Service Trade, Regional Specialization, and Welfare*

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August 14, 2023

Abstract

How much does trade in services affect regional production specialization and welfare? Using unique Canadian trade data, we document that the size of inter-provincial service trade is comparable to that of good trade, and that net exports of services are highly correlated with the value-added share of tradable services across provinces. With a spatial model featuring domestic and international trade, we quantify the effects of service trade. Our results highlight that domestic service trade significantly promotes regional specialization, with heterogeneous welfare gains that reduce regional disparities. Conversely, international service trade generates more uniform welfare gains across provinces.

JEL Classification: E20, F10, L16

Keywords: Service trade; domestic trade; regional specialization; regional disparities; welfare; structural transformation

*We thank seminar participants at the Society of Economic Dynamic Meeting 2021 (Minneapolis), the China International Conference in Macroeconomics 2022 (Shenzhen), the Econometric Society Australian Meeting 2022 (Brisbane), Midwest Macro Meeting 2022 (SMU), Firm Heterogeneity and the Macroeconomy Workshop (UNSW), Macro Development Workshop (Deakin), Australian Conference of Economists (Brisbane), the University of Queensland, Tohoku University, and the Central Bank of Chile. We thank Ali Furkan Kalay for his excellent research assistance. The views in this paper are those of the authors and do not necessarily reflect the views of the International Monetary Fund.

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1 Introduction

Services play a significant role in trade, both within and between countries. The World Trade Organization (WTO, 2019) documents that, during 2005–2017, trade in services grew faster than trade in goods and accounts for over 20% of the world's total trade. Yet, considering that services are the largest sector in the economy, service trade is still relatively small.[1] In this regard, the WTO 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, the existing literature often assumes that services are non-traded.[2]

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 show that service trade, especially domestic service trade, is significant in its volume. We further show that net exports of services are quite heterogeneous across Canadian provinces and highly correlated with the sectoral composition of the regions. Based on these empirical findings, we construct a spatial model featuring domestic and international trade in goods and services. We calibrate the model and quantify the impact of trade in services on regional specialization and welfare in the counterfactual exercises.

We start by documenting that domestic trade in 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 link between net exports of services and regional specialization. To do so, we first classify sectors in the economy into three: good sectors, non-tradable service sectors, and tradable service sectors. In our benchmark definition, tradable service sectors are those with gross trade (imports plus exports) relative to gross output larger than 20%. Non-tradable service sectors are those that display the ratio smaller than 20%.[3][4] We then show that there is a strong positive correlation between the net exports of services to GDP ratio and the value-added share of

[1] See Lewis, Monarch, Sposi and Zhang (2020).

[2] The importance of trade in the allocation of resources is discussed in Levchenko and Zhang (2012) and Coşar and Fajgelbaum (2016), for example, while their focus is on good trade.

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

[4] Our tradable service 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.

tradable services. Furthermore, even when net exports of services are divided into domestic net exports and international net exports, we find, this correlation holds for each, while it is higher for domestic net exports.

To rationalize these findings 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 domestic and international trade in services to the model. In each tradable sector, good and tradable service, there is a continuum of competitive firms that engage in domestic and international trade. Each location 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.

Our calibration of the model takes two steps. First, 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. Second, we 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. The estimates also indicate that non-tradable services are luxuries compared to tradable services.

Using the calibrated model, we conduct a set of counterfactual exercises to quantify the role of domestic and international service trade in shaping regional specialization and welfare. In the exercises, we shut down domestic and international trade in services, one at a time. 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, the income effect outweighs the price effects which then reduces the tradable services consumption expenditure, inducing an even larger decline in provinces' value-added share of tradable services.

These changes brought about by domestic and international trade in services are closely related to the welfare gains in Canadian provinces. Domestic service trade increases the average real wage in Canada by 7%, which is comparable to the gains from domestic good trade. Notably, however, the dispersion of gains across provinces is twice as large for services as for goods. For international service trade, the increase in the average real wage is 5%. Unlike domestic service trade, the gains are more uniform across provinces. To understand the source of heterogeneous welfare gains, we examine the factors contributing to the 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 that import a significant amount of services relative to their GDP. In particular, Northwest Territories displays the largest services imports to GDP ratio in Canada and also the largest welfare gain from service trade (a 25% increase in the real wages). This is an example of how trade in services can mitigate regional disparities by allowing smaller and relatively less productive provinces to access cheaper tradable services and to specialize in the sector with their comparative advantage. As a whole Canada, we find that domestic service trade reduces the standard deviation of log real wages across provinces by 17%.

Finally, we study the implications of service trade for structural transformation. Our results suggest that, while domestic 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 the 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 the value-added share of tradable services over the period 1992–2017.

Related literature

Our work makes contributions to three strands of literature. First, we contribute to the literature investigating the welfare implications of domestic and international trade (e.g., Levchenko and Zhang, 2012; Caliendo and Parro, 2014; Di Giovanni, Levchenko and Zhang, 2014; Coşar and Fajgelbaum, 2016; Lewis, Monarch, Sposi and Zhang, 2020). Within this literature, our paper is novel in that it studies the implications of trade in services on regional welfare. Our results point to economically relevant and heterogeneous welfare consequences of service trade across provinces, and provide new insights into regional disparities.

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 domestic and international trade in services has had on regional industrial structure. 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 inter-sectoral linkages between goods and services (Cravino and Sotelo, 2019; Sposi, 2019). We focus on the direct role that services trade, domestic and international, 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 recent literature that studies the importance of tradable service sectors in shaping regional production specialization (e.g., Rossi-Hansberg, Sarte and Schwartzman, 2019, 2021; Eckert, 2019). Different from these papers, we use available data on regional and international trade in services to quantitatively analyze a spatial model featuring domestic and international trade in goods and services.

2 Empirical findings

This section presents a number of empirical findings on trade in services and regional specialization in Canada. First, we present gross and net trade flows in goods and services in Canada, both domestic and international. We then divide services into tradable and non-tradable services and show the relationship between net exports of services and specialization in the tradable service 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 provincial input-output tables and national account.[5] This unique data set provides detailed information on regional and international trade flows both in goods and services for the period 1992–2017.

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
	(1)	(2)	(3)	(4)
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.

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 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. The table shows those values for good and service sectors, domestic and international, respectively, 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 in services to GDP is 0.21, while that of goods is 0.24.[6] 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.

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

[6] At the national level, Figure A.1 of Appendix A 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.

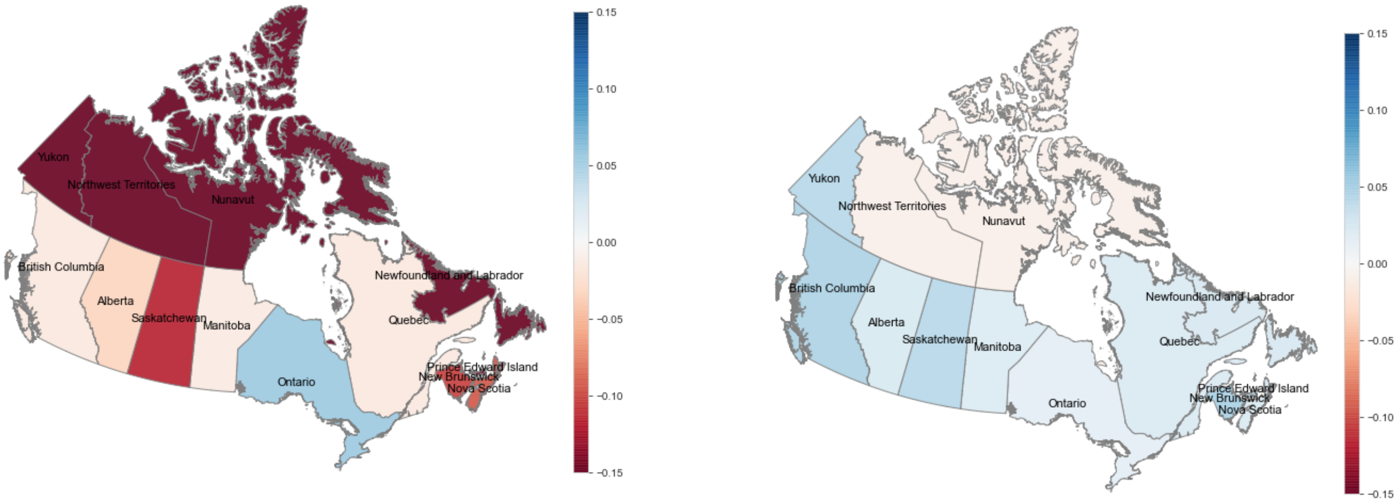


Figure 1 – Domestic net exports of services to GDP ratio (left) and International net exports of services to GDP ratio (right), averaged over 1992–2017

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 Column 3 of Table 1 and 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 Figure 1 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.

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 service sectors based on the annual trade value (imports plus exports) 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 (imports plus exports) relative to the sectoral gross output, because we think this measure is more consistent with the notion of tradability. Later, we also use the measure in Mian and Sufi (2014) for robustness check. We obtain sector information from the Canadian Input-Output Tables with their 2-digit NAICS industrial classifications.[7]

Table 2 reports the trade values (imports plus exports) relative to sectoral gross output for 11 service industries. 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.[8]

[7]The Canadian input-output table was used because it has data on international and domestic 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.

[8]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 Appendix A). This would suggest that our tradable service sector relates to the progressive service sector definition in Duernecker, Herrendorf and Valentinyi (2023).

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

Sector	Industry	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%
Non-tradable 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 non-tradable 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.

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 VA for the period 1992–2017.[9] 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.[10] As observed in the figure, there is very limited heterogeneity in

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

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

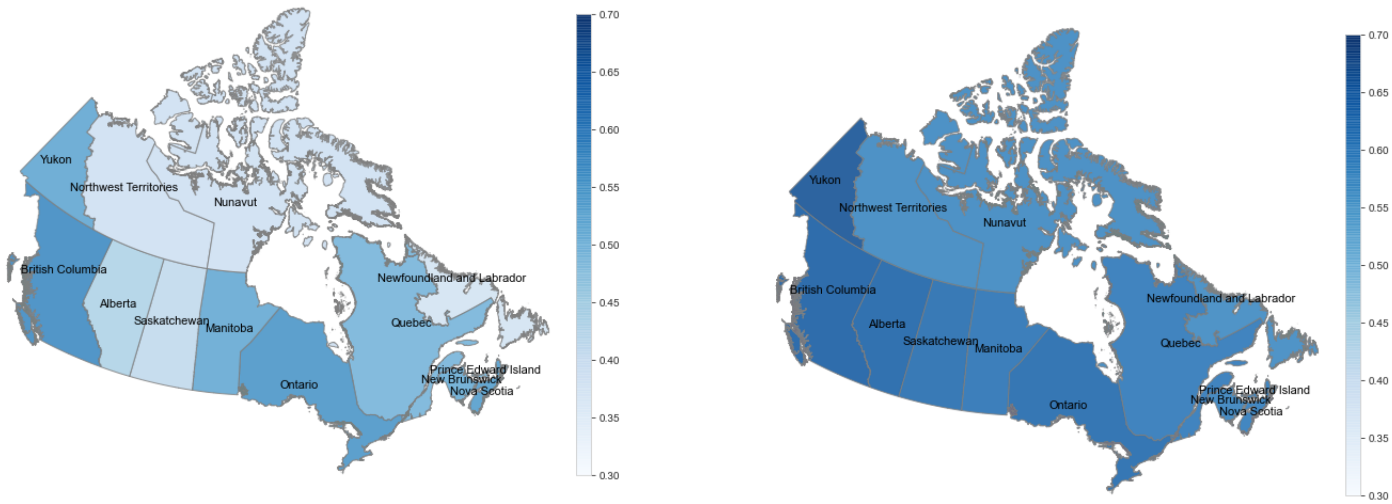


Figure 2 – Value-added share of tradable services (left) and consumption expenditure share of tradable services (right), averaged over 1992–2017.

regional consumption expenditure shares, indicating that regional specialization in production is not driven by regional differences in demand. This point is also evident in Columns 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).[11]

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 (0.58),

[11]The consumption expenditure data used here are on a sectoral gross output basis and cannot be directly compared with the sectoral VA without ad hoc assumptions about the input-output linkage matrix. Therefore, we consider the results in this section to be suggestive evidence and leave more precise analyses to our quantitative model section that has full input-output linkages. The same argument applies to the comparison between net exports and VA.

Table 3 – VA shares, consumption expenditure shares, and net exports 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	0.58	0.51	0.36

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.

which is even higher than that of the consumption expenditure share (0.47).[12] In Columns 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 a somewhat higher correlation, 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 domestic and international trade in 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. Our structural model allows us to answer two relevant questions that empirics alone cannot address. First, what is the role of service trade in shaping the industrial structure in Canada? Second, what are the welfare gains/losses from trade in services?

3 Model

Our model extends the model in Caliendo and Parro (2014) to account for domestic and international trade in services and goods. Our objective is, through the lens of a three-sector multi-regions model, to analyze the role of domestic and international trade in goods

[12]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 export 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.

and services in shaping Canada's industrial structure between 1992–2017. 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 labor and intermediate inputs as factors of production.

We assume that firms in each province export and import goods and tradable services (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 with 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 region 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 $Z_{i,t}^{k}(z)$ is the realization of random efficiency drawn from a Fréchet distribution.: $F(Z) = e^{-Z^{-\theta}}$, 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 $Z_{i,t}^{k}(z)\, {T_{i,t}^{k}}^{\lambda_{i,k}}$.

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 $\tau_{i,j,t}^{k}$ for shipping good in sector k from region j to region i . As standard in the literature, we assume that the trade costs are zero within a region,

$\tau^{g}_{i,i,t} = \tau^{sm}_{i,i,t} = \tau^{sn}_{i,i,t} = 1$ and that the trade cost of non-tradable sector is infinity across regions ($\tau^{sn}_{i,j,t} \to \infty$ for $i \neq j$).

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

$$p^{k}_{i,t}(z) = \frac{v^{k}_{i,t}\tau^{k}_{j,i,t}}{A^{k}_{i,t}(z)} = \frac{v^{k}_{i,t}\tau^{k}_{j,i,t}}{Z^{k}_{i,t}(z)\, {T^{k}_{i,t}}^{\lambda_{i,k}}}$$

where $v^{k}_{i,t}$ is the unit cost of input bundle given by

$$v^{k}_{i,t} = {\lambda_{i,k}}^{(-\lambda_{i,k})} \left(\frac{\prod_{n=g,sm,sn} {\gamma_{i,k,n}}^{-\gamma_{i,k,n}}}{1-\lambda_{i,k}} \right) (w_{i,t})^{\lambda_{i,k}} \left(\prod_{n=g,sm,sn} \left(P^{n}_{i,t}\right)^{\gamma_{i,k,n}} \right)^{1-\lambda_{i,k}} \tag{3.2}$$

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

In each sector k, competitive buyers buy good $Q^{k}_{i,t}(z)$ either from a supplier within the region (region i) or from one in the other region (region j) whichever can offer a lower price, $\hat{p}^{k}_{i,t}(z) = \min\left\{\sum_{j=1}^{J+1} p^{k}_{j,t}(z)\right\}$, where $J+1$ is the total number of regions (J provinces and the RoW). Then, as in Eaton and Kortum (2002), under the Fréchet distribution assumption, the price of composite good $k \in \{g, sm, sn\}$ in region i is $P^{k}_{i,t} = \Gamma\left(\Phi^{k}_{i,t}\right)^{-\frac{1}{\theta}}$, where the constant Γ is the Gamma function evaluated at $\left(1 - \frac{\eta-1}{\theta}\right)^{\frac{1}{1-\eta}}$, and $\Phi^{k}_{i,t} = \sum_{j=1}^{J+1}\left({T^{k}_{j,t}}^{-\lambda_{i,k}} v^{k}_{j,t}\tau^{k}_{i,j,t}\right)^{-\theta}$.[13] Thus, $\Phi^{k}_{i,t}$ describes region 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

$$P^{k}_{i,t} = \Gamma\left[\sum_{j=1}^{J+1}\left({T^{k}_{j,t}}^{-\lambda_{i,k}} v^{k}_{j,t}\tau^{k}_{i,j,t}\right)^{-\theta}\right]^{-\frac{1}{\theta}}. \tag{3.3}$$

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 region i's expenditure on sector-k goods from region j, as

$$\pi^{k}_{i,j,t} = \frac{\left({T^{k}_{j,t}}^{-\lambda_{j,k}} v^{k}_{j,t}\tau^{k}_{i,j,t}\right)^{-\theta}}{\Phi^{k}_{i,t}}, \tag{3.4}$$

[13] 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 region j in region i. Thus, region i's share of imports in the total expenditure depends on region j's average productivity in industry k, the cost of the input bundle, and trade costs to ship goods or services from region j to region i.

3.2 Household preferences

The representative household in region i at time t with non-homothetic CES preferences maximizes the aggregate per-capita consumption $C_{i,t}$, which is implicitly defined as:

$$\sum_k \omega_k^{\frac{1}{\sigma}} \left(\frac{C_{i,t}^k}{L_{i,t}}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{C_{i,t}}{L_{i,t}}\right)^{\frac{\epsilon_k-\sigma}{\sigma}} = 1. \tag{3.5}$$

where $C_{i,t}^k$ is the real consumption of sector-k composite goods; ω_k denotes the relative weight of the consumption bundle in sector k; σ is the price elasticity of substitution and ϵ_k shapes the income elasticity of demand for sector k. Preference parameters are the same across regions.[14] This implicit utility function is also used in Sposi (2019), Lewis, Monarch, Sposi and Zhang (2020) and Comin, Lashkari and Mestieri (2021). Details are outlined in Appendix C.1. To ensure the monotonicity and quasi-concavity of aggregate utility $C_{i,t}$, we restrict income elasticity $\epsilon_k > 0$ and either price elasticity (i) $0 < \sigma < 1$ or (ii) $\sigma > 1$.

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

$$\frac{C_{i,t}}{L_{i,t}} = \left(\omega_g^{\frac{1}{\sigma_g}} \left(\frac{C_{i,t}}{L_{i,t}}\right)^{\frac{\epsilon_g-1}{\sigma_g}} \left(\frac{C_{i,t}^g}{L_{i,t}}\right)^{\frac{\sigma_g-1}{\sigma_g}} + \omega_s^{\frac{1}{\sigma_g}} \left(\frac{C_{i,t}}{L_{i,t}}\right)^{\frac{\epsilon_s-1}{\sigma_g}} \left(\frac{C_{i,t}^s}{L_{i,t}}\right)^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{\sigma_g}{\sigma_g-1}}. \tag{3.6}$$

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

$$\frac{C_{i,t}^s}{L_{i,t}} = \left(\omega_{sm}^{\frac{1}{\sigma_s}} \left(\frac{C_{i,t}}{L_{i,t}}\right)^{\frac{\epsilon_{sm}-1}{\sigma_s}} \left(\frac{C_{i,t}^{sm}}{L_{i,t}}\right)^{\frac{\sigma_s-1}{\sigma_s}} + \omega_{sn}^{\frac{1}{\sigma_s}} \left(\frac{C_{i,t}}{L_{i,t}}\right)^{\frac{\epsilon_{sn}-1}{\sigma_s}} \left(\frac{C_{i,t}^{sn}}{L_{i,t}}\right)^{\frac{\sigma_s-1}{\sigma_s}}\right)^{\frac{\sigma_s}{\sigma_s-1}}. \tag{3.7}$$

[14] When estimating the preference parameters in Section 4.1, we introduce region-fixed effects in the consumption expenditure share equations, which could be interpreted as heterogeneity in $\{\omega_k\}$ across regions.

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

3.3 Budget constraint

The budget constraint of a representative household is

$$P^g_{i,t}C^g_{i,t} + P^{sm}_{i,t}C^{sm}_{i,t} + P^{sn}_{i,t}C^{sn}_{i,t} + \iota_i w_{i,t}L_{i,t} = w_{i,t}L_{i,t} + \xi L_{i,t}, \tag{3.8}$$

s.t.

$$P^g_{i,t}C^g_{i,t} + P^{sm}_{i,t}C^{sm}_{i,t} + P^{sn}_{i,t}C^{sn}_{i,t} = P_{i,t}C_{i,t}, \tag{3.9}$$

where $C^k_{i,t}$ is the consumption of sector-k composite goods for $k \in \{g, sm, sn\}$ in region i at time t, $w_{i,t}$ is the household's wage rate from supplying his/her unit labor inelastically, and $P^k_{i,t}$ 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 payments from a global portfolio. Specifically, we assume that in each period, a representative household in region i spends a fraction ι_i of income on a global portfolio of assets. The returns to this fraction of income are equally distributed lump-sum to all households and ξ specifies this per capita return from the global portfolio. Therefore, $\iota_i w_{i,t}L_{i,t} - \xi L_{i,t}$ governs regional trade imbalance that emerges from both inter-provincial and international transfers and satisfies:

$$\sum_i \iota_i w_{i,t}L_{i,t} = \xi \sum_i L_{i,t}. \tag{3.10}$$

Following Lewis, Monarch, Sposi and Zhang (2020), ι_i is modeled as the ratio of net exports to total value-added for region i. Given that the net exports of Canadian provinces and the rest of the world sum to zero, the lump sum transfer ξ will equal 0 in an open economy. In counterfactual exercises, ξ will absorb the trade imbalances caused by changes in trade costs.

3.4 Equilibrium

Within a region, 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.[15] Let $L_{i,t}$ denote total labor endowment in region i, and $L_{i,t}^k$ denote labor employed in sector k. Then, the following labor market clearing condition holds every period within the region

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

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

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

The above equations relate to 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 region-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 $\{\sigma, \eta, \theta, \{\lambda_{i,k}\}, \{\gamma_{i,k,n}\}, \{\epsilon_k\}, \{\omega_k\}\}$, a competitive equilibrium of the model is defined as follows.

Definition 1. *A competitive equilibrium is a sequence of goods and factor prices* $\left\{P_{i,t}^g, P_{i,t}^{sm}, P_{i,t}^{sn}, w_{i,t}\right\}_{i\in J+1}$, *allocations* $\left\{L_{i,t}^g, L_{i,t}^{sm}, L_{i,t}^{sn}, Q_{i,t}^g, Q_{i,t}^{sm}, Q_{i,t}^{sn}, C_{i,t}^g, C_{i,t}^{sm}, C_{i,t}^{sn}\right\}_{i\in J+1}$ *and trade shares* $\left\{\pi_{i,j,t}^g, \pi_{i,j,t}^{sm}\right\}_{i,j\in J+1}$ *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)-(3.9)*, and satisfy the market clearing conditions* (3.11)-(3.12)*.*

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.

[15] It would be interesting to see how the results change if the assumption of labor immobility across regions in the same country is relaxed. But, we leave it for future research.

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 industrial level. We then aggregate the data to construct nominal and real sectoral expenditure for good sector, tradable service sector, and non-tradable service sector. 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)-(3.9) and taking the first-order condition, we generate model-implied relative sectoral expenditure shares as two layers:

$$\frac{P_{it}^{s}C_{it}^{s}}{P_{it}^{g}C_{it}^{g}} = \frac{\omega_s}{\omega_g}\left(\frac{P_{it}^{s}}{P_{it}^{g}}\right)^{1-\sigma_g}\left(\frac{C_{it}}{L_{it}}\right)^{\epsilon_s-\epsilon_g}, \tag{4.1}$$

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

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

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

s.t.

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

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

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

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

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

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

where "hat" denotes observations from the data. We impose the sum of relative weight 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 (4.3) with panel data for 11 Canadian provinces during the period 1992–2017, using the 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_{it}^s 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_{it}^s 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_{it}^s given C_{it} for each province every year; (vi) Then, update parameters values $\{\epsilon_g, \epsilon_{sm}, \sigma_g, \sigma_s\}$ by minimising the deviation in equation (4.3). (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 ($\sigma_g = 0.59$).[16] 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 DHV of 0.32. Unlike DHV 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.

[16] Our estimate of σ_g is higher than that in DHV, 0.30, which the authors estimate using price data for the US dating back to 1947. Our σ_g is also higher than Lewis, Monarch, Sposi and Zhang (2020), 0.16, which the authors estimate using time series data for 26 countries, including emerging countries such as China and India.

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.

Within services, we obtain an elasticity of substitution $\sigma_s = 0.32$, implying that tradable and non-tradable services are complements.[17] The result contrasts with DHV where $\sigma_s = 1.03$. The authors use a different sectoral classification strategy in a model without trade and measure consumption in value-added terms instead. While we categorize the service sector as tradable and non-tradable based on the ratio of trade volume to gross output, the authors focus on productivity growth of each sub-sector. Our estimate of $\epsilon_{sn} = 1.06$ shows tradable services are necessities and non-tradable services are luxuries. Compared with tradable services like wholesale and transportation, non-tradable services including private schools and private hospitals are luxuries. In this regard, the estimate is similar to DHV 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 observations very well as data points closely located on both sides of the 45° line. The lower panel maps the model fit on the consumption ratio of non-tradable services to tradable services. Provinces with relatively large model-data departures are Prince Edward Island and Northwest Territories & Nunavut. Different from the other provinces, the non-tradable

[17] 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 $\sigma = 0.44$.

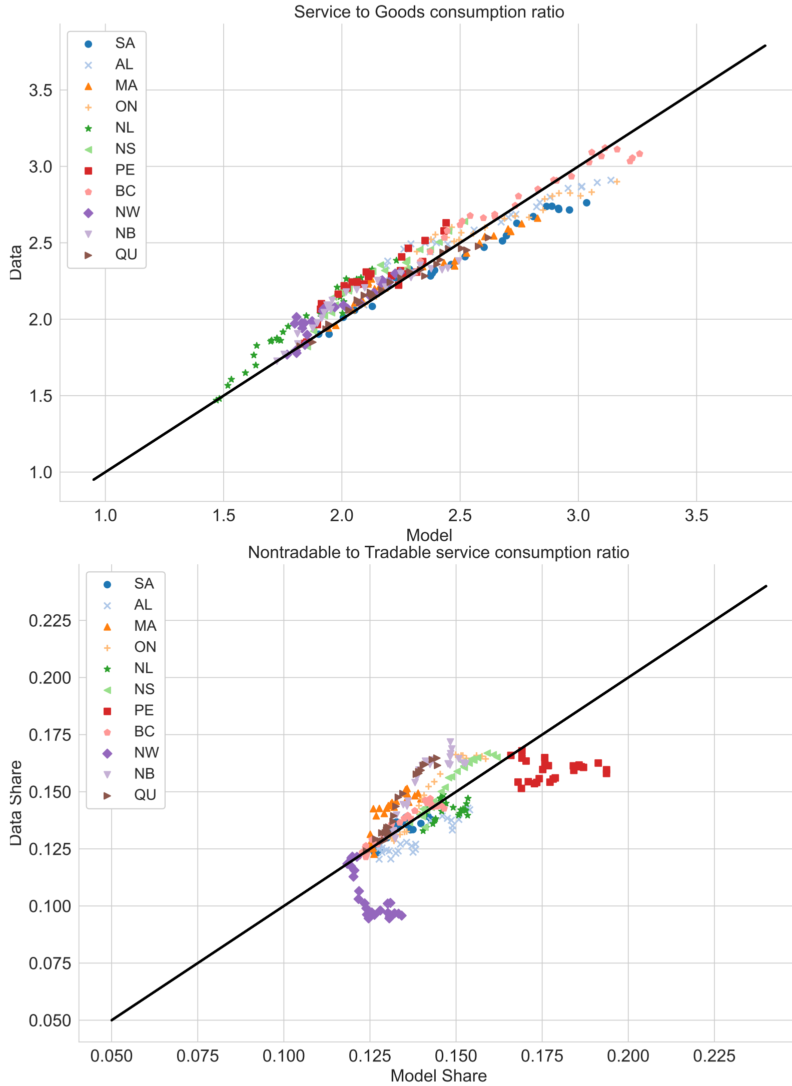


FIGURE 3 – Model fit for consumption ratio

to tradable services consumption ratio in Prince Edward Island and Northwest Territories & Nunavut is decreasing over time. However, our regionally homogeneous preference parameters will generate an increasing pattern on the non-tradable-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. Given the calibrated preference parameters, we can impute the model-implied sectoral price for each province.[18] Figure 4

[18]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 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.

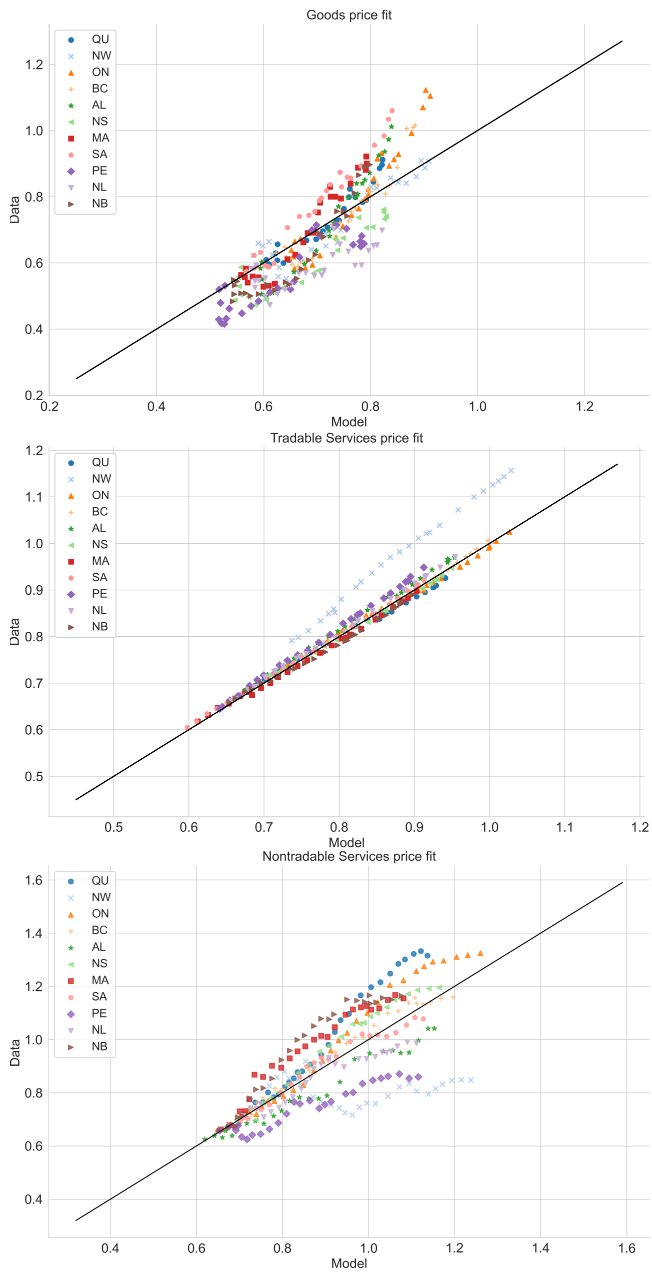


FIGURE 4 – Model fit for untargeted sectoral prices

illustrates how well the calibrated 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 & Nunavut in the middle and lower panel is mainly due to its large deviation between the model and data non-tradable-to-tradable consumption ratio. Overall, our model can closely match the variables that are not directly matched in the data.

4.2 Production parameters

We calibrate production parameters $\lambda_{i,k}, \gamma_{i,k,n}$ using Canadian input-output tables at the provincial level. From firms' maximizing conditions, under Cobb-Douglas technologies, the production parameters have a direct empirical counterpart.

Formally, $\lambda_{i,k}$ denotes the ratio of nominal value-added to gross output and $\gamma_{i,k,n}$ measures the share of sector n goods on intermediates inputs for the production in sector k. Due to the data limitation, provincial input-output tables are available only from 2004 to 2017 annually. We construct the time-invariant $\lambda_{i,k}$ and $\gamma_{i,k,n}$ by taking the average across these years for each province. This is feasible as the time-series variation within each province is negligible.

Mean values of production parameters as well as their maximum and minimum are reported in Table 5. There is huge heterogeneity in production shares across provinces, especially for $\lambda_{i,g}$, where New Brunswick uses goods intermediates more intensively, indicated by $\lambda_{i,g} = 0.27$. We find that those provinces with a higher value-added share in the good sector generally have a higher $\lambda_{i,g}$ than other services-intensive provinces. Furthermore, those goods-intensive provinces utilize more services to produce goods, with a higher $\gamma_{i,g,sm}$ 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 positive domain.

4.3 Production efficiency and trade costs

Production efficiency $T_{i,t}^k$ and trade costs $\tau_{i,j,t}^k$ are calibrated using the bilateral trade flows and sectoral prices. We impute technology $T_{i,t}^k$ from measured productivity $A_{i,t}^k$ and plot the Canada and RoW results in Figure A.3 and A.4 in Appendix. $A_{i,t}^k$ 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:

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

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
$\lambda_{i,g}$	Value-added share in gross output for Goods	0.41	0.52	0.27
$\lambda_{i,sm}$	for Tradable Services	0.62	0.65	0.59
$\lambda_{i,sn}$	for non-tradable Services	0.63	0.68	0.55
$\gamma_{i,g,g}$	Share of intermediate inputs sourced from Goods to Goods	0.71	0.82	0.60
$\gamma_{i,g,sm}$	from Trad. Services to Goods	0.28	0.37	0.17
$\gamma_{i,g,sn}$	from Nontrad. Services to Goods	0.01	0.03	0.009
$\gamma_{i,sm,g}$	from Goods to Trad. Services	0.26	0.33	0.21
$\gamma_{i,sm,sm}$	from Trad. Services to Trad. Services	0.69	0.74	0.63
$\gamma_{i,sm,sn}$	from Nontrad. Services to Trad. Services	0.04	0.05	0.04
$\gamma_{i,sn,g}$	from Goods to Nontrad. Services	0.29	0.33	0.25
$\gamma_{i,sn,sm}$	from Trad. Services to Nontrad. Services	0.43	0.49	0.40
$\gamma_{i,sn,sn}$	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:

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

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

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

where $\pi_{i,i,t}^k$ denotes province i's absorption ratio in sector k, which equals to 1 in a closed economy.

To calibrate trade costs, we target the observed sequence import shares in the data. Combining equations 3.3 and 3.4, we can solve for trade cost as a function of relative import shares and relative sectoral prices:

$$\tau^k_{i,j,t} = \left(\frac{\pi^k_{i,j,t}}{\pi^k_{j,j,t}}\right)^{-\frac{1}{\theta}} \left(\frac{P^k_{i,t}}{P^k_{j,t}}\right). \tag{4.13}$$

We use Equation 4.13 to back out trade costs $\left\{\tau^k_{i,j,t}\right\}$, at every period, such that the model implied import shares $\left\{\pi^k_{i,j,t}\right\}$, given prices, exactly match the observed import shares $\left\{\hat{\pi}^k_{i,j,t}\right\}$.

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 exports construction

To measure model-implied sectoral net exports, we require data on consumption expenditure, input-output coefficients and the import expenditure share $\pi^k_{i,j,t}$, where $k \in \{g, sm\}$. [19] Figure 5 depicts the model fit of sectoral net export share, which is measured by the ratio of sectoral net exports to total value-added for each province. The reasons why the benchmark model closely matches the net export share data are twofold. First, the model import expenditure share $\pi^k_{i,j,t}$ is calibrated to match exactly that from the data. Second, our estimated demand system generates model-implied sectoral consumption expenditure that fits the data quite well (Figure 4).

4.4.2 Value-added construction

As in Uy, Yi and Zhang (2013), we obtain model-implied sectoral value-added using Equation 4.14.[20] This equation expresses the sectoral value as a function of the sectoral expenditure $E^k_{i,t}$ and net exports $NX^k_{i,t}$. Given that expenditure and net exports are expressed in gross-

[19]Formally, we take the following steps: We solve for sectoral total absorption $P^k_{i,t}Q^k_{i,t}$ using the production equilibrium equations C.13 and C.19 in Appendix C.3 along with data on sectoral consumption expenditure. We then compute the model-implied net exports from Equation C.14 in Appendix C.3, using data on import shares $\pi^k_{i,j,t}$.

[20]Details of the proof are shown in Appendix C.3.

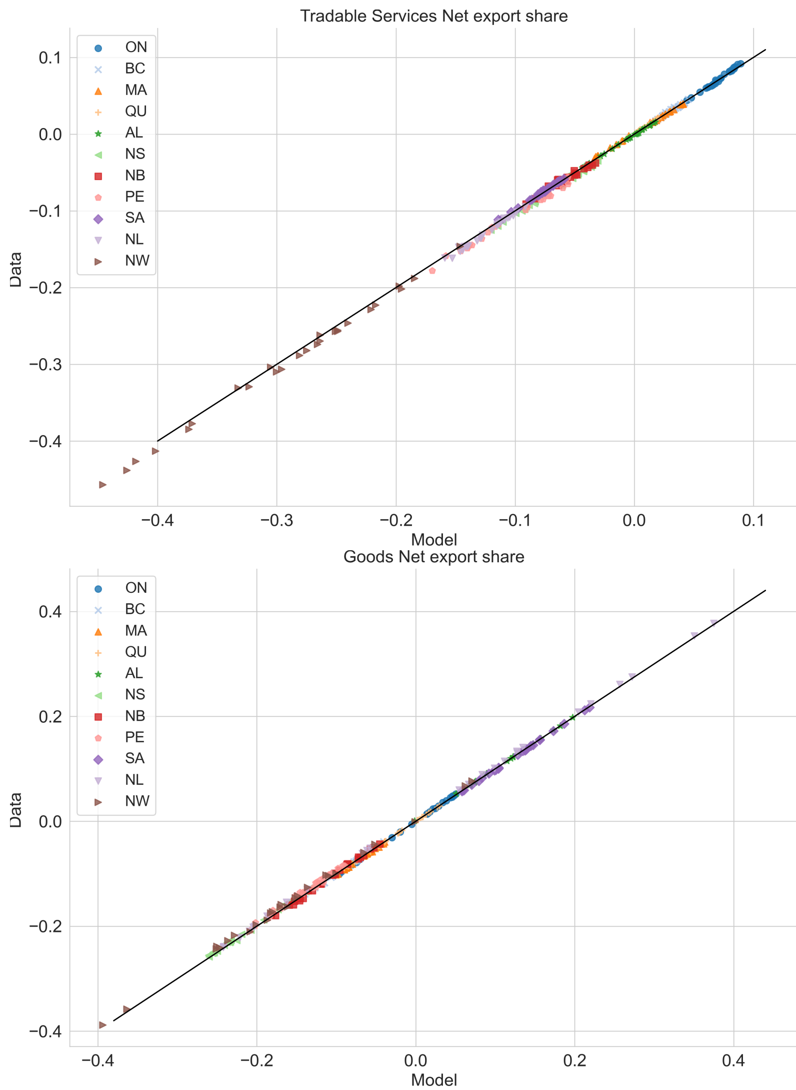


FIGURE 5 – Model fit for sectoral net export share

output terms, Equation 4.14 properly weights them by provincial input-output coefficients (value-added content).

Note that the sectoral expenditure $E_{i,t}^{k}$ refers to final absorption, which includes consumption expenditure $P_{i,t}^{k}C_{i,t}^{k}$, investment $I_{i,t}^{k}$ and government spending $G_{i,t}^{k}$. The expenditure-based Canadian GDP data from Statistics Canada provides us with the investment and government 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 1992-2017 with the sectoral investment and government spending shares from annual provincial input-output tables. While there is significant cross-province variation in sectoral share of investment and government spending, time variation within a 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

$$\begin{bmatrix} VA^{g}_{i,t} \\ VA^{sm}_{i,t} \\ VA^{sn}_{i,t} \end{bmatrix} = \Omega^{-1} \begin{bmatrix} E^{g}_{i,t} \\ E^{sm}_{i,t} \\ E^{sn}_{i,t} \end{bmatrix} + \Omega^{-1} \begin{bmatrix} NX^{g}_{i,t} \\ NX^{sm}_{i,t} \\ 0 \end{bmatrix}, \tag{4.14}$$

where

$$E^{k}_{i,t} = P^{k}_{i,t} C^{k}_{i,t} + I^{k}_{i,t} + G^{k}_{i,t}, \quad k \in \{g, sm, sn\}.$$

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 specializing in the sectors they have a comparative advantage. 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 a 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 domestic and international trade in 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. A 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.4.

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_{sm}/P_{sn} and P_{sm}/P_g, international net export 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-homotheticities 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, non-tradable services are luxuries relative to tradable services. Hence, the reallocation of demand from non-tradable services to goods mitigates the negative income effect on tradable services consumption expenditures.

In Columns 2 and 3 of Table 6, we show that the price of tradable services relative to non-tradable services and goods rises 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 increases. The implications for consumption expenditure shares show that the negative income effect and the positive price effect cancel each other. Indeed,

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

Average change (%) over 1992-2017	C (1)	P_{sm}/P_{sn} (2)	P_{sm}/P_{sn} (3)	PC_{sm}/PC (4)	NX_{sm}/VA (5)	VA_{sm}/VA (6)
	No Domestic Service Trade					
Canadian Provinces						
Quebec	-6.4	3.9	3.8	-0.4	0.7	0.4
Northwest Territories & Nunavut	-25.1	20.3	25.7	-1.5	16.3	28.7
Ontario	-8.5	2.4	0.3	-1.2	-4.1	-5.6
British Columbia	-6.3	3.8	3.8	-0.3	0.6	0.3
Alberta	-7.8	5.0	5.2	-0.4	2.1	2.6
Nova Scotia	-6.1	6.9	9.3	0.5	5.7	7.1
Manitoba	-12.3	7.2	6.5	-1.1	0.1	-1.0
Saskatchewan	-9.5	9.7	11.7	0.3	8.1	14.6
Prince Edward Island	-8.6	11.2	14.8	1.1	9.2	13.7
Newfoundland and Labrador	-7.1	10.3	13.8	1.1	11.0	24.3
New Brunswick	-9.0	9.2	11.6	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.

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 exports 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 (e.g. 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

TABLE 7 – Percentage change (%) on different channels with absence of international service trade

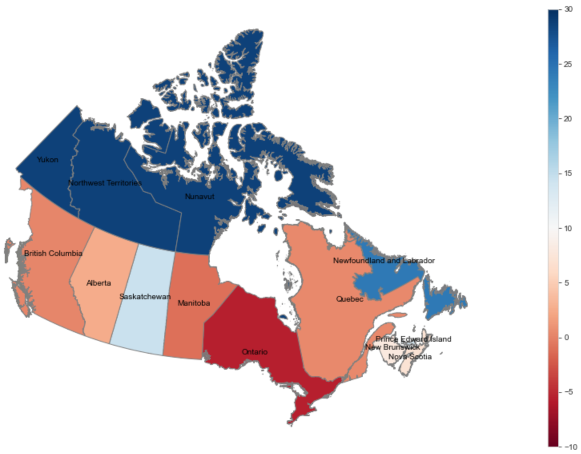
Average change (%) over 1992-2017	C (1)	P_{sm}/P_{sn} (2)	P_{sm}/P_{sn} (3)	PC_{sm}/PC (4)	NX_{sm}/VA (5)	VA_{sm}/VA (6)
	No International Service Trade					
Canadian Provinces						
Quebec	-5.6	1.9	1.0	-0.8	-2.2	-3.7
Northwest Territories & Nunavut	-7.0	1.6	1.3	-1.2	-3.1	-7.6
Ontario	-6.6	2.6	1.6	-0.7	-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	-0.2	-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 the benchmark.

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 due to the lack of heterogeneity in international service trade share. Thus, absent of international service trade, most provinces lose their real income similarly. In addition, higher tradable services price rises the relative price



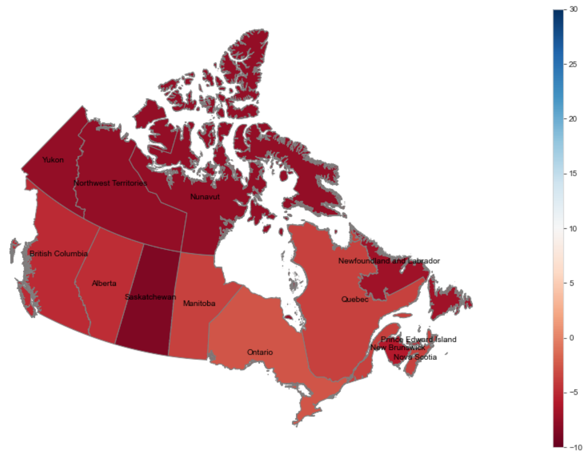


FIGURE 6 – Average percentage change (%) in tradable service VA share with absent domestic (left) and international (right) service trade

and brings about a positive price effect due to the complementarity, as shown in Columns 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 the tradable service sector, which leads to a lower consumption expenditure share of tradable services.

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-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 of 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 good trade, at both inter-provincial and international levels.

Domestic service trade

The average welfare gains from domestic service trade are shown in Column 1 of Table 8. All provinces experience welfare gains above 5%, with the national average welfare 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 of welfare gain from domestic services is higher than those of domestic good trade and international service trade.

To understand the source of heterogeneous 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 the GDP ratio. This implies that the extent of the welfare gains is closely related to that of regional specializations. We also note that imports have a higher correlation than exports. An example of this case 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.

As highlighted in the last row of Table 8, domestic service trade plays a significant role in decreasing real wage disparities in Canada. While the volume of domestic service trade is comparable to that of domestic good trade and one-third of international good trade (Table 1), when it comes to reducing regional disparities, the impact of domestic service trade

Table 8 – Welfare gains from domestic and international trade

Provinces	Domestic trade		International trade	
	Services	Goods	Services	Goods
	(1)	(2)	(3)	(4)
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	0.19
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
Average welfare gain	0.07	0.07	0.05	0.14
S.D. of welfare gain	0.05	0.03	0.01	0.05
Change in S.D. of log real wage	-0.17	-0.04	-0.02	-0.12

Notes: The results in each column are obtained by comparing the benchmark and the counterfactual where domestic or international trade in services or goods is absent. The first 11 rows reports the change in welfare for each province. The 12th row shows the average welfare gain, which is the weighted average of each province's change in welfare, where the number of the labor force in each province is used for the weight. The 13th row shows the standard deviation of the change in welfare across provinces. The last row shows the change in the standard deviation of log real wage across provinces. The weights were not applied for the standard deviation calculations in order to highlight regional heterogeneity.

is much greater. The reason stems from the distribution of comparative advantage across Canadian provinces. Those poor provinces are the ones with comparative disadvantages in tradable services production. The presence of service trade, especially domestic trade, reduces the price of tradable services more for these provinces. This fact is evident from the relative price changes seen in Columns 2 and 3 of Table 6, in which smaller provinces, such as Northwest Territories & Nunavut and Prince Edward Island, experience large rises in the relative price of tradable services when domestic trade in services is absent. As a whole Canada, domestic service trade reduces the standard deviation of log real wages

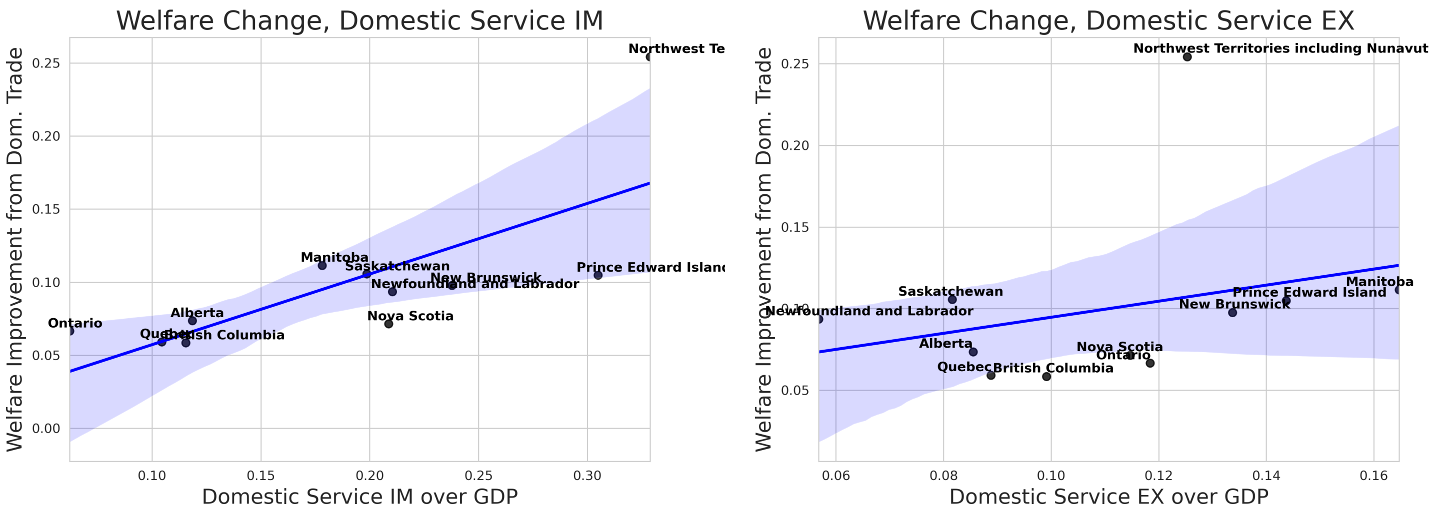


FIGURE 7 – Scatter plot of average welfare gains from domestic service trade against import (IM) or export (EX) share

across provinces by 17% as shown in Table 8.[21][22]

International service trade

Column 3 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 good trade, welfare gains through international service trade only amount to 40% of the gains obtained from good 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 good 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 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

[21] Our finding that smaller provinces benefit more from trade is analogous to that in Eaton and Kortum (2002) that smaller countries benefit more from trade.

[22] We also compute the top-bottom wage differentials across provinces to check the robustness of the result. The top-bottom wage differentials is reduced by 23% with domestic service trade.

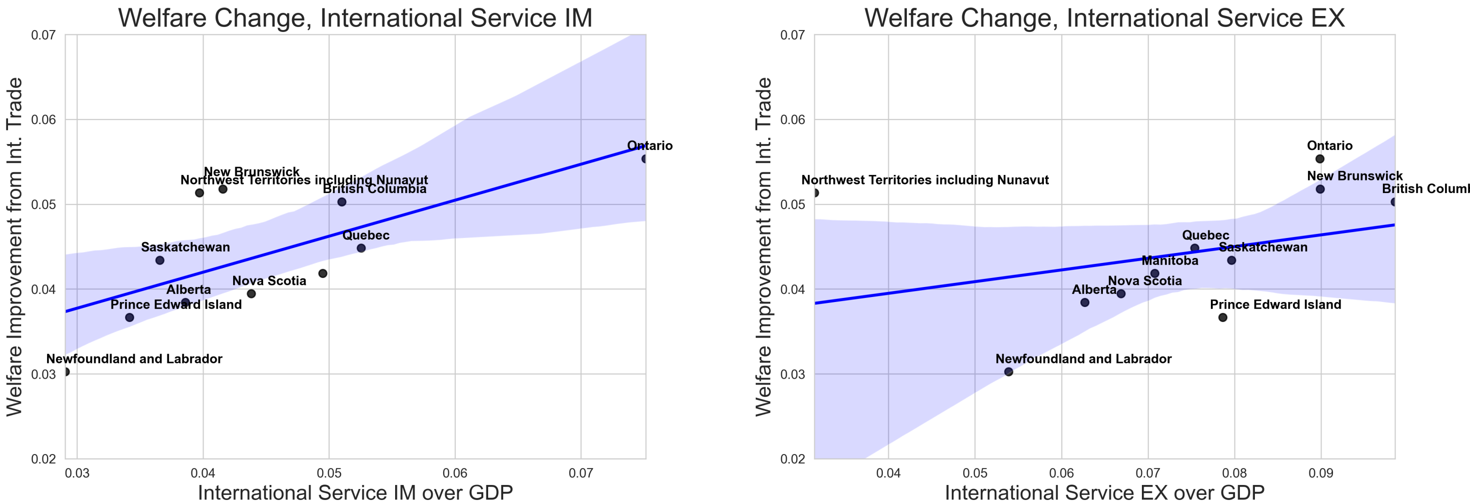


FIGURE 8 – Scatter plot of average welfare gains from international service trade against import (IM) or export (EX) share

the volume of international service trade flows is lower than that of domestic service trade, as seen in Table 1 previously.

5.4 Service trade and structural transformation in Canada

In this section, we analyze how service trade affected the structural transformation of Canadian economy. We show that, despite the great impacts on regional specialization, domestic and international service trade had little effect on the trend of sectoral value-added shares in Canada during the period 1992–2017.[23]

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 on domestic service trade, with a slight decrease in the tradable service value-added share.

Why does domestic trade have significant impacts neither on the trend nor the level of

[23]During this period, we observe only a mild reallocation of sectoral activity in Canada. Figure A.2 in Appendix A 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%.

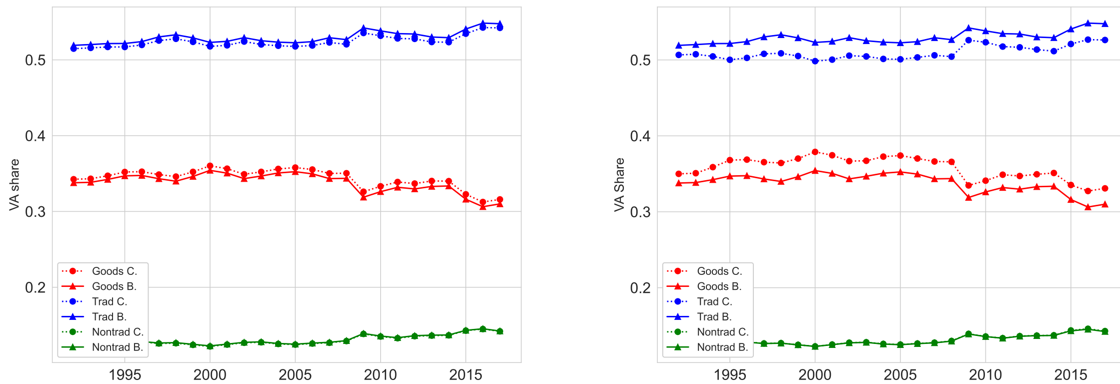


FIGURE 9 – Sectoral VA share with absent domestic and international service trade

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 on tradable service share. 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 when taken as a whole for Canada. If a province is a net exporter of services, the income effect tends to be stronger due to expansion in production. On the other hand, the price effect is stronger if the province is a net importer of services, since those with comparative disadvantages could have more productivity gains through the Ricardian effect. As a whole Canada, these two forces cancel each other. In Appendix A, we conduct further analysis to break down the mechanism into the income effect and price effect. Figure A.6 in Appendix A 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 tradable services value-added share 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 in Appendix A illustrates 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 impacts 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 implications for regional production specialization and welfare. We use unique Canadian data on domestic and international trade in goods and services to show that: First, trade in services, especially domestic trade, is comparable to trade in goods. Second, there is significant regional specialization in the production of tradable services across provinces. And, third, provinces with greater service net exports to GDP ratio display a larger value-added share of tradable services.

Based on these empirical findings, we study the impact of domestic and international trade in services on regional specialization and welfare, using a multi-regional, multi-sector model with non-homothetic preferences. We show that the impact of trade in services is significant. In particular, the effects of domestic trade in services on welfare are as important as that of domestic trade in goods. We also find that regional welfare gains from trade in services are much more heterogeneous than those from trade in goods. Our results highlight that domestic service trade can mitigate regional disparities by allowing smaller and relatively less productive provinces to access cheaper tradable services and to specialize in their comparatively-advantaged sector. We belive that these findings have important implications for the discussions on regional wage disparities and redistribution 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 non-tradable services using imports plus exports per worker in each industry. Mian and Sufi (2014) uses four-digit NAICS industries, while the industries present in the 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.

Table A.2 – Sectoral trade (imports plus 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 non-tradable services. Column "Total" reports the ratio of total imports plus total exports to gross output of each industry, which can be summed up 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.

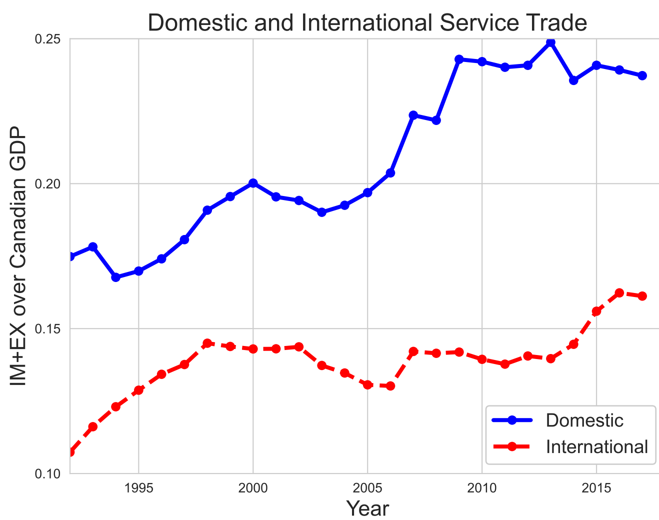

Figure A.1 – Domestic (inter-provincial) and international service trade as a fraction of GDP, 1992–2017, Canada

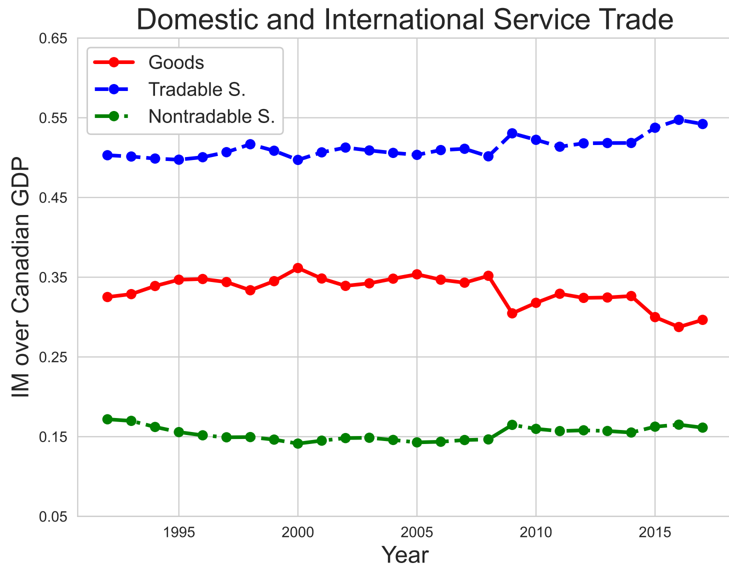

FIGURE A.2 – Structural transformation,1992–2017, Canada

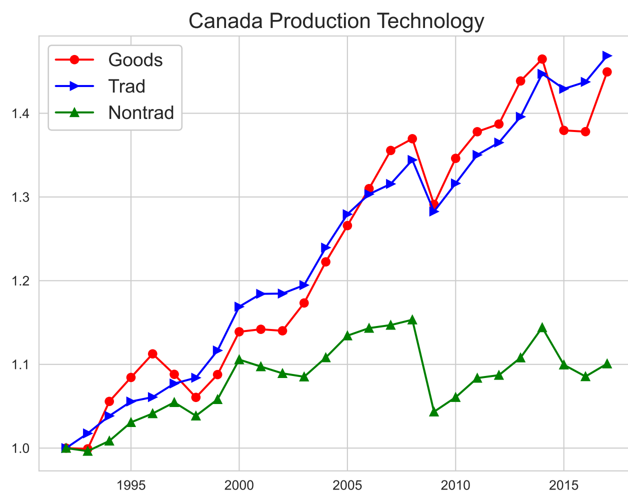

FIGURE A.3 – Sectoral production efficiency (T_i^k), 1992–2017, Canada

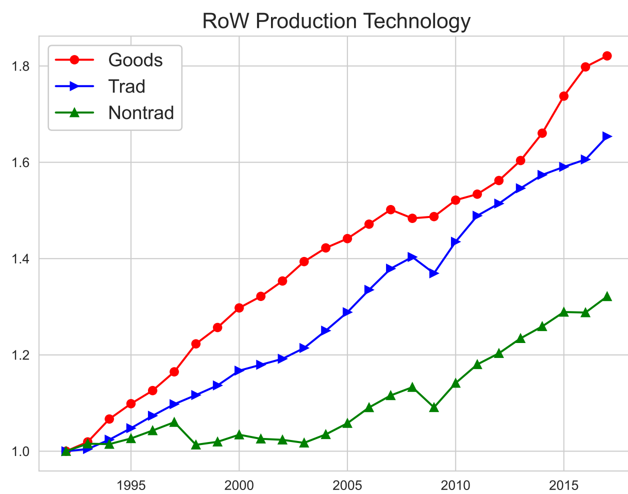

FIGURE A.4 – Sectoral production efficiency (T_i^k), 1992–2017, the rest of the world (RoW)

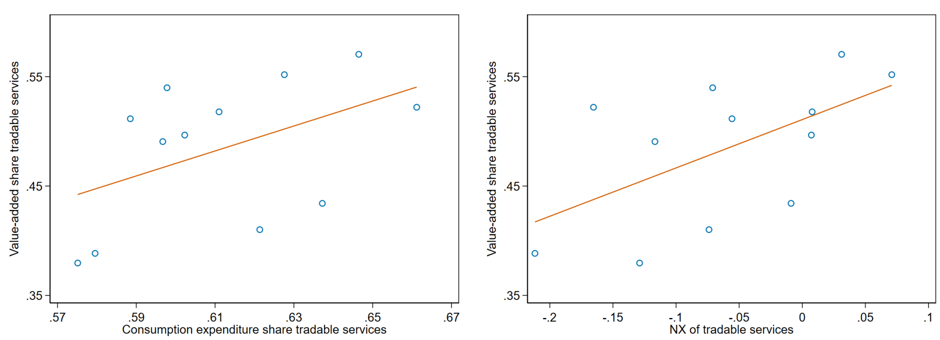

FIGURE A.5 – VA share, consumption expenditure, and net exports of tradable services

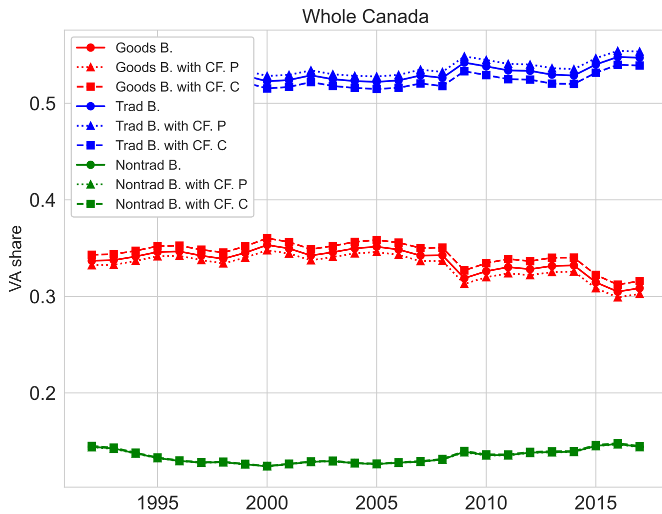

FIGURE A.6 – Income and price effect on sectoral VA share with absent domestic service trade

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_i^k) at the baseline model level and alter the real income values to the case without domestic service trade.

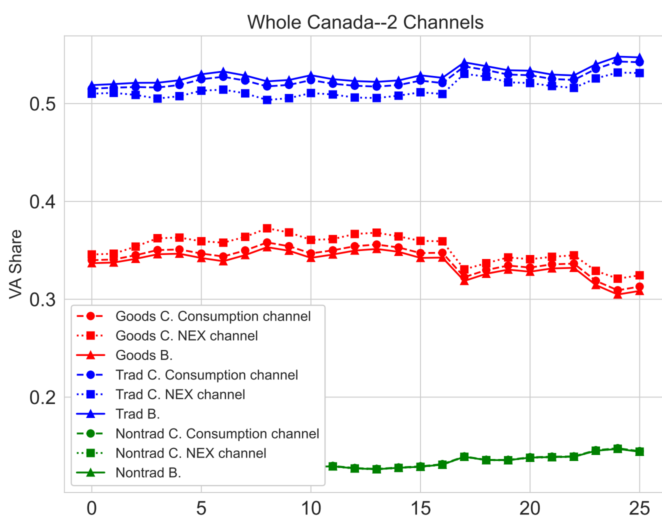

FIGURE A.7 – Consumption and net export channel on sectoral VA share with absent international service trade

Notes: To assess the impact of consumption expenditure in shaping structural transformation, we maintain the net exports at the same level as the baseline model and only adjust the consumption expenditure to the case with the 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 changing the net exports to the case with the absence of international service trade.

B Data

This section describes the strategies for classification and data cleaning. Broadly speaking, we need (a) Canadian bilateral trade flows at inter-provincial and international levels; (b) value-added data in current and constant prices for Canadian provinces and the rest of world; (c) consumption expenditure data in current and constant prices for Canadian provinces; (d) sectoral labor endowment by province in Canada and by country in the rest of worldïŒ (e) coefficients from the provincial input-output matrix; (f) provincial investment and government expenditure data. Web links to data sources are documented in the footnotes.

B.1 Classification

Given the various data sources used in this paper, we are not able to rely on a single classification system for sector aggregation. Generally, we consolidate industries 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) The value-added and employment endowment data in Canada are documented based on NAICS. We take goods/tradable services/non-tradable service sectors in Canada as a collective of 19 sub-sectors. Details of NAICS are listed in Table B.3.[24]

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

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
Non-tradable Services	61	Educational services
	62	Health care and social assistance
	81	Other services (except public administration)

International Standard Industrial Classification System (ISIC) Nominal value-added and employment databases for the rest of the world are measured based on ISIC system. We obtain data that are based on ISIC Rev.4 system for years over 2005-2015, while data for other years contain industry 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 sub-sectors at higher levels. Code numbers for sub-sectors in both Revisions are the same.[25] We list details of ISIC sub-sectors in Table B.4.

[25]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
Non-tradable 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 and consumption expenditure data from 1992 to 2017 are classified according to IOCC system. [26] Different from NAICS and ISIC systems, IOCC system is a product classification rather than an industry classification. Because of the wide diversity of products, the classification structure of IOCC is built at a more detailed level. We provide the IOCC's sectoral details in Table B.5.

[26] Due to data limitations, we do not make sectoral disaggregation for years prior to 2007. See section B.2.1 for more details.

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
	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
Non-tradable Services	M61_	Educational services
	M62_	Health care and social assistance
	M81_	Other services (except public administration)

B.2 Canada

B.2.1 International & inter-provincial trade flows

Derivation on Canadian trade flows since the late nineties was described in detail in Généreux and Langen (2002). In general, Canadian trade flow measures are constructed in two steps. First, raw inter-provincial and international trade flows are collected from various administrative statistics. The measures of inter-provincial trade are obtained from Commodity Surveys for the origin and destination of sales. The international data are primarily sourced from Canadian International Merchandise Trade and Canadian Balance of International Payments. However, such trade patterns may not be consistent with the concept required by the inter-provincial and international trade flows. Hence, in the second step, these trade patterns are adjusted to reconcile with provincial supply and demand from the input-output tables. Finally, trade flows, both inter-provincially and internationally, are adjusted to be entirely in accord with the Canadian national account data.

We take trade data from following three sources:

(a) International & inter-provincial trade flows from 1992–1996,[27]

(b) International & inter-provincial trade flows from 1997–2006,[28]

(c) International & Inter-provincial trade flows from 2007–2017.[29]

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 those 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 comprehensive and robust surveys. We then connect data from the source (a) to obtain trade flows over the period 1992–2017. Specifically, for the years from 1992–1996, we first calculate the annual growth rate of trade flows of each province. We then impute the trade flows prior to 1997 backward using the annual growth rate and the trade value in 1997.

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

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

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

Note that missing values exist in trade flows from source (a). For example, international exports at the sectoral level missing in Quebec for the period 1992–1996. To deal with this issue, we compute the international good and service export ratio in Quebec in 1997. We then multiply the ratio by total international exports and fill in missing values for goods and services prior to 1997. A shortcoming of this strategy is that we assume the constant good-to-service trade ratio over this period. If the trade value is missing in year 1997 of source (a), we will impute the value using the 1996–1997 growth rate from the Statcan Inter-provincial and International Trade 1992–1998 handbook.[30]

B.2.2 Other data except trade flows

Nominal value-added We obtain nominal value-added data in Canada from three sources:

(a) Value-add at current price from 1992–1996,[31]

(b) Value-add at current price from 1997–2017,[32]

(c) National nominal GDP index from 1992–2017,[33]

To begin with, we collect 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 value-added shares 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 backward for the period of 1992–1996.

There are missing values in source (a), for which we've employed specific strategies: We first address these gaps through linear interpolation between the years for which data is available. The interpolation strategy is applied to the missing values in sectors 54 and 71, as detailed in Table B.3. In instances where linear interpolation is not feasible, we extrapolate the sectoral value-added data for years preceding 1997 by using the growth rate of the national GDP index across various sectors. We resort to this method with caution,

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

[31] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610039601

[32] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610040201

[33] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610020801

as it might not capture the provincial heterogeneity in the value-added growth rate. This extrapolation strategy is utilized for sectors 21, 48-49, and 53, as seen in Table B.3.

Real value-added We take real value-added data from two sources:

(a) Value-added at constant price at provincial level from 1997–2017,[34]

(b) National real GDP index from 1992–2017.[35]

To construct Canadian real value-added data, we rely on source (a) and obtain the industry-province-specific real value-added for 1997–2017. Given that provincial real value-added data only starts from 1997, we apply the national real value-added index for the period 1992–1996. The national real value-added index is a chained Fisher quantity index (QI) of GDP with the base year of 2012. [36] We iterate forward and backward to solve for the annual series of real value-added in 2012 U.S. dollars, applying the implied growth rate from QI across sub-sectors. 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 sub-sector price indexes by taking the division of national nominal and real value-added. By assuming a homogeneous price index across provinces, we impute the provincial real value-added growth rate for 1992–1996 using provincial nominal value-added and national price indexes. The growth rate enables us to extrapolate the sub-sector 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), using the computation process as follows:

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

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

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.

[34] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610040201
[35] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610021701
[36] As QI for 1992–1996 is missing in the education services sector, we impute backward using the 1997–1998 growth rate of QI.

Consumption expenditure Consumption expenditure data come from the following sources:

(a) Provincial detailed household final consumption expenditure 1992–2017,[37]

(b) Inter-city indexes of price differentials of consumer products,[38]

(c) GGDC productivity level database.[39]

We collect annual household final consumption expenditure from source (a), in both current and constant 2012 prices. The data sum all sales at the 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 non-tradable services based on IOCC product classification system. The construction of real sectoral consumption follows the same strategy as that of real value-added. To be consistent with the 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 the sectoral consumption price index for each province each year. We then rely on source (b) and (c) to make prices comparable across Canadian provinces and sectors. Specifically, we first use the inter-city price index in source (b) to adjust the aggregate price differentials across Canadian provinces. The city-index data provides the price index across all provincial capitals at aggregate-items level. We then 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 the sectoral level using the nominal value-added weight. Finally, we apply these sectoral differentials to the consumption price index, which makes it comparable both provincially and sectorally.

Employment and wage Employment data is collected from the following source:

(a) Canadian employment data across industries from 1992–2017.[40]

We rely on employment data in the Statcan Labour Force Characteristics Table as our measure of labor endowment. The data provides the number of workers engaged in labor market activities across different sectors over the period of 1992–2017. NAICS classification

[37] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610022501
[38] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000301
[39] https://www.rug.nl/ggdc/productivity/pld/?lang=en
[40] https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1410002301

system makes it consistent with the sectors in nominal value-added data. Thus, we can simply compute a sectoral wage as the ratio of nominal value-added to labor endowment.

Input-output matrix The input-output table comes from:

(a) Provincial input-output ables in Canada 2004–2017.[41]

We rely on Canadian input-output tables to compute both input-output coefficients and value-added to gross output ratios at the 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 the 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 k. 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.

Investment and government expenditures We gather provincial investment and government expenditures for each year from following sources:

(a) Provincial gross domestic product, expenditure-based,[42]

(b) Provincial input-output tables in Canada.[43]

We utilize the provincial GDP by expenditure accounts to further decompose final domestic demand into household, investment and government sectors. By aggregating the expenditure-based GDP across final users, we are able to impute the sectoral value-added for each province using Equation (4.14). It is important to note that the expenditure GDP data is measured on the aggregate level, without breaking down into sectors. Hence, we rely on the symmetric final demand sections in provincial input-output tables for investment and government expenditures at the sectoral level. We calculate the proportion of demand stemming from all industries. This encompasses household expenditures, inventory withdrawals, and government institutions' expenditures. Hence, this final demand share enables us to impute the provincial government and investment expenditures across sectors.

[41] https://www150.statcan.gc.ca/n1/en/catalogue/15-211-X
[42] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610022201
[43] https://www150.statcan.gc.ca/n1/en/catalogue/15-211-X

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 the following data sources to construct nominal and real value-added for the rest of the world:

(a) UN value-added by industries at current prices (ISIC Rev. 3),[44]

(b) UN value-added by industries at constant prices (ISIC Rev. 3),[45]

(c) UN value-added by industries at current prices (ISIC Rev. 4),[46]

(d) UN value-added by industries at constant prices (ISIC Rev. 4),[47]

(e) IMF based exchange rate.[48]

For nominal value-added construction, source (a) from UN statistics division serves as the baseline data. The data provide a detailed breakdown at the sub-sector level for most countries available from the 1970s to 2010s while missing data records for most countries after then. We use source (c) to impute missing sub-sectoral nominal value-added in the rest of the 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 a baseline, these growth rates enable us to complete the nominal value-added for 22 countries over 1992–2017 through backward iteration.[49] Within each source, national account statistics were compiled following different time-series versions. We treat the 1993 SNA national accounts methodology as the baseline and connect with the growth rate of sub-sectoral value-added under the 1968 SNA and 2008

[44] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a201

[45] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a202

[46] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a204

[47] https://data.un.org/Data.aspx?q=value+added&d=SNA&f=group_code%3a204

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

[49] 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 service 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 the same rate in Saudi Arabia.

SNA framework. Finally, given that data is recorded in national currency in sources (a) and (c), we convert the sectoral nominal value-added into US dollar measures using source (e).

Following the same strategy in Canadian real value-added construction, we construct the RoW real value-added using the Tornqvist index and select 2012 as the base year.

Employment and Wages Employment data is collected from the following source:

(a) ILO employment data from 1992–2017.[50]

We collect country-sector specific employment data from ILO database. We aggregate up sectoral nominal value-added and sectoral employment endowment across countries. Same with Canada, the wage for workers in the 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; (d) counterfactual strategy. In this section, we suppress the time subscript t for simplicity.

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

$$\sum_k \omega_k^{\frac{1}{\sigma}} \left(\frac{C_i^k / L_i}{g\left(C_i/L_i\right)^{\phi_k}} \right)^{\frac{\sigma-1}{\sigma}} = 1, \tag{C.1}$$

where ω_k denotes the relative weight of consumption bundle in sector k; C_i^k is the real consumption index for sector k in region i; C_i is the real aggregate consumption index, which measures the aggregate utility for C_i^k across sectors; $g\left(.\right)$ is a differentiable, monotonically

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

increasing function; σ is the elasticity of substitution and ϕ_k controls the relative income effect.

Standard CES utility function is a special case when $g(C_i) = C_i$. Following Duernecker, Herrendorf and Valentinyi (2023), we assign $\phi_k = (\sigma - \epsilon_k) / (\sigma - 1)$ so that we can separate out income effect substitution effect in the household optimization problem. We can then rewrite Equation (C.1) as:

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

Taking account of (C.2) and the budget constraint, we can define a household Lagrangian that is essentially the same with Sposi (2019) and Comin et al. (2021). For the outer layer encompassing two sectors, goods and services, let σ_g represent the elasticity of substitution between goods and services, and let P_i denote the aggregate price index for region i. The outer layer Lagrangian becomes:

$$\mathcal{L} = \frac{C_i}{L_i} - \rho \left[\sum_{k \in \{g,s\}} \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_i^k}{L_i} \right)^{\frac{\sigma_g - 1}{\sigma_g}} \left(\frac{C_i}{L_i} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}} - 1 \right] - \lambda \left[P_i C_i - \sum_{k \in \{g,s\}} P_i^k C_i^k \right].$$

The first order condition with respect to C_i^k results in:

$$-\rho \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_i^k}{L_i} \right)^{\frac{\sigma_g - 1}{\sigma_g} - 1} \left(\frac{\sigma_g - 1}{\sigma_g} \right) \left(\frac{1}{L_i} \right) \left(\frac{C_i}{L_i} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}} - \lambda P_i^k = 0,$$

Then we have:

$$\left(\frac{\sigma_g}{1 - \sigma_g} \right) \frac{\lambda P_i^k C_i^k}{\rho} = \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_i^k}{L_i} \right)^{\frac{\sigma_g - 1}{\sigma_g}} \left(\frac{C_i}{L_i} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}}.$$

Taking summation on both sides of the equation across sectors gives:

$$\left(\frac{\sigma_g}{1 - \sigma_g} \right) \frac{\lambda}{\rho} = \frac{1}{P_i C_i}. \tag{C.3}$$

From the above, the following equation can be derived:

$$P_i^k C_i^k = \omega_k^{\frac{1}{\sigma_g}} \left(\frac{C_i^k}{L_i} \right)^{\frac{\sigma_g - 1}{\sigma_g}} \left(\frac{C_i}{L_i} \right)^{\frac{\epsilon_k - \sigma_g}{\sigma_g}} P_i C_i. \tag{C.4}$$

Next, we have:

$$P_i^k C_i^k = L_i \omega_k \left(\frac{C_i}{L_i}\right)^{\epsilon_k} \left(\frac{P_i^k}{P_i}\right)^{1-\sigma_g} P_i, \qquad k \in \{g, s\}. \tag{C.5}$$

Substituting (C.5) into the budget constraint yields:

$$P_i C_i = \sum_{k\in\{g,s\}} L_i \omega_k \left(\frac{C_i}{L_i}\right)^{\epsilon_k} \left(\frac{P_i^k}{P_i}\right)^{1-\sigma_g} P_i. \tag{C.6}$$

Finally, we get the aggregate price index:

$$P_i = \left[\sum_{k\in\{g,s\}} \omega_k \left(\frac{C_i}{L_i}\right)^{\epsilon_k - 1} (P_i^k)^{1-\sigma_g}\right]^{\frac{1}{1-\sigma_g}}. \tag{C.7}$$

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

$$P_i^k C_i^k = L_i \omega_k \left(\frac{C_i}{L_i}\right)^{\epsilon_k} \left(\frac{P_i^k}{P_i}\right)^{1-\sigma_s} P_i^s, \qquad k \in \{sm, sn\}, \tag{C.8}$$

$$P_i^s = \left[\sum_{k\in\{sm,sn\}} \omega_k \left(\frac{C_i}{L_i}\right)^{\epsilon_k - 1} (P_i^k)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}}. \tag{C.9}$$

Therefore, the solution algorithm starts from the inner layer of household problem. Equation (C.9) enables us to calculate P_i^s using P_i^{sm} and P_i^{sn} from data. We then solve out the aggregate price index P_i by substituting P_i^s into Equation (C.7).

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 $k \in \{g, sm, sn\}$:

$$Y_i^k = A_i^k (L_i^k)^{\lambda_{i,k}} \left[\prod_{n=g,sm,sn} \left(M_i^{k,n}\right)^{\gamma_{i,k,n}}\right]^{1-\lambda_{i,k}},$$

where A_i^k is the average measured gross output TFP. The first order condition for immediate inputs that are sourced from n gives:

$$P_i^n M_i^{k,n} = (1-\lambda_{i,k})\gamma_{i,k,n} P_i^k Y_i^k.$$

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

$$Y_i^k = A_i^k (L_i^k)^{\lambda_{i,k}} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{i,k,n}}{P_i^n}\right)^{\gamma_{i,k,n}} \left[(1-\lambda_{i,k})P_i^k Y_i^k\right]^{\gamma_{i,k,n}} \right]^{1-\lambda_{i,k}}.$$

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

$$Y_i^k = A_i^{k\,\frac{1}{\lambda_{i,k}}} L_i^k \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{i,k,n}}{P_i^n}\right)^{\gamma_{i,k,n}} \left[(1-\lambda_{i,k})P_i^k\right]^{\gamma_{i,k,n}} \right]^{\frac{1-\lambda_{i,k}}{\lambda_{i,k}}}.$$

Given that $\lambda_{i,k}$ denotes the value-added share in output production, we can define the nominal value-added production as:

$$\begin{aligned}(VA_i^k)^{nominal} &= \lambda_{i,k} P_i^k Y_i^k \\ &= A_i^{k\,\frac{1}{\lambda_{i,k}}} L_i^k \lambda_{i,k} P_i^{k\,\frac{1}{\lambda_{i,k}}} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{i,k,n}}{P_i^n}\right)^{\gamma_{i,k,n}} (1-\lambda_{i,k})^{\gamma_{i,k,n}} \right]^{\frac{1-\lambda_{i,k}}{\lambda_{i,k}}}.\end{aligned}$$

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

(1) value-added production function $(VA_i^k)^{real}$:

$$(VA_i^k)^{real} = A_i^{k\,\frac{1}{\lambda_{i,k}}} L_i^k. \tag{C.10}$$

(2) value-added price index $(P_i^k)^{VA}$:

$$(P_i^k)^{VA} = \lambda_{i,k} P_i^{k\,\frac{1}{\lambda_{i,k}}} \left[\prod_{n=g,sm,sn} \left(\frac{\gamma_{i,k,n}}{P_i^n}\right)^{\gamma_{i,k,n}} (1-\lambda_{i,k})^{\gamma_{i,k,n}} \right]^{\frac{1-\lambda_{i,k}}{\lambda_{i,k}}}. \tag{C.11}$$

Equation (C.10) makes it possible to convert value-added TFP to gross output TFP, which implies that measured gross output TFP can be rearranged as:

$$A_i^k = \left(\frac{(VA_i^k)^{real}}{L_i^k}\right)^{\lambda_{i,k}}.$$

C.3 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 a 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 regions and used either as an intermediate input or final consumption. We impute gross output by applying the input-output coefficient to value-added data and construct the following:

$$P_i^k Y_i^k = \frac{w_i L_i^k}{\lambda_{i,k}} = \sum_{j=1}^{J+1} \left(P_j^k C_j^k + \sum_{n \in g,sm,sn} P_j^k M_j^{n,k} \right) \pi_{j,i}^k \tag{C.12}$$

Defining $P_j^k Q_j^k$ as total absorption in sector k region j, yields:

$$P_i^k Y_i^k = \frac{w_i L_i^k}{\lambda_{i,k}} = \sum_{j=1}^{J+1} P_j^k Q_j^k \pi_{j,i}^k \tag{C.13}$$

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

$$\begin{aligned}
\frac{w_i L_i^k}{\lambda_{i,k}} &= \sum_{j=1;j\neq i}^{J+1} P_j^k Q_j^k \pi_{j,i}^k + P_i^k Q_i^k \pi_{i,i}^k \\
&= \sum_{j=1;j\neq i}^{J+1} P_j^k Q_j^k \pi_{j,i}^k + P_i^k Q_i^k \left(1 - \sum_{j=1;j\neq i}^{J+1} \pi_{i,j}^k \right) \\
&= P_i^k Q_i^k + \sum_{j=1;j\neq i}^{J+1} P_j^k Q_j^k \pi_{j,i}^k - \sum_{j=1;j\neq i}^{J+1} P_i^k Q_i^k \pi_{i,j}^k
\end{aligned}$$

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 exports on sector k, it follows that

$$P_i^k Y_i^k = \sum_{j=1}^{J+1} P_j^k Q_j^k \pi_{j,i}^k = P_i^k Q_i^k + NX_i^k, \qquad k \in \{g, sm\} \tag{C.14}$$

$$P_i^k Y_i^k = P_i^k Q_i^k, \qquad k = \{sn\} \tag{C.15}$$

If we link the net exports NX_i^k with the budget constraint 3.8, by summing up equations

C.14 and C.15 across sectors, we have:

$$\sum_{k=g,sm,sn} P_i^k Y_i^k - \sum_{k=g,sm,sn} P_i^k Q_i^k = \iota_i w_i L_i - \xi L_i \tag{C.16}$$

Recall that the market clearing condition on the supply side is

$$Q_i^k = C_i^k + \sum_{n=g,sm,sn} M_i^{n,k},$$

Multiplying by P_i^k implies that sector k's total absorption will either serve as final expenditure or intermediate input:

$$P_i^k Q_i^k = P_i^k C_i^k + \sum_{n=g,sm,sn} P_i^k M_i^{n,k}. \tag{C.17}$$

The firm's optimality condition for intermediates used by sector n gives:

$$P_i^k M_i^{n,k} = (1-\lambda_{i,n})\gamma_{i,n,k} P_i^n Y_i^n. \tag{C.18}$$

Thus,

$$P_i^k Q_i^k = P_i^k C_i^k + \sum_{n=g,sm,sn} (1-\lambda_{i,n})\gamma_{i,n,k} P_i^n Y_i^n. \tag{C.19}$$

We split the tradable sector from the non-tradable sector

$$P_i^k Q_i^k = P_i^k C_i^k + \left(\sum_{n=g,sm} (1-\lambda_{i,n})\gamma_{i,n,k} P_i^n Y_i^n \right) + (1-\lambda_{i,sn})\gamma_{i,sn,k} P_i^{sn} Y_i^{sn},$$

where $Y_i^{sn} = Q_i^{sn}$ in non-tradable sector and $P_i^k Y_i^k = \sum_{j=1}^{J+1} P_j^k Q_j^k \pi_{j,i}^k$ in tradable sector, which gives the following market clearing condition

$$P_i^k Q_i^k = P_i^k C_i^k + \sum_{n=g,sm} (1-\lambda_{i,n})\gamma_{i,n,k} \sum_{j=1}^{J+1} \pi_{j,i}^n P_j^n Q_j^n + (1-\lambda_{i,sn})\gamma_{i,sn,k} P_i^{sn} Q_i^{sn}$$

Using second part of(C.14), we can get:

$$P_i^k Q_i^k = P_i^k C_i^k + \sum_{n=g,sm} (1-\lambda_{i,n})\gamma_{i,n,k} (P_i^n Q_i^n + NX_i^n) + (1-\lambda_{i,sn})\gamma_{i,sn,k} P_i^{sn} Q_i^{sn} \tag{C.20}$$

For each sector, (C.20) can be written as:

$$
\begin{aligned}
P_i^g C_i^g =& [1-(1-\lambda_{i,g})\gamma_{i,g,g}] (P_i^g Q_i^g + NX_i^g) - (1-\lambda_{i,sm})\gamma_{i,sm,g}(P_i^{sm} Q_i^{sm} + NX_i^{sm}) \\
& - (1-\lambda_{i,sn})\gamma_{i,sn,g} P_i^{sn} Q_i^{sn} - NX_i^g;
\end{aligned}
$$

$$
\begin{aligned}
P_i^{sm} C_i^{sm} =& [1-(1-\lambda_{i,sm})\gamma_{i,sm,sm}] (P_i^{sm} Q_i^{sm} + NX_i^{sm}) - (1-\lambda_{i,g})\gamma_{i,g,sm}(P_i^g Q_i^g + NX_i^g) \\
& - (1-\lambda_{i,sn})\gamma_{i,sn,sm} P_i^{sn} Q_i^{sn} - NX_i^{sm};
\end{aligned}
$$

$$
\begin{aligned}
P_i^{sn} C_i^{sn} =& [1-(1-\lambda_{i,sn})\gamma_{i,sn,sn}] P_i^{sn} Q_i^{sn} - (1-\lambda_{i,sm})\gamma_{i,sm,sn}(P_i^{sm} Q_i^{sm} + NX_i^{sm}) \\
& - (1-\lambda_{i,g})\gamma_{i,g,sn}(P_i^g Q_i^g + NX_i^g).
\end{aligned}
$$

Using (C.14) and (C.15) yields

$$
P_i^g C_i^g = \frac{1-(1-\lambda_{i,g})\gamma_{i,g,g}}{\lambda_{i,g}} w_i L_i^g - \frac{(1-\lambda_{i,sm})\gamma_{i,sm,g}}{\lambda_{i,sm}} w_i L_i^{sm} - \frac{(1-\lambda_{i,sn})\gamma_{i,sn,g}}{\lambda_{i,sn}} w_i L_i^{sn} - NX_i^g;
$$

$$
P_i^{sm} C_i^{sm} = \frac{1-(1-\lambda_{i,sm})\gamma_{i,sm,sm}}{\lambda_{i,sm}} w_i L_i^{sm} - \frac{(1-\lambda_{i,g})\gamma_{i,g,sm}}{\lambda_{i,g}} w_i L_i^g - \frac{(1-\lambda_{i,sn})\gamma_{i,sn,sm}}{\lambda_{i,sn}} w_i L_i^{sn} - NX_i^{sm};
$$

$$
P_i^{sn} C_i^{sn} = \frac{1-(1-\lambda_{i,sn})\gamma_{i,sn,sn}}{\lambda_{i,sn}} w_i L_i^{sn} - \frac{(1-\lambda_{i,sm})\gamma_{i,sm,sn}}{\lambda_{i,sm}} w_i L_i^{sm} - \frac{(1-\lambda_{i,g})\gamma_{i,g,sn}}{\lambda_{i,g}} w_i L_i^g. \quad \text{(C.21)}
$$

By applying data on value-added, net exports 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.4 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 $\{\tau_{ij}^k\}$ 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 preference parameters in the benchmark, we solve for equilibrium with the new trade costs.

(ii) Given an initial guess to provincial wage w_i, we obtain sectoral prices P_i^k and input costs v_i^k by jointly solving Equations (3.2) and (3.3).

(iii) Calculate import expenditure share π_{ij}^k using Equation (3.4).

(iv) Compute the per capita return from global portfolio ξ from Equation (3.10). Note that values of ι_i are unchanged in the counterfactual.[51]

(v) Impute the counterfactual aggregate price P_i and aggregate real income C_i by jointly solving Equations (3.8), (4.8) and (4.9). Then, we can construct sectoral expenditure E_i^k in the counterfactual using Equation (4.14).

(vi) Compute sectoral real consumption C_i^k for each province using Equation (3.9), (4.1) and (4.2).

(vii) Compute the sectoral labor L_i^k, gross output $P_i^k Y_i^k$, sectoral absorption $P_i^k Q_i^k$ and intermediate input usages $P_i^k M_i^k$ by combining production equilibrium conditions (C.12), (C.13) and (C.19).

(viii) Use resource constraint (C.16) in appendix and compute the per-capita excess demand as $D_i = \left[\left(\sum_{k=g,sm,sn} P_i^k Y_i^k - \sum_{k=g,sm,sn} P_i^k Q_i^k \right) - (\iota_i w_i L_i - \xi L_i) \right] / L_i$.

(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 δ sufficiently small so that the wage vector w_i can slowly converge to the fixed point.

[51] We assume that I_{ik} and G_{ik} are unchanged in the benchmark and in the counterfactual. Therefore, consumption expenditure shares are the main driver of E_i^k in our counterfactual.