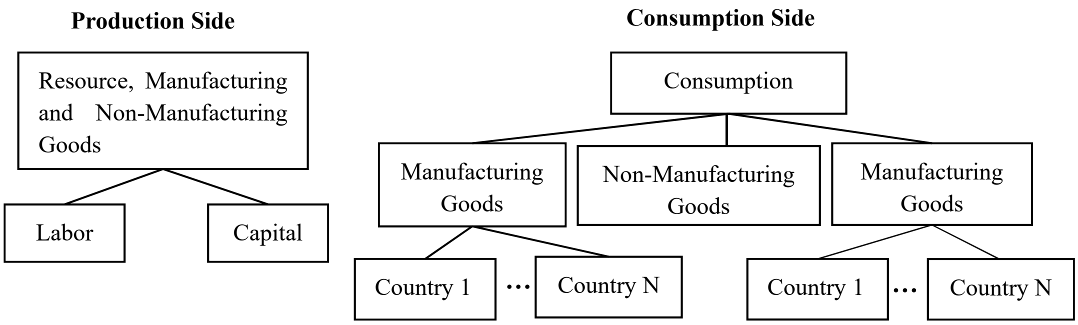
Under the production function transportation cost form, transportation is a separate sector which includes production side and consumption side, the consumption demand equals transportation cost.

3.2 Armington Assumption GE Models

Our Armington assumption GE models have two different structures, one is the iceberg transportation cost structure without transportation sector, and the other one is the production function transportation cost structure with transportation sector. Meanwhile, for each structure, we include both trade balance and imbalance forms.

In the models without transportation sector (iceberg form transportation cost), three sectors are tradable resource goods, tradable manufacturing goods and non-tradable non-manufacturing goods, two production factors are capital and labor. The production function is a CES style, and the consumption function is a two-level nested CES style. The fist level consumption is the choice between resource goods, manufacturing goods and non-manufacturing goods, and the second level consumption is the choice of resource goods and manufacturing goods from different original countries (see Figure 4). In the equilibrium, goods market and factor market will clear, and goods prices and factor prices are determined by their demand and supply.

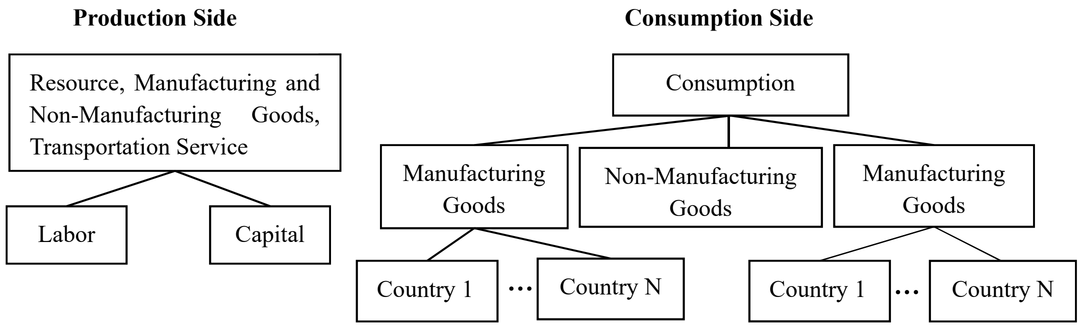
Figure 4: Structure of Armington Goods GE Models with Iceberg Transportation Cost



Source: Compiled by authors.

In the models with transportation sector (production function form transportation cost), we have four sectors which are tradable resource goods, tradable manufacturing goods, non-tradable non-manufacturing goods and transportation sector. On the production side, production functions are of CES type. On the consumption side, the function is a two-level nested CES type. The first level is the consumption choice of resource goods, manufacturing goods and non-manufacturing goods, the second level is the consumption choice of resource goods and manufacturing goods from different countries (see Figure 5). Under this assumption, the transportation cost is one of service provided by transportation sector, the ad valorem transportation cost will increase the consumption price of imported goods. In the equilibrium, all goods and factors market will clear, and goods prices and factor prices are determined by their demand and supply either. The transportation sector clearing condition is that transportation demand by importing equals transportation sector production.

Figure 5: Structure of Armington Goods GE Models with Production Function Transportation



Source: Compiled by authors.

3.3 Homogeneous Goods GE Models

For the homogenous goods GE model, same goods from different countries are homogenous, so the goods market clearance condition will be that the total production of each goods in the world equals the total consumption of this goods in the world.

Homogenous goods in general equilibrium will cause specialization problem, in order to avoid this problems, we use fixed sector specific inputs and diminishing marginal productivity production functions in which the marginal productivity of labor equals zero as output in the sector approaches zero. The form of this production function can be described as

$$Q_i^l = A_i^l (L_i^l)^{\alpha_i^l}, \quad \alpha_i^l < 1; \;\; l = goods, \;\; i = country \tag{10}$$

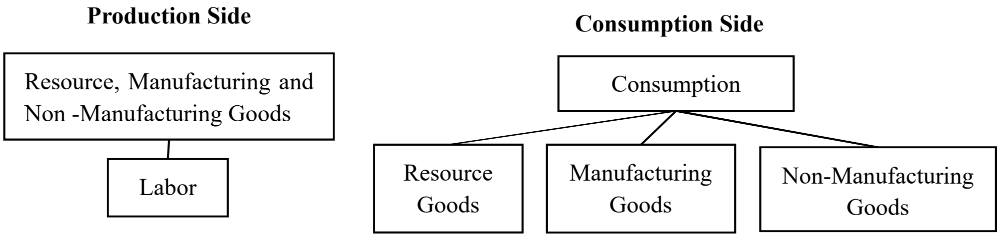
where Q_i^l is the output of the lth industry in country i, L_i^l is the labor inputs in sector l, A_i^l are the scale parameters, α_i^l is the share parameter. Simple calculation implies the factor input demand equations as

$$L_i^l = \left(\frac{Q_i^l}{A_i^l}\right)^{\frac{1}{\alpha_i^l}} \tag{11}$$

Therefore, our homogenous goods general equilibrium models have two countries (Canada and the US), three (tradable resource goods, tradable manufacturing goods, and non-tradable non-manufacturing goods) or four goods (tradable resource goods, tradable manufacturing goods, non-tradable non-manufacturing goods, and transportation service sectors), and one factor (labor).

In the models without transportation sector (iceberg form transportation cost), production functions are fixed sector specific inputs and diminishing marginal productivity functions, consumption functions are one-level CES type (see Figure 6). Transportation costs will be covered by melted exporting goods. In the equilibrium, goods market and factor market will clear, and goods prices and factor prices are determined by their demand and supply.

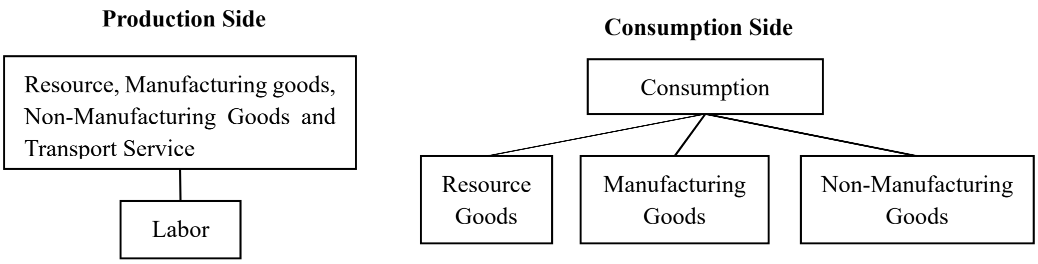
Figure 6: Structure of Homogenous Goods GE Models with Iceberg Transportation Cost



Source: Compiled by authors.

In the models with transportation sector (production function form transportation cost), we have four sectors, resource goods, manufacturing goods, non-manufacturing goods and transportation service goods. The production functions are fixed sector specific inputs and diminishing marginal productivity functions, and consumption functions are one-level CES type (see Figure 7). Transportation costs are covered by transportation service. In the equilibrium, goods market and factor market will clear, and goods prices and factor prices are determined by their demand and supply, transportation production equals transportation cost demand in importing.

Figure 7: Structure of Homogeneous Goods GE Models with Production Function Transportation Cost



Source: Compiled by authors.

4. Data and Parameters Calibration

We set 2015 as our base year in building a global benchmark general equilibrium dataset for use in calibration and simulation according to the methods set out in Shoven and Whalley (1992). There are two countries which are Canada and the US, and three goods which are resource goods, manufacturing goods and non-manufacturing goods in our numerical model. For the three goods, we add the industries of crude material, crude oil, mineral fuels, and manufactured good classified by material together to denote resource goods, assume other secondary industry (manufacturing) together to reflect manufacturing goods, and some primary and tertiary industries (agriculture, extractive industries and services) to yield non-manufacturing goods. For the two factor inputs, capital and labor, we use total labor income to denote labor values for inputs by sector. All data are in billion US dollars.

All data are from the World Bank database (World Development Indicate). We use 1-digital SITC Rev 2 industrial data to yield production data of resource goods, manufacturing goods and non-manufacturing goods, and use industrial capital ratios to yield capital and labor input in production. These basic data are listed in Table 3.

Table 3: Benchmark Data Used in Numerical Models (2015 Data)

Country	GDP	R	M	NM	Capital Input			Labor Input		
					R	M	NM	R	M	NM
Canada	1550.5	405.2	230.6	914.7	81.6	70.9	219.6	323.6	159.7	695.1
US	17946.9	1794.7	2153.6	13998.6	358.9	430.7	2799.8	1435.8	1722.9	11198.8

Notes: (1) Units for production, capital and labor are all billion US$, and labor here denotes factor income (wage). (2) "R" denotes resource goods, "M" denotes manufacturing goods, and "NM" denotes non-manufacturing goods.

Sources: calculated from WDI of World Bank database.

Trade data between each pair of countries are from the UN Comtrade database. For the balanced trade structures, we adjust Canada's manufacturing goods import value to make trade balanced. For the homogeneous goods models, export value equals the net export value, we calculate trade data with the actual export and import values. The trade data we use in Armington goods structures are listed in Table 4 and Table 5, homogeneous goods trade data can be easily calculated from the actual export and import data in Table 4 and Table 5. Using production and trade data, we can then calculate each country's consumption values.

Table 4: Trade between Countries in 2015 (Unit: Billion US$)

Countries		Exporter			
		Resource Goods		Manufacturing Goods	
		US	Canada	US	Canada
Importer	US	0	148.1	0	165.5
	Canada	53.8	0	169.8	0

Sources: United Nations (UN) Comtrade database.

Table 5: Trade between Countries in Balanced Trade Structure (Unit: Billion US$)

Countries		Exporter			
		Resource Goods		Manufacturing Goods	
		US	Canada	US	Canada
Importer	US	0	148.1	0	165.5
	Canada	53.8	0	259.8	0

Sources: adjusted with trade data from United Nations (UN) Comtrade database.

For the production function form transportation costs, transportation sector will be included in our GE models. The transportation service sector production output are endogenously determined by ad valorem transportation cost and trade value. Ad valorem transportation costs data between Canada and the US are reported in the last part. We assume the transportation sector factor input structure in production are the same as the non-manufacturing goods sector.

There are no available estimates of elasticities for individual countries on the demand and production sides of the model. Many of the estimates of domestic and import goods substitution elasticity are around 2 (Betina *et al.*, 2006), so we set all these elasticities in our model to 2 (Whalley and Wang, 2010). We perform sensitivity analysis around these elasticities in the simulation part.

With these data, we calibrate the model parameters. When used in model solution these regenerate the benchmark data as an equilibrium for the model. Then, using these parameters we can form a numerical global general equilibrium system, and can use this system to explore the transportation cost effects under different GE model structures.

5. Simulation Results

We set the numerical GE models with transportation costs as benchmarks, then we remove transportation cost in the benchmark models and get corresponding counterfactual models. Transportation cost effects can be generated by comparing the counterfactual and benchmark equilibrium results.

Our simulation analysis emphasizes on the transportation cost effects on welfare and trade. Welfare effect indicators in this paper include equivalent variation (EV), compensation variation (CV), EV as a percent share of GDP, CV as a percent share of GDP, and percent change of total utility. Trade effects include percent changes on both export and import.

We have two groups of models in general to compare the impact of transportation cost, one is Armington assumption models and the other is homogenous goods models. Under each group models, we also compare the effects of iceberg transportation costs and production function transportation costs, as well as the effects of balanced trade structures and fixed trade imbalance structures. We perform sensitivity analysis to elasticities and ad valorem transportation costs for each group of models.

For each group of model, we use two different kinds of indicators to show the transportation cost influences. The first kind of indicators are the absolute values or percent changes of variables. The second kind of indicators are the percent share of gains from transportation cost elimination, in which we add the gains of Canada and the US from transportation cost together, and report the percent shares of Canada and the US.

5.1 Results of Armington Goods Structure

We report the effects of transportation cost under Armington assumption models in this part. Simulation results of welfare and trade are both reported and compared separately, we perform sensitivity analysis to elasticities by varying elasticity values, and also to ad valorem transportation cost with an indirect transportation cost value.

5.1.1 Simulation Results

Effects on welfare show that eliminating transportation cost will definitely improve welfares of both countries. Comparatively, both countries' absolute welfare gains are close, but Canada's gains as a share of GDP are much larger than the US as Canada is a small country compared with the US. These conclusions can hold under balanced trade and trade imbalance structures, as well as under production function transportation cost structures and iceberg transportation cost structures.

We take the balanced trade and iceberg transportation cost structure case as an example, EV changes for Canada and the US are separately 14.794 billion US$ and14.614 billion US$, two countries nearly divide the welfare gains equally in absolute value. The CV results show the same trend as the EV. Percent changes of utility for Canada and the US are separately 0.947% and 0.081%, results for both EV and CV as a percent shares of GDP are nearly the same. It is clear that Canada's comparative welfare gain variation is larger than the US (see Table 6).

Table 6: The Effects of TC with Armington Goods Structure

Countries	EV (US$ bn)	CV (US$ bn)	EV/GDP (%)	CV/GDP (%)	UTILITY (%)
Balanced Trade, Production Function Transportation Cost					
US	14.734	14.394	0.082	0.080	0.081
Canada	14.739	14.405	0.949	0.928	0.945
Balanced Trade, Iceberg Transportation Cost					
US	14.614	14.286	0.081	0.080	0.081
Canada	14.794	14.457	0.951	0.930	0.947
Fixed Trade Imbalance, Production Function Transportation Cost					
US	13.554	13.322	0.076	0.074	0.075
Canada	12.074	11.787	0.767	0.748	0.810
Fixed Trade Imbalance, Iceberg Transportation Cost					
US	10.603	10.433	0.059	0.058	0.058
Canada	14.948	14.636	0.948	0.929	1.006

Note: Units for the EV and CV are billion US$, Units for all others are %.

Source: by authors.

Comparing the transportation cost effects on welfare under balanced trade and fixed trade imbalance structures, results under different transportation cost forms are different. Welfare gains with balanced trade structures are larger than with fixed trade imbalance structures under production function transportation cost cases, but just opposite under iceberg transportation cost cases (see Figure 8). The reason for the result is that Canada is a trade surplus country with the US, so it export more than import to the US, when under iceberg transportation cost will export countries pay the transportation cost which means Canada will pay more transportation cost compared with balanced trade structure, therefore the transportation cost effects to Canada are larger under trade imbalance structures. Reasons for the results in production function transportation cost are the same.

We take Canada's EV gain shares as examples to specifically compare the results. Under production function transportation cost structures, Canada's EV gain percent share with balanced trade case is 50%, but 47.1% with fixed trade imbalance case. It is clear that gains under balanced trade are larger. Under iceberg transportation cost structures, Canada's EV gain percent share with balanced trade case is 50.3%, but 58.5% with fixed trade imbalance case, so that gains under fixed trade imbalance are larger (see Figure 8).

Comparing the transportation cost effects on welfare under production function transportation cost and iceberg transportation cost, Canada's welfare gains with iceberg transportation cost forms are significantly larger than gains with production function transportation cost. This result is clearer in trade imbalance structures (see Figure 9). The reason for the result is that Canada is a trade surplus country to the US which means it export more than import, meanwhile exporting country pay transportation cost under iceberg transportation assumption but importing country pay transportation cost under production function transportation cost, so that Canada's welfare gain shares with iceberg transportation cost are larger.

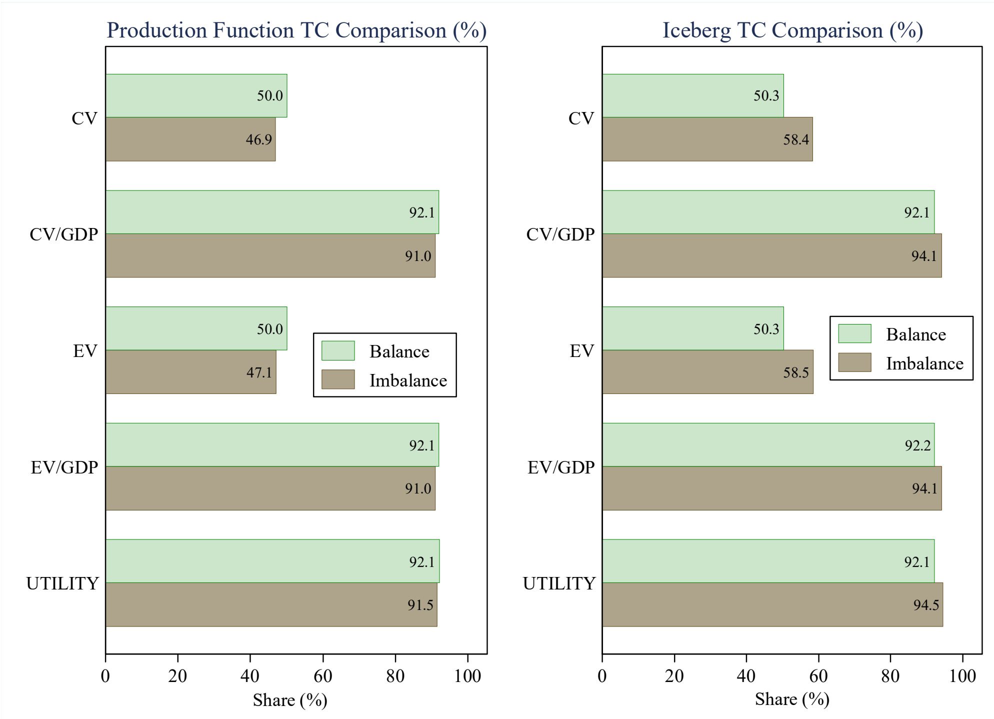


Figure 8: Canada's Welfare Gain Share Comparison with Armington Structures (I)

Source: by authors.

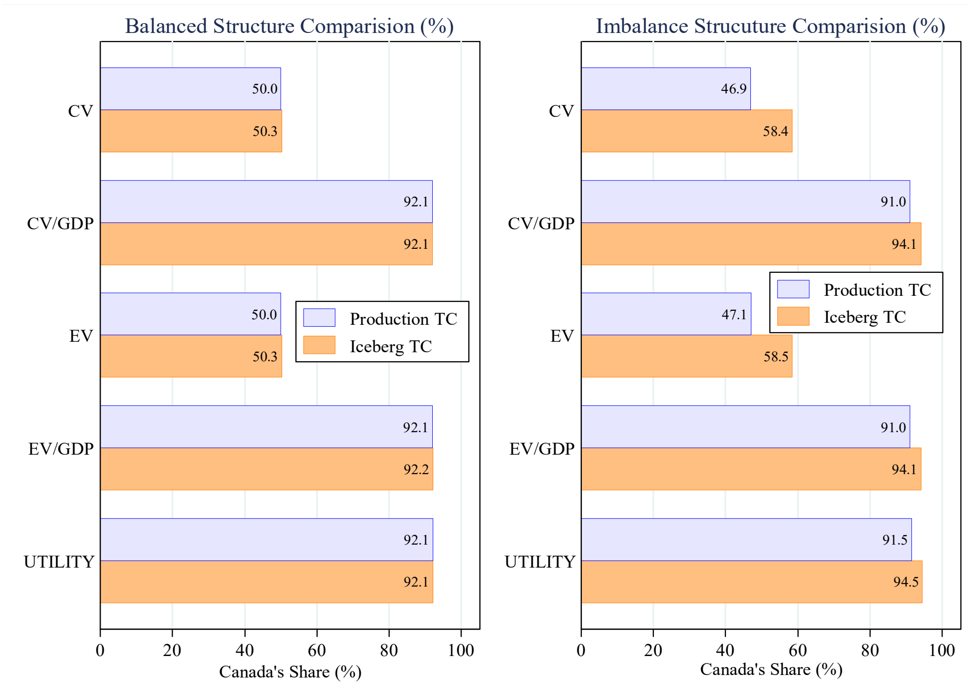


Figure 9: Canada's Welfare Gain Share Comparison with Armington Structures (II)

Source: by authors.

We take Canada's CV gain share as an example to specifically compare the results under different forms of transportation cost. Under the fixed trade imbalance structures, Canada's CV gain percent share with production function TC is 46.9%, but 58.4% with iceberg TC. Under the balanced trade structures, Canada's CV gain percent share with production TC is 50.0%, but 50.3% with iceberg TC (see Figure 9).

Effects on trade show that eliminating transportation cost will increase both export and import between two countries. Comparatively, under balanced trade structures, trade with iceberg TC cases will increase more than production function TC. Under trade imbalance structures, exports of bigger countries and trade deficit countries will increase more but imports decrease less, the trends are more significant under iceberg TC cases (see Table 7).

Specifically, both Canada and the US exports and imports under production function TC will increase 4.646%, and increase 4.699% under iceberg TC. Under trade imbalance structures, the US export and import will separately increase 5.439% and 4.244% with production function TC, and separately increase 6.1% and 4.244% with iceberg TC (see Table 7).

Table 7: Effects of TC on Trade with Armington Structures (% change)

Countries	Export	Import	Export	Import	Export	Import	Export	Import
	Balanced Trade				*Trade Imbalance*			
	Production TC		*Iceberg TC*		*Production TC*		*Iceberg TC*	
US	4.646	4.646	4.699	4.699	5.439	4.244	6.100	3.976
Canada	4.646	4.646	4.699	4.699	4.244	5.439	3.976	6.100

Note: TC denotes transportation cost.

Source: by authors.

5.1.2 Sensitivity Analysis I: with Indirect Transportation Cost

We perform sensitivity analysis to ad valorem transportation cost in this part. We use the indirect ad valorem TC value of 8.1% calculated before to do sensitivity comparison. All sensitivity analysis results are reported in Table 8.

Table 8: Sensitivity Analysis to Indirect TC with Armington Goods Structure

Countries	EV (US$ bn)	CV (US$ bn)	EV/GDP (%)	CV/GDP (%)	UTILITY (%)
Balanced Trade, Production Function Transportation Cost					
US	54.375	50.176	0.303	0.280	0.291
Canada	54.541	50.331	3.484	3.215	3.429
Balanced Trade, Iceberg Transportation Cost					
US	52.764	48.927	0.294	0.273	0.284
Canada	55.771	51.396	3.557	3.278	3.507
Fixed Trade Imbalance, Production Function Transportation Cost					
US	49.838	46.844	0.278	0.261	0.268
Canada	45.023	41.378	2.811	2.583	2.932
Fixed Trade Imbalance, Iceberg Transportation Cost					
US	38.282	36.166	0.213	0.202	0.206
Canada	55.945	51.933	3.489	3.239	3.701

Note: (1) Units for the EV and CV are billion US$, Units for all others are %. (2) TC denotes transportation cost.

Source: by authors.

The ad valorem TC in the sensitivity analysis is about four times larger than the TC in main simulation. We find that all simulation results are also nearly four times bigger than results in our main simulation. All comparative effects under different model structures are the same as in main simulation. These results reveal that TC effects to both Canada and the US are sensitive to ad valorem transportation cost, and the comparative simulation results are stable and robustness to TC.

5.1.3 Sensitivity Analysis II: with Different Elasticities

We perform sensitivity analysis of TC effects to elasticities in this part. Elasticities in preference and production functions changes from 1.5 to 4.5 with interval of 1 to separately simulate TC effects on welfare. Table 9 reports all of the sensitivity analysis results.

Results show that TC effects only have very small changes under different elasticities, which means that simulation results are not sensitive to elasticities. Our main simulation results are reliable.

Table 9: Sensitivity Analysis to Elasticities under Armington Models

Countries	Elasticity	EV	CV	EV/GDP	CV/GDP	UTILITY	Elasticity	EV	CV	EV/GDP	CV/GDP	UTILITY
	Trade Balance + Production Function TC											
US	E=1.5	15.033	14.76	0.084	0.082	0.083	E=2.5	14.596	14.203	0.081	0.079	0.08
Canada		14.291	14.034	0.921	0.904	0.918		15.013	14.598	0.967	0.94	0.96
US	E=3.5	14.535	14.003	0.081	0.078	0.08	E=4.5	14.572	13.898	0.081	0.077	0.079
Canada		15.377	14.8	0.99	0.953	0.979		15.65	14.908	1.007	0.959	0.991
	Trade Balance + Iceberg TC											
US	E=1.5	14.804	14.541	0.082	0.081	0.082	E=2.5	14.522	14.135	0.081	0.079	0.08
Canada		14.471	14.208	0.93	0.913	0.928		15.022	14.605	0.966	0.939	0.96
US	E=3.5	14.484	13.96	0.081	0.078	0.079	E=4.5	14.516	13.861	0.081	0.077	0.079
Canada		15.354	14.777	0.987	0.95	0.976		15.625	14.873	1.005	0.957	0.988
	Fixed Trade Imbalance + Production Function TC											
US	E=1.5	13.778	13.592	0.077	0.076	0.076	E=2.5	13.47	13.191	0.075	0.074	0.074
Canada		11.8	11.588	0.745	0.732	0.789		12.245	11.88	0.78	0.756	0.821
US	E=3.5	13.442	13.065	0.075	0.073	0.073	E=4.5	13.47	13.005	0.075	0.072	0.073
Canada		12.494	11.97	0.797	0.764	0.835		12.708	12.014	0.812	0.768	0.845
	Fixed Trade Imbalance + Iceberg TC											
US	E=1.5	10.311	10.192	0.057	0.057	0.057	E=2.5	10.759	10.53	0.06	0.059	0.059
Canada		15.183	14.953	0.958	0.943	1.019		14.893	14.502	0.947	0.923	1.003
US	E=3.5	10.938	10.613	0.061	0.059	0.06	E=4.5	11.087	10.653	0.062	0.059	0.06
Canada		14.934	14.379	0.953	0.917	1.002		15.039	14.323	0.961	0.915	1.006

Note: (1) Units for the EV and CV are billion US$, Units for all others are %. (2) TC denotes ad valorem transportation cost.

Source: by authors.

5.2 Results of Homogeneous Goods Structure

This part reports the effects of transportation cost under Homogeneous goods models and compare these results with Armington goods models. Effects on welfare and trade are both included. We perform sensitivity analysis to elasticities and to ad valorem transportation cost either.

5.2.1 Simulation Results

Transportation cost effects on welfare in homogeneous goods models show that eliminating transportation cost will improve welfares of both countries. Comparatively, both countries' absolute welfare gains are close, but Canada's gains as a share of GDP are much larger than the US. Comparative effect results between balanced trade and trade imbalance cases, and production function TC and iceberg TC are all the same as in Armington models. So we focus on comparing the effects between Armington structures and homogeneous structures in this part.

Comparing the effects strength, TC welfare effects in homogeneous goods assumption are apparently smaller than the effects in Armington goods. The reason is that trade in homogeneous goods are net export so trade values are much less than in Armington goods.

Table 10: The Effects of Eliminating TC with Homogeneous Goods Structure

Countries	EV (US$ bn)	CV (US$ bn)	EV/GDP (%)	CV/GDP (%)	UTILITY (%)
Balanced Trade, Production Function Transportation Cost					
US	2.508	2.508	0.014	0.014	0.014
CANADA	2.507	2.946	0.138	0.162	0.162
Balanced Trade, Iceberg Transportation Cost					
US	2.216	2.216	0.012	0.012	0.012
CANADA	3.304	2.978	0.159	0.143	0.143
Fixed Trade Imbalance, Production Function Transportation Cost					
US	3.331	3.331	0.019	0.019	0.018
CANADA	1.251	1.251	0.081	0.081	0.086
Fixed Trade Imbalance, Iceberg Transportation Cost					
US	4.713	4.713	0.026	0.026	0.026
CANADA	6.793	6.793	0.438	0.438	0.467

Note: Units for the EV and CV are billion US$, Units for all others are %.

Source: by authors.

We take the EV effects under the balanced trade and iceberg TC structure as an example, EVs for Canada and the US in Armington goods case are separately 14.794 billion US$ and 14.614 billion US$, but are separately 3.304 billion US$ and 2.216 billion US$ in homogeneous goods case (see Table 10). The effect intensity in Armington structure is about 4-5 times larger than in homogeneous goods structure.

Under balanced trade assumption, Canada's welfare gain shares are a little more than the US in general, but nearly the same. Additionally, Canada's gain shares in homogeneous goods cases are significantly larger than in Armington goods cases with iceberg TC, but gain shares in Armington goods cases are a little larger than in homogeneous goods cases with production function TC. Therefore, when the importing country pay the transportation cost under production function TC, welfare gain shares with Armington assumption are nearly the same as with homogeneous goods assumption. When the exporting country pay the transportation cost under iceberg TC, Canada as a trade surplus country can shift transportation cost burden to the US under Armington goods, but cannot shift transportation cost to the US under homogeneous goods, so that Canada's welfare gain shares with homogeneous goods are more than shares with Armington goods.

We take the EV gain shares of Canada as an example to compare the results with Armington goods and homogeneous goods. With production function TC, Canada's EV percent gain shares under the Armington goods and homogeneous goods are separately 50.01% and 49.99%, nearly the same; but with iceberg TC, these two results are separately 50.31% and 59.86%, obviously gain shares under homogeneous goods are larger (see Figure 10).

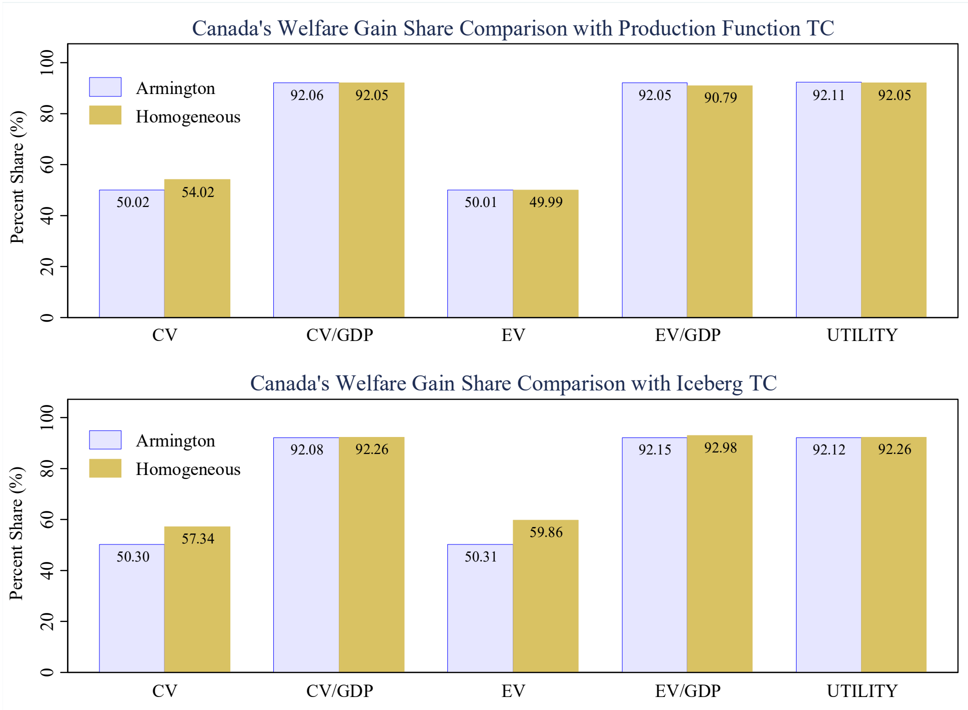


Figure 10: Canada's Welfare Gain Share Comparison with Balanced Trade Structure

Source: by authors.

Under fixed trade imbalance assumption, Canada's percent welfare gain shares in production function TC are less than the US's, the reason is that Canada is a trade surplus country and so that export more than import to the US, when TC are paid by importing countries which determines that trade deficit countries will gain more from removing TC. The results are opposite in iceberg TC as exporting countries pay the TC. Additionally, as countries in homogeneous goods structures are hard to shift TC to trade partners using their market power, so Canada's percent welfare gain shares with homogeneous goods are less than shares with Armington goods in production function TC models, but are more than shares with Armington goods in iceberg TC models.

Canada's specific CV gain shares can prove the above conclusions. With production function TC, Canada's CV gain share in the Armington goods model is 46.94% compared to 27.30% in the homogeneous goods model. With fixed trade imbalance TC, Canada's CV gain share in the Armington goods model is 58.34% compared to 59.04% in the homogeneous goods model (see Figure 11).

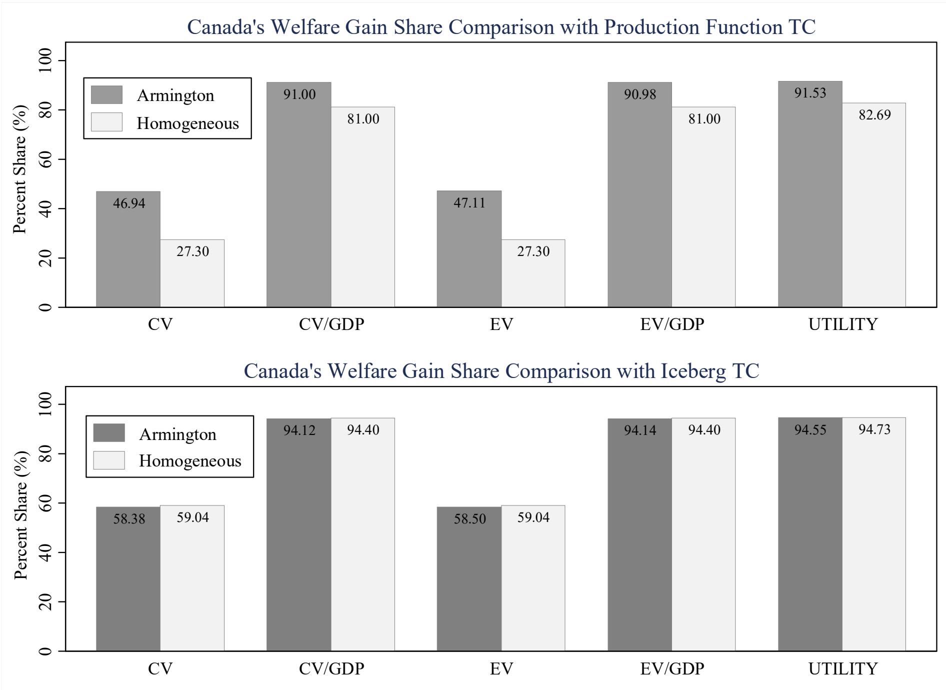


Figure 11: Canada’s Welfare Gain Share Comparison with Trade Imbalance Structure

Source: by authors.

Transportation cost effects on trade in homogeneous goods models are significant and prominent. Compared with trade effects in Armington goods models, both export and import increase much more in homogeneous goods models. The reason for this result is clear, homogeneous goods trade and more sensitive to price changes caused by transportation cost. Meanwhile, balanced trade structure case generates more trade variation than fixed trade imbalance structure, and iceberg TC case generates severer trade variation than production function TC.

Under balanced trade and production function TC structure, both export and import in two countries increase 44.964%. But both export and import in two countries increase 64.44% under balanced trade and iceberg TC structure. Under fixed trade imbalance structures, export for the US in production function TC and iceberg TC increase separately 24.348% and 32.946%, and import increase separately 9.146% and 17.043% (see Table 11).

Table 11: Effects of TC on Trade with Different Model Structures (% change)

Countries	Export	Import	Export	Import	Export	Import	Export	Import
	Balanced Trade				*Trade Imbalance*			
	Production TC		*Iceberg TC*		*Production TC*		*Iceberg TC*	
US	44.964	44.964	64.44	64.44	24.348	9.146	32.946	17.043
CANADA	44.964	44.964	64.44	64.44	9.146	24.348	17.043	32.946

Source: by authors.

5.2.2 Sensitivity Analysis I: with Indirect Transportation Cost

We perform sensitivity analysis for homogeneous goods structure to ad valorem TC in this part. Indirect TC calculation results of 8.1% is used for the sensitivity analysis. All TC effects on welfare are simulated and collected in Table 12.

Sensitivity analysis results show that TC effects are sensitive to ad valorem TC, but the comparative effects are nearly the same, which proves that our main simulation results are reliable.

Table 12: Sensitivity Analysis to Indirect TC with Homogeneous Goods Structure

Countries	EV (US$ bn)	CV (US$ bn)	EV/GDP (%)	CV/GDP (%)	UTILITY (%)
Balanced Trade, Production Function Transportation Cost					
US	2.379	2.379	0.013	0.013	0.013
CANADA	2.38	2.38	0.153	0.153	0.154
Balanced Trade, Iceberg Transportation Cost					
US	13.325	13.325	0.074	0.074	0.074
CANADA	14.43	17.909	0.692	0.859	0.867
Fixed Trade Imbalance, Production Function Transportation Cost					
US	8.091	8.091	0.045	0.045	0.045
CANADA	0.769	0.769	0.05	0.05	0.053
Fixed Trade Imbalance, Iceberg Transportation Cost					
US	16.4	16.4	0.091	0.091	0.091
CANADA	23.723	23.723	1.53	1.53	1.652

Note: (1) Units for the EV and CV are billion US$, Units for all others are %. (2) TC denotes transportation cost.

Source: by authors.

5.2.3 Sensitivity Analysis II: with Different Elasticities

Sensitivity analysis to elasticities for homogeneous goods models is performed in this part. We change elasticities in preference and production functions to 1.5, 2.5, 3.5 and 4.5 to separately explore TC effects. All sensitivity analysis results are put in Table 13.

Comparing these results, we find that TC effects are not sensitive to elasticities. Although the simulation results are different, but changes are small. These results prove that our simulation results in main analysis are robustness.

Table 13: Sensitivity Analysis to Elasticities under Homogeneous Goods Models

Countries	Elasticity	EV	CV	EV/GDP	CV/GDP	UTILITY	Elasticity	EV	CV	EV/GDP	CV/GDP	UTILITY
	Trade Balance + Production Function TC											
US	E=1.5	3.372	3.372	0.019	0.019	0.019	E=2.5	3.344	3.344	0.019	0.019	0.019
Canada		3.372	3.035	0.242	0.217	0.218		3.344	3.01	0.24	0.216	0.216
US	E=3.5	5.021	5.021	0.028	0.028	0.028	E=4.5	5.159	5.159	0.029	0.029	0.029
Canada		5.022	4.52	0.36	0.324	0.325		5.158	4.642	0.37	0.333	0.334
	Trade Balance + Iceberg TC											
US	E=1.5	1.213	1.213	0.007	0.007	0.007	E=2.5	5.086	5.086	0.028	0.028	0.028
Canada		1.458	1.58	0.072	0.078	0.078		7.118	7.832	0.313	0.328	0.329
US	E=3.5	5.159	5.159	0.029	0.029	0.029	E=4.5	5.159	5.159	0.029	0.029	0.029
Canada		9.465	9.886	0.319	0.333	0.334		8.418	7.140	0.392	0.333	0.334
	Fixed Trade Imbalance + Production Function TC											
US	E=1.5	3.417	3.417	0.019	0.019	0.019	E=2.5	5.169	5.169	0.029	0.029	0.029
Canada		1.338	1.338	0.086	0.086	0.092		3.090	3.090	0.199	0.199	0.212
US	E=3.5	3.800	3.800	0.021	0.021	0.021	E=4.5	3.731	3.731	0.021	0.021	0.021
Canada		1.720	1.720	0.111	0.111	0.118		1.652	1.652	0.107	0.107	0.113
	Fixed Trade Imbalance + Iceberg TC											
US	E=1.5	4.713	4.713	0.026	0.026	0.026	E=2.5	4.787	4.787	0.027	0.027	0.027
Canada		6.793	6.793	0.438	0.438	0.467		7.995	7.995	0.43	0.43	0.454
US	E=3.5	4.754	4.754	0.026	0.026	0.026	E=4.5	3.716	3.716	0.021	0.021	0.021
Canada		7.403	7.403	0.434	0.434	0.46		7.562	7.562	0.348	0.348	0.365

Note: (1) Units for the EV and CV are billion US$, Units for all others are %. (2) TC denotes transportation cost.

Source: by authors.

6. Conclusions

This paper uses numerical general equilibrium models to simulate the effects of transportation cost on welfare and trade with the Canada-US case. Two groups of models are used, which are Armington goods structures and homogenous goods structures. Under each model structures, we also compare the transportation cost effects of production function TC with iceberg TC, as well as the transportation cost effects of balanced trade assumption with fixed trade imbalance assumption.

Simulation results are gained by comparing variations from the scenario of benchmark models with transportation cost to models with zero transportation cost. We use comparative percent change, absolute value change and share of change to show the transportation cost effects. We focus on the effects on welfare and trade (export and import).

Our empirical simulation results on welfare reveal that absolute gains in Armington goods models are apparently more than gains in homogeneous goods models. When we compare the welfare gains of Canada and the US, both of their absolute gains are close but Canada's gains as a share of GDP are much larger than the US in both Armington assumptions and homogeneous goods assumptions. When we compare the welfare effects under balanced trade cases to the effects under fixed trade imbalance cases, gains under balanced trade structures are larger than gains under fixed trade imbalance structures with production function transportation cost cases. But the results are opposite with iceberg transportation cost cases. When we compare the welfare effects under production function transportation cost to the effects under iceberg transportation cost, Canada's welfare gains with iceberg transportation cost are significantly larger than gains with production function transportation cost.

The transportation cost effects on trade show that both exports and imports under homogenous goods assumption increase much more than the ones under Armington assumption. Additionally, balanced trade structures can generate more trade variations than fixed trade imbalance structures, and iceberg form transportation cost can generate more trade variations than production function form transportation cost.

Sensitivity analyses find that welfare effects of transportation cost are not sensitive to elasticities but are sensitive to ad valorem transportation costs. Trade effects are very sensitive to ad valorem transportation cost especially under homogenous goods models.

References

Anderson, J.E. and E.V. Wincoop. 2004. "Trade Costs". Journal of Economic Literature, 42(3), pp.691-751.

Baier, S.L. and J.H. Bergstrand. 2001. "The Growth of World Trade: Tariffs, Transport Costs, and Income Similarity". Journal of International Economics, 53(1), pp.1-27.

Betina, V.D., R.A. McDougall and T.W. Herel. 2006. "GTAP Version 6 Documentation: Chapter 20 'Behavioral Parameters'".

Cassing, J.H. 1978. "Transport Costs in International Trade Theory: A Comparison with the Analysis of Nontraded Goods". The Quarterly Journal of Economics, 92(4), pp.535-550.

Chaney, T. 2008. "Distorted Gravity: The Intensive and Extensive Margins of International Trade". American Economic Review, 98(4), pp.1707-1721.

Eaton, J. and S. Kortum. 2002. "Technology, Geography, and Trade". Econometrica, 70(5), pp.1741-1779.

Falvey, R.E. 1976. "Transport Costs in the Pure Theory of International Trade". The Economic Journal, 86(343), pp.536-550.

Finger, J.M. and A.J. Yeats. 1976. "Effective Protection by Transportation Costs and Tariffs: A Comparison of Magnitudes". The Quarterly Journal of Economics, 90(1), pp.169-176.

Geraci, V.J. and W. Prewo. 1977. "Bilateral Trade Flows and Transport Costs". Review of Economics and Statistics, 59(1), pp.67-74.

Harrigan, J. 1993. "OECD Imports and Trade Barriers in 1983". Journal of International Economics, 35(1-2), pp.91-111.

Hummels, D. 1999. "Have International Transportation Costs Declined". University of Chicago Working Paper, July.

Hummels, D. 2007. "Transportation Costs and International Trade in the Second Era of Globalization". Journal of Economic Perspectives, 21(3), pp.131-154.

Hummels, D. and V. Lugovskyy. 2006. "Are Matched Partner Trade Statistics a Usable Measure of Transportation Costs". Review of International Economics, 14(1), pp.69-86.

Hummels, D. and A. Skiba. 2002. "A Virtuous Circle? Regional Tariff Liberalization and Scale Economies in Transport". Purdue University Working Paper, November.

Hummels, D. and A. Skiba. 2004. "Shipping the Good Apples Out? An Empirical Confirmation of the Alchain-Allen Conjecture". Journal of Political Economy, 112, pp.1384-1402.

Kleinert, J. and J. Spies. 2011. "Endogenous Transport Costs in International Trade". IAW Discussion Papers, July.

Krugman, P. 1991. "Increasing Returns and Economic Geography". Journal of Political Economy, 99, pp.483-499.

Laussel, D. and R. Riezman. 2006. "Fixed Transport Costs and International Trade". CESifo Working Paper No. 1764.

Li, C, and J. Whalley. 2014. "China and the Trans-Pacific Partnership: A Numerical Simulation Assessment of the Effects Involved". The World Economy, 37(2), pp.169-192.

Li, C, J. Wang and J. Whalley. 2016. "Impact of mega trade deals on China: A computational general equilibrium analysis". Economic Modelling, 57, pp.13-25.

Limao, N. and A.J. Venables. 2001. "Infrastructure, Geographical Disadvantage, Transport Costs, and Trade". World Bank Economic Review, 15(3), pp.451-479.

Litman, T.A. and E. Doherty. 2009. "Transportation Cost and Benefic Analysis". Victoria Transport Policy Institute Working Paper, January 4.

Moneta, C. 1959. "The Estimation of Transportation Costs in International Trade". The Journal of Political Economy, 67(1), pp.41-58.

Mudell, R.A. 1968. “A Geometry of Transport Costs in International Trade Theory”. In International Economics, New York: Macmillan, pp.65-84.

Novy, D. 2013. “Gravity Redux: Measuring International Trade Costs with Panel Data”. Economic Inquiry, 51(1), pp.101-121.

Ravn, M.O. and E. Mazzenga. 2004. “International Business Cycles: Quantitative Role of Transportation Costs”. Journal of International Money and Finance, 23, pp.645-671.

Rodrigue, J.P. and T. Notteboom. 2013. “The geography of Transport System”. New York: Routledge.

Samuelson, P.A. 1954. “The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments”. The Economic Journal, 64(254), pp.264-289.

Shoven, J.B. and J. Whalley. 1992. “Applying General Equilibrium”. Cambridge University Press.

Whalley, J and L. Wang. 2010. “The Impact of Renminbi Appreciation on Trade Flows and Reserve Accumulation on a Monetary Trade Model”. Economic Modelling, 28, pp.614-621.

Wong, A. 2012. “Measuring Trade Barriers: An Application to China’s Domestic Trade”. Job Market Paper, University of Chicago, January 2012.