Service Trade, Regional Specialization, and Welfare*

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Abstract

We study how trade in services affects the regional patterns of production specialization and welfare. Using unique Canadian trade data, we document that the size of inter-provincial service trade is comparable to good trade, and that net export of services is highly correlated with the value-added share of tradable services across provinces. Using a spatial model featuring domestic and international trade, we quantify the effects of service trade. Our results highlight that domestic service trade significantly influences regional specialization with large heterogeneous effects on welfare. Conversely, international service trade generates more uniform welfare gains across provinces.

JEL Classification: E20, F10, L16

Keywords: Service trade, tradable services value-added, regional specialization

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1 Introduction

Services play a significant role in trade, both within and between countries. In 2019, the World Trade Organization (WTO, 2019) documented that, during 2005-2017, trade in services grew faster than trade in goods and that services account for about half of the value of total international trade. Yet, considering that services are the largest sector in the economy, service trade is still relatively small (Lewis, Monarch, Sposi and Zhang, 2020). The WTO also states that increasing trade in services could "*create significant welfare gains for society through a more efficient allocation of resources, greater economies of scale, and an increase in the variety of services on offer.*" Despite the significance of services and the importance of trade in the allocation of resources (e.g., Levchenko and Zhang, 2012; Coşar and Fajgelbaum, 2016), the existing literature often assumes that services are non-traded.

This paper aims to fill this gap by showing that service trade has significant effects on regional production specialization and welfare. Using unique Canadian trade data, we start by documenting that inter-regional and international trade of services are large in their volume, even comparable to goods trade, especially for inter-regional trade. We further show that inter-regional net exports of services are quite heterogeneous across Canadian provinces and strongly correlated with the sectoral composition of the regions. We then construct a spatial model featuring interprovincial and international trade in goods and services that can match the characteristics of these data and quantify the impact of trade in services on regional specialization and welfare.

We first document that inter-provincial trade of services—imports plus exports— relative to GDP is of similar magnitude to that of goods, while international trade in services is about a fourth of international trade in goods. We then establish the empirical correlation that motivates our quantitative exercise. We show that there is an important relationship between net exports of services and regional specialization. To do so, we first classify sectors in the economy into three: goods sectors, non-tradable services sectors, and tradable services sectors. In our benchmark definition, tradable services sectors are those with the gross trade (imports plus exports) relative to gross output larger than 20%. Non-tradable services are those that display a ratio smaller than 20%.[1][2] We then show the strong positive correlation between net exports of services to GDP ratio and tradable services value-added shares.

[1] We also consider measures of tradability based on gross trade per worker, following Mian and Sufi (2014), and obtain a similar result.

[2] Our tradable services sectors are transportation and warehousing, administrative support, accommodation and food services, professional and technical services, information and cultural industries, arts entertainment and recreation, wholesale and retail trade and finance and real estate. Health care and social assistance, educational services, and other services (except public administration), are classified as non-tradable services.

Furthermore, even when net exports of services are divided into domestic net exports and international net exports, this correlation holds for each. Therefore, our empirical analysis suggests that trade in services plays a key role in shaping regional specialization in tradable services.

To rationalize our facts and to study the different channels in which service trade shapes regional specialization, we develop a three-sector model with multiple regions and the rest of the world in the spirit of Eaton and Kortum (2002). We introduce regional and international trade of services to the model. In each tradable sector, goods and tradable services, there is a continuum of competitive firms that engage in domestic and international trade. Each location also has a non-tradable service sector that domestically supplies non-traded services for final consumption. The economy also displays input-output linkages. A representative household in each region has non-homothetic preferences and heterogeneous income elasticities across consumption goods. We calibrate the production side of the model to match the observed production structure of Canadian provinces and the rest of the world for the period 1992-2017. We then estimate the parameters of our non-homothetic CES demand system using the Non-Linear Least Squares with consumption expenditure shares. Our estimates indicate that tradable and non-tradable services are complements to each other as well as goods and composite services. We also find that non-tradable services are luxuries compared to tradable services.

Using the model calibrated to the Canadian provinces and the rest of the world, we conduct a set of counterfactual exercises to quantify the role of domestic and international service trade in shaping regional specialization and welfare. More specifically, we shut down inter-regional and international trade of services, one at a time, and quantify its effects on regional specialization in production and welfare. Absent domestic service trade, the real income shrinks for all Canadian provinces, leading to a decrease in tradable service share due to non-homotheticities in demand. This income effect is offset by a price effect because of the complementarity, as the relative price of tradable services rises. As a result, the share of tradable services does not vary much across Canada as a whole, while there is significant heterogeneity across provinces in the extent of the price and income effects. The changes in the industrial composition of each province, therefore, vary significantly, depending on these forces and changes in net exports. On the other hand, the absence of international service trade triggers uniform reductions in real income with smaller positive price effects. Therefore, income effect outweighs the price effects which then reduces the tradable services consumption expenditure, inducing an even larger decline in provinces' tradable services value-added share.

These changes brought about by domestic and international trade in services are closely related to the welfare of Canadian provinces. Our results indicate that domestic service trade significantly influences regional production specialization and welfare. Real wage increases by 7% resulting from domestic service trade are comparable to goods trade. However, the dispersion of regional gains is twice as large for services. On the other hand, international trade in services increases average real wages by 5% but the increase is more uniform across provinces. To understand the source of heterogeneous welfare gains, we examine the factors contributing to this heterogeneity. We follow Di Giovanni, Levchenko and Zhang (2014) and plot the regional welfare gains of service trade against the ratio of regional imports or exports of services to GDP. We observe a clear positive relationship between welfare gains and regional trade openness. The provinces with larger gains from service trade are those provinces that either import or export a significant amount of services, relative to their GDP. For example, Northwestern territories display the largest services imports to GDP ratio in Canada. This province also experiences the largest welfare gain from service trade: a 25% increase in the real wage.

Finally, we study the implications of service trade in structural transformation. Our results suggest that, while inter-regional service trade is crucial in accounting for regional specialization, it did not play any role in driving the observed reallocation of economic activity between 1992 and 2017 at national level. We then show that international service trade does play a role in accounting for Canadian's structural transformation, but its contribution is small: 1 percentage point out of 4 percentage points increase in value-added share of tradable services.

Related Literature

Our work makes contributions to three strands of literature. First, we contribute to the literature that studies the importance of service sectors in shaping regional production specialization (e.g., Rossi-Hansberg, Sarte and Schwartzman, 2019, 2021; Lewis, Monarch, Sposi and Zhang, 2020). Different from these papers, we use detailed Canadian data on regional and international trade of services to quantify the role that service trade has had in shaping the patterns of regional industrial specialization and national structural transformation.

We also contribute to the literature studying the role of trade in shaping the industrial structure of an economy (e.g., Uy, Yi and Zhang, 2013; Święcki, 2017; Cravino and Sotelo, 2019). Our paper contributes to this literature by studying the role that inter-regional and international trade of services has had on regional specialization. We show that besides its quantitative importance, incorporating inter-regional trade and trade of services is crucial to better understand the underlying sources of regional specialization and welfare gains from trade in the economy. Most studies emphasize how trade in goods indirectly shapes the service share via affecting goods' relative price and household income (Uy, Yi and Zhang, 2013), and via the structure of intersectoral linkages between goods and services (Cravino and Sotelo, 2019; Sposi, 2019). We focus on the direct role that services trade, domestic and international trade, itself had played in shaping regional specialization. Within this literature (e.g., Buera and Kaboski, 2012; Duarte and Restuccia, 2019; Duernecker, Herrendorf and Valentinyi, 2023), our work also contributes by proposing an alternative approach to disaggregate service sectors, based on their tradability.

Finally, we contribute to the literature investigating the welfare implications of interregional and international trade (e.g., Levchenko and Zhang, 2012; Caliendo and Parro, 2014; Di Giovanni, Levchenko and Zhang, 2014; Coşar and Fajgelbaum, 2016; Eckert, 2019). We use our model to study the implications of service tradability on regional welfare. The results point to economically relevant and heterogeneous welfare consequences of service trade across provinces. To the best of our knowledge, this is the first paper to quantify the welfare gains of interprovincial trade in services across regions. Our results bring new insights into regional wage disparities and have important implications for redistributional policies across regions.

2 Empirical Findings

This section presents a number of empirical findings on trade in services and regional specialisation in Canada. First, we present gross and net trade flows in goods and services in Canada, both inter-regional and international. We then divide services into tradable and non-tradable services and shows the relationship between net exports of tradable services and specialization in the tradable services sector for Canadian provinces.

2.1 Trade Flows in Goods and Services in Canada

Here we document gross and net trade flows at the national and regional levels in Canada using data from Statistics Canada. The data were created by combining several survey data with administrative data, and by adjusting them to be consistent with the state input-output tables and national account.[3] This unique data set provides detailed information on regional

[3] Généreux and Langen (2002) document the derivation of Canadian trade flow data. We leave further details to Appendix B.2.

TABLE 1 – Domestic and international, gross and net trade flows relative to GDP for goods and services, averaged over 1992 – 2007, Canada

Provinces	Goods		Services	
	Domestic	International	Domestic	International
Canada	0.24 (0)	0.60 (-0.01)	0.21 (0)	0.14 (0.02)
Alberta	0.28 (0.03)	0.51 (0.08)	0.20 (-0.03)	0.10 (0.02)
British Columbia	0.19 (-0.05)	0.43 (-0.04)	0.21 (-0.02)	0.15 (0.05)
Manitoba	0.38 (-0.04)	0.49 (-0.03)	0.34 (-0.01)	0.12 (0.02)
New Brunswick	0.49 (0.00)	0.86 (-0.11)	0.37 (-0.10)	0.13 (0.05)
Newfoundland and Labrador	0.33 (-0.03)	0.63 (0.04)	0.27 (-0.15)	0.08 (0.02)
Northwest Territories including Nunavut	0.40 (-0.15)	0.49 (0.10)	0.45 (-0.20)	0.07 (-0.01)
Nova Scotia	0.35 (-0.07)	0.49 (-0.13)	0.32 (-0.09)	0.11 (0.02)
Ontario	0.18 (0.00)	0.71 (-0.02)	0.18 (0.06)	0.17 (0.01)
Prince Edward Island	0.47 (-0.13)	0.39 (-0.01)	0.45 (-0.16)	0.11 (0.04)
Quebec	0.25 (0.02)	0.57 (-0.05)	0.19 (-0.02)	0.13 (0.02)
Saskatchewan	0.39 (-0.00)	0.58 (0.12)	0.28 (-0.12)	0.12 (0.04)
Yukon	0.32 (-0.17)	0.32 (-0.10)	0.47 (-0.21)	0.14 (0.04)

Notes: The numbers outside brackets are for gross trade flows (exports plus imports), and the numbers inside brackets are for net trade flows (exports minus imports). All the values are calculated as the trade flow value in a region relative to the region's GDP. Source: Statistics Canada.

and international trade flows both in goods and services for the period 1992–2017.

Gross Trade Flows

Table 1 reports gross and net trade flows. The numbers outside the brackets are for gross trade flows (exports plus imports), and the numbers inside the rackets are for net trade flows (exports minus imports). All the values are calculated as the trade flow value in a region relative to the regionâs GDP. The table shows those values for goods and services sectors, domestic and international, which are all averaged over the period 1992 – 2007.

For the gross trade flows, two facts stand. First, on average, domestic service trade is of similar magnitude to domestic good trade. At the national level, for the period 1992–2017, the average ratio of total trade of services to GDP is 0.21, while that of goods is 0.24.[4] Second, the magnitude of international service trade is also of significant importance. It is roughly one-fourth of international good trade, which amounts to 0.14 at the national level.

[4]At the national level, Figure A.1 of our Appendix shows the evolution of trade in goods and services in Canada. While the sample period is not particularly long, we do observe a positive trend in domestic service trade. On the other hand, international service trade has also increased mildly.

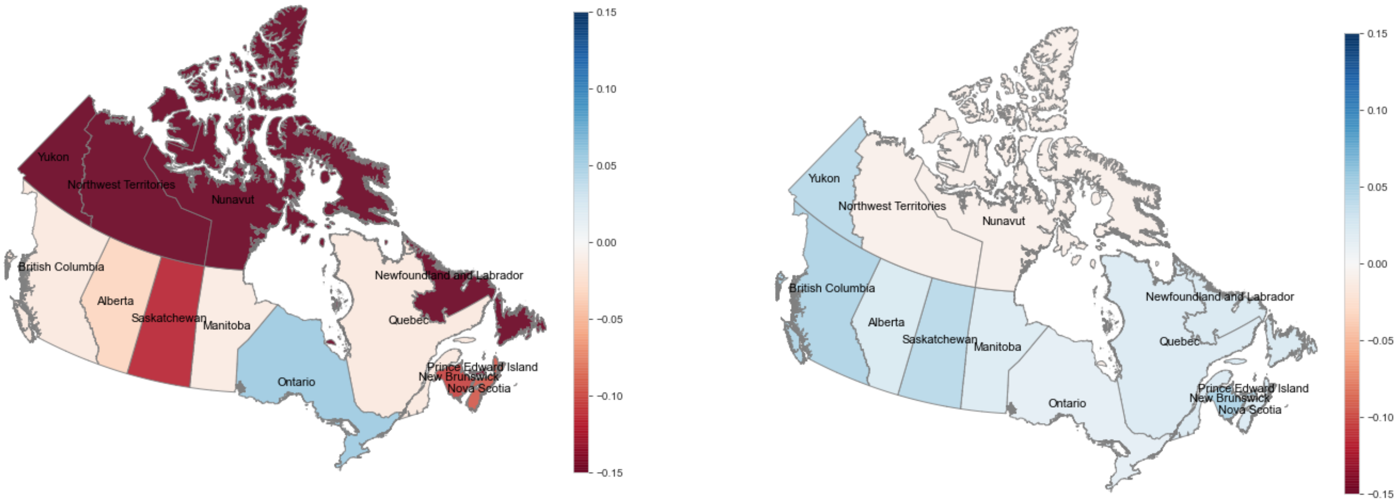


FIGURE 1 – Domestic net exports of services to GDP ratio (left) and International net exports of services to GDP ratio (right). Average 1992-2017.

Net Trade Flows

We next describe the patterns of service trade in terms of net exports (i.e., exports minus imports). In Table 1, the value inside the brackets in each cell reports the average net exports in a region to the region's GDP. In addition, Figure 1 depicts those values on a heatmap for domestic (the left panel) and international (the right panel) service trade flows.

Two important facts stand here. First, as observed in the left panel in Figure 1, there is considerable heterogeneity in domestic net exports of services relative to regional GDP. Ontario, in blue in the figure, is the only Canadian province with positive net exports of services, but it can be seen that there are significant differences among other net importers of services. Second, as the right panel in Figure1 shows, there is very little heterogeneity in terms of international net exports of services. The figure shows that most Canadian provinces are net exporters of services to the rest of the world and do not differ much in the extent to which they do so. This difference in the pattern of heterogeneity between domestic and international service trade leads to an important difference in the impacts of domestic and international service trade on welfare, as will be highlighted later in the analysis using the model.

2.2 Tradable and Non-Tradable Service Sectors

Given the fact that there is a substantial volume of service trade domestically and internationally, we next classify service sectors into *tradable service* and *non-tradable service*. With this classification, we analyze the patterns of trade and industrial specialization across Canadian provinces.

To define tradable services, we take an approach similar to that in Mian and Sufi (2014). Mian and Sufi (2014) classify tradable and non-tradable sectors based on the annual trade value (import plus export) of the sector at four-digit industry classification divided by population. They use $10,000$ U.S. dollar as the threshold value. That is, if the per-capita trade volume of the sector is above this threshold, they consider the sector as a tradable sector. In our approach, instead, we use the annual trade value (import plus export) relative to the sectoral gross output, because we think this measure is more consistent with the notion of tradability. We also use the measure in Mian and Sufi (2014) for robustness check later. We obtain sector information from the Canadian Input-Output Tables with their 2-digit NAICS industrial classifications.[5]

Table 2 reports the trade values (imports plus exports) relative to sectoral gross output for 11 service sectors. Columns 3 to 5 report the values for total trade, domestic trade, and international trade, respectively. For example, more than 60% of gross output is traded in the transportation and warehousing industry and the administrative support industry.

We use the 20% level as a cutoff to define tradable services and non-tradable services. As a result, healthcare, education, and other services are categorized into non-tradable services, while the rest are treated as tradable. Table A.1 in Appendix A shows the results computed by Mian and Sufi (2014)'s method. Notably, healthcare, education, and other services remain the three industries with the smallest trade contribution, even if we follow their approach.[6]

[5]The Canadian input-output table was used because it has data on international and interregional trade flows and gross output by sector. There are some discrepancies in their values between the trade flow data in the input-output table and the original trade flow data used in Section 2.1. However, the differences are negligible.

[6]We note that the most tradable service sectors appear to be significantly different from non-tradable (or less tradable) services in other dimensions. For example, measured productivity of tradable services presents large growth, comparable to goods productivity, while non-tradable services present a flat trend (Figure A.3 of our Appendix A). This would suggest that our tradable services sector relates to the progressive services sector definition in Duernecker, Herrendorf and Valentinyi (2023).

Table 2 – Sectoral trade (imports+exports) to gross output ratio in 2017

Sector	Sector	Total	Domestic	International
Tradables services	Transportation and warehousing	63.52%	32.64%	30.88%
(> 20%)	Administrative and support	60.77%	31.48%	29.29%
	Accommodation and food services	57.34%	19.49%	37.85%
	Professional and technical services	53.81%	32.59%	21.23%
	Information and cultural industries	52.60%	33.13%	19.47%
	Arts, entertainment and recreation	50.68%	19.63%	31.05%
	Wholesale and retail trade	38.10%	26.62%	11.48%
	Finance, insurance, real estate and leasing	23.92%	16.32%	7.61%
Nontradable services	Other services (except public administration)	18.84%	15.16%	3.68%
(< 20%)	Educational services	9.14%	2.80%	6.34%
	Health care and social assistance	2.85%	1.93%	0.92%

Notes: This table classifies service industries into tradable and nontradable services. Column "Total" reports the ratio of total imports plus total exports to gross output in each sector, which can be decomposed by the domestic trade-to-output ratio (Column "Domestic") and international trade-to-output ratio (Column "International"). The industry "other services (except public administration)" is constructed by a) repair and maintenance, b) grant-making, civic and similar organizations and c) personal and laundry services. Source: Canadian Regional Input-Output Tables from Statistics Canada.

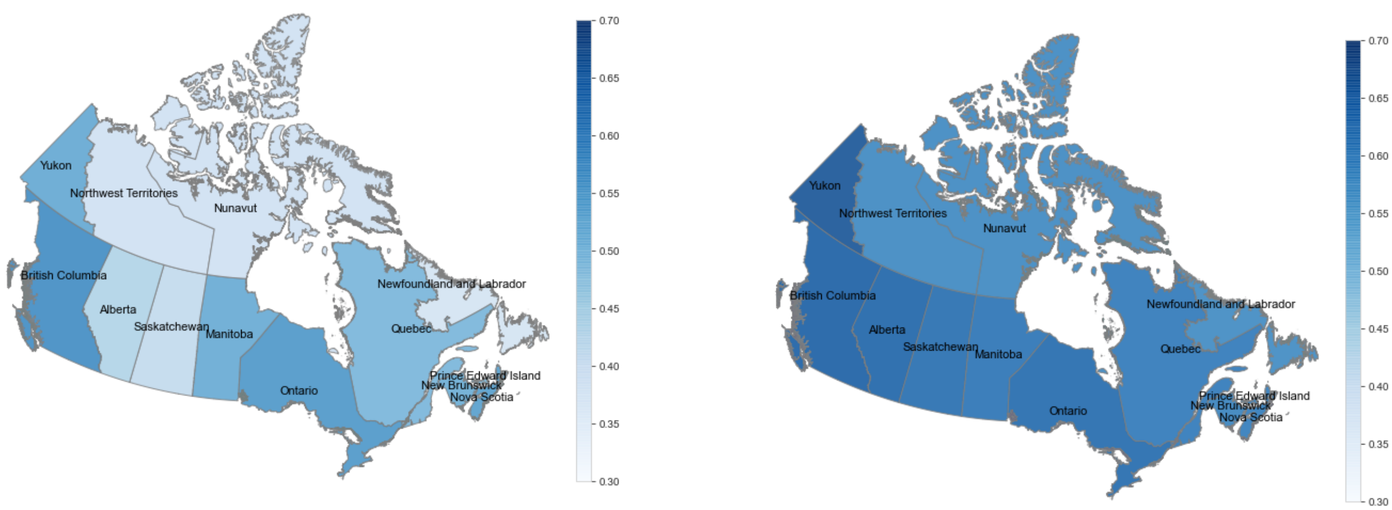


Figure 2 – Value-added share of tradable services (left) and Consumption expenditure share of tradable services (right). Averaged over the period 1992–2017. Source: See Appendix B.2.2.

2.3 Regional Specialization in Tradable Services

A natural implication of the trade patterns documented in Section 2.1 is that certain provinces in Canada specialize in the production of tradable services. We confirm this point here by documenting the significant degree of regional specialization in tradable service value-added (VA) shares.

The left panel of Figure 2 shows the degree of regional heterogeneity in tradable service production in value-added for the period 1992–2017.[7] Provinces with lighter colors present smaller VA shares in tradable services, while provinces with darker colors are more specialized in tradable services. For example, British Columbia, the most tradable service-intensive province, has an average VA share of tradable services for the period 1992–2017 of 57%, contrasting with the 38% in Newfoundland and Labrador.

In the right panel of Figure 2, we plot the consumption expenditure share of tradable services across provinces.[8] As observed in the figure, there is very limited heterogeneity in regional consumption expenditure shares, indicating that regional specialization in production is not driven by regional differences in demand. This point is also evident in Column 1 and 2 in Table 3, where the standard deviation of tradable services consumption expenditure shares (0.03) is less than half of that of VA shares (0.07).

The sharp contrast between the left and right panels of Figure 2 raises the question of what determines regional heterogeneity in VA shares. One possible explanation is domestic and international trade: as demonstrated in Uy et al. (2013), in an open economy setting, the VA share is a function of domestic consumption expenditure and net international exports. Therefore, if the consumption expenditure share of tradable services does not exhibit regional heterogeneity, whereas the VA share does, then trade could be considered a plausible explanation.

The third row of Table 3 confirms that the service trade plays an important role in explaining the regional heterogeneity in VA shares. As observed in Column 3, the net service trade value relative to regional GDP exhibits a positive correlation with the VA share (0.57), which is even higher than that of the consumption expenditure share (0.47).[9] In Columns

[7]We obtained sectoral nominal VA data by provinces from Statistics Canada. See Appendix B.2.2 for details.

[8]We provide details on how we constructed the Consumption Expenditure data by sector in Appendix B.2.2.

[9]Figure A.5 in our Appendix plots provinces' VA shares in tradable services (average 1992-2017) in the y-axis and the consumption expenditure share of tradable services (left panel) and the net exports share of tradable services (right panel). We observe a clear positive relationship, indicating that trade and consumption are key drivers of regional specialization in production.

Table 3 – VA shares, consumption expenditure shares, and net export of tradable services in Canadian provinces

	(1)	(2)	(3)	(4)	(5)
	VA share	Cons. share	$\frac{\text{NEX}}{\text{regional GDP}}$	$\frac{\text{Dom. NEX}}{\text{regional GDP}}$	$\frac{\text{Int. NEX}}{\text{regional GDP}}$
Mean value	0.48	0.61	-0.06	-0.09	0.03
Standard dev.	0.07	0.03	0.09	0.08	0.02
Correlation with VA share	-	0.47	0.57	0.51	0.35

Notes: This table reports the mean (row 1) and the standard deviation (row 2) of the value added share (Column 1), the consumption expenditure share (Column 2), and the net export share in GDP (Columns 3 to 5) of tradable services for Canadian provinces (averaged over the period 1992–2017). The last row shows the correlation of each variable with tradable service VA share. Source: Statistics Canada.

4 and 5, we also show the correlations with VA shares for domestic and international net exports in services relative to the regional GDP. While both are positive, domestic service trade shows somewhat higher correlaiton, suggesting that regional specialization is a key to explain the heterogeneity in tradable service shares across Canadian provinces.

In the next section, we develop a model multi-region and multi-sector model to study the role that service trade plays in shaping trade patterns and regional specialization in Canada. The model displays inter-regional and international trade of goods and services, heterogeneity in sectoral productivity growth, and non-homotheticity in preferences, which will allow us to disentangle the different mechanisms at play. This is, i) sectoral productivity differentials across regions; ii) income heterogeneity and non-homotheticities in demand; and iii) trade in services. Additionally, our structural model allows us to answer two relevant questions that empirics alone cannot address. First, what is role of service trade in shaping the industrial structure in Canada? Second, what are the welfare gains/losses of trade in services?

3 Model

Our model extends the model in Caliendo and Parro (2014) to account for interregional and international trade in services and non-homothetic preferences. Our objective is, through the lens of a three-sector multi-regions model, to analyze the role of inter-regional trade and international trade of goods and services in shaping Canada's structural transformation between 1997-2017. We consider two countries: Canada and the rest of the world (ROW). In Canada, we assume there are J provinces. In each province, there are three sectors, goods (g), tradable services (sm), and non-tradable services (sn). Firms use labour and intermediate inputs as factor of production.

We assume that firms in each province export and import goods and tradable servcies (for intermediate input purposes) with other provinces, as well as with the rest of the world. Trade is costly and we model that through the existence of iceberg costs. As in Eaton and Kortum (2002), trade has Ricardian motives. Producers differ in their productivity and the trade costs associated in trading with different regions. In equilibrium, firms source the cheapest intermediate input. There is a representative household in each province who consumes the three goods produced domestically.

3.1 Production and trade

In province i and sector $k \in \{g, sm, sn\}$ there is a continuum of goods' producers $z \in [0, 1]$ whose production technology is given by

$$Y_{i,t}^{k}(z) = Z_{i,t}^{k}(z) \left[T_{i,t}^{k} L_{i,t}^{k}(z)\right]^{\lambda_{i,k}} \left[\prod_{n=g,sm,sn} \left(M_{i,t}^{k,n}(z)\right)^{\gamma_{i,k,n}}\right]^{1-\lambda_{i,k}}, \tag{3.1}$$

where $Y_{i,t}^{k}(z)$ is output, $Z_{i,t}^{k}(z)$ denotes variety-specific component of gross output productivity, $L_{i,t}^{k}(z)$ is labor input, and $M_{i,t}^{k,n}(z)$ is sector-n's good used as an intermediate input in the production of sector k's good. Note that $\{Y_{i,t}^{k}(z), Z_{i,t}^{k}(z), L_{i,t}^{k}(z), M_{i,t}^{k,n}(z)\}$ are all variety-sector-province-year specific. $T_{i,t}^{k}$ governs the fundamental exogenous component of measured value-added productivity, namely production efficiency. The two production parameters, $\lambda_{i,k}$ and $\gamma_{i,k,n}$, determine the value-added share and the share of intermediates from sector n in the production function, respectively. As in Eaton and Kortum (2002), we assume that, in every period, gross output productivity $Z_{i,k}$ is the realization of random efficiency drawn from a Fréchet distribution.: $F_{i,t}^{k}(Z) = e^{-Z^{-\theta}}$, where $\theta > 1$ governs the within region and sector variation in firms' productivity. A bigger θ implies lower dispersion in productivities. Therefore, as in Sposi (2019), we can refer the measured gross output productivity $A_{i,t}^{k}(z)$ as the composite $Z_{i,t}^{k}(z)\, {T_{i,t}^{k}}^{\lambda_k}$.

We assume the existence of iceberg costs in shipping goods and services to different regions. Shipping costs include tariffs, transportation costs, and other barriers to trade. In particular, we assume iceberg costs $\tau_{ij,t}^{g}$ for shipping good z from the goods sector to country i from country j. As standard in the literature, we assume that the trade costs are zero within a country, $\tau_{ii,t}^{g} = \tau_{ii,t}^{sm} = \tau_{ii.t}^{sn} = 1$ and that the trade cost of non-tradable sector is infinity ($\tau_{ji,t}^{sn} \to \infty$).

Markets are competitive. From the firms' cost minimization problem, subject to technology (3.1), the price of shipping good z in sector k from region i to region j is

$$p_{i,t}^{k}\left(z\right)=\frac{v_{i,t}^{k}\tau_{ji,t}^{k}}{A_{i,t}^{k}\left(z\right)}=\frac{v_{i,t}^{k}\tau_{ji,t}^{k}}{Z_{i,t}^{k}\left(z\right)T_{i,t}^{k}{}^{\lambda_{k}}}$$

where $\tau_{ji}\leq 1$ is the trade cost of shipping goods or services from region i to region j and $v_{i,t}^{k}$ is the unit cost of input bundle given by

$$v_{i,t}^{k}=\lambda^{i,k\left(-\lambda^{i,k}\right)}\left(\frac{\prod_{n=g,sm,sn}\gamma^{i,k,n-\gamma^{i,k,n}}}{1-\lambda^{i,k}}\right)\left(w_{i,t}\right)^{\lambda_{k}}\left(\prod_{n=g,sm,sn}\left(P_{i,t}^{n}\right)^{\gamma^{i,k,n}}\right)^{1-\lambda^{k}} \tag{3.2}$$

where $w_{i,t}$ is the wage and $P_{i,t}^{n}$ is the price of sector-n's composite good .

In each sector k, competitive buyers buy good $Q_{i,t}^{k}\left(z\right)$ either from the domestic (country i's) or the foreign (country j's) supplier whichever can offer a lower price, $\hat{p}_{i,t}^{k}\left(z\right)=\min\left\{\sum_{j=1}^{J}p_{j,t}^{k}\left(z\right)\right\}$, where J is the total number of regions. Then, as in Eaton and Kortum (2002), under the Fréchet distribution assumption, the price of composite good $k\in\{g,sm,sn\}$ in country i is $P_{i,t}^{k}=\Gamma\left(\Phi_{i,t}^{k}\right)^{-\frac{1}{\theta}}$, where the constant Γ is the Gamma function evaluated at $\left(1-\frac{\eta-1}{\theta}\right)^{\frac{1}{1-\eta}}$, and $\Phi_{i,t}^{k}=\sum_{j=1}^{J}\left(T_{j,t}^{k}{}^{\lambda_{i,k}}v_{j,t}^{k}\tau_{i,j,t}^{k}\right)^{-\theta}$ [10]. Thus, $\Phi_{i,t}^{k}$ describes country i's access to global production technologies in sector k scaled by the relevant unit costs for inputs and trade costs. For composite good in sector $k\in\{g,sm,sn\}$, the price is

$$P_{i,t}^{k}=\Gamma\left[\sum_{j=1}^{J}\left(T_{j,t}^{k}{}^{\lambda_{i,k}}v_{j,t}^{k}\tau_{i,j,t}^{k}\right)^{-\theta}\right]^{-\frac{1}{\theta}} \tag{3.3}$$

Trade patterns in this model depend on the dispersion of productivities (comparative advantage) and trade barriers (geographic or economic). A lower value of θ generates more room for comparative advantage, rather than trade barriers, in driving trade patterns. Eaton and Kortum (2002) show that, under the Fréchet distribution assumption, we can derive the share of country j's expenditure on sector-k goods from country i, as

$$\pi_{j,i,t}^{k}=\frac{\left(T_{i,t}^{k}{}^{\lambda_{i,k}}v_{i,t}^{k}\tau_{j,i,t}^{k}\right)^{-\theta}}{\Phi_{j,t}^{k}}, \tag{3.4}$$

[10] To ensure a well-defined price index, we assume $\eta-1<\theta$ which is standard in the literature. Under this assumption, the parameter η, which governs the elasticity of substitution across goods within a sector, can be ignored because it appears only in the constant term Γ.

which equals the probability of importing sector-k goods from country i in country j. Thus, country j's share of imports in the total expenditure depends on country i's average productivity in industry k, the cost of the input bundle, and trade costs to ship goods from country i to country j.

3.2 Household preferences

The representative household in region i with non-homothetic CES preferences maximizes the aggregate per-capita consumption C_i, which is implicitly defined as:

$$\sum_k \omega_k^{\frac{1}{\sigma_k}} \left(\frac{C_i^k}{L_i}\right)^{\frac{\sigma-1}{\sigma_k}} \left(\frac{C_i}{L_i}\right)^{\frac{\epsilon_k-\sigma}{\sigma_k}} = 1 \tag{3.5}$$

where C_i^k is the consumption of sector-k composite goods; ω_k denotes the relative weight of consumption bundle in sector k; σ_k is the price elasticity of substitution and ϵ_k shapes the income elasticity of demand for sector k. Preference parameters are constant across regions. This implicit utility function is also used in Comin, Lashkari and Mestieri (2021), Lewis, Monarch, Sposi and Zhang (2020) and Sposi (2019). Details are outlined in appendix B.1.To ensure the monotonicity and quasi-concavity of aggregate utility C_i, we restrict income elasticity $\epsilon_k > 0$ and either price elasticity (i) $0 < \sigma_k < 1$ or (ii) $\sigma_k > 1$.

As in Duernecker, Herrendorf and Valentinyi (2023), we can construct a nested non-homothetic CES utility function. In the outer layer, aggregate real consumption, C_i, is a non-homothetic CES aggregator of real goods and aggregate services consumption, C_i^g and C_i^s, which comes from (3.5) by setting $\sigma = \sigma_g$, $k \in \{g, s\}$:

$$\frac{C_i}{L_i} = \left(\omega_g^{\frac{1}{\sigma_g}} \left(\frac{C_i}{L_i}\right)^{\frac{\epsilon_g-1}{\sigma_g}} \left(\frac{C_i^g}{L_i}\right)^{\frac{\sigma_g-1}{\sigma_g}} + \omega_s^{\frac{1}{\sigma_g}} \left(\frac{C_i}{L_i}\right)^{\frac{\epsilon_s-1}{\sigma_g}} \left(\frac{C_i^s}{L_i}\right)^{\frac{\sigma_g-1}{\sigma_g}} \right)^{\frac{\sigma_g}{\sigma_g-1}}, \tag{3.6}$$

In the inner layer, real consumption of aggregate services, C_i^s, is decomposed into real consumption of tradable and nontradable services, C_i^{sm} and C_i^{sn}, by setting $\sigma = \sigma_s$, $k \in \{sm, sn\}$ in (3.5):

$$\frac{C_i^s}{L_i} = \left(\omega_{sm}^{\frac{1}{\sigma_s}} \left(\frac{C_i}{L_i}\right)^{\frac{\epsilon_{sm}-1}{\sigma_s}} \left(\frac{C_i^{sm}}{L_i}\right)^{\frac{\sigma_s-1}{\sigma_s}} + \omega_{sn}^{\frac{1}{\sigma_s}} \left(\frac{C_i}{L_i}\right)^{\frac{\epsilon_{sn}-1}{\sigma_s}} \left(\frac{C_i^{sn}}{L_i}\right)^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s-1}} \tag{3.7}$$

For $\epsilon_k = 1$, the nested utility function collapsed into standard CES utility with homothetic demand function. By setting $\sigma_k = \epsilon_k = 1$, representative household behaves a Cobb-Douglas preference.

3.3 Budget constraint

The budget constraint of representative household is

$$P_i^g C_i^g + P_i^{sm} C_i^{sm} + P_i^{sn} C_i^{sn} + \iota_i w_i L_i = w_i L_i + \xi L_i. \tag{3.8}$$

s.t.

$$P_i^g C_i^g + P_i^{sm} C_i^{sm} + P_i^{sn} C_i^{sn} = P_i C_i \tag{3.9}$$

where $C_{i,t}^k$ is the consumption of sector-k composite goods for $k \in g, sm, sn$, $w_{i,t}$ is the household's wage rate from supplying his unit labour inelastically and $P_{i,t}^k$ is the price of the sector-k composite good. As in Caliendo, Parro, Rossi-Hansberg and Sarte (2017), the model measures trade imbalances as net payment from a global portfolio. Specifically, we assume that in each period, representative household in region i spends a fraction ι_i of income on a global global portfolio of assests. The returns to this fraction of income is equally distributed lump-sum to all households and ξ specifies this per capita return from global portfolio. Therefore, $\iota_i w_i L_i - \xi L_i$ governs regional trade imbalance that emerges from both inter-provincial and international transfers and satisfies:

$$\sum_i \iota_i w_i L_i = \xi \sum_i L_i \tag{3.10}$$

Following Lewis, Monarch, Sposi and Zhang (2020), ι_i is modeled as the ratio of net export to GDP for province i. Given that the net export of Canadian provinces and rest of the world sum to zero, the lump sum transfer ξ will equal to 0 in open economy. In counterfactuals, ξ will absorb the trade imbalances caused by changes in trade costs.

3.4 Equilibrium

Within a country, we assume perfect competition for all the goods and factor markets. In particular, we assume labor is mobile across sectors but immobile across regions or countries.[11] Let $L_{i,t}$ denote total labor endowment in county i, and $L_{i,t}^k$ labor employed in sector

[11] In the future, we plan to relax the assumption of labor immobility across regions of the same country.

k. Then, the following labor market clearing condition holds every period within the country

$$L_{i,t} = L_{i,t}^{g} + L_{i,t}^{sm} + L_{i,t}^{sn}. \tag{3.11}$$

The goods and services markets also clear every period. For each sector $k \in g, sm, sn$, we have

$$Q_{i,t}^{k} = C_{i,t}^{k} + \sum_{n=g,sm} (1-\lambda^{n})\,\gamma^{n,k} \sum_{j=1}^{J} \frac{\pi_{j,i,t}^{n} P_{j,t}^{n} Q_{j,t}^{n}}{P_{i,t}^{k}} + (1-\lambda^{sn})\,\gamma^{sn,k} \frac{P_{i,t}^{sn} Q_{i,t}^{sn}}{P_{i,t}^{k}}. \tag{3.12}$$

The above equations relate the total production of goods or services in sector k, $Q_{i,t}^{k}$, to the sum of the quantity demanded for domestic final production, $C_{i,t}^{k}$, for the usage of intermediate inputs in the production of domestic tradable goods and services, and the usage of intermediate inputs in the production of domestic non-tradable services.

Given country-specific labor endowment $\{L_{i,t}\}$, trade costs $\left\{\tau_{i,j,t}^{g}, \tau_{i,j,t}^{sm}\right\}$ productivity process $\left\{T_{i,t}^{g}, T_{i,t}^{sm}, T_{i,t}^{sn}\right\}$, and common structural parameters $\left\{\sigma, \eta, \theta, \left\{\lambda^{k}, \gamma^{k,n}, \bar{C}^{k}, \omega^{k}\right\}_{n,k\in\{g,sm,sn\}}\right\}$, a competitive equilibrium of the model is defined as follows.

Definition 1. *A competitive equilibrium is a sequence of goods and factor prices* $\left\{P_{i,t}^{g}, P_{i,t}^{sm}, P_{i,t}^{sn}, w_{i,t}\right\}_{i\in J}$, *allocations* $\left\{L_{i,t}^{g}, L_{i,t}^{sm}, L_{i,t}^{sn}, Q_{i,t}^{g}, Q_{i,t}^{sm}, Q_{i,t}^{sn}, C_{i,t}^{g}, C_{i,t}^{sm}, C_{i,t}^{sn}\right\}_{i\in J}$ *and trade shares* $\left\{\pi_{i,j,t}^{g}, \pi_{i,j,t}^{sm}\right\}_{i,j\in J}$ *such that, given prices, the allocations solve the firms' maximization problems associated with technologies* (3.1)*, an the household's maximization problem characterized by* (3.6)-(3.8)*, and satisfy the market clearing conditions* (3.11)-(3.12)*.* [12]

4 Calibration

In this section, we calibrate and estimate the key parameters of the model. We assume that preference parameters are common across all provinces, while production coefficients are province-specific.

4.1 Preference parameters

We estimate sectoral expenditure shares' weights (ω_k) and consumption elasticities (σ_k), and income elasticities (ϵ_k) using data on household final consumption expenditure in current and constant prices at the sectoral level. We then aggregate the data to construct nominal

[12]Equilibrium conditions are outlined in detail in Appendix.

and real sectoral expenditure for goods sectors, tradable service sectors, and non-tradable service sectors. We create the sectoral consumption price index as the ratio of nominal to real household consumption expenditure. We also use Canadian provincial employment data as labor demand L_{it}. Details of data construction are described in appendix B.2.

We structurally estimate the elasticities of both income and price channels by minimizing the distance between the observed sectoral expenditures and those implied by the model, given the observed prices. Combining (3.6)-(3.8) and taking the first-order condition, we generate model-implied relative sectoral expenditure shares as two layers:

$$\frac{P^s_{it}C^s_{it}}{P^g_{it}C^g_{it}} = \frac{\omega_s}{\omega_g}\left(\frac{P^s_{it}}{P^g_{it}}\right)^{1-\sigma_g}\left(\frac{C_{it}}{L_{it}}\right)^{\epsilon_s-\epsilon_g} \tag{4.1}$$

$$\frac{P^{sm}_{it}C^{sm}_{it}}{P^{sn}_{it}C^{sn}_{it}} = \frac{\omega_{sm}}{\omega_{sn}}\left(\frac{P^{sm}_{it}}{P^{sn}_{it}}\right)^{1-\sigma_s}\left(\frac{C_{it}}{L_{it}}\right)^{\epsilon_{sm}-\epsilon_{sn}} \tag{4.2}$$

Equations 4.1 and 4.2 enable us to separate the relative price effect and income effect respectively. We can calibrate preference parameters by jointly minimizing two squared distances between model-implied sectoral expenditures ratio and those from the data:

$$\min_{\sigma_g,\sigma_s,\epsilon_g,\epsilon_{sn}} \sum_{i,t}\left(\frac{\omega_s}{\omega_g}\left(\frac{\widehat{P^s_{it}}}{\widehat{P^g_{it}}}\right)^{1-\sigma_g}\left(\frac{C_{it}}{\widehat{L_{it}}}\right)^{\epsilon_s-\epsilon_g} - \frac{P^s_{it}C^s_{it}}{\widehat{P^g_{it}C^g_{it}}}\right)^2 + \left(\frac{\omega_{sm}}{\omega_{sn}}\left(\frac{\widehat{P^{sm}_{it}}}{\widehat{P^{sn}_{it}}}\right)^{1-\sigma_s}\left(\frac{C_{it}}{\widehat{L_{it}}}\right)^{\epsilon_{sm}-\epsilon_{sn}} - \frac{\widehat{P^{sm}_{it}C^{sm}_{it}}}{\widehat{P^{sn}_{it}C^{sn}_{it}}}\right)^2, \tag{4.3}$$

s.t.

$$\omega_g + \omega_s = 1 \tag{4.4}$$

$$\omega_{sm} + \omega_{sn} = 1 \tag{4.5}$$

$$\epsilon_s = 1 \tag{4.6}$$

$$\epsilon_{sm} = 1 \tag{4.7}$$

$$P^s_{it} = \left(\omega_{sm}\left(\frac{C_{it}}{\widehat{L_{it}}}\right)^{\epsilon_{sm}-1}\widehat{P^{sm}_{it}}^{1-\sigma_s} + \omega_{sn}\left(\frac{C_{it}}{\widehat{L_{it}}}\right)^{\epsilon_{sn}-1}\widehat{P^{sn}_{it}}^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}} \tag{4.8}$$

$$P_{it}C_{it} = \left(\omega_g\left(\frac{C_{it}}{\widehat{L_{it}}}\right)^{\epsilon_g-\sigma_g}\widehat{P^g_{it}}^{1-\sigma_g} + \omega_s\left(\frac{C_{it}}{\widehat{L_{it}}}\right)^{\epsilon_s-\sigma_g}P^{s\,1-\sigma_g}_{it}\right)^{\frac{1}{1-\sigma_g}} \tag{4.9}$$

where "hat" denotes observations from the data. We impose the sum of relative weight

Table 4 – Preference parameters values

Preference parameters		Estimates	S.E.
ω_g	Relative weight for Goods	0.33	-
ω_{sm}	Relative weight for Tradable Services	0.89	-
ϵ_g	Income elasticity on Goods	0.41	0.03
ϵ_s	Income elasticity on Services	1.00	-
ϵ_{sn}	Income elasticity on Nontrad. Services	1.06	0.03
ϵ_{sm}	Income elasticity on Tradable Services	1.00	-
σ_g	Price elasticity for Goods and Services	0.59	0.04
σ_s	Price elasticity for Trad. and Nontrad. Services	0.32	0.10

Notes: We compute standard errors by bootstrapping the same number of province-time observations with replacement. We apply the calibration procedure to the simulated data in each replication and record the value of calibrated preference parameters for 1000 repetitions.

ω_k equal to 1 in equation (4.4) and (4.5) respectively. Similar to Lewis et al. (2020), we adjust the value of ω_k to the average expenditure share at the beginning of the sample. As ω_k is identical across provinces, we introduce a province-fixed effect to make up the deviation between provincial sectoral expenditure share and ω_k in 1992. Provided that income elasticities are calibrated only in differences, we normalize ϵ_s and ϵ_{sm} to one, which is only a monotonic transformation of utility function Comin et al. (2021).

We estimate the parameters $\{\epsilon_g, \epsilon_{sm}, \sigma_g, \sigma_s\}$ in equation (4.1) with panel data for 11 Canadian provinces during the period 1992 - 2017, using non-linear least squares. The estimation strategy goes as follows: (i) Give an initial guess to four preference parameters $\{\epsilon_g, \epsilon_{sm}, \sigma_g, \sigma_s\}$; (ii) create the services price index P^s_{it} as a function of aggregate real consumption C_{it} using equation (4.8) for each province, every year; (iii) substitute the constructed service price P^s_{it} into equation (4.9). Then, aggregate expenditure, $P_{it}C_{it}$, becomes a non-linear function with only one unknown, C_{it}; (iv) we then feed equation (4.9) with data on aggregate expenditure, goods price and total employment. Provided that total expenditure is strictly increasing with C_{it}, we can solve out C_{it} in a one-to-one mapping. (v) We revisit (4.8) and compute P^s_{it} given C_{it} for each province every year; (vi) to then update parameters values $\{\epsilon_g, \epsilon_{sm}, \sigma_g, \sigma_s\}$ by minimising the deviation in . (vii) We go back to step (ii) with updated parameters and keep repeating the procedure until the objective function reaches its global minimum value.

Our estimated preference parameters are reported in Table 4. The estimates satisfy the basic regularity conditions, such as monotonicity and quasi-concavity, given $\epsilon > 0$ and $\sigma \neq 1$ for all sectors. The demand elasticities for goods and services are qualitatively similar to those in previous literature. The price elasticity estimate indicates that goods and services are complements ($\sigma_g = 0.59$).[13] The income elasticity suggests that goods are necessities and services are luxuries ($\epsilon_g = 0.41$) . Our estimate of $\epsilon_s - \epsilon_g$ (0.59) is higher than the estimate in Duernecker, Herrendorf and Valentinyi (2023) of 0.32. Unlike Duernecker, Herrendorf and Valentinyi (2023) who use value-added consumption, we use consumption expenditure data. Consumption share in services rises faster than value-added share in services, which brings about a stronger income effect in our benchmark estimation.

Within services, we obtain an elasticity of substitution $\sigma_s = 0.31$, implying that tradable and nontradable services are complements. [14] The result contrasts with Duernecker, Herrendorf and Valentinyi (2023) where $\sigma_s = 1.03$. The authors use a different sectoral classification strategy in a model without trade and measuring consumption in value-added terms instead. We categorize services sector as tradable and nontradable based on the ratio of trade volume to GDP, the authors focus on productivity growth of each sub-sector. Our estimate of $\epsilon_{sn} = 1.06$ shows tradable services are necessities and nontradable services are luxuries. Compared with tradable services like wholesale and transportation, nontradable services including private schools and private hospitals are luxuries. The estimate is similar to Duernecker, Herrendorf and Valentinyi (2023) where education and health care, classified as stagnant services, are also luxuries.

The upper panel of figure 3 illustrates the calibrated consumption expenditure ratio of aggregate services to goods from the model and the data. The calibration matches the targeted moment very well with data points closely located on both sides of 45° line. This implies Canadian consumers behave similarly on allocating between goods and services. On the other hand, the middle panel maps the model fit on the consumption ratio of non-tradable services to tradable services. Provinces with large model-data departures are Prince Edward Island (PE) and Northwest Territories (NW). The reason is the different structural patterns in PE and NW: in contrast to other 9 provinces, the non-tradable to tradable services consumption ratio in PE and NW is decreasing overtime. However, our calibrated preference

[13]Our estimate of σ_g is higher than that in Duernecker, Herrendorf and Valentinyi (2023), 0.30. While we focus on Canada for the period 1992-2018, the authors collect price data for the US dating back to 1947. Our σ_g is also higher than Lewis, Monarch, Sposi and Zhang (2020), 0.16. The authors use time series data for 26 countries, including emerging countries such as China and India.

[14]If we take the average of σ_g and σ_s, we obtain an elasticity that is similar to that in Comin, Lashkari and Mestieri (2021) and Sposi (2019), where single price elasticity is used. We also estimate an alternative model with single price elasticity and find that $\sigma = 0.44$.

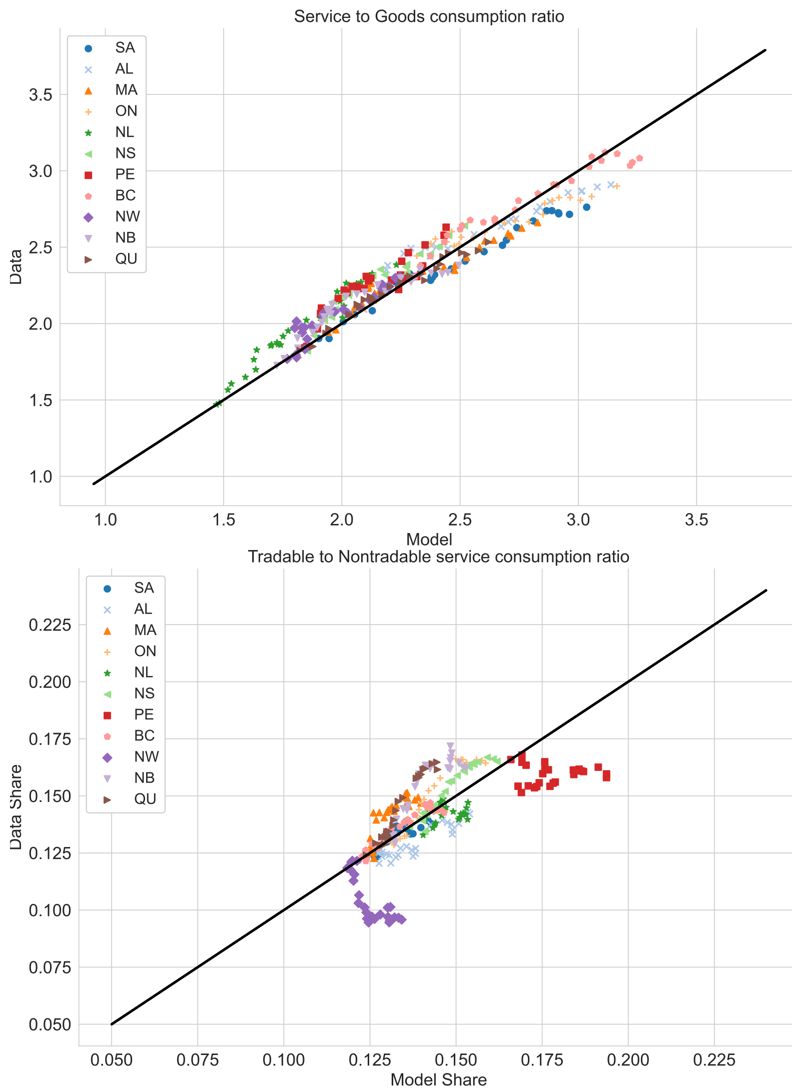


FIGURE 3 – Model fit for consumption ratio

parameters will generate a increasing pattern on nontradable-tradable consumption ratio, which brings some measurement noises for these two provinces.

We check the robustness of our calibration by plotting the model fit for untargeted moments. In particular, we look at the fit of sectoral prices. We proceed in the following steps: (i) We compute the construct nominal and real consumption for aggregate service following the strategy in appendix B.2. (ii) We define the observed service price as the ratio of nominal to real services consumption in the data. We then make these prices it comparable across sectors by adjusting the price level in CGDC Productivity database. (iii) We feed this constructed service data, along with the observed consumption expenditure share in the data, into equation 4.1, 4.2 and 4.8. Given the calibrated preference parameters, we can impute the model-implied sectoral price for each province. Figure 4 illustrates how well the calibrated

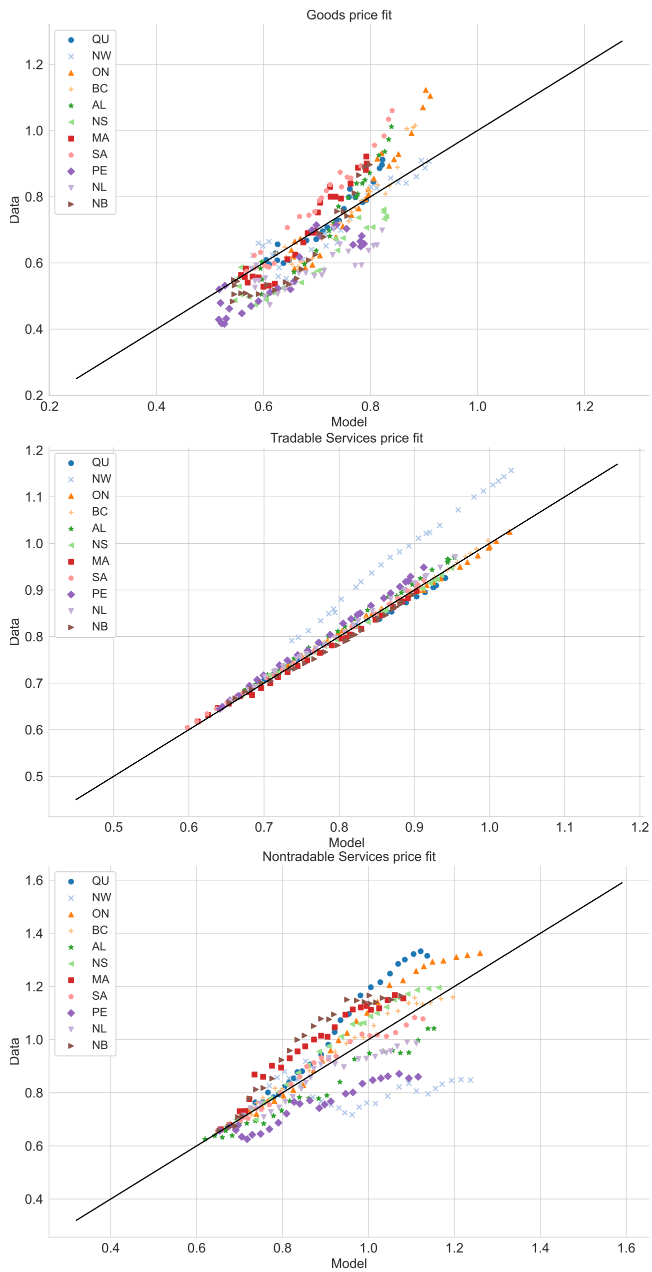


FIGURE 4 – Model fit for untargeted sectoral prices

model fits the sectoral prices data. The model-constructed sectoral prices achieve the goal well, especially for tradable services. The correlation between sectoral prices in the model and in the data is 0.87, 0.96 and 0.79 for goods, tradable services and non-tradable services, respectively. The poor model fit for Northwest Territories (NW) in middle and lower panel is mainly due to its large deviation between the model and data nontradable-to-tradable consumption ratio. Overall, our model can closely match the moments that are not directly matched in the data.

4.2 Production parameters

We calibrate production parameters $\lambda_{ik}, \gamma_{ikn}$ using Canadian input-output tables at the provincial level. From firms' maximizing conditions, under Cobb-Douglas technologies, the production parameters have direct empirical counterpart. Formally, λ_{ik} denotes the ratio of nominal value added to gross output and γ_{ikn} measures the share of sector n goods on intermediates inputs for the production in sector b. Due to the data limitation, provincial input-output tables are available only from 2004 to 2017 annually. We construct the time-invariant λ_{ik} and γ_{ikn} by taking average across these years for each province. This is feasible as the time-series variation within each province is negligible.

Average production parameters values as well as their maximum and minimum are reported in Table 5. There is huge heterogeneity on production shares across province, especially for λ_g, where New Brunswick uses goods intermediates more intensively, indicated by $\lambda_g = 0.27$. We find that those provinces with higher value added share in goods sector are generally have a higher λ_g than other services-intensive provinces. Furthermore, those goods-intensive provinces utilises more services to produce goods, with a higher $\gamma_{g,sm}$ than services-intensive provinces. As in Sposi (2019) and Lewis, Monarch, Sposi and Zhang (2020), goods production sources itself as intermediate more intensively while services production is more service-intensive, which holds for all provinces. Consistent with Simonovska and Waugh (2014), we set trade elasticity $\theta = 4$ for all sectors. $\eta = 4$ in our paper to ensure that Gamma function Γ evaluates at at positive domain.

4.3 Production efficiency and trade costs

Production efficiency T_{ik} and trade costs τ_{ijk} are calibrated using the bilateral trade flows data and model-implied sectoral prices. We impute technology T_{ik} from measured productivity $A_{i,k}$ and plot the Canada and RoW results in Figure A.3 and A.4. $A_{i,k}$ is the average realization of random efficiency drawn from a Fréchet distribution. We measure productivity as the ratio of cost of input bundle to sectoral price, and is given by:

$$A_{i,k} = v_{i,k}/P_{i,k} \tag{4.10}$$

Equation 4.10 implies the quantitative link among input cost, sectoral price and measured productivity: either two terms are sufficient statistics for the third. Given the constant cost of input bundle, composite good with lower price indicates a higher measured productivity. Combined with the input cost specification in equation 3.2, we can rewrite measured

Table 5 – Production parameters values

Production parameters		Avg	Max	Min
λ_g	Value-added share in gross output for Goods	0.41	0.52	0.27
λ_{sm}	for Tradable Services	0.62	0.65	0.59
λ_{sn}	for Nontradable Services	0.63	0.68	0.55
$\gamma_{g,g}$	Share of intermediate inputs sourced from Goods to Goods	0.71	0.82	0.60
$\gamma_{g,sm}$	from Trad. Services to Goods	0.28	0.37	0.17
$\gamma_{g,sn}$	from Nontrad. Services to Goods	0.01	0.03	0.009
$\gamma_{sm,g}$	from Goods to Trad. Services	0.26	0.33	0.21
$\gamma_{sm,sm}$	from Trad. Services to Trad. Services	0.69	0.74	0.63
$\gamma_{sm,sn}$	from Nontrad. Services to Trad. Services	0.04	0.05	0.04
$\gamma_{sn,g}$	from Goods to Nontrad. Services	0.29	0.33	0.25
$\gamma_{sn,sm}$	from Trad. Services to Nontrad. Services	0.43	0.49	0.40
$\gamma_{sn,sn}$	from Nontrad. Services to Nontrad. Services	0.28	0.32	0.22
θ	Trade elasticity	4.0		
η	Elasticity of substitution across goods within a sector	4.0		

productivity as a function of sectoral price:

$$A_{i,k} = (\frac{1}{\lambda_{i,k}})^{\lambda_{i,k}} \frac{w_i}{P_{ik}} \left(\prod_{n \in \{g,sm,sn\}} \left(\frac{P_{in}}{w_i \gamma_{i,k,n} (1-\lambda_{i,k})} \right)^{\gamma_{i,k,n}} \right)^{1-\lambda_{i,k}} \tag{4.11}$$

As in Święcki (2017) and Sposi (2019), we make use of equation 4.11 and construct measured productivity with model-implied prices. The next step is to adjust for the Ricardian selection effect and recover $T_{i,k}$. Holding the state of technology constant, trade openness increases average productivity (Finicelli, Pagano and Sbracia (2013)). Thus, we map fundamental technology $T_{i,k}$ from measured gross output productivity $A_{i,k}$ using

$$A_{i,k} = \Gamma^{-1} (T_{i,k})^{\lambda_k} (\pi_{i,i,k})^{\frac{-1}{\theta}}, \tag{4.12}$$

where $\pi_{i,i,k}$ denotes province i's absorption ratio in sector k, which equals to 1 in closed economy. [15]

To calibrate trade costs, we target the observed sequence import shares in the data ($\hat{\pi}_{j,j,k,t}$). Combining equations 3.3 and 3.4, we can solve for trade cost as a function of relative import shares and relative sectoral prices:

$$\tau_{i,j,k} = \left(\frac{\pi_{i,j,k}}{\pi_{j,j,k}}\right)^{-\frac{1}{\theta}} \left(\frac{P_{i,k}}{P_{j,k}}\right). \tag{4.13}$$

We use equation 4.13 to back out trade costs $\tau_{i,j,k}$, at every period, such that the model implied import shares ($\pi_{j,j,k}$), given prices, exactly match the observed import shares ($\hat{\pi}_{j,j,k}$).

4.4 Measurement

In this section, we describe our approach to measure model-implied net exports and value-added shares in a way they are internally consistent.

4.4.1 Net export construction

To measure model-implied sectoral net exports we require data on consumption expenditure, input-output coefficients and the import expenditure share π_{ijk}, where $k \in \{g, sm\}$. Formally, we take the following steps: (i) We solve for sectoral total absorption $P_{i,k}Q_{i,k}$ using the production equilibrium equations C.14 and C.20, along with data on sectoral consumption expenditure. We then compute the model-implied net export from equation C.15, using data on import shares π_{ijk}.

Figure 5 depicts the model fit of sectoral net export share, which is measured by the ratio of sectoral net export to total value added for each province. The reason why the benchmark model closely matches the net export share data is twofold. First, the model import expenditure share π_{ijk} is calibrated to match exactly that from the data. Second, our estimated demand system generates model-implied sectoral consumption expenditure that fit the data quite well (Figure 4).

[15] $\Gamma = \Gamma\left(1 - \frac{1}{\theta}\left(1-\eta\right)\right)^{1/(1-\eta)}$

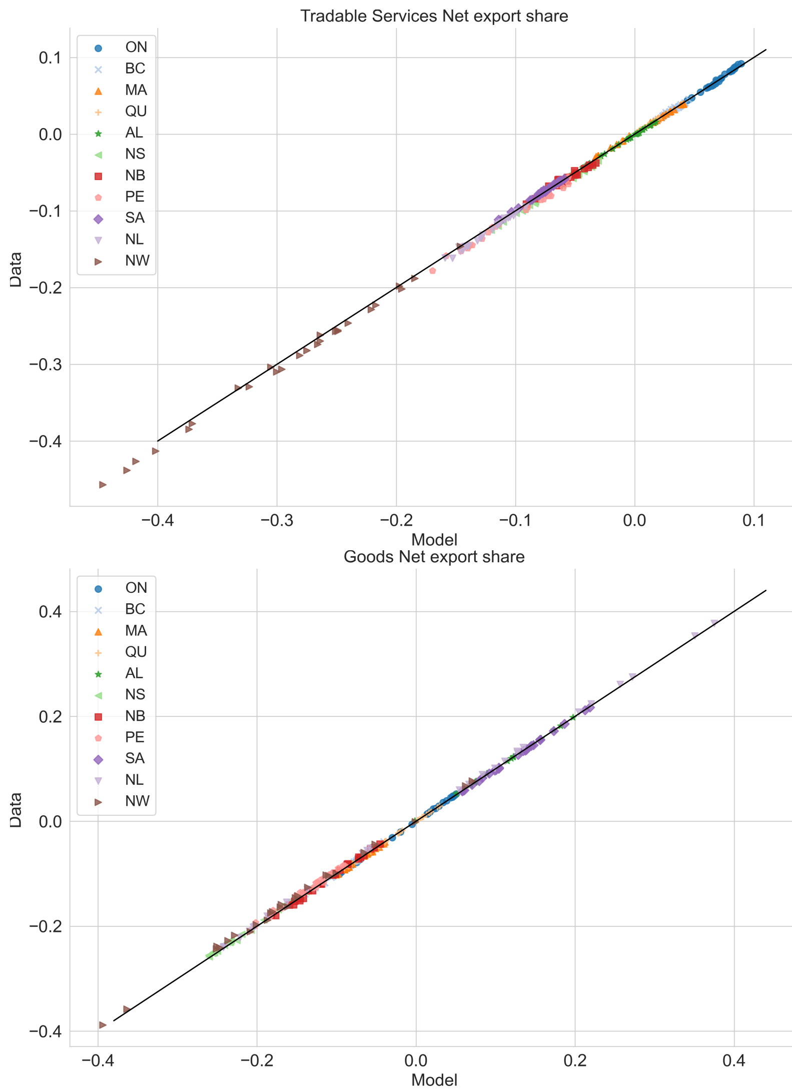


FIGURE 5 – Model fit for sectoral net export share

4.4.2 Value added construction

As in Uy, Yi and Zhang (2013), we obtain model-implied sectoral value added using equation 4.14[16]. This equation expresses sectoral value as a function of sectoral expenditure $E_{i,k}$ and net exports $NX_{i,k}$. Given that expenditure and net exports are expressed in gross-output terms, equation 4.14 properly weights them by provincial input-output coefficients (value-added content).

Note that the sectoral expenditure $E_{i,k}$ refers to final absorption, which includes consumption expenditure $P_{ik}C_{ik}$, investment I_{ik} and government spending G_{ik}. The expenditure-based Canadian GDP data from Statistics Canada provides us with the investment and govern-

[16]Details of the proof are shown in Appendix C.4

ment spending data at the aggregate level. To construct a time series of sectoral investment and government spending at the regional level, we combine the aggregate data for the period 1997-2017 with the sectoral investment shares from provincial input-output tables for the period 2004-2017. While there is significant cross-province variation in sectoral share of investment and government spending, time variation within province is very mild. Therefore, we use the average province-sector investment/government shares to construct a times series of sectoral investment and government spending measures, at the province level, that are consistent with the aggregate data. Hence, we obtain the model-implied sectoral value-added for each province using

$$\begin{bmatrix} VA_{i,g} \\ VA_{i,sm} \\ VA_{i,sn} \end{bmatrix} = \Omega^{-1} \begin{bmatrix} E_{i,g} \\ E_{i,sm} \\ E_{i,sn} \end{bmatrix} + \Omega^{-1} \begin{bmatrix} NX_{i,g} \\ NX_{i,sm} \\ 0 \end{bmatrix}, \tag{4.14}$$

where

$$E_{i,k} = P_{i,k}C_{i,k} + I_{i,k} + G_{i,k}, k \in \{g, sm, sn\}.$$

Equation 4.14 underlines two channels through which trade matters for regional specialization. First, the consumption expenditure channel. Trade alters relative prices and income. The selection effect of trade openness enhances average productivity in tradable sectors, which in turn lowers tradable sector prices. Trade also rises real income as regions face lower prices while also specialize in the sectors they have comparative advantage in. Given that price and income elasticities in our calibration are significantly different from 1, opening to trade changes sectoral consumption expenditure shares through price and income effects. Second, trade affects regional value-added shares directly through the net export channel. When a province experiences trade surplus in its comparative advantage sector(s), workers move towards that sector(s), which then shapes employment shares and, therefore, value-added shares.

5 Counterfactual experiments

In this section, we perform a set of counterfactual exercises to examine the role of interregional and international trade of services in shaping regional specialization, structural transformation, and welfare in Canadian provinces.

5.1 Counterfactual strategy

Our counterfactual strategy follows Alvarez and Lucas (2007) and Lewis, Monarch, Sposi and Zhang (2020). The strategy involves setting trade cost to an immense value so that there are no exports of service k from province j to province i. We start iteration with an initial guess to provincial wage w_i. We compute sectoral price, input cost, import share, real income, and gross output subsequently and update w_i. New general equilibrium is then solved with these new trade costs, keeping production and household preferences parameters the same as in the benchmark economy. Details of the counterfactual strategy can be found in Appendix C.5.

5.2 Service trade and regional specialization

Here we study the role of domestic and international services trade in shaping Canadian regional specialization in tradable services. We first set the domestic service trade cost to 10^6, and analyze its effects on the economy of each Canadian province. We do the same exercise for international service trade second.

Domestic service trade

Table 6 summarizes the cross-sectional percentage change on different value added components by switching off domestic service trade. We compute the percentage change on aggregate real consumption C, relative price P_{sn}/P_{sm} and P_g/P_{sn}, international net exports share of tradable services NX_{sm}/VA and value added share VA_{sm}/VA for each year each province respectively and report time-averaging results in each column. Hence, the first five columns reflect the income effect, the price effect, and the net export channels; while the last column, value added share, reflects the resulting effect through these three channels.

Column 1 of Table 6 shows that, absent domestic service trade, real income shrinks for all Canadian provinces. This result confirms the results in Frankel and Romer (1999) and Irwin and Terviö (2002) in which trade has a quantitatively large and robust positive effect on income. Through non-homotheticicities in demand, the decline in real income generates a decline in the consumption share of services, which are luxuries compared to goods. Note that, within the service sector, nontradable services are luxuries relative to tradable services. Hence, the reallocation of demand from nontradable services to goods mitigates the negative income effect on tradable services consumption expenditures.

Table 6 – Percent change (%) on different channels with absence of domestic service trade

Average change (%) over 1992-2017	C (1)	P_{sn}/P_{sm} (2)	P_g/P_{sm} (3)	PC_{sm}/PC (4)	NX_{sm}/VA (5)	VA_{sm}/VA (6)
	No Domestic Service Trade					
Canadian Provinces						
Quebec	-6.4	-3.7	-3.7	-0.4	0.7	0.4
Northwest Territories & Nunavut	-25.1	-16.7	-20.3	-1.5	16.3	28.7
Ontario	-8.5	-2.3	-0.3	-1.2	-4.1	-5.6
British Columbia	-6.3	-3.7	-3.6	-0.3	0.6	0.3
Alberta	-7.8	-4.8	-4.9	-0.4	2.1	2.6
Nova Scotia	-6.1	-6.5	-8.5	0.5	5.7	7.1
Manitoba	-12.3	-6.7	-6.1	-1.1	0.1	-1.0
Saskatchewan	-9.5	-8.9	-10.4	0.3	8.1	14.6
Prince Edward Island	-8.6	-10.1	-12.9	1.1	9.2	13.7
Newfoundland and Labrador	-7.1	-9.4	-12.1	1.1	11.0	24.3
New Brunswick	-9.0	-8.4	-10.4	0.3	6.5	8.1

Notes: Each column reports the average percent deviation, for the period 1992-2017, in the no domestic service trade economy, compared to the benchmark economy.

In Columns 2 and 3 of Table 6, we show that the price of non-tradable services and goods relative to tradable services declines in all provinces, which is natural since, in the absence of domestic trade, there is limited production specialization across regions. Hence, in the presence of complementarities in consumption previously shown in Table 4, the consumption share of tradable services tends to increase. The implications for consumption expenditure shares show that the negative income effect and the positive price effect tend to cancel each other. Indeed, the net effect on tradable services consumption expenditure in Column 4 is small and depends on the strength of the income and the price effects. In general, relatively large provinces with greater tradable service productivities (such as Ontario, Quebec, and British Columbia) have stable prices for services when domestic service trade is closed. Thus, the income effect dominates and dampens consumption expenditure share in tradable services in these wealthier provinces.

Column 5 of Table 6 presents the changes in the net export of tradable services when domestic service trade is absent. Ontario, the sole net exporter of domestic services, experiences a decrease in its net export, while all other provinces have varying degrees of increase. These changes, combined with the impacts on consumption expenditure shares, lead to diverse effects on the value-added shares of tradable services. In general, the share of net exports in GDP decreases in a province that is a net domestic exporter of tradable services for Ontario. This effect, combined with a further income effect, significantly reduces the value-added share of tradable services. Conversely, in the majority of provinces that are net importers of tradable services, net exports of tradable services increase, which, combined with the price effect, increases the value-added share of tradable services.

International service trade

Table 7 illustrates the impact of the absence of international service trade on real income, relative price, consumption expenditure share, net export, and value-added share. Similar to the results in the no domestic service trade exercise, prohibition in international service trade dampens real income C and results in a negative income effect on tradable services consumption expenditure for all provinces, as shown in Column 1. Compared with the absent domestic service trade counterpart in Table 6, the absence of international service trade triggers uniform changes in real income. This is because all the Canadian provinces are net exporters of tradable services internationally. Thus, absent of international service trade, most provinces lose their real income similarly. In addition, higher tradable services price lowers down the relative price and brings about a positive price effect due to the complementarity, as shown in Column 2 and 3. This effect is relatively minor and uniform across Canadian provinces, as Canadian provinces all have a comparative advantage in tradable service production relative to the rest of the world. As the force from the price effect becomes much weaker, the income effect outweighs and dominates in shaping the tradable services consumption expenditure. Hence, all Canadian provinces shift economic activities away from tradable services sector, which leads to a lower consumption expenditure share.

Furthermore, unlike domestic service trade, all Canadian provinces gain trade surplus from international service trade. By switching off the international service trade flows, the service net export share, therefore, drops for all provinces (Column 5). Both the consumption expenditure channel and the net export channel have negative effects, causing a decline in the share of value added from tradable services for all provinces (Column 6). For provinces with higher international service export to the value-added ratio (i.e. Saskatchewan, New Brunswick), the decrease in tradable services value-added share is relatively stronger. On the other hand, the reduction in value-added in northern Canada is mainly attributed to the shrunk in the consumption expenditure share through the income effect channel. Although there are these minor variations among provinces, the absence of international service trade generally leads to a decrease in the value-added share of tradable services.

Figure 6 visually summarises the average percentage change in the tradable-services value-

Table 7 – Percentage change (%) on different channels with absence of intenational service trade

Average change (%) over 1992-2017	No International Service Trade C (1)	P_{sn}/P_{sm} (2)	P_g/P_{sm} (3)	PC_{sm}/PC (4)	NX_{sm}/VA (5)	VA_{sm}/VA (6)
Canadian Provinces						
Quebec	-5.6	-1.9	-0.9	-0.8	-2.2	-3.7
Northwest Territories & Nunavut	-7.0	-1.6	-1.2	-1.2	-3.1	-7.6
Ontario	-6.6	-2.5	-1.5	-0.7	-1.8	-2.6
British Columbia	-6.7	-1.8	-0.3	-0.9	-3.4	-5.0
Alberta	-5.3	-1.5	-0.9	-0.7	-2.8	-4.8
Nova Scotia	-5.3	-1.5	-0.2	-0.9	-1.9	-3.5
Manitoba	-5.4	-1.8	-0.9	-0.7	-2.1	-3.6
Saskatchewan	-6.0	-1.6	-0.8	-0.8	-4.3	-8.7
Prince Edward Island	-5.1	-1.4	-0.1	-0.8	-3.2	-5.3
Newfoundland and Labrador	-4.3	-1.2	-0.5	-0.8	-2.8	-6.9
New Brunswick	-6.8	-1.8	0.1	-1.2	-3.6	-5.8

Notes: Each column reports the average percentage change for no international service trade model over 1992-2017 for each province by comparing with benchmark.

added share in the counterfactual exercise with no domestic services trade (the left figure) and in the exercise with no international services trade (the right figure). It can be seen that domestic service trade has heterogeneous impacts on the sectoral value-added share of the provinces, while international trade has relatively homogeneous impacts. Notably, whether the impact of service trade is heterogeneous or homogeneous is closely related to how service trade affects the welfare in each province. The next section analyzes this point in more detail.

5.3 Service trade and welfare

In this section, we analyze how domestic and international service trade affects welfare. We measure welfare using the real wage from baseline to counterfactual model. Thus the welfare gains from service trade can be defined as $1 - \frac{w_i'/P_i'}{w_i/P_i}$, where w_i' and P_i' denotes the nominal wage and aggregate price by shutting down trade flows. This formulation allows for a meaningful comparison of welfare gains from service trade with those from goods trade, at both interprovincial and international level.

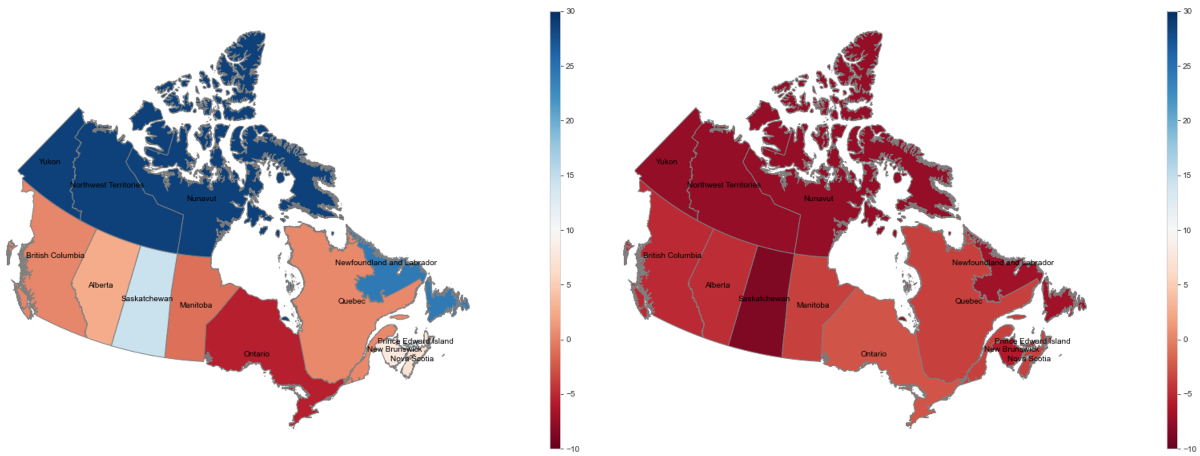


FIGURE 6 – Average percentage change (%) in tradable service VA share with absent domestic (left) and international (right) service trade

TABLE 8 – Average welfare gains of domestic and international trade

Provinces	Domestic trade		International trade	
	Services	Goods	Services	Goods
Alberta	0.07	0.08	0.04	0.07
British Columbia	0.06	0.05	0.05	0.09
Manitoba	0.11	0.12	0.04	0.10
New Brunswick	0.10	0.14	0.05	0.20
Newfoundland and Labrador	0.09	0.08	0.03	0.07
Northwest Territories including Nunavut	0.25	0.09	0.05	0.10
Nova Scotia	0.07	0.10	0.04	0.09
Ontario	0.07	0.06	0.06	0.21
Prince Edward Island	0.10	0.11	0.04	0.05
Quebec	0.06	0.08	0.04	0.12
Saskatchewan	0.11	0.11	0.04	0.10
S.D.	0.05	0.03	0.01	0.05
National Average	0.07	0.07	0.05	0.14

Notes: Each column reports the average percentage change in welfare improvement from domestic and international trade across sectors and regions. National average welfare are labor-weighted average welfare gains across provinces.

Domestic service trade

The average welfare gains from domestic service trade is shown in the first column of Table 8. All provinces experience welfare gains above 5%, with the national average welfare

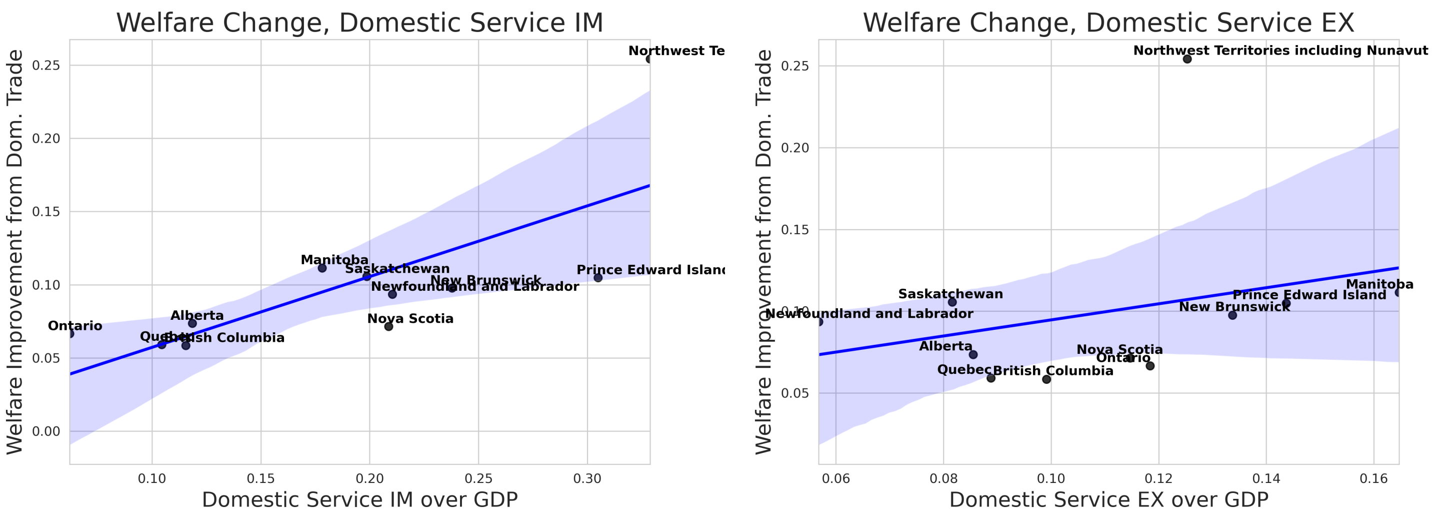
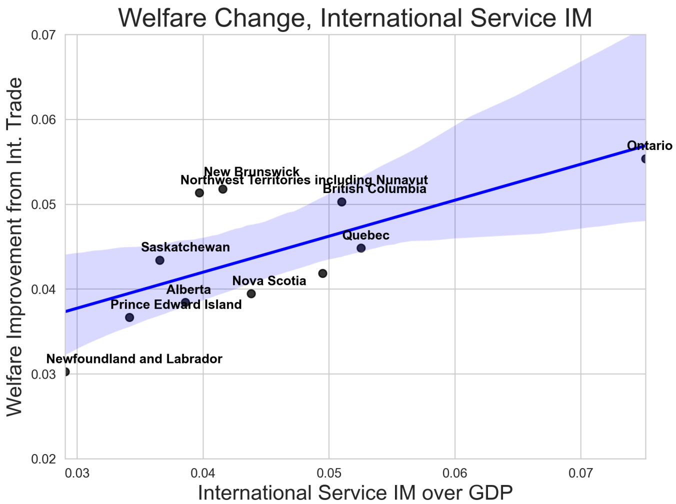


Figure 7 – Scatter plot of average welfare gains from domestic service trade against IM/EX share

gains equal to 7%. The comparison of the first and second columns in the table reveals that the welfare gains through domestic service trade are comparable to that of domestic good trade. Furthermore, there is huge heterogeneity across regions regarding welfare gains through domestic service trade. The standard deviation is higher than both goods trade and international service trade.

To understand the source of heterogenous welfare gains, we examine the factors contributing to this heterogeneity in welfare gains. We follow Di Giovanni, Levchenko and Zhang (2014) and plot welfare gains against the degree of specialization (Figure 7). The figure reveals a strong positive correlation between welfare gains and both the service imports and exports GDP ratio. implying that the extent of the welfare gains is closely related to that of regional specializations. For example, the province with the highest welfare gain is Northwest Territories, which heavily relies on domestic service imports. As seen in Section 5.2, domestic service trade has heterogeneous impacts on the industrial structures of provinces, which also leads to significant heterogeneity in welfare gains across provinces.



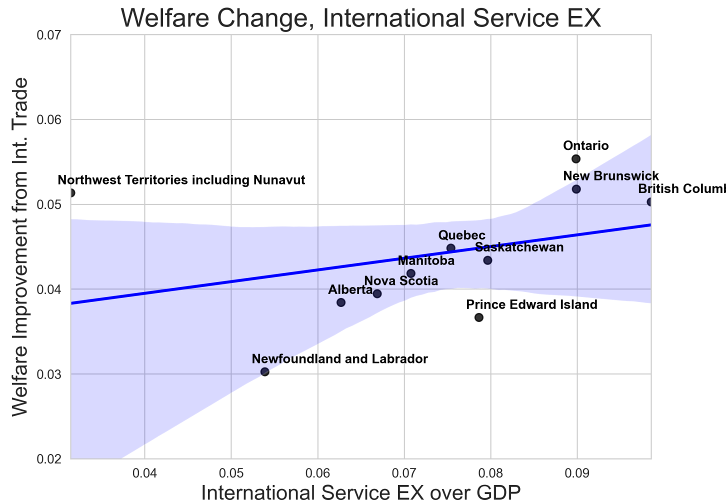


FIGURE 8 – Scatter plot of average welfare gains from international service trade against IM/EX share

International service trade

The third column of Table 8 presents the welfare gains resulting from international service trade. Similar to domestic service trade, all provinces experience positive welfare gains from international service trade, but at a smaller magnitude of around 5%. While welfare gains from domestic service trade are comparable to those from goods trade, welfare gains through international service trade only amount to 40% of the gains obtained from goods trade. In addition, in contrast to domestic service trade, welfare gains from international service trade exhibit a more uniform distribution across regions. The standard deviation is significantly smaller compared to both goods trade and domestic service trade. This is closely related to the fact that international service trade has uniform impacts on regional specialization, as discussed in Section 5.2.

Once again, we plot the welfare gains from international service trade against the degree of specialization, as depicted in Figure 8. The figure demonstrates a similar positive correlation between welfare gains and the share of international service trade, although the welfare gains are much smaller than those of domestic service trade. This can be attributed to the fact that the volume of international service trade flows is lower than that of domestic service trade, as seen in Table 1.

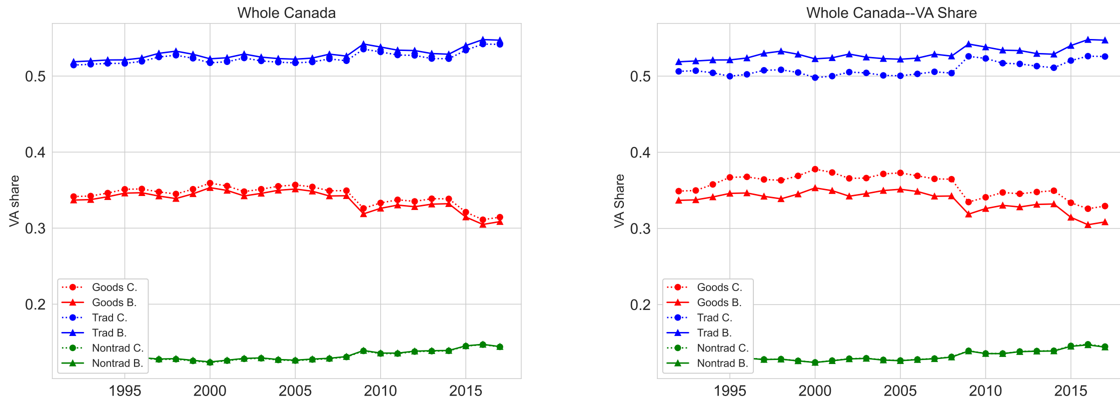


FIGURE 9 – Sectoral VA share with absent domestic and international service trade

5.4 Service trade and structural transformation in Canada

In this section, we analyze how service trade affected structural transformation of the Canadian economy. We show that, despite the great impacts on regional specialization, domestic and international service trade had little effects on the trend of sectoral value-added shares in Canada during the period 1992 – 2017.[17]

Domestic service trade

We study the effect of domestic service trade in shaping the pattern of structural transformation. The left panel of Figure 9 compares the trend of sectoral value-added share in the absence of domestic service trade with the baseline pattern. Notably, we observe a minor impact of domestic service trade, with a slight decrease in the tradable service value added share.

Why does domestic trade has significant impacts neither on the trend nor the level of sectoral value added shares? The main reason is that, when domestic service trade is absent, we observe a negative income effect resulting from non-homotheticity CES preference and a positive price effect resulting from less specialization across provinces. Although there is heterogeneity across provinces as to which of these two forces is stronger, when aggregated for Canada as a whole, they cancel each other out.

This is related to the fact that domestic trade, by its very definition, has zero net exports

[17]During this period, we observe only a mild reallocation of sectoral activity in Canada. Figure A.2 in the appendix shows that the value-added share of tradable services in Canada increased from 50% in 1992 to 54% in 2017. At the same time, the value-added share of goods decreased from 32% to 29%.

when taken as a whole for Canada. If a province is a net exporter of services, the income effect tends to be stronger, while the price effect is stronger if the province is a net exporter of services. As a whole Canada, these two forces cancel each other. We conduct further analysis to break down the mechanism into its components: the income effect and price effect in Appendix. Figure A.6 illustrates the relationship between the benchmark sectoral value-added share and the contributions of trade-induced price effect and income effect separately.

International service trade

The right panel of Figure 9 demonstrates the impact of international service trade on the structural transformation pattern. In contrast to domestic service trade, international service trade substantially contributes to the level of the tradable service value-added share. However, its effect on the trend of value-added shares is rather small. In particular, absent international service trade, Canadian value-added share or tradable services would have increased by 3 percentage points instead of 4 percentage points.

International service trade contributes to the increase of tradable service value-added share through two channels: the consumption expenditure channel and the net export channel. Figure A.7 illustrate the relative importance of these two channels by comparing the relative value-added change with the benchmark model. The figure indicates that international service trade impact the value-added share primarily through the net export channel. Unlike domestic service trade, all provinces in Canada act as net exporters regarding international service, generating a relatively strong effect through the net export channel, while the consumption expenditure channel only impacts value-added share mildly.

6 Conclusion

In this paper, we show that service trade has important effects in shaping regional production specialization and welfare. We use unique Canadian data on inter-provncial and international trade of goods and services to show that i) trade in services, especially inter-provincial trade of services, is comparable to trade in goods; ii) there is significant regional specialization in the production of tradable services across provinces; and iii) provinces with greater services net exports to GDP ratio display larger value-added share of tradable services.

We use a multi-region and multi-sector model with non-homothetic demand to study the different channels in which domestic and international trade of services affect regional specialization in tradable service sectors. We show that the influence of service trade on regional production specialization and welfare is large. In particular, the effects of inter-provincial trade in services can be as important as the well-studied effects of inter-provincial trade in goods. However, the regional welfare gains from service trade are far more heterogeneous than the gains from goods trade. Therefore, our results have important implications for regional wage disparities and redistributional policies across regions.

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Appendix

A Additional Figures and Tables

Table A.1 – Alternative Tradable and Non-Tradable Categories

Sector	Industry	Trade per Worker (Canadian $)
Tradable Services	Transportation and warehousing	161680
	Finance and insurance	153334
	Information and cultural industries	152610
	Real estate and leasing	136130
	Professional and technical services	123376
	Administrative and support	96822
	Arts, entertainment and recreation	50056
	Wholesale and retail trade	45069
	Accommodation and food services	44374
Nontradable Services	Other services (except public administration)	25291
	Educational services	8059
	Health care and social assistance	2130

Notes: This table classifies tradable and nontradable services using imports plus exports per worker in each industry. Mian and Sufi (2014) uses four-digit NAICS industries, while the industries present in table are two-digit NAICS industries. Since there are significant differences in the size of sectors between two-digit and four-digit industries, we cannot use their cutoff value of 10,000 US dollars to define tradable-service sectors here.

Figure A.1 the evolution of total domestic and international service trade as a fraction of Canadian GDP for the period 1992-2017.

Figure A.2 the evolution of sectoral value-shares in Canada for the period 1992-2017.

Figures A.3 and A.4 plot the model-implied sectoral production efficiency (T_i^k) in Canada and the RoW for the period 1992-2017.

A.1 Regional VA shares and net export of services

Figure A.5 depicts the relationship between regional VA shares and regional consumption expenditure shares (panel A) and regional net exports of services (panel B). We can confirm, visually, that the positive relationship between production specialization and trade is somewhat stronger than the relationship between VA shares and consumption.

Table A.2 – Sectoral trade (imports+exports) to gross output ratio in 2004 and 2017

	Industry	**2017**	**2004**	**Change**
Tradable Services	Transportation and warehousing	63.52%	62.54%	0.98%
	Administrative and support	60.77%	45.35%	15.42%
	Accommodation and food services	57.34%	48.78%	8.56%
	Professional and technical services	53.81%	44.65%	9.16%
	Information and cultural industries	52.60%	51.2%	1.4%
	Arts, entertainment and recreation	50.68%	42.63%	8.05%
	Wholesale and retail trade	38.10%	38.19%	-0.09%
	Finance, insurance, real estate and leasing	23.92%	21.54%	2.38%

Notes: This table classifies service industries into tradable and nontradable services. Column "Total" reports the ratio of total imports plus total exports to gross output each industry, which can be summed up by domestic trade to output ratio (Column "Domestic") and international trade to output ratio (Column "International"). The industry "Other services (except public administration)" is constructed by a.Repair and maintenance, b.Grant-making, civic and similar organizations and c.Personal and Laundry Services. Source: Canadian regional input-output tables from Statistics Canada.

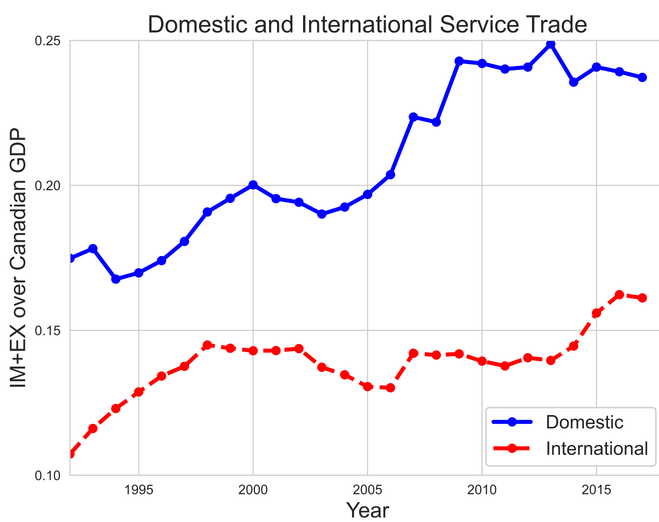

Figure A.1 – Domestic (Inter-provincial) and International Service Trade as a Fraction of GDP, 1992–2017, Canada

B Data

This section describes main data sources and data cleaning strategies. To estimate value-added shares and calibrate preference parameters, we need (a) nominal and real value-added across various sectors for both Canada and the rest of world; (b)sectoral labor endowment by province in Canada and by country in rest of world (c) Canadian bilateral trade flows

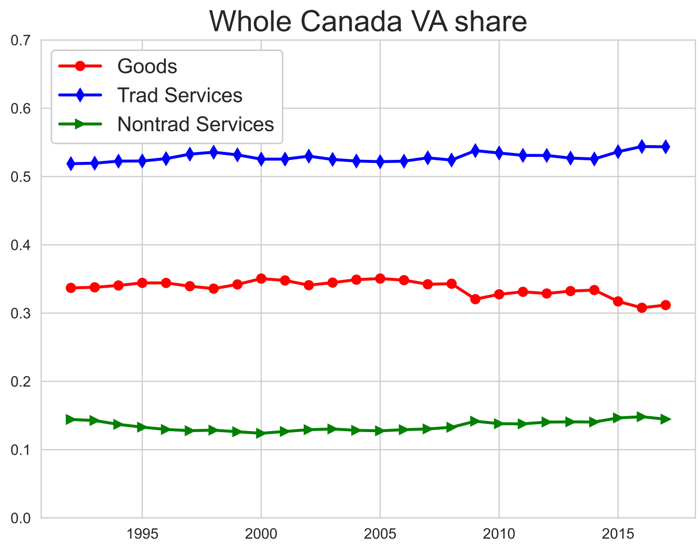

FIGURE A.2 – Structural Transformation in Canada

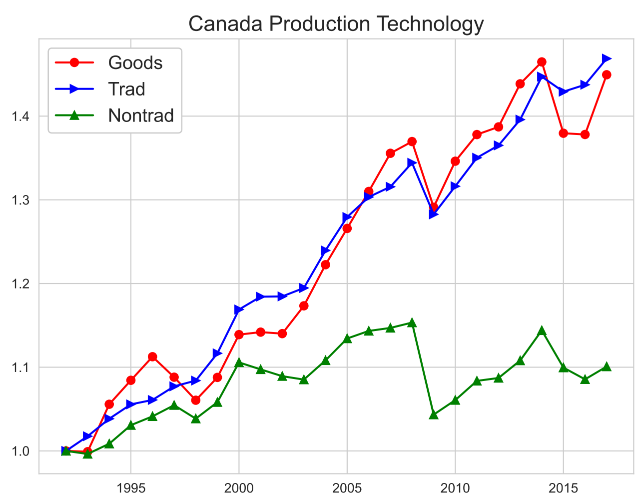

FIGURE A.3 – Sectoral production efficiency (T_i^k) in Canada

at inter-provincial and international level; (d) coefficients from Input-Output Matrix. Web links of data sources are documented in footnote.

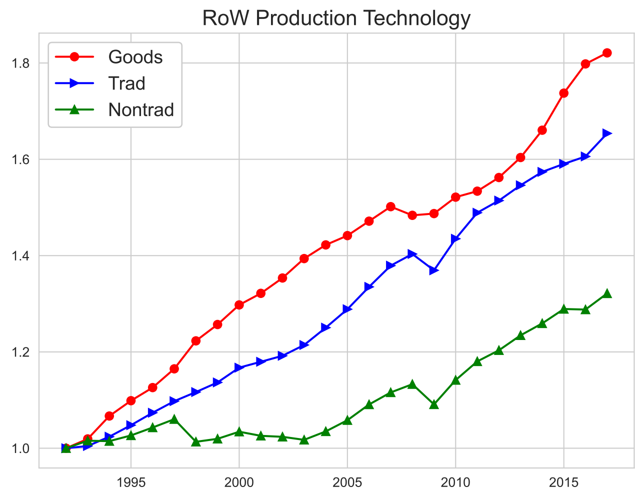

FIGURE A.4 – Sectoral production efficiency (T_i^k) in RoW

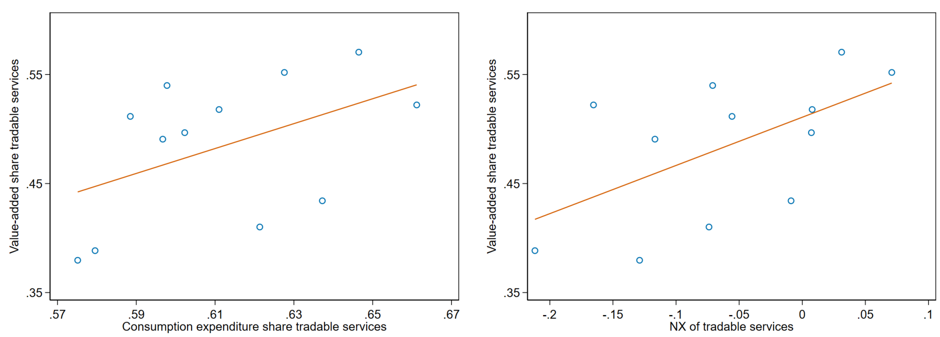

FIGURE A.5 – VA share, consumption expenditure, and net exports of tradable services

B.1 Classification

Given the various data sources used in this paper, we cannot rely on a single classification system for sector aggregation. In general, we aggregate sub-sectors into three main sectors according to three different classifications systems: (1) North American Industry Classification System (NAICS) (2) International Standard Industrial Classification System (ISIC) (3) Input - Output Commodity Classification System (IOCC).

North American Industry Classification System (NAICS) We collected data for Canadian value added and employment endowment at the sub-sector level based on NAICS. We take goods/tradable services/nontradable services sectors in Canada as the combination of 19

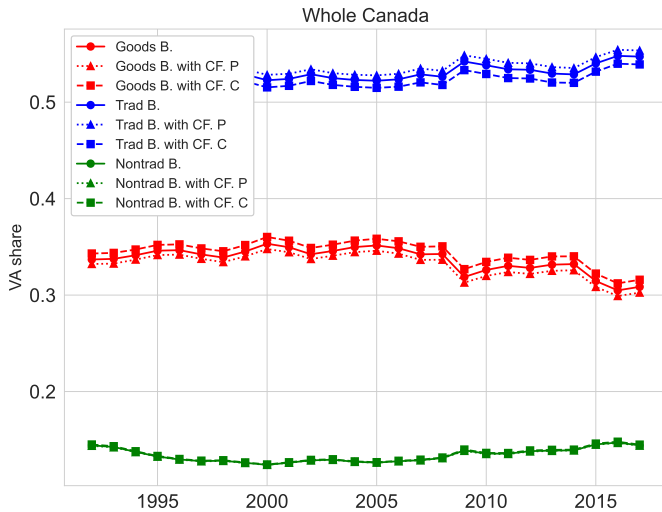

FIGURE A.6 – Income and price effect on sectoral VA share with absent domestic service trade

Notes: To analyze the price effect, we keep the real income (C_i) unchanged from the baseline model and only adjust the sectoral prices to the counterfactual case without domestic service trade. Conversely, to examine the income effect, we maintain the sectoral prices (p_{ik}) at the baseline model level and alter the real income values to the case without domestic service trade.

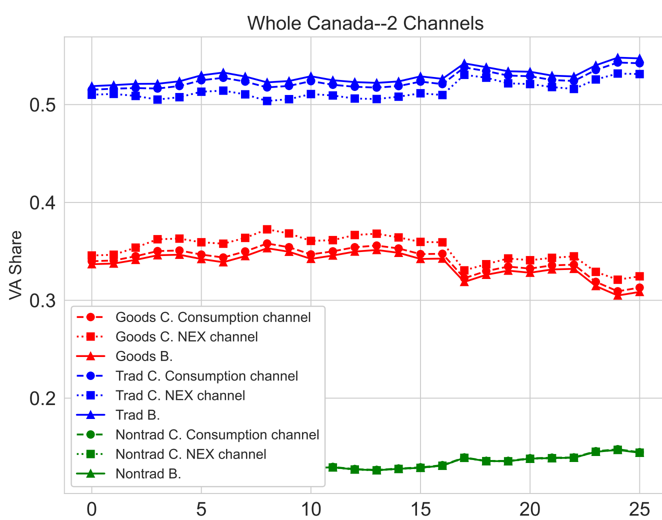

FIGURE A.7 – Consumption and net export channel on sectoral VA share with absent international service trade

Notes: To assess the impact of consumption expenditure in shaping structural transformation, we maintain the net export at the same level as the baseline model and only adjust the consumption expenditure to the case with absence of international service trade. On the other hand, we measure net export contribution by setting the consumption expenditure unchanged at the baseline level and change the net export to the case with absence of international service trade.

Table B.3 – Sectors Classification (NAICS)

Classification system: North American Industry Classification System (NAICS)		
Sector	**NAICS No.**	**Subsector name**
Goods	11	Agriculture, forestry, fishing and hunting
	21	Mining, quarrying, and oil and gas extraction
	22	Utilities
	23	Construction
	31-33	Manufacturing
Tradable Services	41	Wholesale trade
	44-45	Retail trade
	48-49	Transportation and warehousing
	51	Information and cultural industries
	52	Finance and insurance
	53	Real estate and rental and leasing
	54	Professional, scientific and technical services
	55	Management of companies and enterprises
	56	Waste management and remediation services
	71	Arts, entertainment and recreation
	72	Accommodation and food services
Nontradable Services	61	Educational services
	62	Health care and social assistance
	81	Other services (except public administration)

sub-sectors in total. Details of sub-sectors are listed in Table B.3. [18]

International Standard Industrial Classification System (ISIC) Nominal value added and employment database for rest of the world are measured based on ISIC system. For years over 2005-2015, we obtain data that are based on ISIC Rev.4 system, while data for other years contain sub-sector information according to ISIC Rev.3 system. ISIC Rev.4 and its predecessor, ISIC Rev.3, only differ in code numbers of industries within each sub-sector. ISIC's structure is hierarchical and industries are aggregated into the subsectors at higher level. Hence, code numbers for sub-sectors in both Revisions are the same.[19] We list details of ISIC sub-sectors in Table B.4

[18] Public administration [91] is not included in sectoral classification this paper.

[19] UN Statistics Division provides the link between ISIC Rev.3 and ISIC Rev.4, https://unstats.un.org/unsd/classifications/Econ/ISIC.cshtml

Table B.4 – Sectors Classification (ISIC)

Classification system: International Standard Industrial Classification (ISIC)		
Sector	**ISIC No.**	**Subsector name**
Goods	A+B	Agricultural, Hunting, Forestry, Fishing
	C	Mining, quarrying, and oil
	D	Manufacturing
	E	Electricity, gas and water supply
	F	Construction
Tradable Services	G	Wholesale, retail trade, repair of vehicles and personal and household goods
	H	Hotels and restaurants
	I	Transport, storage and communications
	J	Financial intermediation
	K	Real estate, renting and business activities
Nontradable Services	M	Educational services
	N	Health and social work
	O	Other services (except public administration)

Input - Output Commodity Classification System (IOCC) Canadian provincial trade flows from 2007 to 2017 are classified according to IOCC system. Due to data limitation, we do not make sectoral disaggregation for years prior to 2007. Different from NAICS and ISIC system, IOCC system is a product classification rather than an industry classification. Because of the wide diversity of products, classification structure of IOCC is built at a more detailed level. We provide the IOCC's sectoral details in Table B.5

B.2 Canada

B.2.1 International & Inter-Provincial Trade Flows

Derivation on Canadian trade flows since late nineties was described in details in Généreux and Langen (2002). In general, Canadian trade flows measures are constructed with two steps. First, raw inter-provincial and international trade flows are collected from various administrative statistics. On the one hand, international data are primarily sourced from Canadian International Merchandise Trade and Canadian Balance of International Payments. On the other hand, measures of inter-provincial trade are obtained from Commodity Surveys

Table B.5 – Sectors Classification (IOCC)

Classification system: North American Industry Classification System (IOCC)		
Sector	**IOCC No.**	**Subsector name**
Goods	M11_	Agricultural and farm products
	M21_	Mineral,oil and gas products
	M22_	Utilities
	M23_	Construction
	M31_	Processed food and beverages
	M32_	Chemical, plastic and wood products
	M33_	Industrial machinery, electronic products and Transportation equipment
Tradable Services	M41_	Wholesale margins and commissions
	M4A_	Retail margins, sales of used goods
	M4B_	Transportation and related services
	M51_	Information, cultural and media products
	M52_	Depository credit, finance and insurance products
	M53_	Real estate and rental and leasing
	M54_	Professional research and development (except software)
	M5E_	Software products
	M5G_	Administrative and support, head office, waste management and remediation services
	M71_	Arts, entertainment and recreation services
	M72_	Accommodation and food services
Nontradable Services	M61_	Educational services
	M62_	Health care and social assistance
	M81_	Other services (except public administration)

for the origin and destination of Sales. However, such trade patterns may not be consistent with the concept required by the inter-provincial and international trade flows program. Hence, as the second step, these trade patterns are adjusted to reconcile with provincial supply and demand from Input-Output tables. Finally, trade flows, both inter-provincially and internationally, should entirely accord with Canadian national account data.

Trade, especially inter-provincial trade, mainly contributes to our paper in two ways. First, it allows for balanced provincial input-out tables, which enables us to obtain production parameters at provincial level. Second, trade flows are treated as an important component to construct sectoral value added in an open economy. Instead of acting through sectoral expenditure, trade itself could serve as an external channel in determination of sectoral value added share across provinces.

We take trade data from following three sources: *a.* International & Inter-Provincial trade flows from 1992-1996 [20]
b. International & Inter-Provincial trade flows from 1997-2006 [21]
c. International & Inter-Provincial trade flows from 2007-2017 [22]

For each province in Canada, we collect trade data on International exports, International imports and inter-provincial exports. We compute inter-provincial imports by assuming the amount that province 1 exports to province 2 is equivalent to the amount that province 2 imports to province 1. We obtain trade flows for goods and tradable services by aggregating trade values across various sub-sectors over the period 2007-2017. For years prior to 2007, we measure trade values for tradable services as the values for total services. This strategy is feasible as we assume zero trade flows in non-tradable services. We take trade flows from 1997-2017 as baseline data, since trade flows from 1997 onwards rely on more conprehensive and robust surveys. We then splice data from the source *a* to obtain trade flows over the period 1992-2017. Specifically, for years from 1992-1996, we start with calculating the annual growth rate of trade flows of each province. We then backwards impute the trade flows prior to 1997 using the annual growth rate and the trade value in 1997.

Note that missing values exist in trade flows from source *a*. For example, the international exports on total goods and total service are missing in Quebec from 1992-1996. To handle this issue, we compute the international services and goods export ratio in Quebec in 1997. Finally, we multiply the ratio by total international exports and fill in missing values for goods and services prior to 1997 respectively. A shortcoming of this strategy is that we assume no structural transformation happens on international exports from Quebec over this period. If the trade value is missing in year 1997 of source *a*, we will impute the value by obtaining the 96-97 growth rate from the Statcan Inter-provincial and International Trade 1992-1998 handbook [23].

[20] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1210008501

[21] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1210008601

[22] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1210008801

[23] Check pdf version of handbook for more details: https://www150.statcan.gc.ca/n1/en/pub/15-546-x/15-546-x1998001-eng.pdf?st=XnNBEgzL

B.2.2 Other Data Except Trade Flows

Nominal Value Added We obtain nominal value added data in Canada from three sources:
a. Nominal value add from 1984-1996[24]
b. Nominal value add from 1997-2017[25]
c. National nominal GDP index from 1984-2017[26]
d. Monthly average retail prices for gas and fuel oil[27]

To begin with, we gather provincial nominal value added data for 19 sub-sectors over the period 1997-2017 from source *b* and use it as baseline data. This comprehensive dataset enables us to keep track of structural transformation on a provincial level. For years prior to 1997, we rely on source *a* and compute annual nominal value added growth rates for each province and each sector. We use growth rates here to avoid discontinuity caused by different measurement methods between source *a* and *b*. By applying growth rates to baseline data, we can impute the nominal value added data backwards for period over 1984-1996.

Missing values exist in source *a* and we apply following strategies: 1. We fill in the missing values by linear interpolation between observed years. We linearly interpolate missing values in sector 54 and 71 of Table B.3. 2. We extrapolate the sectoral value added data prior to year 1997 using the growth rate of national GDP index across different sectors. This strategy is only applied when linear interpolation cannot work, since provincial heterogeneity of value added growth rate will lose. We use strategy 2 in sector 21, 48-49 and 53 of Table B.3.

Due to the large fluctuation of oil price, the price in oil and gas extraction sector is smoothed using a HP filter before it is fed into the calibration. We obtain monthly regular gasoline prices at self service filling stations from source *d*. We multiply the smoothed oil price by the real value added in oil sector and re-construct the nominal oil value added with less volatility.

Real Value Added We take real value added data from two sources:
a. Provincial real value added from 1997-2017 [28]
b. National real value added index from 1992-2017 [29]

[24] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610039601
[25] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610040201
[26] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610020801
[27] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000101
[28] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610040201
[29] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610021701

To construct Canadian real value added data, we rely on source *a* and obtain the sector-province-specific real value added for 1997-2017. Since provincial real value added data only starts from 1997, we apply national real value added index for imputation during 1992-1996. National real value added index is the a chained Fisher quantity index(QI) of GDP with base year of 2012. As QI for 1992-1996 are missing in education services sector, we impute backwards using the 1997-1998 growth rate of QI. We can then iterate forward and backward to solve for annual series of real value added in 2012 U.S. dollars, applying the implied growth rate from sectoral QI. In particular, by setting $VA_{2012}^{Real} = VA_{2012}^{Nominal}$, we have

$$\frac{VA_t^{Real}}{VA_{2012}^{Real}} = \frac{VA_t^{Real}}{VA_{2012}^{Nominal}} = \frac{QI_t}{QI_{2012}}.$$

The next step is to generate annual series of sectoral price index by taking the division of national nominal value added to national real value added. By assuming homogeneous price index across provinces, we are able to impute annual real value added growth rate for 1992-1996 at provincial level. The growth rate enable us to extrapolate the sectoral real value added data prior to 1997 using the baseline data from source *a*. Finally, we aggregate the sub-sectors up to three sectors (goods, tradable services and non-tradable services), same with the case for nominal value added.

Employment and Wage Employment data is from following source:
a. Canadian employment data across industries from 1984-2017 [30]

We rely on employment data in Statcan Labour force characteristics table as our measure of labor endowment. The data measures the number of workers engaged in labor market activities across different sectors over the period of 1984-2017. NAICS classification system makes it consistent with the sectors in nominal value added data. Thus, we can simply compute wage as the ratio of nominal value added to labor endowment.

Consumption Expenditure Consumption Expenditure comes from following sources:
a. Provincial detailed household final consumption expenditure [31]
b. Inter-city indexes of price differentials of consumer products [32]
c. GGDC Productivity Level Database [33]

[30] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1410002301
[31] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610022501
[32] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000301
[33] https://www.rug.nl/ggdc/productivity/pld/?lang=en

We collect annual household final consumption expenditure from source a, in both current and constant 2012 prices. The data sums all sales at product level which firms have made to households on capital account, or in export markets. We aggregate both current and constant 2012 price expenditure into goods, tradable services and nontradable services based on IOCC product classification system. The construction of real sectoral consumption follows the same strategy with that of real value added. To be consistent with value added database, public administration is not taken into account.

For sectoral consumption price, we take the ratio between nominal consumption and real consumption so as to obtain sectoral consumption price index for each province each year. Given that the prices are indexed 1 in 2012, they are not comparable across Canadian provinces. We use the inter-city price index in source b to adjust the price differentials across Canadian provinces. The city-index data provides the price index across all provincial capitals at aggregate-items level. We the make provincial prices comparable across sectors via source c. The GGDC Productivity Level Database provides data on relative prices and labor productivity across countries up to 35 industries in 2005. We select the data for Canada and aggregate the industrial level price into sectoral level using the value added weight. We then adjust these sectoral differentials to consumption price index, which makes it comparable both provincially and sectorally.

Input-Output Matrix The input-output table comes from:
a. Provincial Input-Output Tables in Canada [34]

We rely on Canadian input-output tables compute both input-output coefficients and value added to gross output ratios at provincial level. Each table documents inter-industry transactions and purchases by final demand annually. Parameter values are very different across provinces; whereas the time-series variation for each province is negligible. Therefore, we compute those provincial production parameters annually and take an average over whole period. The parameter $\lambda_{i,k}$ denotes the ratio of nominal value added to gross output. $\gamma_{i,k,n}$ measures the share of sector n goods on intermediates spendings for the production in sector b. Therefore, for each province i, we can construct a 3×1 vector for $\lambda_{i,k}$ and 3×3 matrix for $\gamma_{i,k,n}$ through a straightforward calculation from input-output data.

[34] https://www150.statcan.gc.ca/n1/en/catalogue/15-211-X

Investment and Government expenditures We gather provincial investment and government expenditures for each year from following source:
*a.*Provincial gross domestic product, expenditure-based [35]
b. Provincial Input-Output Tables in Canada [36]

We utilize the provincial GDP by expenditure accounts to further decompose final domestic demand into household, investment and government sectors. It is not possible to produce an equivalent to the GDP by Income and by Expenditure Accounts, except at the aggregate level. By aggregating the expenditure-based GDP across final users, we are able to back out the sectoral value added for each province. Note that the expenditure GDP data is measured on aggregate level, which does not categorize the expenditure demand into sectors. Hence, we rely on the the provincial symmetric final demand sections in provincial input-output tables. We compute the share of demand from all other industries, including expenditures on households and inventory withdrawals as well as government institutions. Hence, this final users demand share enables us to impute the provincial government and investment expenditures across sectors.

B.3 The Rest of the World

Countries These Rest of the World data cover 1992-2017 for 22 countries/ regions: Argentina, Australia, China, Denmark, Finland, France, Germany, India, Indonesia, Italy, Japan, Mexico, Norway, Peru, Poland, Saudi Arabia, South Korea, Sweden, Switzerland, Turkey, United Kingdom, United States.

Value Added We use following data sources to construct nominal and real value added for rest of the world:
a. UN Value added by industries at current prices (ISIC Rev. 3) [37]
b. UN Value added by industries at constant prices (ISIC Rev. 3) [38]
c. UN Value added by industries at current prices (ISIC Rev. 4) [39]
d. UN Value added by industries at constant prices (ISIC Rev. 4) [40]

[35] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610022201
[36] https://www150.statcan.gc.ca/n1/en/catalogue/15-211-X
[37] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a201
[38] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a202
[39] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a204
[40] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a204

e. IMF based exchange rate [41]

For nominal value added construction, source *a* from UN statistics division serves as the baseline data. The data source provides detailed breakdown at sub-sector level for most countries available from 1970s to 2010s, while misses data records for most countries after then. We rely on source *c* to impute missing sub-sectoral nominal value added in rest years. To handle the measurement discrepancy between ISIC Rev.3 and ISIC Rev.4, for each country-sector in source *c*, we compute the annual growth rate over the missing period. Using nominal value added data in source *a* as baseline, these growth rates enable us to complete the nominal value added for 22 countries over 1992-2017 through backwards iteration.[42] Within each source, data was complied following compiled following different time-series versions of national accounts statistics. We treat the 1993 SNA national accounts methodology as the baseline and splice with the growth rate of sub-secoral value added under 1968 SNA and 2008 SNA framework. Gievn that data is recorded in national currency in source *a* and *c*, we convert the sectoral nominal value added into US dollars measures using source *e*.

Same with Canadian data, we construct RoW real value added using Tornqvist index and select 2012 as base year. Thus, we can summarize the computation process as follows:

$$VA_{k,t}^{Nominal} = VA_{k,t}^{Nominal} \qquad \text{if} \qquad t = 2012;$$

$$\Delta \log VA_{k,t}^{Real} = \sum_{b \in k} \frac{1}{2}(w_{b,t} + w_{b,t-1}) \Delta \log VA_{b,t}^{Real} \qquad \text{if} \qquad t \quad \text{in other years}$$

where $VA_{b,t}^{Real}$ is the value added at constant price in year t in sub-sector b and $w_{b,t}$ is the nominal value added weight of sub-sector b in sector k.

Employment and Wages Employment data is from following source:
a. ILO Employment data from 1992-2017 [43]

We collect country-sector specific employment data from ILO database. We aggregate up

[41] https://unstats.un.org/unsd/snaama/downloads

[42] Among 22 countries, China's nominal value-added data in non-tradable services was not documented in both source *a* and *c*. Therefore, we assume zero employment in China's non-tradable services sector for consistency. Additionally, Saudi Arabia's nominal value added data is unavailable in 2016 and 2017. We extrapolate the missing values from UN aggregate database, with the assumption that tradable and non-tradable service grows at same rate in Saudi Arabia.

[43] https://www.ilo.org/shinyapps/bulkexplorer16/?lang=en&segment=indicator&id=EMP_2EMP_SEX_ECO_NB_A

sectoral nominal value added and sectoral employment endowment across countries. Same with Canada, wage for workers in RoW is the ratio of these two terms.

C Derivation

This section characterizes the proofs of formulas that are used in this paper. We document the derivations for (a) household's problem with CES utility function (b) sectoral gross output price and productivity; (c) final consumption expenditure.

C.1 Household's optimization with CES utility

Sato (1975) derived a general group of CES utility functions: homothetic CES functions in separable class and non-homethetic CES functions in both separable and non-separable classes. Comin et al. (2021) took the form of separable non-homethetic CES class and implicitly formulated the utility function:

$$\sum_k \omega_k^{\frac{1}{\sigma}} \left(\frac{C_k/L}{g_k\left(C/L\right)^{\phi_k}} \right)^{\frac{\sigma-1}{\sigma}} = 1 \tag{C.1}$$

where ω_k denotes the relative weight of consumption bundle in sector k; C_k is the real consumption index for sector k in time t; C is the real aggregate consumption index, which measures the aggregate utility for C_k across sectors; $g\left(.\right)$ is a differentiable, monotonically increasing function; σ_k is the elasticity of substitution and ϕ_k controls the relative income effect.

Standard CES utility function is a special case when $g_k\left(C\right) = C$ for all sectors k. Following Duernecker et al. (2023) , we assign $\phi_k = \left(\sigma - \epsilon_k\right)/\left(\sigma_k - 1\right)$ so that we can separate out income effect substitution effect in household optimisation problem. We can then rewrite equation (C.1) as:

$$\sum_k \omega_k^{\frac{1}{\sigma}} \left(\frac{C_k}{L} \right)^{\frac{\sigma-1}{\sigma}} \left(\frac{C}{L} \right)^{\frac{\epsilon_k-\sigma}{\sigma}} = 1 \tag{C.2}$$

Taking account of (C.3) and budget constraint, we can define a household Lagrangian that is essentially same to Sposi (2019) and Comin et al. (2021). For outer layer with two sectors, goods and services, let σ_g denote elasticity of substitution between goods and services; let P imply aggregate price index. By omitting the time and province subscript for brevity, we can obtain the outer layer Lagrangian as:

$$\mathcal{L} = \frac{C}{L} - \rho \left[\sum_{k=g,s} \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_k}{L} \right)^{\frac{\sigma_g - 1}{\sigma_g}} \left(\frac{C}{L} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}} - 1 \right] - \lambda \left[PC - \sum_{k=g,s} P_k C_k \right]$$

The first order condition with respect to C_k yields:

$$-\rho \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_k}{L} \right)^{\frac{\sigma_g - 1}{\sigma_g} - 1} \left(\frac{\sigma_g - 1}{\sigma_g} \right) \left(\frac{1}{L} \right) \left(\frac{C}{L} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}} - \lambda P_k = 0$$

$$\left(\frac{\sigma_g}{1 - \sigma_g} \right) \frac{\lambda P_k C_k}{\rho} = \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_k}{L} \right)^{\frac{\sigma_g - 1}{\sigma_g}} \left(\frac{C}{L} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}}$$

Taking summation on both sides of equation gives:

$$\left(\frac{\sigma_g}{1 - \sigma_g} \right) \frac{\lambda}{\rho} = \frac{1}{PC}$$

Then the equation follows that:

$$P_k C_k = \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_k}{L} \right)^{\frac{\sigma_g - 1}{\sigma_g}} \left(\frac{C}{L} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}} PC$$

$$\frac{C_k}{L} = \omega_k \left(\frac{C}{L} \right)^{\epsilon_k} \left(\frac{P_k}{P} \right)^{-\sigma_g}$$

$$P_k C_k = L \omega_k \left(\frac{C}{L} \right)^{\epsilon_k} \left(\frac{P_k}{P} \right)^{1 - \sigma_g} P, \qquad k \in \{g, s\} \tag{C.3}$$

Substituting (C.3) into the budget constraint yields:

$$PC = \sum_{k=g,s} L \omega_k \left(\frac{C}{L} \right)^{\epsilon_k} \left(\frac{P_k}{P} \right)^{1 - \sigma_g} P$$

Finally we get the aggregate price index:

$$P = \left[\sum_{k=g,s} \omega_k \left(\frac{C}{L} \right)^{\epsilon_k - 1} P_k^{1-\sigma_g} \right]^{\frac{1}{1-\sigma_g}} \tag{C.4}$$

Likewise, we can solve household inner layer problem following the same method. The first order condition for C_k in inner layer implies that:

$$P_k C_k = L \omega_k \left(\frac{C}{L} \right)^{\epsilon_k} \left(\frac{P_k}{P} \right)^{1-\sigma_s} P_s, \qquad k \in \{sm, sn\} \tag{C.5}$$

$$P_s = \left[\sum_{k=sm,sn} \omega_k \left(\frac{C}{L} \right)^{\epsilon_k - 1} P_k^{1-\sigma_s} \right]^{\frac{1}{1-\sigma_s}} \tag{C.6}$$

Therefore, the solution algorithm starts from the inner layer of household problem. Equation (C.6) enables us to calculate P_s using P_{sm} and P_{sn} from data. We then solve out the aggregate price index P by substituting P_s into equation (C.4) .

C.2 Price and Productivity for gross output

Due to the data limitation, it is difficult to observe the sectoral gross output TFP and prices directly. Similar to Uy et al. (2013) and Sposi (2019), we derive a nominal value added function and decompose it into value added price index and quantities. We can then infer gross output TFP and prices implicitly from these two components. We start with the aggregate production function in sector $k \in \{g, sm, sn\}$:

$$Y_{i,t}^k = A_{i,t}^k \left[L_{i,t}^k \right]^{\lambda_k} \left[\prod_{n=g,sm,sn} \left(M_{i,t}^{k,n} \right)^{\gamma_{k,n}} \right]^{1-\lambda_k}$$

Ignoring time subscripts, the first order condition for immediate inputs that are sourced from n gives:

$$P_{i,n} M_{i,k,n} = (1 - \lambda_k) \gamma_{k,n} P_{i,k} Y_{i,k}$$

Substituting optimal value of M, the aggregate production function can be re-written as:

$$Y_{i,k} = A_{i,k} L_{i,k}^{\lambda_k} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{k,n}}{P_{i,n}} \right)^{\gamma_{k,n}} [(1-\lambda_k) P_{i,k} Y_{i,k}]^{\gamma_{k,n}} \right]^{1-\lambda_k}$$

Recall that $\sum_{n=g,sm,sn} \gamma_{k,n} = 1$, we can rearrange and obtain:

$$Y_{i,k} = A_{i,k}^{\frac{1}{\lambda_k}} L_{i,k} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{k,n}}{P_{i,n}} \right)^{\gamma_{k,n}} [(1-\lambda_k) P_{i,k}]^{\gamma_{k,n}} \right]^{\frac{1-\lambda_k}{\lambda_k}}$$

Given that λ_k denotes the value added share in output production, we can define the nominal value added production as:

$$\begin{aligned} VA_{i,k}^{nominal} &= \lambda_k P_{i,k} Y_{i,k} \\ &= A_{i,k}^{\frac{1}{\lambda_k}} L_{i,k} \lambda_k P_{i,k}^{\frac{1}{\lambda_k}} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{k,n}}{P_{i,n}} \right)^{\gamma_{k,n}} (1-\lambda_k)^{\gamma_{k,n}} \right]^{\frac{1-\lambda_k}{\lambda_k}} \end{aligned}$$

Thus, the sectoral nominal value added function can be decomposed into two components:

(1) Value added production function $VA_{i,k}^{real}$:

$$VA_{i,k}^{real} = A_{i,k}^{\frac{1}{\lambda_k}} L_{i,k} \tag{C.7}$$

(2) Value added price index $P_{i,k}^{VA}$:

$$P_{i,k}^{VA} = \lambda_k P_{i,k}^{\frac{1}{\lambda_k}} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{k,n}}{P_{i,n}} \right)^{\gamma_{k,n}} (1-\lambda_k)^{\gamma_{k,n}} \right]^{\frac{1-\lambda_k}{\lambda_k}} \tag{C.8}$$

Equation (C.7) makes it possible to convert value added TFP to gross output TFP, which implies that measured gross output TFP can be rearranged as:

$$A_{i,k} = \left(\frac{VA_{i,k}^{real}}{L_{i,k}} \right)^{\lambda_k}$$

C.3 Production efficiency and trade costs

Production efficiency T_{ik} and trade costs τ_{ijk} are calibrated using the bilateral trade flows data and model-implied sectoral prices. We impute technology T_{ik} from measured productivity $A_{i,k}$ and plot the Canada and RoW results in Figure A.3 and A.4. $A_{i,k}$ is the average realization of random efficiency drawn from a Fréchet distribution. We measure productivity as the ratio of cost of input bundle to sectoral price, and is given by:

$$A_{i,k} = v_{i,k}/P_{i,k} \tag{C.9}$$

Equation C.9 implies the quantitative link among input cost, sectoral price and measured productivity: either two terms are sufficient statistics for the third. Given the constant cost of input bundle, composite good with lower price indicates a higher measured productivity. Combined the input cost specification in equation 3.2, we can rewrite measured productivity as a function of sectoral price:

$$A_{i,k} = (\frac{1}{\lambda_{i,k}})^{\lambda_{i,k}} \frac{w_i}{P_{ik}} \left(\prod_{n \in \{g,sm,sn\}} \left(\frac{P_{in}}{w_i \gamma_{i,k,n} \left(1 - \lambda_{i,k}\right)} \right)^{\gamma_{i,k,n}} \right)^{1-\lambda_{i,k}} \tag{C.10}$$

As in Święcki (2017) and Sposi (2019), we make use of equation C.10 and construct measured productivity with model-implied prices. The next step is to adjust for the Ricardian selection effect and recover $T_{i,k}$. Holding the state of technology constant, trade openness increases average productivity (Finicelli et al. (2013)). Thus, we map fundamental technology $T_{i,k}$ from measured gross output productivity $A_{i,k}$ using

$$A_{i,k} = \Gamma^{-1} \left(T_{i,k}\right)^{\lambda_k} \left(\pi_{i,i,k}\right)^{\frac{-1}{\theta}}, \tag{C.11}$$

where $\pi_{i,i,k}$ denotes province i's absorption ratio in sector k, which equals to 1 in closed economy. [44]

Combining 3.3 and 3.4 in model section, we can solve out trade cost as a function of relative import share and relative sectoral price:

$$\tau_{i,j,k} = \left(\frac{\pi_{i,j,k}}{\pi_{j,j,k}} \right)^{-\frac{1}{\theta}} \left(\frac{P_{i,k}}{P_{j,k}} \right), \tag{C.12}$$

[44] $\Gamma = \Gamma\left(1 - \frac{1}{\theta}\left(1-\eta\right)\right)^{1/(1-\eta)}$

The exogenous trade costs enable us to shut down trade flows by simply setting $\tau_{i,j,k} = 10^6$ in the counterfactual. We also assume $\tau_{i,j,sn} = 10^6$ for all provinces.

C.4 Final consumption expenditure

We generate sectoral consumption expenditure using value added and import-export data for each province and the RoW. Uy et al. (2013) documented this decomposition structure in a two-country case and Sposi (2019) extended it to multi-country version in which all sectors are able to trade. Details are shown below:

First, the sectoral gross output of province i can be purchased by any province/country and used either as an intermediate input or final consumption. We impute gross output by applying input-output coefficient to value added data and construct following:

$$P_{i,k}Y_{i,k} = \frac{w_i L_{i,k}}{\gamma_k} = \sum_{j=1}^{J} \left(P_{j,k}C_{j,k} + \sum_{n \in g,sm,sn} P_{j,k}M_{j,n,k} \right) \pi_{j,i,k} \tag{C.13}$$

Defining $P_{j,k}Q_{j,k}$ as total absorption in sector k province/country j, yields:

$$P_{i,k}Y_{i,k} = \frac{w_i L_{i,k}}{\gamma_k} = \sum_{j=1}^{J} P_{j,k}Q_{j,k}\pi_{j,i,k} \tag{C.14}$$

Separate out domestic absorption implies that
for $k \in \{g, sm\}$

$$\begin{aligned}
\frac{w_i L_{i,k}}{\gamma_k} &= \sum_{j=1;j\neq i}^{J} P_{j,k}Q_{j,k}\pi_{j,i,k} + P_{i,k}Q_{i,k}\pi_{i,i,k} \\
&= \sum_{j=1;j\neq i}^{J} P_{j,k}Q_{j,k}\pi_{j,i,k} + P_{i,k}Q_{i,k}\left(1 - \sum_{j=1;j\neq i}^{J} \pi_{i,j,k}\right) \\
&= P_{i,k}Q_{i,k} + \sum_{j=1;j\neq i}^{J} P_{j,k}Q_{j,k}\pi_{j,i,k} - \sum_{j=1;j\neq i}^{J} P_{i,k}Q_{i,k}\pi_{i,j,k}
\end{aligned}$$

Thus, region i's gross output function is decomposed into total absorption, total export and total import on sector k's composite good. we define $NX_{i,k}$ as the region i's net export on sector k, it follows that

$$P_{i,k}Y_{i,k} = \sum_{j=1}^{J} P_{j,k}Q_{j,k}\pi_{j,i,k} = P_{i,k}Q_{i,k} + NX_{i,k}, \qquad k \in \{g, sm\} \tag{C.15}$$

$$P_{i,k}Y_{i,k} = P_{i,k}Q_{i,k}, \qquad k = sn \tag{C.16}$$

If we link the net export $NX_{i,k}$ with the budget constraint 3.8, by summing up equations C.15 and C.16 across sectors, we have:

$$\sum_{k=g,sm,sn} P_{i,k}Y_{i,k} - \sum_{k=g,sm,sn} P_{i,k}Q_{i,k} = \iota_i w_i Li - \xi L_i \tag{C.17}$$

Recall that the market clearing condition on supply side is

$$Q_{i,k} = C_{i,k} + \sum_{n=g,sm,sn} M_{i,n,k},$$

Multiplying by P_{ik} implies that sector k's total absorption will either serve as final expenditure or intermediate input:

$$P_{i,k}Q_{i,k} = P_{i,k}C_{i,k} + \sum_{n=g,sm,sn} P_{i,k}M_{i,n,k}. \tag{C.18}$$

Firm's optimality condition for intermediates used by sector b gives:

$$P_{i,k}M_{i,n,k} = (1-\lambda_n)\gamma_{n,k}P_{i,n}Y_{i,n}, \tag{C.19}$$

Thus,

$$P_{i,k}Q_{i,k} = P_{i,k}C_{i,k} + \sum_{n=g,sm,sn} (1-\lambda_n)\gamma_{n,k}P_{i,n}Y_{i,n}. \tag{C.20}$$

We split tradable sector from non-tradables

$$P_{i,k}Q_{i,k} = P_{i,k}C_{i,k} + \Big(\sum_{n=g,sm} (1-\lambda_n)\gamma_{n,k}P_{i,n}Y_{i,n}\Big) + (1-\lambda_{sn})\gamma_{sn,k}P_{i,sn}Y_{i,sn},$$

where $Y_{i,sn} = Q_{i,sn}$ in non-tradables and $P_{ik}Y_{ik} = \sum_{j=1}^{J} P_{jk}Q_{jk}\pi_{jik}$ in tradables, which gives the following market clearing condition

$$P_{i,k}Q_{i,k} = P_{i,k}C_{i,k} + \sum_{n=g,sm} (1-\lambda_n)\gamma_{n,k}\sum_{j=1}^{J} \pi_{j,i,n}P_{j,n}Q_{j,n} + (1-\lambda_{sn})\gamma_{sn,k}P_{i,sn}Q_{i,sn}$$

Using second part of(C.15), we can get:

$$P_{i,k}Q_{i,k} = P_{i,k}C_{i,k} + \sum_{n=g,sm} (1-\lambda_n)\gamma_{n,k}(P_{i,n}Q_{i,n} + NX_{i,n}) + (1-\lambda_{sn})\gamma_{sn,k}P_{i,sn}Q_{i,sn} \quad \text{(C.21)}$$

For each sector, (C.21) can be written as:

$$\begin{aligned} P_{i,g}C_{i,g} = &\left[1-(1-\lambda_g)\gamma_{g,g}\right](P_{i,g}Q_{i,g} + NX_{i,g}) - (1-\lambda_{sm})\gamma_{sm,g}(P_{i,sm}Q_{i,sm} + NX_{i,sm}) \\ &- (1-\lambda_{sn})\gamma_{sn,g}P_{i,sn}Q_{i,sn} - NX_{i,g}; \end{aligned}$$

$$\begin{aligned} P_{i,sm}C_{i,sm} = &\left[1-(1-\lambda_{sm})\gamma_{sm,sm}\right](P_{i,sm}Q_{i,sm} + NX_{i,sm}) - (1-\lambda_g)\gamma_{g,sm}(P_{i,g}Q_{i,g} + NX_{i,g}) \\ &- (1-\lambda_{sn})\gamma_{sn,sm}P_{i,sn}Q_{i,sn} - NX_{i,sm}; \end{aligned}$$

$$\begin{aligned} P_{i,sn}C_{i,sn} = &\left[1-(1-\lambda_{sn})\gamma_{sn,sn}\right]P_{i,sn}Q_{i,sn} - (1-\lambda_{sm})\gamma_{sm,sn}(P_{i,sm}Q_{i,sm} + NX_{i,sm}) \\ &- (1-\lambda_g)\gamma_{g,sn}(P_{i,g}Q_{i,g} + NX_{i,g}). \end{aligned}$$

Using (C.15) and (C.16) yields

$$P_{i,g}C_{i,g} = \frac{1-(1-\lambda_g)\gamma_{g,g}}{\lambda_g}w_iL_{i,g} - \frac{(1-\lambda_{sm})\gamma_{sm,g}}{\lambda_{sm}}w_iL_{i,sm} - \frac{(1-\lambda_{sn})\gamma_{sn,g}}{\lambda_{sn}}w_iL_{i,sn} - NX_{i,g};$$

$$P_{i,sm}C_{i,sm} = \frac{1-(1-\lambda_{sm})\gamma_{sm,sm}}{\lambda_{sm}}w_iL_{i,sm} - \frac{(1-\lambda_g)\gamma_{g,sm}}{\lambda_g}w_iL_{i,g} - \frac{(1-\lambda_{sn})\gamma_{sn,sm}}{\lambda_{sn}}w_iL_{i,sn} - NX_{i,sm};$$

$$P_{i,sn}C_{i,sn} = \frac{1-(1-\lambda_{sn})\gamma_{sn,sn}}{\lambda_{sn}}w_iL_{i,sn} - \frac{(1-\lambda_{sm})\gamma_{sm,sn}}{\lambda_{sm}}w_iL_{ism} - \frac{(1-\lambda_g)\gamma_{g,sn}}{\lambda_g}w_iL_{i,g}. \quad \text{(C.22)}$$

By applying data on value added, net export and input-output coefficients to the equation system above, we can generate the sector-province final expenditure. Data-implied sectoral expenditure share can then be simply constructed and used for calibration.

C.5 Counterfactual strategy

We compare our benchmark economy with an economy with no service trade following these steps. (i) Assume that in our no-service-trade economy trade costs $\{\tau_{ijk}\}$ take a large value, 10^6, such that there are no exports of service k from province j to province i, in equilibrium. Given the production and household's preference parameters in the benchmark, we solve for an equilibrium with the new trade costs. (ii) Given an initial guess to provincial wage w_i, we obtain sectoral prices P_{ik} and input costs v_{ik} by jointly solving equation 3.2 and 3.3. (iii) Compute the per capita return from global portfolio ξ from equation 3.10. Note that values of ι_i are unchanged in the counterfactual.[45] (iv) Impute the counterfactual aggregate price P_i and aggregate real income C_i by jointly solving equation 3.8, 4.8 and 4.9. Then, we can construct sectoral expenditure $E_{i.k}$ in the counterfactual. (v) Compute sectoral real consumption C_{ik} for each province using equation 3.9, 4.1 and 4.1. (vi) Calculate import expenditure share π_{ijk} using equation 3.4. (vii) Compute the sectoral labor L_{ik}, gross output $P_{ik}Y_{ik}$, sectoral absorption $P_{ik}Q_{ik}$ and intermediate input usages $P_{ik}M_{ik}$ by combining production equilibrium conditions C.13, C.14 and C.20 in appendix. (viii) Use resource constraint C.17 in appendix and compute the per-capita excess demand as $D_i = \left[\left(\sum_{k=g,sm,sn} P_{i,k}Y_{i,k} - \sum_{k=g,sm,sn} P_{i,k}Q_{i,k}\right) - (\iota_i w_i Li - \xi L_i)\right]/L_i$. (ix) We slowly update the wage until the global market clears, $D_i = 0$. Specifically, we iterate provincial wage using $w_i^{'} = w_i + \delta D_i$, where we set $\delta = 0.01$ so that the wage vector w_i can slowly converge to the fixed point.

[45]We assume that I_{ik} and G_{ik} are unchanged in the benchmark and in the counterfactual. Therefore, consumption expenditure share are the main driver of $E_{i,k}$ in our counterfactual.