Regional Computable General Equilibrium Model of Japan and the Global Economy*

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1 Introduction

There has been growing interest in sub-regional economic impact of mega-FTAs (Free Trade Agreements), such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) and the Regional Comprehensive Economic Partnership (RCEP). Our aim in this study is to explore the linkages between all forty seven prefectures in Japan and the global economy, by incorporating the sub-regions of Japan into a global computable general equilibrium (CGE) model of international trade. We take all prefectures in Japan as a set of sub-regions to be introduced to the Global Trade Analysis Project (GTAP) database (Aguiar et al., 2019), and we modify the database and the comparative static GTAP model (Hertel, 1997; McDougall, 2003) to accommodate this alternation[1]. Input-Output (IO) tables from prefectures (Table A1, A2) and Japan (Ministry of Internal Affairs and Communications, 2015) provide a starting point for our modification process. Industrial sectors from these IO tables are aggregated to match with the classification obtained from the GTAP database. The IO linkages between production, international trade,

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[1]This can be applied to the latest GTAP model version 7 (Corong et al., 2017).

and consumption are split by distinguishing prefectures. In the modified model, we add a new module of domestic inflows and outflows of goods and services within Japan. To illustrate sub-regional impact of national trade policy change, we experiment a set of trade liberalization scenarios of RCEP.

Introduction of sub-regions, or sub-national regions, into a CGE model has strands of literature and wide variety of applications (McGregor et al., 2010), and multi-regional IO tables within a country have been utilized as fundamental data inputs for constructing regional CGE models. For example, the Centre of Policy Studies (CoPS), Victoria University in Australia, has pioneered the development of regional CGE models, such as The Enormous Regional Model (TERM) which has been applied to Australia, USA, China, and other countries (Wittwer, 2012, 2017; Horridge and Wittwer, 2008)[2]. In Japan, there exists only a few studies which developed regional CGE model based on multi-regional IO tables (Ban, 2007; Takeda and Ban, 2008; Shirai et al., 2011; Bunditsakulchai and Taguchi, 2011). One of the reasons behind the scarcity of existing studies in Japan is that the public release of multi-regional IO tables in Japan discontinued since the 2005 multi-regional IO tables were published in 2010. This study contributes to circumvent this lack of recent multi-regional IO tables. Our modeling approach can be applied to any prefecture with IO tables. In fact, all of the 47 prefectures in Japan published their own IO tables for 2011, and for the latest IO tables of 2015 most prefectures have made it publicly available. This study also contributes to extend global CGE modeling by embedding sub-regions into the global economy. Our approach is to focus on one country in the global CGE model and to break down the country into sub-regions while keeping the other countries intact. One advantage in our approach is to relaxing the small country assumption on which regional CGE model of a single country framework often relies, and threby the prices of goods and services are determined in the world markets.

Among the national policies affecting its sub-regions, we take one recent mega-FTA such as the RCEP as our simulation example to study in this paper. Potentially, there exist many application areas of our global CGE model with sub-regional structure to explore the nexus between the global, the national, and the sub-regional effects. In the context of climate change, a national policy to mitigate greenhouse gas emission may differently affect sub-regions. For the issues relating to aging society, difference in growth rate of age cohorts may have diverse impacts on sub-regions as well as countries.

[2]Homepage of the CoPs provides a number of regional CGE models; https://www.copsmodels.com/regmods.htm

There remain several caveats in this study which are left for further improvements and future projects. First, international trade data in all prefectures in Japan do not have bilateral trade information about partner countries. We adopt bilateral trade share taken from the country level by sector and impose them onto the prefectures. Secondly, domestic trade flows between prefectures are estimated based on partial information. Some prefectures do not report inflows and outflow of goods and services, and we apply average shares from available prefectures. Bilateral domestic trade by sector and by partner prefectures are computed based on estimates from a simple Gravity-RAS method which can be improved with more information. Thirdly, under the current setting of the model, factors of production are not allowed to endogenously move across national borders nor prefectural borders. Movements of factors of production can be addressed with model extension towards dynamic framework instead of comparative static analysis used in this study. Lastly, the trade liberalization simulated in this study is meant for investigate our model's behavior, not for reflecting the reality of the RCEP trade agreement. This is also the case with the limited number of foreign regions in the model.

In the next section, we overview the database for forty seven prefecture in the global economy. Our extension of the domestic trade module in global CGE model is explained in the section 3. Experimental simulation of the RCEP agreement, an example of mega-FTAs, with the modified model is conducted and reports results in the section 4, and a summary follows.

2 Sub-regional Data for Japan

The Global Trade Analysis Project (GTAP) database (Aguiar et al., 2019) describes 141 regions in the world with the balanced data set on production, trade and consumption. Our aim is to split Japan in the GTAP database into sub-regions, i.e. forty seven prefectures. We apply Input-Output tables from all prefectures in Japan, and Japan as a whole (Table A1, A2) to compute weights for the split. We aggregate the IO tables and the GTAP database to 39 industrial sectors by identifying the common sector classification (Itakura and Iwamoto, 2021), as listed in Table 1. Thus, each prefecture's sector classification is mapped to the 39 sectors, and similarly the 190 sectors in the Japanese IO table (Ministry of Internal Affairs and Communications, 2015) are aggregated to the 39 sectors. We choose the benchmark year of 2011 for the fact that all prefectures in Japan have published their IO tables for that year. More recent IO tables for the year of 2015 become available for most Japanese prefectures, but not all prefectures make it publicly available yet.

Table 1: Industrial Sectors

No.	39 Sectors	GTAP 65 sectors	No.	39 Sectors	GTAP 65 Sectors
1	Agriculture	pdr, wht, gro, v_f, osd, c_b, pfb, ocr	21	Transport equipment	otn
2	Livestocks	ctl, oap, rmk, wol	22	Other manufacturing	omf
3	Forestry	frs	23	Construction	cns
4	Fishing	fsh	24	Electricity and gas	ely, gdt
5	Foods	cmt, omt, vol, mil, pcr, sgr, ofd	25	Water	wtr
6	Beverages and tobacco	b_t	26	Trade	trd
7	Textiles and apparels	tex, wap, lea	27	Finance and insurance	ofi, ins
8	Lumber	lum	28	Real estate	rsa, dwe
9	Paper products	ppp	29	Land transport	otp
10	Chemicals	chm, bph	30	Water transport	wtp
11	Extractions	coa, oil, gas, oxt, p_c	31	Air transport	atp
12	Rubber and plastics	rpp	32	Warehousing	whs
13	Non-metallic mineral	nmm	33	Communication	cmn
14	Iron and steel	i_s	34	Public services	osg
15	Non-Ferrous metal	nfm	35	Education	edu
16	Fabricated metal	fmp	36	Other business	obs
17	Machinery and equipment	ome	37	Health and social work	hht
18	Computer and electronics	ele	38	Recreation and other	ros
19	Electrical equipment	eeq	39	Accommodation	afs
20	Motorvehicle	mvh			

Source: Aggregation based on Itakura and Iwamoto (2021)

Aggregation results on GDP, export, import, domestic trade of inflow and outflow are summarized in Table 2. The GTAP database stores the data on 141 regions in the world, including Japan which has 47 prefectures. The largest regional GDP (or GRP, Gross Regional Product) in Japan is Tokyo while the smallest is Tottori prefecture. The largest economy in the world by GDP in 2011 is the United States. Aichi prefecture and China are the biggest exporter, in Japan and in the world respectively. Tokyo and the United States are the largest importer. Kochi prefecture is the smallest in exports and imports.

Prefectures exchange goods and services with each other within Japan, and this domestic trade is not covered in the GTAP database. Therefore, we need to extend the GTAP

Table 2: GDP and Trade of Sub-regions in Japan and the World (2011, bi. US$)

	Group	N	Max	Mean	Min	SD
GDP	Japan	47	785.0	125.7	25.6	140.2
	World	141	15500.0	515.7	0.2	1603.4
Export	Japan	47	135.9	21.1	2.1	24.1
	World	141	2053.3	146.4	0.1	308.0
Import	Japan	47	100.8	19.7	1.3	21.6
	World	141	2490.5	146.4	0.1	325.0
Outflow	Japan	47	1591.2	225.4	37.6	270.3
	World	-				
Inflow	Japan	47	1467.3	225.4	41.7	257.9
	World	-				

Source: Authors

database with domestic trade data of Japan. To estimate the data array of outflow (domestic export) and inflow (domestic import) by sector and by prefecture, we apply a simple RAS method and a Gravity-RAS method. A simple RAS method takes equally weighted data array as initial value for the iterations with the control totals of outflow and inflow. Gravity-RAS method uses initial value of the weights estimated by a Gravity equation with the control totals. Most prefectures report the outflow total and inflow total by sector, but some prefectures report the aggregates of outflow and export or the aggregate of inflow and import. For the missing prefecture, we apply the share of outflow (inflow) over export (import) to obtain the totals, and make sure that in Japan sum of outflows equal sum of inflows by sector to be balanced. In Table 2, outflow and inflow report each prefecture's totals. Reflecting its size of economy in Japan, Tokyo trades the most of outflows and inflows and Tottori prefecture does the least. It is remarkable that the size of domestic inflows and outflows are significantly larger than the international transactions.

For the Gravity-RAS method, we use the 2005 Inter-Regional Input-Output Table (Ministry of Economy, Trade and Industry, 2011) for our estimation. It has 53 industrial sectors and 4 final demands for 9 aggregated regions in Japan. Since our aim is to obtain weights, not levels, used as initial value for the subsequent RAS iteration process, this inter-regional IO may be the best available information. We estimate a simple gravity equation with fixed effects of source and destination, using Poisson pseudo maximum likelihood estimator as follows;

$$\mathrm{E}(D_{ij}) = \exp(\gamma_i + \gamma_j + \beta \ln \mathrm{Dist}_{ij}), \tag{1}$$

where D_{ij} is bilateral domestic transactions between source i and destination j, Dist_{ij} is bilateral distance between i and j in km, and γ are fixed effects on source and destination.

Table 3: Estimation Result

[Insert Table here]

We use the estimation result with prefectural distance to project the bilateral domestic transactions, and then compute weights which are used as a prior in the subsequent RAS iterations. Improvements can be made for this estimation process with more data points, variables and controls.

As the domestic inflows and outflows are incorporated into the GTAP database, we redefine the formula and the equation for regional GDP expenditure to include them for the sub-regions. In the next section, we outline this incorporation in terms of modeling.

3 Demand module of domestic and import goods

We extend the comparative static GTAP model (Hertel, 1997; McDougall, 2003) to accommodate the inflow and the outflow that are assumed to be domestically differentiated by prefecture. This assumption is analogous to the product differentiation by country of origin as known as the Armington assumption (Armington, 1969). The demand structure is depicted in Figure 1. Imports of good i from region r to s, Q_{irs}, are aggregated to import composite, M_{is}, by constant elasticity of substitution (CES) function, and then with domestic composite, D_{is}, to a composite good, X_{is} by CES function. The domestic composite, D_{is}, consists of products from prefecture r to s, $D_{i,r,s}$. Substitution elasticities defined in these CES functions are σ_i^D for domestic and import composites, and σ_i^M for imports, and σ_i^P for inflows in s. With the extended GTAP database, we implement this demand module in the comparative static GTAP model. Note that this implementation is only applicable to Japan, leaving other countries in the database intact.

Producers (indexed with j) and a representative regional household in region s demand the composite good (X_{is}), as shown in Figure 2. Producer j uses them as intermediate inputs (X_{ijs}), and combines with a value added composite (VA_{js}) which aggregates skilled and unskilled labor, capital, land and natural resources, to produce output (O_{js}) by Leontief function. Then, the output is supplied either to domestic markets (D_{jrs}) or to foreign markets (Q_{jsr}). Demands for private consumption (X_{is}^P) and government consumption (X_{is}^G) forms sub-utility of the representative regional household, U_s^P and U_s^G respectively, along with the sub-utility from future consumption via savings (U_s^S), and they determine economic welfare for the region, U_s. Constant difference of elasticities (CDE) function is applied for the private consumption, CES function is for the government consumption, and modified Cobb-Douglas function is used for the overall utility.

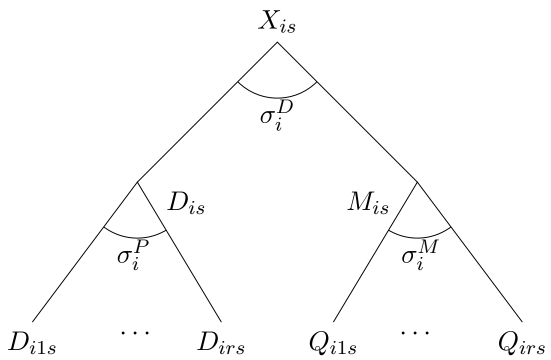

Figure 1: Demand Structure

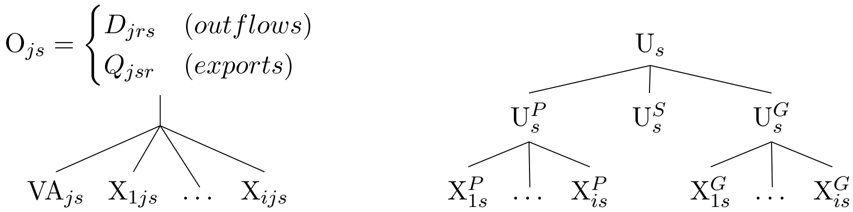

Figure 2: Structure of Production and Consumption

4 Experimental Simulation

Having extended the database and the model, we experiment a hypothetical simulation of trade liberalization for the RCEP member countries and sub-regions in Japan. Our aim here is to examine the model behavior of the prefectures in Japan when the import tariffs are eliminated, and trade are facilitated by logistic improvements. We aggregate all countries except Japan in the GTAP database into either RCEP[3] or the rest of world (ROW) for simplicity. RCEP is the aggregation of the countries participating in the RCEP agreement except for Japan. ROW is an aggregated region of the rest of the countries and regions in the GTAP database.

Average applied ad valorem tariff rates on merchandise imports are reported in Table 4. Since there is no tariff rates available for services trade (sector 23 to 39) in the GTAP database, we report for the merchandise imports (sector 1 to 22). Given the tariff rates at the national level in Japan, the same rates are applied to all prefectures. Relatively high tariff rates are observed in foods (23.1%), textile and apparels (9.1%), and agriculture (8.2%) in Japan. On the other hand, most of the manufacturing imports are subject to almost no tariffs or very low rates. In the RCEP simulation, we assumed that efficiency improvements stemming from trade facilitation on goods and services reduce effective trading cost by 10% for the RCEP as well as prefectures. As these simulation settings are intended for an experiment with the modified GTAP database and model (call it JPN47 for reference), there remains more elaborations for realistic simulation, for example Lee and Itakura (2018) and Itakura (2022). For our simulation in this study, bilateral import tariffs are completely eliminated for the RCEP and prefectures, and the effective trade costs are exogenously reduced by 10%. We use the GEMPACK economic modelling software (Harrison and Pearson, 1996) for the simulation as well as the modification of database and model.

[3]RCEP is a group of countries, and they are ten ASEAN member states, Japan, China, Korea, Australia, and New Zealand.

Table 4: Average Applied Ad Valorem Tariff Rates on Merchandise Imports (%)

No.	Sector	RCEP	ROW	Japan
1	Agriculture	22.2	3.9	8.2
2	Livestocks	12.3	3.5	4.5
3	Forestry	0.2	1.5	0.1
4	Fishing	7.8	1.7	3.8
5	Foods	10.2	6.9	23.1
6	Beverages and tobacco	18.9	7.6	5.7
7	Textiles and apparels	7.4	7.2	9.1
8	Lumber	1.8	1.7	2.1
9	Paper products	1.8	1.4	0.0
10	Chemicals	3.9	1.7	0.9
11	Extractions	1.0	0.8	0.1
12	Rubber and plastics	6.2	2.7	0.8
13	Non-metallic mineral	7.8	3.8	0.4
14	Iron and steel	3.7	1.8	0.3
15	Non-Ferrous metal	1.3	1.6	0.4
16	Fabricated metal	5.9	3.0	0.5
17	Machinery and equipment	3.7	1.7	0.0
18	Computer and electronics	2.3	1.1	0.0
19	Electrical equipment	5.0	2.4	0.0
20	Motorvehicle	15.8	3.1	0.0
21	Transport equipment	2.4	3.3	0.0
22	Other manufacturing	5.1	2.3	0.6

Source: Authors based on (Aguiar et al., 2019)

There are seven experimental simulations which implement the same exogenous shocks with different settings for the model, parameter on substitution elasticity of domestic products (σ_i^P in Figure 1), and alternative weight data used for the RAS procedures. We also run a simulation with the standard comparative static GTAP model for reference. Then, to compare, we switch the model to the extended GTAP model with sub-regions of Japan (JPN47), and we alter parameter values and the weight data.

s1: Reference simulation with the standard GTAP model.

s2: JPN47 model with inelastic substitution of the source prefectures ($\sigma_i^P = 0$).

s3: JPN47 model with unit substitution elasticity ($\sigma_i^P = 1$), and the domestic trade array estimated by a simple RAS method which uses a prior of equal weights (A prior).

s4: Same as s3, except for the Gravity-RAS method is used (B prior)

s5: Same as s4, except for $\sigma_i^P = \sigma_i^D$, the substitution elasticity of source prefecture is set equal to the substitution elasticity of import composite and domestic composite.

s6: Same as s4, except for $\sigma_i^P = \sigma_i^M$, which set the elasticity equal to the substitution elasticity of import sources.

s7: Same as s4, except for $\sigma_i^P = 2 \times \sigma_i^M$, the elasticity is set twice larger than σ_i^M.

Note that all experiments share the same exogenous shocks of tariff removals and logistic improvements. Except s1 and s3, the domestic trade array is estimated by the Gravity-RAS method.

Results from these experimental simulations on real GDP, regional GDP for prefectures, are reported in Table 5. Reference simulation (1) with the GTAP model shows real GDP increase for the RCEP (2.38%) and Japan (1.1%). Simulation (2) with our extended model (JPN47) with inelastic substitution elasticity produces the results very close to the reference simulation (1). This implies that inelastic substitution negates the interplay among the prefectures even when incorporating the sub-regional details into the model, generating the result close to the model without sub-regions. Once we allow substitution of domestic sources under the simulations (3) to (7), real GDP of Japan begins declining as the degree of substitution increases. The parameter values in the GTAP database has following relation;

$$1 < \sigma_i^D = \frac{\sigma_i^M}{2}$$

Because the results on real GDP are influenced by the substitution for other source prefectures, obtaining realistic estimates on the substitution may have profound importance in policy simulation.

By comparing the simulation (3) with (4), choice of a prior set of weight values used in a simple RAS method (A prior) or a Gravity-RAS method (B prior) does not affect Japan at the aggregated level. Similarly, there aren't much significant differences between (3) and (4) at the disaggregated level of prefectures.

Table 5: Impact on Real GDP (%)

Model:	GTAP	JPN47					
		σ_i^P =0	σ_i^P =1 A prior	σ_i^P =1	σ_i^P =σ_i^D	σ_i^P =σ_i^M	σ_i^P =2σ_i^M
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RCEP	2.38	2.39	2.39	2.39	2.38	2.37	2.35
ROW	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.08
Japan	1.10	1.09	1.04	1.04	0.76	0.16	-1.06
Aichi		1.1	0.6	0.6	0.1	-0.1	0.1
Akita		1.1	1.7	1.3	1.4	1.0	-0.3
Aomori		1.1	2.8	2.4	2.9	3.0	2.7
Chiba		1.2	0.8	0.9	0.3	-0.9	-3.9
Ehime		2.0	2.4	2.4	2.5	2.3	1.6
Fukui		1.1	1.3	1.4	1.7	1.9	2.2
Fukuoka		0.9	0.3	0.2	-0.3	-0.6	-1.1
Fukushima		0.7	1.4	1.2	1.1	0.2	-1.8
Gifu		1.1	1.1	1.2	0.8	-0.2	-2.2
Gunma		0.0	0.0	0.0	-0.6	-1.7	-3.8
Hiroshima		1.2	0.9	1.0	0.6	0.4	0.3
Hokkaido		1.0	1.9	1.8	2.2	2.2	1.6
Hyogo		0.8	0.6	0.7	0.5	0.4	0.8
Ibaraki		1.8	1.7	1.6	1.5	1.5	1.4
Ishikawa		0.8	0.8	0.7	0.3	-0.6	-2.1
Iwate		1.2	1.6	1.1	1.0	0.5	-0.8
Kagawa		1.4	1.6	1.7	1.7	1.6	1.5
Kagoshima		0.9	3.4	3.3	3.6	2.9	0.5
Kanagawa		2.6	2.2	2.4	2.2	1.8	0.4
Kochi		2.2	2.6	2.7	2.8	2.4	0.9

continue.

Model:	GTAP	JPN47					
		σ_i^P =0	σ_i^P =1	σ_i^P =1	σ_i^P =σ_i^D	σ_i^P =σ_i^M	σ_i^P =2σ_i^M
			A prior				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Kumamoto		1.2	1.9	1.8	2.1	1.9	1.0
Kyoto		0.5	0.2	0.2	-0.5	-1.5	-3.4
Mie		1.6	2.0	2.2	2.7	3.2	4.2
Miyagi		1.0	1.4	1.2	1.5	2.0	2.7
Miyazaki		0.8	1.2	1.0	1.0	0.5	-1.0
Nagano		0.9	0.7	0.8	0.3	-0.5	-1.7
Nagasaki		1.0	1.3	1.3	1.0	-0.1	-2.7
Nara		1.0	2.1	2.1	2.4	2.5	2.5
Niigata		0.8	1.1	0.9	0.6	-0.4	-2.6
Oita		1.4	0.8	0.9	0.3	-0.6	-2.2
Okayama		2.4	2.0	2.1	2.1	2.0	1.0
Okinawa		2.2	1.8	1.8	1.4	1.2	0.5
Osaka		0.7	0.6	0.6	0.5	0.5	0.5
Saga		1.0	1.5	1.6	1.6	1.3	0.0
Saitama		1.1	1.6	1.7	1.6	0.8	-0.6
Shiga		1.0	1.1	1.2	1.0	0.5	-0.2
Shimane		0.6	0.4	0.6	0.1	-1.1	-3.4
Shizuoka		2.9	2.4	2.5	1.9	0.9	-0.5
Tochigi		-0.8	-0.5	-0.7	-1.1	-2.4	-5.0
Tokushima		1.2	1.6	1.7	1.9	2.0	2.1
Tokyo		0.3	-0.1	-0.1	-0.8	-2.3	-5.1
Tottori		0.7	1.1	1.3	1.1	0.0	-2.9
Toyama		0.8	1.0	1.0	0.9	0.5	-0.1
Wakayama		1.7	1.2	1.3	0.8	0.0	-1.6
Yamagata		1.2	1.3	0.9	0.7	0.2	-0.7
Yamaguchi		1.7	1.5	1.5	1.2	0.4	-1.7
Yamanashi		1.9	1.4	1.6	0.9	-0.5	-3.0

Source: Authors simulation results.

Table 6 reports the impact of RCEP on economic welfare, measured in terms of per cent change in utility (U_s in Figure 2). The results confirms that the mega-FTA leads to higher welfare for the RCEP, Japan and its prefectures. We obtain almost same results from the standard GTAP model (1) as well as the extended model (JPN47) with inelastic substitution (2). Japanese welfare tends to slightly increase as the substitution elasticity increases from simulation (2) to (7). This makes a contrast with the results on real GDP.

Table 6: Impact on Welfare (%)

Model:	GTAP			JPN47			
		σ_i^P =0	σ_i^P =1 A prior	σ_i^P =1	σ_i^P =σ_i^D	σ_i^P =σ_i^M	σ_i^P =2σ_i^M
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RCEP	3.24	3.26	3.25	3.25	3.24	3.20	3.13
ROW	-0.31	-0.30	-0.30	-0.30	-0.30	-0.30	-0.31
Japan	2.38	2.29	2.25	2.25	2.32	2.50	2.86
Aichi		4.3	4.1	4.1	4.1	4.1	4.3
Akita		1.1	1.1	1.1	1.1	1.2	1.2
Aomori		1.2	1.2	1.2	1.3	1.5	1.9
Chiba		1.6	1.7	1.7	2.0	2.9	4.4
Ehime		2.3	2.4	2.4	2.7	3.0	3.9
Fukui		2.1	2.1	2.1	2.2	2.2	2.5
Fukuoka		3.9	3.1	3.1	3.0	3.0	3.1
Fukushima		0.9	1.0	1.0	1.1	1.2	1.4
Gifu		2.0	2.0	2.1	2.1	2.1	2.2
Gunma		2.5	2.5	2.5	2.6	2.6	2.8
Hiroshima		3.1	3.1	3.1	3.0	3.1	3.3
Hokkaido		0.9	0.9	0.9	0.9	1.0	1.1
Hyogo		2.5	2.4	2.5	2.5	2.5	2.6
Ibaraki		3.5	3.5	3.5	3.7	4.2	5.2
Ishikawa		2.3	2.3	2.3	2.3	2.3	2.4
Iwate		1.6	1.4	1.6	1.7	1.8	2.1
Kagawa		2.1	2.2	2.3	2.4	2.7	3.5
Kagoshima		0.7	1.2	1.2	1.4	1.6	1.9
Kanagawa		1.9	2.1	2.0	2.3	2.9	3.9
Kochi		0.9	0.9	0.9	0.8	0.8	0.7
Kumamoto		1.5	1.5	1.6	1.6	1.7	1.8
Kyoto		1.7	1.7	1.7	1.7	1.7	1.6

continue.

Model:	GTAP	JPN47					
		$\sigma_i^P = 0$	$= 1$	$= 1$	$= \sigma_i^D$	$= \sigma_i^M$	$= 2\times\sigma_i^M$
			A prior				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mie		3.8	3.8	3.8	3.9	4.0	4.4
Miyagi		1.2	1.2	1.2	1.2	1.2	1.3
Miyazaki		1.2	1.2	1.2	1.2	1.3	1.4
Nagano		2.4	2.3	2.4	2.4	2.4	2.6
Nagasaki		1.4	1.4	1.4	1.5	1.5	1.5
Nara		0.9	1.0	0.9	0.9	0.8	0.8
Niigata		1.5	1.5	1.5	1.5	1.6	1.7
Oita		4.0	4.0	4.0	4.1	4.6	5.8
Okayama		4.2	4.1	4.1	4.3	4.9	6.0
Okinawa		1.3	1.2	1.2	1.1	1.0	0.8
Osaka		3.0	2.9	2.9	2.9	3.1	3.4
Saga		1.5	1.7	1.7	2.0	2.4	3.1
Saitama		0.9	1.0	0.9	0.9	0.9	0.9
Shiga		3.4	3.5	3.4	3.4	3.3	3.3
Shimane		1.3	1.3	1.3	1.3	1.3	1.4
Shizuoka		4.1	4.0	4.1	4.1	4.1	4.4
Tochigi		2.2	2.3	2.3	2.5	2.7	3.0
Tokushima		1.8	1.7	1.7	1.7	1.6	1.4
Tokyo		2.1	1.9	1.9	2.0	2.0	2.2
Tottori		0.9	1.0	1.0	1.0	1.1	1.1
Toyama		2.6	2.7	2.6	2.7	2.8	2.9
Wakayama		2.4	2.4	2.5	2.6	3.2	4.5
Yamagata		1.7	1.7	1.7	1.8	1.8	2.0
Yamaguchi		2.5	2.8	2.8	3.5	5.0	7.4
Yamanashi		3.1	3.0	3.1	3.1	3.1	3.2

Source: Authors simulation results.

We experiment additional simulation to relaxing the assumption of immobile factors of production. For labor, each prefecture is endowed with skilled and unskilled labors which are mobile between production sectors in that prefecture but immobile across prefectures. What are the wage rates for them if we assume mobility of labors within Japan? One way to ponder this question, we can use the standard GTAP model to gain some insights. The simulation result (1) reports wage rates of the skilled and the unskilled as 3.0% and 3.1% respectively. By assuming these wage rates to realize when labors can move freely within Japan, we run additional RCEP simulation and obtain the seemingly infeasible result on real GDP of Japan (11.4%). This is not surprising because the wage rates from the simulation (4) are, on average of prefectures, 7.4% for the skilled labor and 7.1% for the unskilled labor, so that for each prefecture labors become available for production activity with less cost (3% against 7%), leading to higher regional GDPs and Japan's GDP. Mobility of labors in Japan needs to be investigate further, as well as capital.

5 Summary

In this study, we incorporated forty seven prefectures of Japan into a global computable general equilibrium (CGE) model. We treat prefectures as new sub-regions in the Global Trade Analysis Project (GTAP) database, along with the RCEP region and the rest of world. Input-Output (IO) tables of prefectures and Japan are aggregated to the 39 sectors to match with the GTAP database. Then, the IO linkages between production, international trade, and consumption are split by prefectures. Corresponding to the database extension, we modify the comparative static GTAP model. In the modified model, we add a new module of domestic trade of inflows and outflows of goods and services within Japan. To illustrate sub-regional impact of national trade policy change, we conduct a set of experimental simulations of the RCEP trade liberalization. All prefectures in Japan gains from the freer trade in terms of the positive impact on economic welfare. In contrast, regional real GDP of prefectures are mixed in effect where some prefectures gain and some lose. As the parameter value of substitution of domestic trade among prefectures increases, real GDP in Japan tends to decrease while economic welfare slightly increases. However, further examination of the simulation results, the modified database and the extended model should be warranted.

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Appendix A: Input Output Tables, 2011

Table A1: Source of Input Output Table of Prefectures

No.	Prefecture	Sectors	Source Institution
1	Hokkaido	104	Hokkaido Regional Development Bureau
2	Aomori	108	Department of Planning and Policies, Aomori Prefectural Government
3	Iwate	189	Survey Statistics Division, Hometown Promotion Department
4	Miyagi	110	Planning Department Statistics Division
5	Akita	108	Survey Statistics Division, Planning Promotion Department
6	Yamagata	108	Statistics Planning Division, Mirai Planning and Creation Department
7	Fukushima	107	Statistics Division, Planning and Coordination Department
8	Ibaraki	190	Statistics Division, Department of Policy Planning, Ibaraki Prefectural Government
9	Tochigi	103	Statistical department, Inhabitant of Prefecture Living Part
10	Gunma	108	Statistics Division, General Affairs Department
11	Saitama	190	Statistics Division, Department of General Affairs
12	Chiba	191	Statistics Division, Policy and Planning Department
13	Tokyo	190	Management and Coordination Section, Statistics Division, Bureau of General Affairs
14	Kanagawa	190	Statistics Center, Policy Bureau
15	Nigata	178	Statistics Division, General Affairs Management Department
16	Toyama	187	Statistical Survey Division, Business Administration Department
17	Ishikawa	190	Statistics Information Office, Prefectural Culture and Sports Department
18	Fukui	104	Statistics Information Department, Area Strategy Part
19	Yamanashi	190	Statistics and Survey Division, Resident Affairs Department
20	Nagano	190	Statistical Room, Overall Policy Planning and Evaluation Division, Plan Promotion Part
21	Gifu	190	Statistics Division, Gifu Prefectural Government
22	Shizuoka	190	Data Utilization Promotion Division, Digital Strategy Bureau
23	Aichi	188	Statistics Division, Community Affairs Department, Bureau of Community and Cultural Affairs
24	Mie	188	Mie Prefecture Department of Strategic Planning
25	Shiga	108	Statistics Division, General Planning Department
26	Kyoto	105	Planning and Statistics Division
27	Osaka	190	Statistics Division, Department of General Affairs
28	Hyogo	188	Data & Analysis Division, Hyogo Vision Planning Bureau, Government Civil Policy Planning & Administration Department
29	Nara	108	Statistical Analysis Division, Governor's Office of General Affairs Department
30	Wakayama	190	Research and Statistics Division, Policy Plan Bureau , Wakayama Planning Department
31	Tottori	108	Statistics Division, Reiwa Era Development Office
32	Shimane	98	Statistical Survey Division, Policy Planning Bureau
33	Okayama	108	Statistical Analysis Division, General Policy Bureau
34	Hiroshima	108	Statistics Division, General Affairs Bureau
35	Yamaguchi	108	Statistical Analysis Division, General Planning Department
36	Tokushima	108	Statistical Data Division, Policy Studies Department
37	Kagawa	108	Statistical Survey Division
38	Ehime	178	Statistical Analysis Section, Planning and Statistics Division, Planning and Development Department
39	Kochi	108	Statistical Analysis Division, General Affairs Department
40	Fukuoka	107	Policy Planning and Regional Development Department
41	Saga	108	Statistical Analysis Division, Policy Department
42	Nagasaki	108	Statistics Division, Civil Life & Environmental Affairs Department
43	Kumamoto	104	Statistics and Research Division, Department of Planning and Development
44	Oita	104	Statistical Survey Division, Planning Promotion Department
45	Miyazaki	108	Statistics and Research Division, General Policy Planning Department
46	Kagoshima	106	Statistical Department
47	Okinawa	401×343	Statistics Devision, Department of Planning