A Supplement to 'A CGE Analysis of the Welfare Effects of Trade Liberalization under Different Market Structures'.

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Abstract

This is a supplementary paper to the paper "A CGE Analysis of the Welfare Effects of Trade Liberalization under Different Market Structures". In this paper, we present results of the simulation omitted in the main paper, and describe the complete model structure, parameterizations, data construction.

Contents

*Email: zbc08106@park.zero.ad.jp. The computer programs for the simulation is available from the author upon request or the author's website: http://park.zero.ad.jp/zbc08106/

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1 Results of the sensitivity analysis

In the main paper, we only presented the summary of the sensitivity analysis. In this section, we present the complete results of the sensitivity analysis. The sensitivity analysis includes: (1) barriers to services trade, (2) the alternative calibration method, (3) the value of Armington elasticity, and (4) the value of benchmark CDR. In the following, the case assumed in the main paper is called the base case.

1.1 Barriers to services trade

In the base case, we introduced barriers to services trade as hypothetical tariffs in order to analyze the liberalization of services trade. Although it is desirable to consider barriers to services trade, our data of services trade barriers may not be appropriate. Thus, we attempted to analyze the case where there is no barrier to services trade. Table 1 reports the welfare effects of trade liberalization in the case without services barriers. As in the main paper, the values in the table are shaded according to the size of welfare change, that is, the darker the area, the larger the value. Because of the absence of services barriers, the effects of liberalization generally become smaller except for in a few regions. In addition, the rank order of models by welfare change has slightly changed. Compared to the base case, regional differences in the rank order of models are generally expanded and the tendency is somewhat obscured. Nevertheless, there is no change in the result that models IC, IB, and LGMC have a large welfare impact and models CF, CH, and CD have a small impact. Similarly, the result that model PC generates a medium-sized impact has not changed.

1.2 The alternative calibration method

In the base case, models CD, CH, CF, BD, IC, and IB calibrate the benchmark number of firms, given the value of CDR exogenously. As our calibration method may not be appropriate, we attempted to check its sensitivity. In this case, we adopted the alternative calibration method and examined how the results were affected. The method adopted in this case is to calibrate the benchmark value of CDR (fixed cost), given the number of firms exogenously.[1] For the benchmark number of firms, we assume 50, which is used for the calibration in model QCV. Note that because model PC does not consider the number of firms, it generates the same results as in the base case. Similarly, as models LGMC and QCV adopt different methods for calibration, their calibration method is not changed in this case.

Table 2 provides the results. As a result of the change in the calibration method, welfare gains of models CD, CH, CF, and BD generally become larger. On the other hand, the welfare increase of models IC and IB is lowered in this case. In addition, model CH, which has only a small impact in the base case, generates large welfare gains in some regions. These results indicate that the results of the simulation are likely to change, depending on the methods of calibration. However, there is no change in the result that models IC and LGMC have a large welfare impact and models CF and CD have a small welfare impact. Similarly, the result that model PC generates a medium-sized impact has not changed.

[1] As in the base case, markup rates are calibrated also in this method.

1.3 The value of Armington elasticity

One of the most important parameters in CGE analysis of trade policy is the Armington elasticity. As it is common in CGE analysis, we conducted the sensitivity analysis on the Armington elasticity. At the same time, we tested the sensitivity of the elasticity of substitution of imports from different regions and elasticity of substitution of varieties. In particular, we conducted an experiment where values of all four elasticities of substitution are increased by 50%.[2]

Table 3 reports the results. The results of model BD are not reported because model BD cannot be solved in this case. Similarly, results of model IB in scenario SG, SF1, and SF3 are NA because the model cannot be solved. A large value of elasticity means smooth substitution between domestic and imported goods and thus it is likely to increase welfare gains from trade liberalization. The table shows that results are consistent with this prediction. In addition, the difference in welfare effect by model is significantly expanded. As this result demonstrates, quantitative results are changed considerably. However, as in the base case, models IC, IB, and LGMC generate large welfare gains, while models CF, CH, CD generate small welfare gains. It follows that although the absolute size of welfare change is significantly altered, qualitative results are not greatly affected.

1.4 The value of benchmark CDR

In all imperfectly competitive models except model LGMC, parameters and variables are calibrated based on the exogenously given CDR. This assumption of giving CDR exogenously is frequently used and is not uncommon. However, we assume 0.15 as the CDR for all regions and sectors. As precise values of CDR for individual regions and sectors are difficult to obtain, this assumption may be acceptable. However, our results can depend on the value of 0.15. Thus, we changed the value of CDR to 0.2 and examined how this change affects the results.[3] In this case, we do not consider models BD because model BD cannot be solved in this case. Results are presented in Table 4. It shows that welfare impact of model CD, CH, and CF is reduced but that of model QCV and IC is increased. As a result of this, difference in welfare impact by model is expanded. However, the qualitative results are not very different from those in the base case.

[2]Although it is desirable to consider the case where the values of elasticity are reduced, calibration cannot be done in such a case. Thus, we only consider the case where values of elasticity are raised.

[3]When we lower the value of CDR, calibration fails. Thus, we only consider the case of increased CDR.

Table 5: List of sectors.

Symbol	Description	The original GTAP sectors
AFF	Agriculture, forestry, and fishery	PDR, WHT, GRO, V_F, OSD, C_B, PFB, OCR, CTL, OAP, RMK, WOL, FRS, FSH.
MIN	Minings	COA, OIL, GAS, OMN.
FBT	Foods, Beverages and Tobacco*	CMT, OMT, VOL, MIL, PCR, SGR, OFD, B_T.
TWA	Textiles, Wearing Apparel, and Leather products	TEX, WAP, LEA.
WPP	Wood and Paper products*	LUM, PPP.
CHM	Chemical products*	P_C, CRP, NMM.
MET	Metal products*	I_S, NFM, FMP.
MVT	Motor vehicles and transport equipment*	MVH, OTN
ELE	Electronic equipment*	ELE.
OME	Machinery and equipment nec*	OME.
OMF	Manufactures nec*	OMF
EGW	Electricity, gas manufacture, and water*	ELY, GDT, WTR.
CNS	Construction*	CNS
TAT	Trade and transport*	TRD, OTP, WTP, ATP.
OSP	Other private services*	CMN, OFI, ISR, OBS, ROS, DWE.
OSG	Government services*	OSG
CGD	Investment goods	CGD

$*$ indicates sectors which are assumed to be imperfectly competitive in imperfectly competitive models.

2 Model

Our analysis is based on a multisector multiregion static general equilibrium model. Sectors and regions in the model are listed in Table 5 and 6. We consider not only a perfectly competitive model with CRTS technology but also imperfectly competitive models with IRTS technology. However, sector AFF, MIN, and TAT are assumed to be perfectly competitive even in imperfectly competitive models.

First, we explain perfectly competitive model and then explain imperfect competition models. In what follows, notations are defined as follows:

- $i, j \cdots$ Index of sectors and goods.
- $r, s, r' \cdots$ Index of regions.
- $v, v', l \cdots$ Index of firms (varieties).
- $f \cdots$ Index of primary factors.
- $I \cdots$ Set of sectors and goods.
- $C \cdots$ Set of perfectly competitive sectors.
- $K \cdots$ Set of imperfectly competitive sectors.
- CGD $\cdots$ Index of investment goods.

2.1 Perfectly competitive model

As the perfectly competitive model, we use the simplified version of the GTAP standard model (Hertel, 1997) Our model differs from the GTAP model in three main aspects. First, savings and investment are determined endogenously in the GTAP model, while they are exogenously constant

Table 6: List of regions.

Symbol	Description	The original GTAP regions
OCE	Oceania	AUS, NZL, XOC
CHN	China (including Hong-Kong)	CHN, HKG
JPN	Japan	JPN
KOR	Korea	KOR
ASE	ASEAN 10 regions	IDN, MYS, PHL, SGP, THA, VNM, XSE.
XAS	Rest of Asia	TWN, XEA, BGD, IND, LKA, XSA.
CAN	Canada	CAN
USA	USA	USA
MEX	Mexico	MEX
XCS	Rest of Central and Southern America	COL, PER, VEN, XAP, CHL, XCA, XFA, XCB.
MER	MERCOSUR	ARG, BRA, CHL, URY, XSM.
EUR	European Union (25 countries)	AUT, BEL, DNK, FIN, FRA, DEU, GBR, GRC, IRL, ITA, LUX, NLD, PRT, ESP, SWE, CHE, CYP, CZE, HUN, MLT, POL, SVK, SVN, EST, LVA, LTU.
XER	Rest of European countries and the former Soviet Union	CHE, XEF, XER, ALB, BGR, HRV, ROM, RUS, XSU.
ROW	Rest of the world	XNA, TUR, XME, MAR, TUN, XNF, BWA, ZAF, XSC, MWI, MOZ, TZA, ZMB, ZWE, XSD, MDG, UGA, XSS.

at the benchmark level in our model.[4] Second, the regional welfare (utility) in the GTAP model is determined through a Cobb-Douglas function of private demand, government expenditure, and savings, while we aggregate private demand and government expenditure into a single final demand and assume that utility is derived only from this final demand. Third, the GTAP model assumes that the aggregation of domestic and imported goods (Armington aggregation) is conducted separately according to their uses, while our model assumes that Armington aggregation is conducted as a whole irrespective of their uses. In the remainder of this section, we take region r for an example. However, the same arguments can be applied to other regions.

2.1.1 Production side

Using intermediate inputs and primary factors, firms produce goods under constant returns to scale (CRS) technology to maximize profits. All markets are assumed to be perfectly competitive and thus all producers are price takers. The production function is a nested CES function represented by Figure 1. The sigmas in the figure represent elasticities of substitution between inputs. Output is produced with fixed coefficient aggregation of intermediate inputs and primary-factor composite. The primary factor composite is a CES aggregation of four primary factors (capital, skilled labor, unskilled labor and land) with an elasticity of $\sigma_{ir}^{\mathrm{PF}}$.

Let Q_{ir} denote output of sector i, Q_{jir}^{I} denote intermediate input j of sector i, and Q_{ir}^{PF} denote primary factor composite of sector i. Then, the production function is represented as follows:

$$Q_{ir} = Q_{ir}(\{Q_{jir}^{I}\}_{j\in I}, Q_{ir}^{\mathrm{PF}}) = \min \left[\left\{ \frac{Q_{jir}^{I}}{a_{jir}^{I}} \right\}_{j\in I}, \frac{Q_{ir}^{\mathrm{PF}}}{a_{ir}^{\mathrm{PF}}} \right]$$

where a_{jir}^{I} fixed input coefficient of intermediate goods j, and a_{ir}^{PF} is fixed input coefficient of primary factor composite. Since the primary factor composite is a CES aggregation of primary factors,

[4] Based on this assumption, the balance of payments in our model is also fixed.

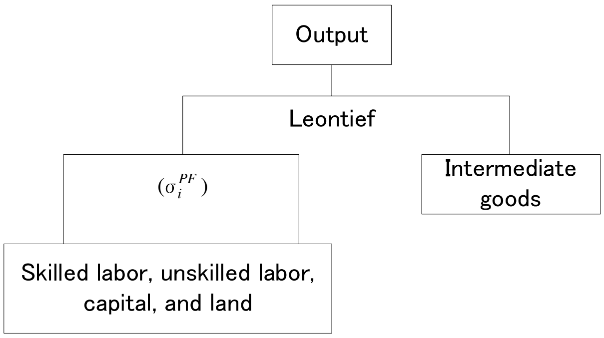

Figure 1: Production function.

it is represented as follows:

$$Q_{ir}^{\mathrm{PF}} = Q_{ir}^{\mathrm{PF}}(\{Q_{fir}^{F}\}) = \left[\sum_{f} \alpha_{fir}^{F} (Q_{fir}^{F})^{\frac{\sigma_i^{\mathrm{PF}}-1}{\sigma_i^{\mathrm{PF}}}}\right]^{\frac{\sigma_i^{\mathrm{PF}}}{\sigma_i^{\mathrm{PF}}-1}}$$

where Q_{fir}^{F} denotes the amount of primary factor f used in sector i. Note that elasticities of substitution among four primary factors (σ_i^{PF}) have different values across sectors.

Profit maximizing behavior means that firms choose a combination of production inputs so as to minimize cost. Thus, the (unit) cost function is defined as follows:

$$\begin{aligned} c_{ir}^{Y} &\equiv \min_{\{Q_j^I\}, Q^{\mathrm{PF}}} \left[\sum_{j} \tilde{p}_{Ijir}^{A} Q_j^{I} + p_{ir}^{\mathrm{PF}} Q^{\mathrm{PF}} \mid Q_{ir}(\{Q_j^I\}, Q^{\mathrm{PF}}) = 1\right] \\ &= \sum_{j} \tilde{p}_{Ijir}^{A} a_{jir}^{I} + p_{ir}^{\mathrm{PF}} a_{jir}^{\mathrm{PF}} \end{aligned}$$

where $\tilde{p}_{Ijir}^{A} = (1 + t_{jir}^{I}) p_{jr}^{A}$ is a producer price of intermediate goods j , t_{jir}^{I} is a tax rate on intermediate inputs, and p_{ir}^{PF} is price index of a primary factor composite of sector i.

Similarly, the combination of primary factors is determined so as to minimize cost. Thus, price index of a primary factor composite is defined as follows:

$$\begin{aligned} p_{ir}^{\mathrm{PF}} &\equiv \min_{\{Q_f^F\}} \left[\sum_{f} \tilde{p}_{fir}^{F} Q_f^{F} \mid Q_{ir}^{\mathrm{PF}}(\{Q_f^F\}) = 1\right] \\ &= \left[\sum_{f} (\alpha_{fir}^{F})^{\sigma_i^{\mathrm{PF}}} (\tilde{p}_{fir}^{F})^{1-\sigma_i^{\mathrm{PF}}}\right]^{\frac{\sigma_i^{\mathrm{PF}}}{\sigma_i^{\mathrm{PF}}-1}} \end{aligned}$$

where $\tilde{p}_{fir}^{F}$ is the producer price of primary factor f which is equal to $(1 + t_{fir}^{F}) p_{fr}^{F}$.

Next, let us consider output side. In CGE analysis, it is often assumed that goods produced for domestic market and goods produced for export are differentiated. However, we assume that goods of an industry are perfect substitutes regardless of destination. Thus, the price of output is given by a single price p_{ir}^{Y}. Since a tax whose rate is t_{ir}^{Y} is imposed on output, the produced price of output is $(1 - t_{ir}^{Y}) p_{ir}^{Y}$.

From the results derived above, the zero profit condition (the condition for profit maximization) for sector i is given by

$$c_{ir}^{Y} = (1 - t_{ir}^{Y}) p_{ir}^{Y}$$

Next, we derive demand function for inputs. First, demand for intermediate input is given by $a^I_{jir}Q_{ir}$. On the other hand, demand for primary factors can be derived by applying Shephard's lemma to the price index of primary factor composites. Let a^F_{fir} denote the unit demand for primary factor f. Then, a^F_{fir} is represented as follows:

$$a^F_{fir} = \frac{\partial c^Y_{ir}}{\partial \tilde{p}^F_{fir}} = \frac{\partial c^Y_{ir}}{\partial p^{\text{PF}}_{ir}} \frac{\partial p^{\text{PF}}_{ir}}{\partial \tilde{p}^F_{fir}} = a^{\text{PF}}_{ir} \left[\frac{\alpha^F_{fir} p^{\text{PF}}_{ir}}{\tilde{p}^F_{fir}} \right]^{\sigma^{\text{PF}}_i}$$

Total demand for factor f of sector i is given by $a^F_{fir}Q_{ir}$.

2.1.2 Demand side

To represent the demand side, we assume a representative household for each region. Since we do not consider government explicitly, final demand is the sum of private demand and government expenditure. Final demand is derived from the optimizing behavior of this household. The utility function for the household is a Cobb-Douglas function of consumption goods. Thus, utility U_r is represented as follows:

$$U_r = U_r(\{C_{ir}\}) = \prod_i (C_{ir})^{\theta^C_{ir}}$$

where C_{ir} is final demand of goods i.

From the utility function, we can define the unit expenditure function as follows:

$$\begin{aligned} p^U_r &\equiv \min_{\{C_i\}} \left[\sum_i \tilde{p}^A_{Cir} C_i \mid U_r(\{C_i\}) = 1 \right] \\ &= \prod_i \left[\frac{\tilde{p}^A_{ir}}{\theta^C_{ir}} \right]^{\theta^C_{ir}} \end{aligned}$$

where $\tilde{p}^A_{Cir}$ is demand price of goods i which is equal to $(1 + t^C_{ir})p^A_{ir}$. Using the unit expenditure, the level of utility is derived by

$$U_r = H_r / p^U_r$$

where H_r indicates income spent on consumption.

From Shephard's lemma, compensated demand function is given by

$$C^D_{ir} = \frac{\partial p^U_r}{\partial \tilde{p}^A_{Cir}} U_r = \frac{\theta^C_{ir} p^U_r}{\tilde{p}^A_{Cir}} U_r$$

2.1.3 Investment

Investment INV_r is assumed to be constant at the benchmark level.

2.1.4 International trade

Like other CGE analyses, we use the Armington assumption to explain cross-hauling in trade (Armington, 1969). The Armington assumption implies that domestically produced goods and imported goods are imperfect substitutes. Domestic and imported goods are aggregated through a CES function (see Figure 2). Moreover, we assume that imports from different regions are imperfect substitutes. Imports from different regions are aggregated through a CES function, too. Armington goods are used for intermediate input and final consumption.

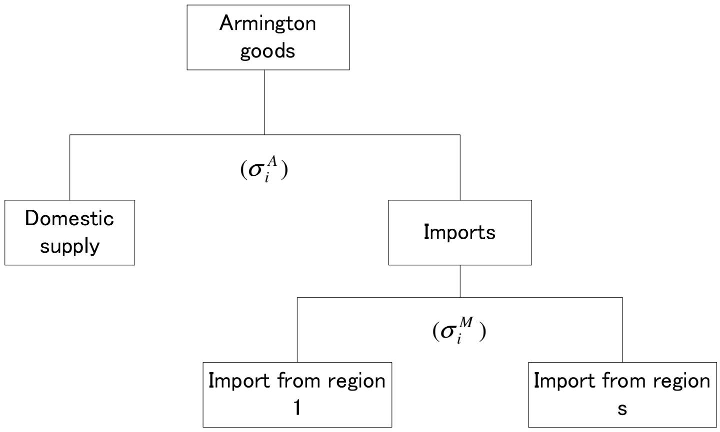

Figure 2: Armington structure in perfectly competitive model.

Imports from different regions are aggregated through a CES function, the import composite of region r is given by

$$\mathrm{AM}_{ir} = \mathrm{AM}_{ir}(\{M_{isr}\}_s) = \left[\sum_s \alpha_{isr}^M (M_{isr})^{\frac{\sigma_i^M - 1}{\sigma_i^M}} \right]^{\frac{\sigma_i^M}{\sigma_i^M - 1}}$$

where M_{isr} denote import of goods i from region s to region r.

The import composite AM_{ir} and domestic goods AD_{ir} are are aggregated into Armington goods A_{ir} through a CES function.

$$A_{ir} = A_{ir}(\mathrm{AD}_{ir}, \mathrm{AM}_{ir}) = \left[\alpha_{ir}^{\mathrm{AD}} (\mathrm{AD}_{ir})^{\frac{\sigma_i^A - 1}{\sigma_i^A}} + (1 - \alpha_{ir}^{\mathrm{AD}})(\mathrm{AM}_{ir})^{\frac{\sigma_i^A - 1}{\sigma_i^A}} \right]^{\frac{\sigma_i^A}{\sigma_i^A - 1}}$$

It is assumed that the combination of imports from different regions are chosen so as to minimize cost. Thus, we can define the price index of the import composite as follows:

$$\begin{aligned} p_{ir}^{\mathrm{AM}} &\equiv \min \left[\sum_s \tilde{p}_{isr}^M M_{is} \mid \mathrm{AM}_{ir}(\{M_{is}\}_s) = 1 \right] \\ &= \left[\sum_s (\alpha_{isr}^M)^{\sigma_i^M} (\tilde{p}_{isr}^M)^{1-\sigma_i^M} \right]^{\frac{1}{1-\sigma_i^M}} \end{aligned}$$

where $\tilde{p}_{isr}^M$ is the price of import from region s to region r. This import price includes export tax, import tax and transport cost. Let t_{isr}^X and t_{isr}^M denote export subsidy and import tax imposed on good i from region s to region r. Moreover, let τ_{isr} denote the amount of transport services required to ship one unit of good i from region s to region r and let p^T denote the price of transport services. Then, $\tilde{p}_{isr}^M$ is written as follows:

$$\tilde{p}_{isr}^M = (1 + t_{isr}^M)[(1 - t_{isr}^X) p_{is}^X + p^T \tau_{isr}]$$

Similarly, the price index of Armington goods is

$$\begin{aligned} p_{ir}^A &\equiv \min \left[p_{ir}^Y \mathrm{AD} + p_{ir}^{\mathrm{AM}} \mathrm{AM} \mid A_{ir}(\mathrm{AD}, \mathrm{AM}) = 1 \right] \\ &= \left[(\alpha_{ir}^{\mathrm{AD}})^{\sigma_i^A} (p_{ir}^Y)^{1-\sigma_i^A} + (\alpha_{ir}^{\mathrm{AM}})^{\sigma_i^A} (p_{ir}^{\mathrm{AM}})^{1-\sigma_i^A} \right]^{\frac{1}{1-\sigma_i^A}} \end{aligned}$$

From the price indices defined above, we can derive demand functions for domestic goods and imports. First, region r's demand for import of good i from region s is

$$M^D_{isr} = \frac{\partial p^A_{ir}}{\partial p^{\mathrm{AM}}_{ir}} \frac{\partial p^{\mathrm{AM}}_{ir}}{\partial \tilde{p}^M_{isr}} A_{ir} = \left[\frac{\alpha^{\mathrm{AM}}_{ir} p^A_{ir}}{p^{\mathrm{AM}}_{ir}}\right]^{\sigma^A_i} \left[\frac{\alpha^M_{isr} p^{\mathrm{AM}}_{ir}}{\tilde{p}^M_{isr}}\right]^{\sigma^M_i} A_{ir}$$

On the other hand, demands for domestic goods are given by

$$\mathrm{AD}^D_{ir} = \frac{\partial p^A_{ir}}{\partial p^Y_{ir}} A_{ir} = \left[\frac{\alpha^{\mathrm{AD}}_{ir} p^A_{ir}}{p^Y_{ir}}\right]^{\sigma^A_i} A_{ir}$$

2.1.5 International transport sector

International trade of goods requires transport service. Transport service is supplied by international transport sector. Transport service is produced through a Cobb–Douglas production function. Let Q^T_{ir} denote input to transport service. Then, output of transport service T is represented as follows:

$$T = \prod_{i,r} (Q^T_{ir})^{\theta^T_{ir}}$$

From this, we can define the price index of transport service p^T as

$$p^T = \prod_{i,r} \left[\frac{p^Y_{ir}}{\theta^T_{ir}}\right]^{\theta^T_{ir}}$$

By applying Shephard's lemma, demand for input is given by

$$a^T_{ir} = \frac{\theta^T_{ir} p^T}{p^Y_{ir}}$$

On the other hand, demand for transport service associated with import of goods i from region s to region r is given by

$$\tau_{isr} M^D_{isr}$$

where τ_{isr} is unit of transport service required to ship one unit of goods i from region s to region r.

2.2 Imperfectly competitive sector

Next, we explain imperfectly competitive models. There are a lot of approaches to incorporate scale economies and imperfect competition into a CGE model. For example, the following researches employ imperfect competition model in CGE models: Harris (1984), Cox and Harris (1985), de Melo and Tarr (1992), Cox (1994), Brown (1994), Francois and Roland-Holst (1997), Harrison, Rutherford and Tarr (1997), Lejour, de Mooij and Nahuis (2001), Bchir, Decreux, Guérin and Jean (2002), and Brown, Deardorff and Stern (2003); Brown, Kiyota and Stern (2004). These studies use different models to incorporate imperfectly competitive behavior and there is no standard approach for modeling imperfect competition. Our main purposes is to show how the results from trade liberalization will change according to model structures. Thus, we employ the following nine different models (see Table 7):

Table 7 lists the models examined in the simulation. Model PC is a perfectly competitive model explained in the previous section. Model CD is a benchmark model of all imperfectly competitive models.[5] Alternative imperfectly competitive models are derived from model CD by changing the assumptions. So, we first explain the structure of model CD in detail. In model CD, we make the following assumptions.

[5] Bchir et al. (2002) employ a model similar to model CD.

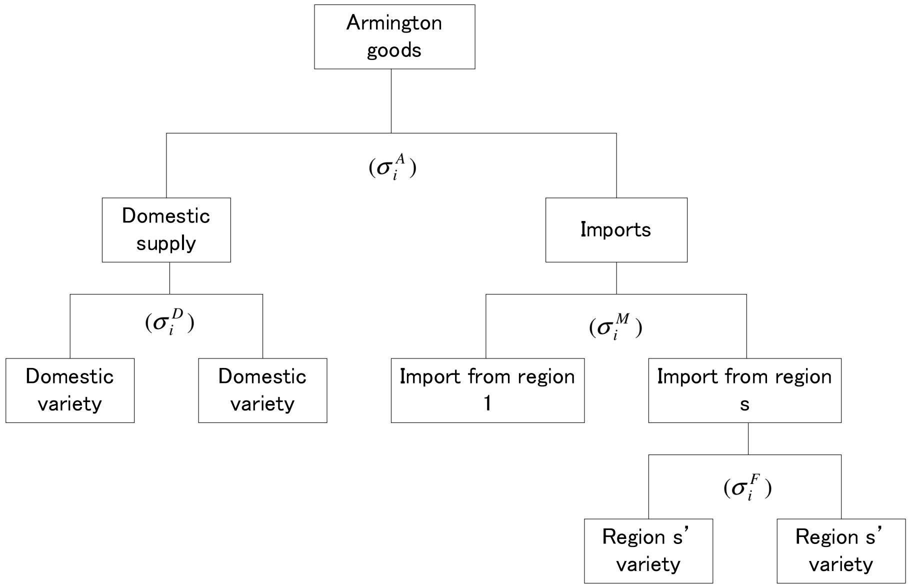

Figure 3: Armington aggregation with IRTS goods.

Table 7: Model list.

Model name	Description
Model PC	perfectly competitive model.
Model CD	Cournot model.
Model LGMC	Large group monopolistic competition model.
Model CH	Cournot model with homogeneous varieties.
Model CF	Cournot model with fixed number of firms.
Model QCV	Quantity competition model with non-Cournot conjectural variation.
Model IC	Integrated market Cournot model.
Model BD	Bertrand model.

Figure 4: Armington aggregation.

A1: Economies of scale arise from the existence of fixed costs.

A2: Varieties of different firms in a sector are assumed to be differentiated and aggregated using a CES function. Following this assumption, Armington structure is modified as in Figure 4.

A3: Each firm behaves in a Cournot fashion, that is, each firm determines its output, taking the output of all other firms as fixed.

A4: Markets in different regions are segmented. Thus, firms can independently control output and prices in different regions.

A5: Free entry and exit are possible. This implies that the number of firms is endogenously determined so that the zero profit conditions are satisfied.

A1 is applied to all imperfectly competitive models, while A2-A5 are modified according to the different models. Model LGMC is the large group monopolistic competition model frequently used in theoretical analysis. In this model, it is assumed that each firm recognizes the number of firms as sufficiently large. As a result, model LGMC has the following two features: (1) markup rate is kept constant (equal to the inverse of the elasticity of substitution), and (2) scale of each firm (total output of each firm) is kept constant. As these features seem to be somewhat unrealistic, the validity of this model may be questionable. However, this model is frequently used not only in theoretical analysis but also in CGE studies, and thus we decided to consider also this model.[6]

Model CH changes the assumption of product variety. It assumes that product varieties of different firms are perfect substitutes (homogeneous). By comparing model CH with model CD, we can examine the role of the love of variety. In model CF, the assumption on entry is modified. It assumes that the number of firms is fixed at the benchmark level. This assumption indicates (1) a situation where there are strong entry barriers to markets, or (2) a situation in the short run. The former situation is of importance because entry barriers are often observed in actual economies; the latter situation is also worth analyzing because it often takes some time for economies to adjust to external shocks. In addition, theoretical analysis such as that in Horstmann and Markusen (1986) and Markusen and Venables (1988) shows that the effects of trade policy can vary drastically, depending on whether free entry and exit are possible or not. Thus, we consider the model of a fixed number of firms as well. Note that in our model, each firm produces one variety and thus the assumption of a fixed number of firms implies the fixed number of varieties.

Model QCV changes the assumption on conjectural variation. Model CD assumes Cournot conjecture, that is, each firm determines its output, taking the output of all other firms as fixed. On the other hand, in model QCV, each firm determines its output, taking the output of all other firms as variable. Although this non-Cournot conjecture model may rarely be used in theoretical analysis due to its complexity, it is often used in CGE analysis.[7] The Cournot competition model is the representative model in the imperfect competition models and is used in both theoretical and empirical analysis. However, this does not necessarily guarantee the actual validity of the Cournot competition model. Moreover, Eaton and Grossman (1986) demonstrate that the welfare effects of trade policy can be strongly influenced by the assumptions on conjectural variation. Thus, it is of great importance to show how the assumptions on conjectural variation affect results.

Model BD is a Bertrand competition version of model CD, that is, it assumes that a firm's strategic variable is price and that each firm determines its prices, taking the prices of all other firms as fixed.[8] As with the Cournot model, the Bertrand model is one of the most popular imperfectly competitive models and is used frequently in both theoretical and empirical works. However, because it is difficult to evaluate which model is the more realistic, we decided to consider the Bertrand model as well as the Cournot model.

Although all models listed so far assume segmented markets, there is another frequently used model: the integrated market model. In the integrated market model, where arbitrage trade across different regions is possible, firms cannot independently set output for markets in different regions and only control total output. Moreover, they cannot set different prices for different regions. Studies such as Markusen and Venables (1988) show that the effects on trade policy can vary significantly, depending on whether the market is segmented or integrated. Thus, we attempted to consider the integrated market model (model IC) and examine differences generated by the two alternative assumptions.

2.2.1 Cost structure

In this section, using model CD as an example, we explain in detail the structure of the imperfectly competitive models. In imperfectly competitive models, economies of scale internal to firms

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[6]For example, the following papers employ model LGMC: Francois, McDonald and Nordström (1996), Francois and Roland-Holst (1997), and Francois (1998).

[7]For example, the following studies adopt a non-Cournot conjectural variation models: Burniaux and Waelbroeck (1992), Melo and Tarr (1992, Chap.7), Harrison, Rutherford and Tarr (1996); Harrison et al. (1997), Francois and Roland-Holst (1997), and de Santis (2002a,b).

[8]Models that we call the "Bertrand model" are often called the "monopolistic competition model" in other studies. For example, the Michigan model (Brown, Deardorff and Stern, 2002; Brown et al., 2003, 2004) is almost the same as the model BD except that the former assumes one-stage Armington aggregation and integrated market. However, the Michigan model is called the "monopolistic competition model" in their paper. Because we want to distinguish clearly whether the strategic variable is quantity or price, we use the term "Bertrand model".

are present in all sectors except in sectors AFF, MIN, and TAT. In the following, a sector with economies of scale is called the IRTS sector, and a sector without economies of scale is called the CRTS sector. The structure of CRTS sectors is the same as in the perfectly competitive model.

It is assumed that economies of scale arise from the existence of fixed cost. Let Q denote the total output of each firm. Then, the total cost TC is given by

$$\mathrm{TC} = \mathrm{MC}(Q + \mathrm{fc}) \tag{1}$$

where MC is the marginal cost and $\mathrm{MC} \times \mathrm{fc}$ is the fixed cost.[9] The marginal cost is assumed to be independent from output. Moreover, we assume that the input structure (production function) is the same as that in the perfectly competitive model. The form of $\mathrm{MC} \times \mathrm{fc}$ means that intermediate goods and primary factors are used in the same proportion for both fixed and variable costs.

2.2.2 Output side

As to the output side, model CD assumes that product varieties of different firms in a sector are differentiated. Since each variety is aggregated using a CES function, the Armington structure for model QD is modified as in Figure 4. Markets in different regions are assumed to be segmented; each firm determines separately the level of supply to different regions. Given the Armington structure of Figure 4, the firm determines the optimal supply to different regions.

The profit of firm v of IRTS sector i in region r is given by

$$\pi_{vir} = (1 - t^Y_{ir}) \left[p^D_{vir} q^D_{vir} + \sum_s p^X_{virs} q^X_{virs} \right] - \mathrm{MC}_{vir} \left[q^D_{vir} + \sum_s q^X_{virs} - \mathrm{fc}_{vir} \right] \tag{2}$$

where t^Y_{ir} is the output tax rate, q^D_{vir} is the supply to the domestic market, q^X_{virs} is the supply to region s, p^D_{vir} is the price in the domestic market, p^X_{virs} is the export price to region s, MC_{vir} is the marginal cost, and $\mathrm{MC}_{vir} \times \mathrm{fc}_{vir}$ is the fixed cost. In the perfectly competitive model, domestic supply and export supply have a common price, that is, p^Y_{ir}. On the contrary, in the imperfectly competitive model, prices are distinguished by destination because all markets in different regions are segmented.

Each firm determines supply to the domestic and export markets so as to maximize profit. FOCs of profit maximization of firm v are

$$\frac{\partial \pi_{vir}}{\partial q^D_{vir}} = 0 : \quad (1 - t^Y_{ir}) p^D_{vir} \left[1 - \frac{1}{\varepsilon^D_{vir}} \right] = \mathrm{MC}_{vir} \tag{3}$$

$$\frac{\partial \pi_{vir}}{\partial q^X_{virs}} = 0 : \quad (1 - t^Y_{ir}) p^X_{virs} \left[1 - \frac{1}{\varepsilon^X_{virs}} \right] = \mathrm{MC}_{vir} \tag{4}$$

where ε^D_{vir} and ε^X_{virs} denote the perceived elasticities of demand in domestic and export markets, respectively, and defined as follows:

$$\varepsilon^D_{vir} \equiv -\frac{\partial \ln q^D_{vir}}{\partial \ln p^D_{vir}} \qquad \varepsilon^X_{virs} \equiv -\frac{\partial \ln q^X_{virs}}{\partial \ln p^X_{virs}}$$

Let us define $\mu^D_{vir} \equiv 1/\varepsilon^D_{vir}$, $\mu^X_{virs} \equiv 1/\varepsilon^X_{virs}$ and $\hat{p}^D_{vir} = (1 - t^Y_{ir}) p^D_{ir}$, $\hat{p}^X_{virs} = (1 - t^Y_{ir}) p^X_{virs}$. Then, (3)–(4) are written as

$$\mu^D_{vir} = \frac{\hat{p}^D_{vir} - \mathrm{MC}_{vir}}{\hat{p}^D_{vir}} \qquad \mu^X_{virs} = \frac{\hat{p}^X_{virs} - \mathrm{MC}_{vir}}{\hat{p}^X_{virs}} \tag{5}$$

From these equations, we can see that μ^D_{vir} and μ^X_{virs} represent markup rates for domestic and export markets, respectively.

[9] Although we use the term "fixed cost", it does not mean that $\mathrm{MC} \times \mathrm{fc}$ is constant. If the marginal cost MC changes, $\mathrm{MC} \times \mathrm{fc}$ also changes. The term "fixed cost" in this case means that it does not depend on the level of output.

2.2.3 Markup rates

To incorporate (3)–(4) (or (5)) into the simulation, it is necessary to derive explicit formula of markup rates. Below, we assume that all firms (varieties) in an IRTS industry are symmetric.

Markup rate for domestic market

First, we derive markup formula for the domestic market (μ^D_{vir}). Since μ^D_{vir} is a reciprocal of the price elasticity of the domestic demand (ε^D_{vir}), we need to derive ε^D_{vir}. It is assumed that each firm determines its output, taking account of the Armington structure depicted in Figure 3. Aggregation in all stages is conducted with CES functions. Thus, the structure of aggregation is represented as follows:

$$A_{ir} = \left[\alpha^{\mathrm{AD}}_{ir} (\mathrm{AD}_{ir})^{\frac{\sigma^A_i - 1}{\sigma^A_i}} + (1 - \alpha^{\mathrm{AD}}_{ir}) (\mathrm{AM}_{ir})^{\frac{\sigma^A_i - 1}{\sigma^A_i}} \right]^{\frac{\sigma^A_i}{\sigma^A_i - 1}} \tag{6}$$

$$\mathrm{AM}_{ir} = \left[\sum_s \alpha^M_{isr} (M_{isr})^{\frac{\sigma^M_i - 1}{\sigma^M_i}} \right]^{\frac{\sigma^M_i}{\sigma^M_i - 1}} \tag{7}$$

$$\mathrm{AD}_{ir} = \left[\sum_v \beta^D_{vir} (q^D_{vir})^{\frac{\sigma^D_i - 1}{\sigma^D_i}} \right]^{\frac{\sigma^D_i}{\sigma^D_i - 1}} \tag{8}$$

$$M_{isr} = \left[\sum \beta^M_{visr} (q^X_{visr})^{\frac{\sigma^F_i - 1}{\sigma^F_i}} \right]^{\frac{\sigma^F_i}{\sigma^F_i - 1}} \tag{9}$$

where A_{ir} is Armington goods i which is created from domestic and imported goods, AM_{ir} is a composite import, AD_{ir} is a composite of domestic varieties, and M_{isr} is a composite of import varieties.

Since all quantity indices are linearly homogeneous CES functions, we can defines price indices as follows:

$$p^A_{ir} = \left[(\alpha^{\mathrm{AD}}_{ir})^{\sigma^A_i} (p^{\mathrm{AD}}_{ir})^{1-\sigma^A_i} + (1 - \alpha^{\mathrm{AD}}_{ir})^{\sigma^A_i} (p^{\mathrm{AM}}_{ir})^{1-\sigma^A_i} \right]^{\frac{1}{1-\sigma^A_i}} \tag{10}$$

$$p^{\mathrm{AM}}_{ir} = \left[\sum_s (\alpha^M_{isr})^{\sigma^M_i} (\tilde{p}^M_{isr})^{1-\sigma^M_i} \right]^{\frac{1}{1-\sigma^M_i}} \tag{11}$$

$$p^{\mathrm{AD}}_{ir} = \left[\sum_v (\beta^D_{vir})^{\sigma^D_i} (p^D_{vir})^{1-\sigma^D_i} \right]^{\frac{1}{1-\sigma^D_i}} \tag{12}$$

$$p^M_{isr} = \left[\sum_v (\beta^M_{visr})^{\sigma^F_i} (\tilde{p}^X_{visr})^{1-\sigma^F_i} \right]^{\frac{1}{1-\sigma^F_i}} \tag{13}$$

where $\tilde{p}^M_{isr} = (1 + t^M_{isr}) p^M_{isr}$ and $\tilde{p}^X_{visr} = (1 - t^X_{isr}) p^X_{visr} + p^T \tau_{isr}$.

From the price indices, we can derive compensated demand functions.

$$\mathrm{AD}_{ir} = \frac{\partial p_{ir}^{A}}{\partial p_{ir}^{\mathrm{AD}}} A_{ir} = \left[\frac{\alpha_{ir}^{\mathrm{AD}} p_{ir}^{A}}{p_{ir}^{\mathrm{AD}}} \right]^{\sigma_i^A} A_{ir} \tag{14}$$

$$\mathrm{AM}_{ir} = \frac{\partial p_{ir}^{A}}{\partial p_{ir}^{\mathrm{AM}}} A_{ir} = \left[\frac{(1-\alpha_{ir}^{\mathrm{AD}}) p_{ir}^{A}}{p_{ir}^{\mathrm{AM}}} \right]^{\sigma_i^A} A_{ir} \tag{15}$$

$$M_{isr} = \frac{\partial p_{ir}^{\mathrm{AM}}}{\partial \tilde{p}_{isr}^{M}} \mathrm{AM}_{ir} = \left[\frac{\alpha_{isr}^{M} p_{ir}^{\mathrm{AM}}}{\tilde{p}_{isr}^{M}} \right]^{\sigma_i^M} \mathrm{AM}_{ir} \tag{16}$$

$$q_{vir}^{D} = \frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^{D}} \mathrm{AD}_{ir} = \left[\frac{\beta_{vir}^{D} p_{ir}^{\mathrm{AD}}}{p_{vir}^{D}} \right]^{\sigma_i^D} \mathrm{AD}_{ir} \tag{17}$$

$$q_{visr}^{X} = \frac{\partial p_{isr}^{M}}{\partial \tilde{p}_{visr}^{X}} M_{isr} = \left[\frac{\beta_{visr}^{M} p_{isr}^{M}}{\tilde{p}_{visr}^{X}} \right]^{\sigma_i^F} M_{isr} \tag{18}$$

From the above results, let us derive markup rates (price elasticity of demand). First, we derive inverse demand function for domestic variety from (17).

$$p_{vir}^{D} = \left[\frac{\mathrm{AD}_{ir}}{q_{vir}^{D}} \right]^{1/\sigma_i^D} \beta_{vir}^{D} p_{ir}^{\mathrm{AD}} \tag{19}$$

Taking logarithm of both sides, we have

$$\ln p_{vir}^{D} = \frac{1}{\sigma_i^D} \ln A_{ir} - \frac{1}{\sigma_i^D} q_{vir}^{D} + \ln p_{ir}^{\mathrm{AD}} + \ln \beta_{vir}^{D}$$

From this, the following relationship holds.

$$\frac{\partial \ln p_{vir}^{D}}{\partial \ln q_{vir}^{D}} = -\frac{1}{\sigma_i^D} + \frac{1}{\sigma_i^D} \frac{q_{vir}^{D}}{\mathrm{AD}_{ir}} \frac{\partial \mathrm{AD}_{ir}}{\partial q_{vir}^{D}} + \frac{q_{vif}^{D}}{p_{ir}^{\mathrm{AD}}} \frac{\partial p_{ir}^{\mathrm{AD}}}{\partial \mathrm{AD}_{ir}} \frac{\partial \mathrm{AD}_{ir}}{\partial q_{vir}^{D}} \tag{20}$$

By (8), $\partial \mathrm{AD}_{ir} / \partial q_{vir}^{D}$ in (20) is written as

$$\frac{\partial \mathrm{AD}_{ir}}{\partial q_{vir}^{D}} = (\mathrm{AD}_{ir})^{1/\sigma_i^D} \left[\beta_{vir}^{D} (q_{vir}^{D})^{-1/\sigma_i^D} + \sum_{v' \neq v} \beta_{v'ir}^{D} (q_{v'ir}^{D})^{-1/\sigma_i^D} \frac{q_{v'ir}^{D}}{q_{vir}^{D}} \phi_{vir}^{D} \right] \tag{21}$$

where ϕ_{vir}^{D} is firm v's conjectural elasticity defined as follows.

$$\phi_{vir}^{D} \equiv \frac{\partial \ln q_{v'ir}^{D}}{\partial \ln q_{vir}^{D}} \qquad v' \neq v$$

Substituting (19) into (21), we get

$$\frac{\partial \mathrm{AD}_{ir}}{\partial q_{vir}^{D}} = \frac{p_{vir}^{D}}{p_{ir}^{\mathrm{AD}}} \left[1 + \sum_{v' \neq v} \frac{p_{v'ir}^{D} q_{v'ir}^{D}}{p_{vir}^{D} q_{vir}^{D}} \phi_{vir}^{D} \right]$$

From this, (20) is written as follows:

$$\frac{\partial \ln p_{vir}^{D}}{\partial \ln q_{vir}^{D}} = -\frac{1}{\sigma_i^D} + \left[\frac{1}{\sigma_i^D} \frac{p_{vir}^{D} q_{vir}^{D}}{p_{ir}^{\mathrm{AD}} \mathrm{AD}_{ir}} + \frac{p_{vir}^{D} q_{vir}^{D}}{p_{ir}^{\mathrm{AD}} \mathrm{AD}_{ir}} \frac{\partial p_{ir}^{\mathrm{AD}}}{\partial \mathrm{AD}_{ir}} \frac{\mathrm{AD}_{ir}}{p_{ir}^{\mathrm{AD}}} \right] \left[1 + \sum_{v' \neq v} \frac{p_{v'ir}^{D} q_{v'ir}^{D}}{p_{vir}^{D} q_{vir}^{D}} \phi_{vir}^{D} \right]$$

$p^D_{vir}q^D_{vir}/(p^{\mathrm{AD}}_{ir}\mathrm{AD}_{ir})$ in the above equation indicates share of a firm in the domestic market. Since we assume symmetry of all firms, we have $p^D_{vir}q^D_{vir}/(p^{\mathrm{AD}}_{ir}\mathrm{AD}_{ir}) = 1/n_{ir}$. Similarly, symmetry means $p^D_{vir} = p^D_{v'ir}$ and $q^D_{vir} = q^D_{v'ir}$. Thus, the following relation holds.

$$\sum_{v' \neq v} \frac{p^D_{v'ir}q^D_{v'ir}}{p^D_{vir}q^D_{vir}}\phi^D_{vir} = (n_{ir}-1)\phi^D_{ir}$$

In addition, we define

$$\varepsilon^{\mathrm{AD}}_{ir} \equiv -\frac{\partial \mathrm{AD}_{ir}}{\partial p^{\mathrm{AD}}_{ir}}\frac{p^{\mathrm{AD}}_{ir}}{\mathrm{AD}_{ir}}$$

From above results, markup rate μ^D_{ir} is given by

$$\mu^D_{ir} = \frac{1}{\varepsilon^D_{ir}} = -\frac{\partial \ln p^D_{vir}}{\partial \ln q^D_{vir}} = \frac{1}{\sigma^D_i} + \left[\frac{1}{\varepsilon^{\mathrm{AD}}_{ir}} - \frac{1}{\sigma^D_i}\right]\frac{1+(n_{ir}-1)\phi^D_{ir}}{n_{ir}} \tag{22}$$

This indicates markup rate of each firm of IRTS sector i in region r. Since all firms in an industry are assumed to be symmetric, index v is omitted.

Following the similar procedure, $1/\varepsilon^{\mathrm{AD}}_{ir}$ is derived as follows:

$$\frac{1}{\varepsilon^{\mathrm{AD}}_{ir}} = \frac{1}{\sigma^A_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i}\right]\left[S^{\mathrm{AD}}_{ir} + (1-S^{\mathrm{AD}}_{ir})\phi^{\mathrm{DM}}_{ir}\right] \tag{23}$$

where S^{AD}_{ir} is share of domestic supply, ϕ^{DM}_{ir} is conjectural elasticity, and ε^A_{ir} is price elasticity of Armington demand defined as follows:

$$S^{\mathrm{AD}}_{ir} \equiv \frac{p^{\mathrm{AD}}_{ir}\mathrm{AD}_{ir}}{p^A_{ir}A_{ir}} \qquad \phi^{\mathrm{DM}}_{ir} \equiv \frac{\partial \ln AM_{ir}}{\partial \ln AD_{ir}} \qquad \varepsilon^A_{ir} \equiv -\frac{\partial \ln A_{ir}}{\partial \ln p^A_{ir}}$$

Combining (22) and (23), markup rate can be written as follows:

$$\mu^D_{ir} = \frac{1}{\sigma^D_i} + \left\{\frac{1}{\sigma^A_i} - \frac{1}{\sigma^D_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i}\right]\left[S^{\mathrm{AD}}_{ir} + (1-S^{\mathrm{AD}}_{ir})\phi^{\mathrm{DM}}_{ir}\right]\right\}\frac{1+(n_{ir}-1)\phi^D_{ir}}{n_{ir}} \tag{24}$$

Since model CD assumes Cournot conjecture, conjectural elasticity parameters ϕ^D_{ir} and ϕ^{DM}_{ir} are zero. Thus, (24) reduces to

$$\mu^D_{ir} = \frac{1}{\sigma^D_i} + \left\{\frac{1}{\sigma^A_i} - \frac{1}{\sigma^D_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i}\right]S^{\mathrm{AD}}_{ir}\right\}\frac{1}{n_{ir}}$$

This is the markup rate for domestic supply.

Markup rate for export markets

Next, let us consider markup rate for export market μ^X_{visr}. The procedure is the same as in the derivation of μ^D_{vir}. First, from (18), inverse demand for import from region s to region r is given by

$$\tilde{p}^X_{visr} = \left[\frac{M_{isr}}{q^X_{visr}}\right]^{1/\sigma^F_i}\beta^M_{visr}p^M_{isr} \tag{25}$$

Taking logarithm of both sides, we have

$$\ln \tilde{p}^X_{visr} = \frac{1}{\sigma^F_i}\ln M_{isr} - \frac{1}{\sigma^F_i}\ln q^X_{visr} + \ln p^M_{isr} + \ln \beta^M_{visr}$$

This leads to

$$\frac{\partial \ln \tilde{p}^X_{visr}}{\partial \ln q^X_{visr}} = -\frac{1}{\sigma^F_i} + \frac{1}{\sigma^F_i}\frac{q^X_{visr}}{M_{isr}}\frac{\partial M_{isr}}{\partial q^X_{visr}} + \frac{q^X_{visr}}{p^M_{isr}}\frac{\partial p^M_{isr}}{\partial M_{isr}}\frac{\partial M_{isr}}{\partial q^X_{visr}} \tag{26}$$

From (9), $\partial M_{isr}/\partial q^X_{visr}$ is written as

$$\frac{\partial M_{isr}}{\partial q^X_{visr}} = (M_{isr})^{1/\sigma^F_i}\left[\beta^M_{visr}(q^D_{vir})^{-1/\sigma^F_i} + \sum_{v'\neq v}\beta^M_{v'isr}(q^X_{v'isr})^{-1/\sigma^F_i}\frac{q^X_{v'isr}}{q^X_{visr}}\phi^X_{visr}\right] \tag{27}$$

where ϕ^X_{visr} is conjectural elasticity defined as follows:

$$\phi^X_{visr} \equiv \frac{\partial \ln q^X_{v'isr}}{\partial \ln q^X_{visr}} \qquad v' \neq v \tag{28}$$

Applying (25) to this, we have

$$\frac{\partial M_{isr}}{\partial q^X_{visr}} = \frac{\tilde{p}^X_{visr}}{p^M_{isr}}\left[1 + \sum_{v'\neq v}\frac{\tilde{p}^X_{v'isr}q^X_{v'isr}}{\tilde{p}^X_{visr}q^X_{visr}}\phi^X_{visr}\right]$$

From this, (26) is written as

$$\frac{\partial \ln \tilde{p}^X_{visr}}{\partial \ln q^X_{visr}} = -\frac{1}{\sigma^F_i} + \left[\frac{1}{\sigma^F_i}\frac{q^X_{visr}}{M_{isr}}\frac{\tilde{p}^X_{visr}}{p^M_{isr}} + \frac{q^X_{visr}}{M_{isr}}\frac{\tilde{p}^X_{visr}}{p^M_{isr}}\frac{\partial p^M_{isr}}{\partial M_{isr}}\frac{M_{isr}}{p^M_{isr}}\right]\left[1 + \sum_{v'\neq v}\frac{\tilde{p}^X_{v'isr}q^X_{v'isr}}{\tilde{p}^X_{visr}q^X_{visr}}\phi^X_{visr}\right]$$

By the symmetry assumption, $q^X_{visr}/M_{isr} = 1/n_{is}$ holds. Similarly, symmetry means

$$\sum_{v'\neq v}\frac{\tilde{p}^X_{v'isr}q^X_{v'isr}}{\tilde{p}^X_{visr}q^X_{visr}}\phi^X_{visr} = (n_{is}-1)\phi^X_{isr}$$

In addition, we define elasticity as follows:

$$\varepsilon^M_{isr} \equiv -\frac{\partial M_{isr}}{\partial p^M_{isr}}\frac{p^M_{isr}}{M_{isr}} \tag{29}$$

Then, markup rates are derived as follows:

$$\tilde{\mu}^X_{isr} = \frac{1}{\tilde{\varepsilon}^X_{isr}} = -\frac{\partial \ln \tilde{p}^X_{isr}}{\partial \ln q^X_{isr}} = \frac{1}{\sigma^F_i} + \left[\frac{1}{\varepsilon^M_{isr}} - \frac{1}{\sigma^F_i}\right]\frac{1+(n_{is}-1)\phi^X_{isr}}{n_{is}} \tag{30}$$

Index v is omitted here because of symmetry assumption.

Following the similar procedure, elasticities are derived as follows:

$$\frac{1}{\varepsilon^M_{isr}} = \frac{1}{\sigma^M_i} + \left[\frac{1}{\varepsilon^{\mathrm{AM}}_{ir}} - \frac{1}{\sigma^M_i}\right][S^M_{isr} + (1-S^M_{isr})\phi^{\mathrm{XM}}_{isr}] \tag{31}$$

$$\frac{1}{\varepsilon^{\mathrm{AM}}_{ir}} = \frac{1}{\sigma^A_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i}\right][S^{\mathrm{AM}}_{ir} + (1-S^{\mathrm{AM}}_{ir})\phi^{\mathrm{XMD}}_{isr}] \tag{32}$$

where

$$S^M_{isr} \equiv \frac{\tilde{p}^M_{isr}M_{isr}}{p^{\mathrm{AM}}_{ir}\mathrm{AM}_{ir}} \qquad S^{\mathrm{AM}}_{ir} \equiv \frac{p^{\mathrm{AM}}_{ir}\mathrm{AM}_{ir}}{p^A_{ir}A_{ir}} = 1 - S^{\mathrm{AD}}_{ir}$$

$$\phi^{\mathrm{XM}}_{isr} \equiv \frac{\partial \ln M_{is'r}}{\partial \ln M_{isr}} \qquad \phi^{\mathrm{XMD}}_{isr} \equiv \frac{\partial \ln \mathrm{AD}_{ir}}{\partial \ln \mathrm{AM}_{ir}}$$

From (30)–(32), markup rate for export of region s to region r is represented by

$$\tilde{\mu}^X_{isr} = \frac{1}{\sigma^F_i} + \left\{ \frac{1}{\sigma^M_i} - \frac{1}{\sigma^F_i} + \left[\frac{1}{\sigma^A_i} - \frac{1}{\sigma^M_i} + \left(\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i} \right) \right.\right.$$
$$\left.\left. \times [S^{\mathrm{AM}}_{ir} + (1 - S^{\mathrm{AM}}_{ir})\phi^{\mathrm{XMD}}_{isr}] \right] [S^M_{isr} + (1 - S^M_{isr})\phi^{\mathrm{XM}}_{isr}] \right\} \frac{1 + (n_{is} - 1)\phi^X_{isr}}{n_{is}} \tag{33}$$

Since model CD assumes Cournot conjecture, conjectural elasticity parameters ϕ^X_{isr}, $\phi^{\mathrm{XMD}}_{isr}$, and ϕ^{XM}_{isr} are zero. Thus, (33) reduces to

$$\tilde{\mu}^X_{isr} = \frac{1}{\sigma^F_i} + \left\{ \frac{1}{\sigma^M_i} - \frac{1}{\sigma^F_i} + \left[\frac{1}{\sigma^A_i} - \frac{1}{\sigma^M_i} + \left(\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i} \right) S^{\mathrm{AM}}_{ir} \right] S^M_{isr} \right\} \frac{1}{n_{is}} \tag{34}$$

In our model, it is necessary to make further adjustment to (34) because $\tilde{\mu}^X_{isr}$ deviates from markup rate for firms μ^X_{isr}. The difference between two markup rates is due to transport cost.

$\tilde{\varepsilon}^X_{isr}$ is defined as follows:

$$\tilde{\varepsilon}^X_{isr} = -\frac{\partial \ln q^X_{isr}}{\partial \ln \tilde{p}^X_{isr}}$$

Since $\tilde{p}^X_{isr} = (1 - t^X_{isr})p^X_{isr} + p^T \tau_{isr}$, we have

$$\tilde{\varepsilon}^X_{isr} = -\frac{\partial q^X_{isr}}{\partial p^X_{isr}} \frac{\partial p^X_{isr}}{\partial \tilde{p}^X_{isr}} \frac{\tilde{p}^X_{isr}}{q^X_{isr}} = -\frac{\partial q^X_{isr}}{\partial p^X_{isr}} \frac{p^X_{isr}}{q^X_{isr}} \frac{\tilde{p}^X_{isr}}{(1 - t^X_{isr})p^X_{isr}}$$

From this, markup rate for each firm μ^X_{isr} is given by

$$\mu^X_{isr} = \tilde{\mu}^X_{isr} \frac{\tilde{p}^X_{isr}}{(1 - t^X_{isr})p^X_{isr}}$$

2.2.4 Profit maximization

In this section, we summarize results derived above. Below, we assume that all firms in an IRTS sector are symmetric. This means that all firms in an the same sector set the same prices, outputs, and markup rates.

The FOCs of profit maximization of a firm of IRTS sector s in region r are given by (3)–(4). Since we assume symmetry, index v can be omitted from these conditions.

$$(1 - t^Y_{ir})p^D_{ir} \left[1 - \mu^D_{ir} \right] = \mathrm{MC}_{ir} \tag{35}$$

$$(1 - t^Y_{ir})p^X_{irs} \left[1 - \mu^X_{irs} \right] = \mathrm{MC}_{ir} \tag{36}$$

(35) is the FOC for domestic supply q^D_{ir} and (36) is the FOC for export supply q^X_{irs}. By these conditions, each firm determines q^D_{ir} and q^X_{irs}.

Markup rates are given by

$$\mu^D_{ir} = \frac{1}{\sigma^D_i} + \left\{ \frac{1}{\sigma^A_i} - \frac{1}{\sigma^D_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i} \right] S^{\mathrm{AD}}_{ir} \right\} \frac{1}{n_{ir}} \tag{37}$$

$$\tilde{\mu}^X_{irs} = \frac{1}{\sigma^F_i} + \left\{ \frac{1}{\sigma^M_i} - \frac{1}{\sigma^F_i} + \left[\frac{1}{\sigma^A_i} - \frac{1}{\sigma^M_i} + \left(\frac{1}{\varepsilon^A_{is}} - \frac{1}{\sigma^A_i} \right) S^{\mathrm{AM}}_{is} \right] S^M_{irs} \right\} \frac{1}{n_{ir}} \tag{38}$$

$$\mu^X_{irs} = \tilde{\mu}^X_{irs} \frac{\tilde{p}^X_{irs}}{(1 - t^X_{irs})p^X_{irs}} \tag{39}$$

$$\tilde{p}^X_{irs} = (1 - t^X_{irs})p^X_{irs} + p^T \tau_{irs} \tag{40}$$

Share variables are defined as follows:

$$S_{ir}^{\mathrm{AD}} = \frac{p_{ir}^{\mathrm{AD}}\mathrm{AD}_{ir}}{p_{ir}^{A}A_{ir}} \qquad S_{is}^{\mathrm{AM}} = \frac{p_{is}^{\mathrm{AM}}\mathrm{AM}_{is}}{p_{is}^{A}A_{is}} = 1 - S_{is}^{\mathrm{AD}}$$

$$S_{irs}^{M} = \frac{\tilde{p}_{irs}^{M}M_{irs}}{p_{is}^{\mathrm{AM}}\mathrm{AM}_{is}} \qquad \sum_{r} S_{irs}^{M} = 1$$

2.2.5 Zero profit conditions

Model CD assumes free entry–exit. So, zero profit condition is satisfied in the equilibrium. Zero profit condition is given by (2). Since we assume that input structure is common in all models, marginal cost of production in IRTS models (i.e. MC_{ir}) is equal to marginal cost in perfectly competitive model (c_{ir}^{Y}). Thus, zero profit condition for IRTS sector i is given by

$$(1 - t_{ir}^{Y}) \left[p_{ir}^{D}q_{ir}^{D} + \sum_{s} p_{irs}^{X}q_{irs}^{X} \right] - c_{ir}^{Y} \left[q_{ir}^{D} + \sum_{s} q_{irs}^{X} - \mathrm{fc}_{ir} \right] = 0 \tag{41}$$

The number of firms in IRTS sector i is determined so that this zero profit condition is satisfied.

2.2.6 Average cost

Here, we see average cost of each firm. Let q_{ir}^{T} denote total output of each firm in IRTS sector i. That is, $q_{ir}^{T} = q_{ir}^{D} + \sum_{s} q_{irs}^{X}$. Then, total cost is represented as $c_{ir}^{Y}(q_{ir}^{T} + \mathrm{fc}_{ir})$. $c_{ir}^{Y}q_{ir}^{T}$ indicates variable cost and $c_{ir}^{Y}\mathrm{fc}_{ir}$ indicates fixed cost. Since average cost is defined as total cost divided by total output, it is represented as follows:

$$\mathrm{AC}_{ir} = \frac{c_{ir}^{Y}(q_{ir}^{T} + \mathrm{fc}_{ir})}{q_{ir}^{T}} = c_{ir}^{Y} \left[1 + \frac{\mathrm{fc}_{ir}}{q_{ir}^{T}} \right]$$

From this, we can confirm that average cost of each firm declines as total output increases. In view of this, increase in scale of each firm generates positive impacts on the economy.

2.2.7 Price index

By (12) and (13), we define price indices for aggregated varieties. Here, we derive price indices in a symmetric model. First, by symmetry, β_{vir}^{D} and p_{vir}^{D} are equal for any v. Thus, summation with respect to v means multiplication by n_{ir}. It follows that (12) is written as

$$p_{ir}^{\mathrm{AD}} = \left[n_{ir}(\beta_{ir}^{D})^{\sigma_i^D}(p_{ir}^{D})^{1-\sigma_i^D} \right]^{\frac{1}{1-\sigma_i^D}} = (n_{ir})^{\frac{1}{1-\sigma_i^D}}(\beta_{ir}^{D})^{\frac{\sigma_i^D}{1-\sigma_i^D}} p_{ir}^{D}$$

From this, we can see effects of n_{ir} on price index. Assume that $\sigma_i^D > 1$ (this is indeed assumed in the simulation). Then, we have $\partial p_{ir}^{\mathrm{AD}}/\partial n_{ir} < 0$. That is, the increase in n_{ir} decreases p_{ir}^{AD}.

Similarly, p_{isr}^{M} is written as

$$p_{isr}^{M} = \left[n_{is}(\beta_{isr}^{M})^{\sigma_i^F}(\tilde{p}_{isr}^{X})^{1-\sigma_i^F} \right]^{\frac{1}{1-\sigma_i^F}} = (n_{is})^{\frac{1}{1-\sigma_i^F}}(\beta_{isr}^{M})^{\frac{\sigma_i^F}{1-\sigma_i^F}} \tilde{p}_{isr}^{X}$$

Also in this case, increase in varieties lowers the price index.

2.2.8 Demand function

In this section, we consider demand functions of IRTS sectors. These demand functions are derived from (14)–(18). First, demand for outputs of a firm in region r is given by

$$\tilde{q}_{vir}^{D} = \frac{\partial p_{ir}^{A}}{\partial p_{ir}^{\mathrm{AD}}} \frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^{D}} A_{ir} = \left[\frac{\alpha_{ir}^{\mathrm{AD}} p_{ir}^{A}}{p_{ir}^{\mathrm{AD}}} \right]^{\sigma_i^A} \left[\frac{\beta_{vir}^{D} p_{ir}^{\mathrm{AD}}}{p_{vir}^{D}} \right]^{\sigma_i^D} A_{ir}$$

Similarly, demand of region r for outputs of a firm in region s is

$$\tilde{q}_{isr}^{X} = \frac{\partial p_{ir}^{A}}{\partial p_{ir}^{\mathrm{AM}}} \frac{\partial p_{ir}^{\mathrm{AM}}}{\partial \tilde{p}_{isr}^{M}} \frac{\partial \tilde{p}_{isr}^{M}}{\partial \tilde{p}_{isr}^{X}} A_{ir} = \left[\frac{(1-\alpha_{ir}^{\mathrm{AD}}) p_{ir}^{A}}{p_{ir}^{\mathrm{AM}}} \right]^{\sigma_i^A} \left[\frac{\alpha_{isr}^{M} p_{ir}^{\mathrm{AM}}}{\tilde{p}_{isr}^{M}} \right]^{\sigma_i^M} \left[\frac{\beta_{isr}^{M} p_{isr}^{M}}{\tilde{p}_{isr}^{X}} \right]^{\sigma^F} A_{ir}$$

2.3 Market clearing conditions

Below, we present market clearing conditions. These conditions are different across CRTS sectors and IRTS sectors. Market clearing conditions for the perfectly competitive model is represented by the case where $C = I$ (i.e. $K = \emptyset$). In equations below, the LHS represents supply and the RHS represents demand.

2.3.1 Output of CRTS sectors ($i \in C$)

First, let us consider output of CRTS sectors. Supply is given by Q_{ir}. Demand is the sum of domestic demand (AD_{ir}^{D}), import demand of region s (M_{irs}^{D}), and demand from international transport sector ($a_{ir}^{T} T$).

$$Y_{ir} \geq \mathrm{AD}_{ir}^{D} + \sum_{s} M_{irs}^{D} + a_{ir}^{T} T \qquad i \in C, i \neq \mathrm{CGD}$$

With respect to investment goods (i.e. $i = \mathrm{CGD}$), demand consists of only investment demand INV_r. Thus, market clearing condition is given by

$$Y_{ir} \geq \mathrm{INV}_r \qquad i = \mathrm{CGD}$$

Note that investment demand INV_r is exogenously given constant.

2.3.2 Markets for goods of IRTS sectors ($i \in K$)

As to IRTS goods, we must consider market clearing conditions for an individual firm. First, domestic supply of a IRTS firm in region r is q_{ir}^{D}. On the other hand, domestic demand for a IRTS firm in region r is $\tilde{q}_{ir}^{D}$.

$$q_{ir}^{D} \geq \tilde{q}_{ir}^{D}$$

Similarly, export supply of IRTS sector i in region r to region s is q_{irs}^{X} and demand for it is $\tilde{q}_{irs}^{X}$. Thus, we have

$$q_{irs}^{X} \geq \tilde{q}_{irs}^{X}$$

2.3.3 Markets for Armington goods

Supply of Armington goods is given by A_{ir} and demand is sum of intermediate demand and final demand. Final demand is represented by C_{ir}^{D}. Intermediate demand of CRTS sector j is $a_{ijr}^{I} Q_{jr}$. On the other hand, intermediate demand of a single firm in IRTS sector j is $a^I_{ijr}(q^D_{jr} + \sum_s q^X_{jrs}) + a^I_{ijr}\mathrm{fc}_{jr}$. Thus, market clearing condition for Armington goods i is

$$A_{ir} \geq \sum_{j\in C} a^I_{ijr} Q_{jr} + \sum_{j\in K} n_{jr} a^I_{ijr} q_{jr} + C^D_{ir} \tag{42}$$

where q_{jr} is defined as follows:

$$q_{jr} \equiv q^D_{jr} + \sum_s q^X_{jrs} + \mathrm{fc}_{jr} \qquad j \in K$$

2.3.4 Market clearing condition for international transport service

Supply of transport service is T and demand is the sum of $\tau_{irs} M^D_{irs}$.

$$T \geq \sum_{i,r,s} \tau_{irs} M^D_{irs}$$

2.3.5 Markets of primary factors

Supply of primary factors is $(\bar{F}_{fr})$ which is assumed to be constant. On the other hand, demand of primary factors is demand from production.

$$\bar{F}_{fr} \geq \sum_{i\in C} a^F_{fir} Q_{ir} + \sum_{i\in K} n_{ir} a^F_{fir} q_{ir}$$

2.4 Income of the household

In this section, we derive income of the household (H_r).[10] Income is derived from factor income, tax revenue, and net capital inflow. Taxes include production tax, intermediate tax, factor tax, consumption tax, export tax, and tariff. Net capital inflow is represented by $p^U_{\mathrm{USA}}\mathrm{BOP}_r$.[11] Finally, we subtract investment expenditure from income.

$$\begin{aligned}
H_r = & \sum_f p^F_{fr} \bar{F}_{fir} \\
& + \sum_{i\in C} t^Y_{ir} p^Y_{ir} Y_{ir} + \sum_{i\in K} t^Y_{ir} n_{ir} \left[p^D_{ir} q^D_{ir} + \sum_s p^X_{irs} q^X_{irs} \right] \\
& + \sum_j t^I_{jir} p^A_{jr} a^I_{jir} \left[\sum_{i\in C} Y_{ir} + \sum_{i\in K} n_{ir} q_{ir} \right] \\
& + \sum_{i,f} t^F_{fir} p^F_{fr} a^F_{fir} \left[\sum_{i\in C} Y_{ir} + \sum_{i\in K} n_{ir} q_{ir} \right] \\
& - \sum_{i\in C,s} t^X_{irs} p^Y_{ir} M^D_{irs} - \sum_{i\in K,s} t^X_{irs} p^X_{irs} n_{ir} \tilde{q}^X_{irs} \\
& + \sum_{i\in C,s} t^M_{isr} \tilde{p}^X_{isr} M^D_{isr} + \sum_{i\in K,s} t^M_{isr} \tilde{p}^X_{isr} n_{is} \tilde{q}^X_{isr} \\
& + \sum_i t^C_{ir} p^A_{ir} a^C_{ir} U_r \\
& + \; p^U_{\mathrm{USA}} \mathrm{BOP}_r - p^{\mathrm{INV}}_r \mathrm{INV}_r
\end{aligned}$$

[10] The term income here indicates income spent on consumption.

[11] We use p^U_{USA} for the price index of international capital flow.

2.5 Other imperfectly competitive models

So far, we have used model CD to represent the imperfectly competitive model. Below, we explain other variants of imperfectly competitive models. Note that cost structure is the same as model CD.

2.5.1 Model LGMC

Model LGMC presents the large group monopolistic competitive model frequently used in theoretical analyses (for example Krugman, 1980). In this model, each firm recognizes that the number of firms in the industry is sufficiently large. By this assumption, markup rates are modified as follows:

$$\mu_{ir}^{D} = 1/\sigma_i^{D} \qquad \tilde{\mu}_{irs}^{X} = 1/\sigma_i^{F} \tag{43}$$

These markup rates are derived by setting $n_{ir} \to \infty$ in (37)–(38). [12]

As the above equations show, markup rates in model LGMC are equal to the reciprocals of elasticities of substitution and are constant. Other components in the model are the same as model CD.

2.5.2 Model CH

Model CD assumes that all varieties in an industry are differentiated. On the other hand, model CH assumes that all varieties in an industry are homogeneous. The assumption of homogeneous varieties means that elasticities of substitution among varieties are infinite. Thus, we can get markup rates for model CH by setting $\sigma_i^{D} \to \infty$ and $\sigma_i^{F} \to \infty$ in (37) and (38).

$$\mu_{ir}^{D} = \left[\frac{1}{\sigma_i^{A}} + \left(\frac{1}{\varepsilon_{ir}^{A}} - \frac{1}{\sigma_i^{A}}\right) S_{ir}^{\mathrm{AD}}\right] \frac{1}{n_{ir}}$$

$$\tilde{\mu}_{irs}^{X} = \left\{\frac{1}{\sigma_i^{M}} + \left[\frac{1}{\sigma_i^{A}} - \frac{1}{\sigma_i^{M}} + \left(\frac{1}{\varepsilon_{ir}^{A}} - \frac{1}{\sigma_i^{A}}\right) S_{is}^{\mathrm{AM}}\right] S_{irs}^{M}\right\} \frac{1}{n_{ir}}$$

2.5.3 Model CF

In model CD, free entry–exit is assumed. On the other hand, model CF assumes that the number of firms (varieties) in an industry is fixed. This change in the assumption means that zero profit condition is not satisfied. We assume that profit is transferred to the household in lump-sum fashion.

2.5.4 Model QCV

Model CD assumes that each firm competes under Cournot conjecture. That is, each firm determines his outputs, viewing the outputs of all other firms as fixed. Model QCV also assumes quantity competition as in model CD, but assumes non-zero conjectural variation. Markup rates with conjectural variation parameters are given by (24) and (34). In addition, we assume that conjectural elasticity parameters of a firm against all rival firms in a market are equalized. Let ϕ_{ir}^{D} denote conjectural elasticity of rival's supply with respect to a change in own supply, and ϕ_{irs}^{X} denote conjectural elasticity of rival's supply to region s. Then, the above assumption implies the

[12] Although we assume $n_r \to \infty$ in deriving markup rates, it is merely a firm's conjecture and it does not mean that the actual number of firms is infinite. The actual number of firms is endogenously determined so that the zero profit condition is satisfied.

following relations.

$$\phi_{ir}^{D} \equiv \frac{\partial \ln q_{v'ir}^{D}}{\partial \ln q_{vir}^{D}} = \frac{\partial \ln q_{lisr}^{X}}{\partial \ln q_{vir}^{D}} \qquad v' \neq v$$

$$\phi_{irs}^{X} \equiv \frac{\partial \ln q_{v'irs}^{X}}{\partial \ln q_{virs}^{X}} = \frac{\partial \ln q_{lir's}^{X}}{\partial \ln q_{virs}^{X}} = \frac{\partial \ln q_{lis}^{D}}{\partial \ln q_{virs}^{X}} \qquad v' \neq v,\ r' \neq r$$

In the following, using ϕ_{ir}^{D} and ϕ_{irs}^{X}, we rewrite ϕ_{ir}^{DM}, ϕ_{irs}^{XM}, and $\phi_{irs}^{\mathrm{XMD}}$ in (24) and (34). First, let us consider ϕ_{ir}^{DM}. It is defined as

$$\phi_{ir}^{\mathrm{DM}} \equiv \frac{\partial \ln \mathrm{AM}_{ir}}{\partial \ln \mathrm{AD}_{ir}}$$

From (8) and (19), we have

$$d \ln \mathrm{AD}_{ir} = \sum_{v' \neq v} S_{v'ir}^{D} d \ln q_{v'ir}^{D} + S_{vir}^{D} d \ln q_{vir}^{D}$$

where

$$S_{v'ir}^{D} \equiv p_{v'ir}^{D} q_{v'ir}^{D} / (p_{ir}^{\mathrm{AD}} \mathrm{AD}_{ir})$$

By the definition of ϕ_{vir}^{D}, this reduces to

$$d \ln \mathrm{AD}_{ir} = \left[\sum_{v' \neq v} S_{v'ir}^{D} \phi_{vir}^{D} + S_{vir}^{D} \right] d \ln q_{vir}^{D}$$

In addition, from the symmetry assumption, $S_{v'ir}^{D} = S_{vir}^{D} = 1/n_{ir}$ holds. So, we have

$$d \ln \mathrm{AD}_{ir} = \frac{1 + (n_{ir} - 1)\phi_{ir}^{D}}{n_{ir}} d \ln q_{ir}^{D} \tag{44}$$

Similarly, from (7), (9), (16), and (18), we have

$$d \ln \mathrm{AM}_{ir} = \sum_{s} S_{isr}^{M} d \ln M_{isr} \qquad d \ln M_{isr} = \sum_{z} S_{zisr}^{X} d \ln q_{zisr}^{X}$$

where

$$S_{zisr}^{X} \equiv \tilde{p}_{zisr}^{X} q_{zisr}^{X} / (p_{isr}^{M} M_{isr})$$

From the definition of ϕ_{ir}^{D}, we have $d \ln q_{zisr}^{X} = \phi_{ir}^{D} d \ln q_{ir}^{D}$. Thus, $d \ln M_{isr}$ is represented as

$$d \ln M_{isr} = \sum_{z} S_{zisr}^{X} \phi_{ir}^{D} d \ln q_{ir}^{D} = \phi_{ir}^{D} d \ln q_{ir}^{D}$$

Using this relation, we can express $d \ln \mathrm{AM}_{ir}$ as follows:

$$d \ln \mathrm{AM}_{ir} = \sum_{s} S_{isr}^{M} \phi_{ir}^{D} d \ln q_{ir}^{D} = \phi_{ir}^{D} d \ln q_{ir}^{D} \tag{45}$$

From (44) and (45), we have

$$\phi_{ir}^{\mathrm{DM}} = \frac{\phi_{ir}^{D}}{[1 + (n_{ir} - 1)\phi_{ir}^{D}]/n_{ir}} \tag{46}$$

Using Eq. (46), we can rewrite (24) as follows:

$$\mu_{ir}^{D} = \frac{1}{\sigma_i^D} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^D}\right] \frac{1 + (n_{ir} - 1)\phi_{ir}^D}{n_{ir}} + \left[\frac{1}{\varepsilon_{ir}^A} - \frac{1}{\sigma_{ir}^A}\right] \frac{S_{ir}^{\mathrm{AD}} + (n_{ir} - S_{ir}^{\mathrm{AD}})\phi_{ir}^D}{n_{ir}} \tag{47}$$

This is the markup rate for domestic supply in model QCV.

Following the same procedure, we next rewrite (34). ϕ_{isr}^{XM} and $\phi_{isr}^{\mathrm{XMD}}$ in (34) are defined as follows:

$$\phi_{isr}^{\mathrm{XM}} \equiv \frac{\partial \ln M_{is'r}}{\partial \ln M_{isr}} \qquad \phi_{isr}^{\mathrm{XMD}} \equiv \frac{\partial \ln \mathrm{AD}_{ir}}{\partial \ln \mathrm{AM}_{ir}}$$

From (9) and (18), we have

$$d \ln M_{isr} = \sum_{v' \neq v} S_{v'isr}^X d \ln q_{v'isr}^X + S_{visr}^X d \ln q_{visr}^X$$

By the definition of ϕ_{visr}^X and the symmetry assumption, we have

$$d \ln M_{isr} = \frac{1 + (n_{is} - 1)\phi_{isr}^X}{n_{is}} d \ln q_{visr}^X \tag{48}$$

Following the same procedure, $d \ln M_{is'r}$ is expressed as

$$d \ln M_{is'r} = \sum_{v'} S_{v'is'r}^X d \ln q_{v'is'r}^X$$

By the definition of ϕ_{visr}^X, we have $d \ln q_{v'is'r}^X = \phi_{isr}^X d \ln q_{visr}^X$ for $\forall v'$ and s'. Thus,

$$d \ln M_{is'r} = \phi_{isr}^X d \ln q_{isr}^X \tag{49}$$

From (48) and (49), ϕ_{isr}^{XM} reduces to

$$\phi_{isr}^{\mathrm{XM}} = \frac{\phi_{isr}^X}{[1 + (n_{is} - 1)\phi_{isr}^X]/n_{is}} \tag{50}$$

Next, we consider $\phi_{isr}^{\mathrm{XMD}}$. First, from (8) and (17), we have

$$d \ln \mathrm{AD}_{ir} = \sum_{v'} S_{v'ir}^D d \ln q_{v'ir}^D = \sum_{v'} S_{v'ir}^D \phi_{visr}^X d \ln q_{visr}^X = \phi_{visr}^X d \ln q_{visr}^X \tag{51}$$

Similarly, from (7), (18), (48), and (49), we have

$$\begin{aligned} d \ln \mathrm{AM}_{ir} &= \sum_{s' \neq r} S_{is'r}^M d \ln M_{is'r} + S_{isr}^M d \ln M_{isr} \\ &= \sum_{s' \neq r} S_{is'r}^M \phi_{isr}^X d \ln q_{isr}^X + S_{isr}^M \frac{1 + (n_{is} - 1)\phi_{isr}^X}{n_{is}} d \ln q_{isr}^X \end{aligned} \tag{52}$$

From (51) and (52), $\phi_{isr}^{\mathrm{XMD}}$ is expressed as follows:

$$\phi_{isr}^{\mathrm{XMD}} = \frac{\phi_{isr}^X}{\phi_{isr}^X + (1 - \phi_{isr}^X) S_{isr}^M / n_{is}} \tag{53}$$

Substituting (50) and (53) into (34), markup rate for export supply in model QCV is given by

$$\begin{aligned} \mu_{irs}^X = \frac{1}{\sigma_i^F} &+ \left[\frac{1}{\sigma_i^M} - \frac{1}{\sigma_i^F}\right] \frac{1 + (n_{ir} - 1)\phi_{irs}^X}{n_{ir}} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^M}\right] \frac{S_{irs}^M + (n_{ir} - S_{irs}^M)\phi_{isr}^X}{n_{ir}} \\ &+ \left[\frac{1}{\varepsilon_{is}^A} - \frac{1}{\sigma_i^A}\right] \frac{S_{irs}^M S_{is}^{\mathrm{AM}} + (n_{ir} - S_{irs}^M S_{is}^{\mathrm{AM}})\phi_{isr}^X}{n_{ir}} \end{aligned}$$

2.5.5 Model BD

Model BD is a Bertrand competition version of model CD, that is, it assumes that firm's strategic variable is price and that each firm determines his prices, viewing the prices of all other firms as fixed.

First, we derive markup rate for domestic supply. From (17), we have

$$\frac{\partial \ln q_{vir}^D}{\partial \ln p_{vir}^D} = -\sigma_i^D + \sigma_i^D \frac{p_{vir}^D}{p^{\mathrm{AD}_{ir}}} \frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^D} + \frac{p_{vir}^D}{\mathrm{AD}_{ir}} \frac{\partial \mathrm{AD}_{ir}}{\partial p_{ir}^{\mathrm{AD}}} \frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^D} \tag{54}$$

From (12), we have

$$\frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^D} = (p_{ir}^{\mathrm{AD}})^{\sigma_{ir}^D} \left[(\beta_{vir}^D)^{\sigma_{ir}^D} (p_{vir}^D)^{-\sigma_{ir}^D} + \sum_{v' \neq v} (\beta_{v'ir}^D)^{\sigma_{ir}^D} (p_{v'ir}^D)^{-\sigma_{ir}^D} \frac{p_{v'ir}^D}{p_{vir}^D} \frac{\partial \ln p_{v'ir}^D}{\partial \ln p_{vir}^D} \right] \tag{55}$$

Since model BD assumes Bertrand conjecture, we have $\partial \ln p_{v'ir}^D / \partial \ln p_{vir}^D = 0$. Thus, (55) reduces to

$$\frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^D} = \left[\frac{p_{ir}^{\mathrm{AD}} \beta_{vir}^D}{p_{vir}^D} \right]^{\sigma_{ir}^D}$$

From (12), this equation is rewritten as

$$\frac{\partial p_{ir}^{\mathrm{AD}}}{\partial p_{vir}^D} = \frac{q_{vir}^D}{\mathrm{AD}_{ir}}$$

Thus, (54) is

$$\frac{\partial \ln q_{vir}^D}{\partial \ln p_{vir}^D} = -\sigma_i^D - (\varepsilon_{ir}^D - \sigma_i^D) \frac{1}{n_{ir}} \tag{56}$$

Similarly, ε_{ir}^D is

$$\varepsilon_{ir}^D = -\frac{\partial \ln \mathrm{AD}_{ir}}{\partial \ln p_{ir}^{\mathrm{AD}}} = \sigma_i^A + (\varepsilon_{ir}^A - \sigma_i^A) S_{ir}^{\mathrm{AD}} \tag{57}$$

Combining (56) and (57), markup rate for domestic supply is given by

$$1/\mu_{ir}^D = \varepsilon_{ir}^D = \sigma_i^D + [\sigma_i^A - \sigma_i^D + (\varepsilon_{ir}^A - \sigma_i^A) S_{ir}^{\mathrm{AD}}] \frac{1}{n_{ir}}$$

Following the same procedure, markup rates for export supply are derived as follows:

$$1/\tilde{\mu}_{isr}^X = \sigma_i^F + \{\sigma_i^M - \sigma_i^F + [\sigma_i^A - \sigma_i^M + (\varepsilon_{ir}^A - \sigma_i^A) S_{ir}^{\mathrm{AM}}] S_{isr}^M\} \frac{1}{n_{is}}$$

2.5.6 Model IC

Model IC is the integrated market version of model CD. In contrast to the case of the segmented market model, each firm in the integrated market model sets a common price for all markets. Moreover, each firm can control only total outputs. Thus, the first order condition for profit maximization of each firm reduces to a single equation.

$$(1 - t_{ir}^Y) p_{ir} (1 - \mu_{ir}) = c_{ir}^Y \tag{58}$$

In integrated market Cournot model, it is assumed that each firm determines his outputs, viewing domestic and foreign firms do not change their total outputs. From this assumption, we can derive the expression of markup rates. However, it is quite difficult to derive explicit expression. So, we derive markup rates implicitly in this case.

First, the overall markup rate is expressed as follows:

$$\mu_{ir} = -\hat{p}_{vir} / \hat{q}^T_{vir} \tag{59}$$

where hat variable means the rate of change. This relation means that it is necessary to obtain $\hat{p}_{vir}$ and $\hat{q}^T_{vir}$ to derive markup rate.

First, we consider change in own quantity of firm v in region r. Since $q^T_{vir} \equiv q^D_{vir} + \sum_{s \neq r} q^X_{virs}$, $\hat{q}^T_{vir}$ is expressed as follows:

$$\hat{q}^T_{vir} = \delta^D_{ir} \hat{q}^D_{vir} + \sum_s \delta^X_{irs} \hat{q}^X_{virs} \tag{60}$$

where

$$\delta^D_{ir} \equiv q^D_{ir} / q^T_{ir} \qquad \delta^X_{irs} \equiv q^X_{irs} / q^T_{ir}$$

From (17) and (18), $\hat{q}^D_{vir}$ and $\hat{q}^X_{virs}$ in (60) are given by

$$\hat{q}^D_{vir} = -\sigma^D_i \hat{p}_{vir} + (\sigma^D_i - \sigma^A_i) \hat{p}^{\mathrm{AD},r}_{ir} + (\sigma^A_i - \varepsilon^A_{ir}) \hat{p}^{A,r}_{ir} \tag{61}$$

$$\hat{q}^X_{virs} = -\sigma^F_i \hat{p}^X_{virs} + (\sigma^F_i - \sigma^M_i) \hat{p}^{M,r}_{irs} + (\sigma^M_i - \sigma^A_i) \hat{p}^{\mathrm{AM},r}_{is} + (\sigma^A_i - \varepsilon^A_{is}) \hat{p}^{A,r}_{is} \tag{62}$$

Note that superscript r indicates that changes in variables are conjectured by firm v in region r.

Next, we consider changes in quantity of rival firms implied by Cournot conjecture. Rate of change in outputs of rival firms is given by

$$\delta^D_{it} \hat{q}^{D,r}_{it} + \sum_s \delta^X_{its} \hat{q}^{X,r}_{its} = 0 \tag{63}$$

$$\hat{q}^{D,r}_{it} = -\sigma^D_i \hat{p}^r_{it} + (\sigma^D_i - \sigma^A_i) \hat{p}^{\mathrm{AD},r}_{it} + (\sigma^A_i - \varepsilon^A_{it}) \hat{p}^{A,r}_{it} \tag{64}$$

$$\hat{q}^{X,r}_{its} = -\sigma^F_i \hat{p}^{X,r}_{its} + (\sigma^F_i - \sigma^M_i) \hat{p}^{M,r}_{its} + (\sigma^M_i - \sigma^A_i) \hat{p}^{\mathrm{AM},r}_{is} + (\sigma^A_i - \varepsilon^A_{is}) \hat{p}^{A,r}_{is} \tag{65}$$

where $t = r$ means the domestic rival firm and $t \neq r$ means the foreign rival firm. Note that conjectured change in total outputs of rival firms is set to zero due to Cournot conjecture.

(61)–(65) include conjectured rate of change in price. Next, let us derive these price changes. First, from (12), $\hat{p}^{\mathrm{AD},r}_{ir}$ is given by

$$\hat{p}^{\mathrm{AD},r}_{ir} = \sum_l S^D_{lir} \hat{p}^r_{lir} = \frac{\hat{p}_{vir} + (n_{ir} - 1)\hat{p}^r_{ir}}{n_{ir}} \tag{66}$$

Similarly, $\hat{p}^{\mathrm{AD},r}_{is}$ $(s \neq r)$ is

$$\hat{p}^{\mathrm{AD},r}_{is} = \sum_l S^D_{lis} \hat{p}^r_{lis} = \hat{p}^r_{is} \tag{67}$$

From (13), $\hat{p}^{M,r}_{its}$ is

$$\hat{p}^{M,r}_{irs} = \sum_l S^X_{lirs} \hat{p}^{X,r}_{lir} = \frac{\hat{p}^X_{virs} + (n_{ir} - 1)\hat{p}^{X,r}_{irs}}{n_{ir}} \tag{68}$$

$$\hat{p}^{M,r}_{its} = \sum_l S^X_{lits} \hat{p}^{X,r}_{lit} = \hat{p}^{X,r}_{its} \qquad t \neq r \tag{69}$$

Following the same procedure, other price variables are derived as follows.

$$\hat{p}^{\mathrm{AM},r}_{is} = \sum_t S^M_{its} \hat{p}^{M,r}_{its} \tag{70}$$

$$\hat{p}^{A,r}_{is} = S^{\mathrm{AD}}_{is} \hat{p}^{\mathrm{AD},r}_{is} + S^{\mathrm{AM}}_{is} \hat{p}^{\mathrm{AM},r}_{is} \tag{71}$$

$$\hat{p}^X_{virs} = \beta_{irs} \hat{p}_{vir} \tag{72}$$

$$\hat{p}^{X,r}_{its} = \beta_{its} \hat{p}^r_{it} \tag{73}$$

Finally, we normalize $\hat{p}_{vir}$ to unity.

$$\hat{p}_{vir} = 1 \tag{74}$$

In the simulation, we incorporate a system of (59)–(74) and then derive the value of μ_{ir} implicitly.

2.5.7 Model IB

As in model IC, each firm sets a common price for all markets and can control only total outputs. Thus, the first order condition for profit maximization of each firm reduces to a single equation.

$$(1 - t^Y_{ir}) p_{ir} (1 - \mu_{ir}) = c^Y_{ir}$$

In the integrated market Bertrand model, overall elasticity of demand is equal to the weighted average of elasticity of demand in each market. Thus, we have

$$\varepsilon_{ir} = \sum_s \delta^X_{irs} \varepsilon^X_{irs} + \delta^D_{ir} \varepsilon^D_{ir}$$

Since markup rates are reciprocals of demand elasticity, the following relation holds for markup rates.

$$\begin{aligned} 1/\mu_r &= \sum_s \delta_{rs}/\mu_{rs} + \delta_{rr}/\mu_{rr} \\ \delta_{rs} &\equiv q_{rs} / \sum_{r'} q_{rr'} \end{aligned}$$

Table 8: The benchmark average tariff rates (%)

	OCE	CHN	JPN	KOR	ASE	XAS	CAN	USA	MEX	XCS	MER	EUR	XER	ROW
AFF	1.9	32.5	22.6	123.9	9.4	10.9	1.2	1.1	10.7	8.9	2.9	3.7	13.8	10.5
MIN	3.8	0.3	0.0	3.7	0.7	10.2	0.0	0.0	3.5	3.8	0.4	0.0	0.3	2.3
FBT	7.8	9.8	31.4	26.2	16.3	35.2	13.6	3.2	12.1	12.0	8.2	5.6	21.2	18.3
TWA	14.4	9.8	9.7	9.5	10.7	14.2	9.0	9.8	7.8	13.0	12.6	2.7	8.1	24.6
WPP	5.0	6.9	1.1	4.0	5.4	9.6	0.4	0.2	2.7	8.0	7.8	0.3	3.9	9.6
CHM	3.0	10.4	1.1	6.7	5.2	12.9	0.6	1.9	3.8	7.1	7.5	0.7	3.3	7.5
MET	3.4	6.0	0.5	3.8	5.6	14.3	0.4	1.1	4.6	7.8	10.2	0.9	2.2	7.2
MVT	10.8	15.7		3.9	14.6	19.7	0.8	1.1	5.4	12.3	12.4	1.1	3.2	10.8
ELE	1.2	6.9		1.1	0.8	2.2	0.1	0.2	3.5	6.8	11.2	0.5	2.7	5.5
OME	3.5	10.7	0.1	6.1	3.3	8.2	0.4	1.0	4.2	7.7	12.0	0.6	2.6	7.0
OMF	4.3	6.2	1.2	9.5	5.3	26.2	1.2	1.2	11.4	13.1	17.6	0.9	23.6	5.5
CNS	4.0	31.0	3.0	4.0	15.4	12.0	3.0	9.0	15.0	18.0	18.0	9.0	9.0	1.0
TAT		28.0	15.0	16.0	21.2	15.0	13.0	27.0	27.0	32.0	32.0	16.0	16.0	11.0
OSP		57.0	12.0	26.0	25.0	19.0	27.0	31.0	32.0	34.0	34.0	19.0	19.0	17.0
OSG		60.0	28.0		9.6			25.0		17.0	17.0	23.0	23.0	4.0
Average	4.4	14.1	7.0	11.8	7.5	12.2	4.0	5.3	7.3	12.2	13.7	4.4	7.8	10.2

3 Data

3.1 Source of data

As the benchmark data, we use GTAP version 6 whose benchmark year is 2001.[13] The original GTAP 6 data contain 87 regions and 57 sectors. We first aggregate the original data into 14 regions and 16 sectors and then convert it into the format which can be used in GAMS.[14] Correspondence between original classification and aggregated one is reported in Table 5 and 6.

3.2 Services trade barriers

Although the main content of liberalization is removal of barriers to goods trade, removal of barriers to services trade is becoming an important issue. However, we cannot analyze effects of removal of services barriers by GTAP 6 data because services barriers are not build into it. Thus, in order to analyze services barriers, it is necessary to create data of services barriers from other sources. Brown et al. (2002, 2003, 2004) are researches along this line. These analyses derive data of services barriers from data on gross margins of multinational firms. This study derives data for services barriers from data on gross margins of multinational firms. In this paper, we use the hypothetical tariff rates on services trade (trade of EGW, TAT, OSP, and OSG) derived in Brown et al. (2002). By introducing services tariffs, value of imports including tariffs increase. This reduces value of total final demand. To restore final demand balance, we adjust value of final demand as well.

3.3 Benchmark tariff rates

In this section, we confirm the characteristics of the benchmark tariff rates. Table 8 reports the benchmark tariff rates of each region. Although original tariff rates are distinguished according to the origin of import, tariffs in the table are averaged over all regions. Tariff rates on services goods (CNS, TAT, OSP, and OSG) are those derived in the previous section. From the table, the estimated tariffs on services are significantly high. Moreover, it is observed that tariffs on some goods are still high in some regions. For example, developing countries generally impose high tariffs, in particular on manufacturing goods (the average tariff rate exceeds 10% in many developing countries). On the other hand, developed regions (USA, CAN, EUR, and JPN) have relatively low

[13]For the details of GTAP data, see the GTAP web site `http://www.gtap.agecon.purdue.edu/`.

[14]For GAMS, see `http://www.gams.com/`. For data conversion, we use GTAP6inGAMS utility by Rutherford (2006).

Table 9: Values of elasticity of substitution (σ_i^A and σ_i^{PF}).

Sectors and goods	σ_i^A	σ_i^{PF}
AFF	2.418939	0.233
MIN	5.746361	0.2
FBT	2.488809	1.12
TWA	3.77608*	1.26
WPP	3.101767	1.26
CHM	2.916045	1.26
MET	3.559631	1.26
MVT	3.147633	1.26
ELE	4.4*	1.26
OME	4.05	1.26
OMF	3.75*	1.26
EGW	2.8	1.26
CNS	1.9	1.4
TAT	1.9	1.68
OSP	1.9	1.26
OSG	1.9	1.26

Source: GTAP data,version 6.
∗Values of TWA, ELE, and OMF are derived by multiplying original values by 0.8.

tariffs. In particular, tariffs on manufacturing goods are almost zero in these regions. However, tariffs on AFF, FBT, and TWA are still high in JPN. Regions and goods with high tariffs are likely to be the most affected by trade liberalization. It follows that the developing countries (in particular, the manufacturing sectors), the agricultural sector in some developed countries, and the services sectors in general are especially likely to be affected by trade liberalization.

4 Simulation

4.1 Elasticity of substitution

Values of elasticity parameters are determined exogenously. We use GTAP 6 values for elasticity of substitution among primary factors (σ_i^{PF}). As to Armington elasticity (σ_i^A), we basically use GTAP 6 values. However, as to sector TWA, ELE, and OMF, we use values derived by multiplying the original GTAP values by 0.8 for computational reason.[15] As to elasticity of substitution among imports from different regions (σ_i^M), we assume $\sigma_i^M = 2 \times \sigma_i^A$, following the GTAP model. In addition to two elasticities above, imperfectly competitive models include elasticity of substitution of varieties (σ_i^D and σ_i^F). For these two parameters, we assume $\sigma_i^D = \sigma_i^F = 2 \times \sigma_i^M$, following Harrison et al. (1996). With regards to these elasticity parameters, we conduct sensitivity analysis.

4.2 Calibration

Imperfectly competitive models include parameters and variables which do not appear in the perfectly competitive model such as fixed cost, the number of firms, markup rates, and elasticity of substitution of varieties. In addition to these parameters and variables, model QCV includes conjectural variation parameters. Among these parameters, elasticity parameters are determined exogenously.[16] To conduct the simulation, it is necessary to determine values of other parameters

[15]We use smaller values because when we use the original values, we encounter computational difficulty in solving the model.

[16]Some studies employ the approach where elasticity parameters are calibrated given other parameters and variables (e.g. Smith and Venables 1988). In this approach, elasticity parameters can take quite different values according to models. This feature is undesirable when we compare different models. Thus, this paper does not employ such an approach.

and variables by some approach. Since results of the simulation are likely to be influenced by the approach for determining parameters and variables, it is desirable to choose the proper approach. However, there exists no standard method for it and different researches use different methods under the present situation.[17] Here we choose the approach we think the most appropriate for comparing various imperfect competition models in a unified framework. In the following, taking model CD as an example, we explain the approach for calibration.

4.2.1 Fixed cost

Fixed cost is calibrated by determining cost-disadvantage ratio (CDR) exogenously.[18]

The detailed procedure is as follows. The cost function is given by (1). So, CDR is represented as follows:

$$\mathrm{CDR} = \frac{\mathrm{AC} - \mathrm{MC}}{\mathrm{AC}} = \frac{\mathrm{FC}}{\mathrm{TC}} \tag{75}$$

where AC is average cost, MC is marginal cost, FC is fixed cost, and TC is total cost. Since the benchmark value of total cost TC is given by the benchmark data, if we determine the value of CDR, we can determine the value of fixed cost from (75). In the calibration, we assume 0.15 (15%) as the value of CDR for all sectors and regions.

4.2.2 The number of firms and markup rates

The number of firms and markup rates are calibrated so that FOCs for profit maximization and zero profit condition are satisfied simultaneously. Substituting (35) and (36) into zero profit condition (41), we get

$$(1 - t^Y_{ir}) \left[p^D_{ir} q^D_{ir} \mu^D_{ir} + \sum_s p^X_{irs} q^X_{irs} \mu^X_{irs} \right] = c^Y_{ir} \mathrm{fc}_{ir} \tag{76}$$

On the other hand, markup rates in model CD are

$$\mu^D_{ir} = \frac{1}{\sigma^D_i} + \left\{ \frac{1}{\sigma^A_i} - \frac{1}{\sigma^D_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i} \right] S^{\mathrm{AD}}_{ir} \right\} \frac{1}{n_{ir}} \tag{77}$$

$$\tilde{\mu}^X_{irs} = \frac{1}{\sigma^F_i} + \left\{ \frac{1}{\sigma^M_i} - \frac{1}{\sigma^F_i} + \left[\frac{1}{\sigma^A_i} - \frac{1}{\sigma^M_i} + \left(\frac{1}{\varepsilon^A_{is}} - \frac{1}{\sigma^A_i} \right) S^{\mathrm{AM}}_{is} \right] S^M_{irs} \right\} \frac{1}{n_{ir}} \tag{78}$$

Solving this system of equations, we calibrate n_{ir}, μ^D_{ir}, and μ^X_{irs}.[19]

4.2.3 Other imperfectly competitive models

In this section, we explain calibration used for other imperfectly competitive models. First, model CF use the same approach as model CD.[20] Model CH and BD also use the same approach as model CD except that markup rate formula is changed.

Model LGMC

In model LGMC, markup rates are independent of the number of firms and depend only on elasticities of substitution (see (43)) and therefore we cannot apply the approach of model CD to model LGMC. Thus, we use the following approach.

[17] For example, Smith and Venables (1988), Harrison et al. (1996), Francois and Roland-Holst (1997), Grether and Müller (2000), Bchir et al. (2002), and Santis (2002b) adopt different methods for determining parameters and variables.

[18] CDR is defined as $\mathrm{CDR} \equiv (\mathrm{AC} - \mathrm{MC})/\mathrm{AC}$.

[19] Strictly speaking, we also use (39) and (40).

[20] In model CF, we assume the constant number of firms. This means that zero profit condition is not satisfied in model CF. However, zero profit is assumed

Step 1: First, we calibrate markup rates (43) from elasticities of substitution.

Step 2: Second, we determine the number of firms exogenously.

Step 3: Using markup rates and the number of firms determined above, we calibrate fixed cost so that zero profit condition is satisfied.

The number of firms determined exogenously in Step 2 does not affect results of the simulation (rates of change in variables against shocks).[21] Thus, choice of the number of firms is of no importance.

Model QCV

(76) holds in model QCV. However, markup rates for model QCV are changed to

$$\mu_{ir}^D = \frac{1}{\sigma_i^D} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^D}\right] \frac{1+(n_{ir}-1)\phi_{ir}^D}{n_{ir}} + \left[\frac{1}{\varepsilon_{ir}^A} - \frac{1}{\sigma_{ir}^A}\right] \frac{S_{ir}^{\mathrm{AD}} + (n_{ir} - S_{ir}^{\mathrm{AD}})\phi_{ir}^D}{n_{ir}} \tag{79}$$

$$\begin{aligned}\mu_{irs}^X = {} & \frac{1}{\sigma_i^F} + \left[\frac{1}{\sigma_i^M} - \frac{1}{\sigma_i^F}\right] \frac{1+(n_{ir}-1)\phi_{irs}^X}{n_{ir}} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^M}\right] \frac{S_{irs}^M + (n_{ir} - S_{irs}^M)\phi_{isr}^X}{n_{ir}} \\ & + \left[\frac{1}{\varepsilon_{ir}^A} - \frac{1}{\sigma_i^A}\right] \frac{S_{irs}^M S_{is}^{\mathrm{AM}} + (n_{ir} - S_{irs}^M S_{is}^{\mathrm{AM}})\phi_{isr}^X}{n_{ir}}\end{aligned} \tag{80}$$

Since conjectural variation parameters ϕ_{ir}^D and ϕ_{irs}^X are added, we cannot apply the approach of model CD to this case. Thus, we adopt the approach of Harrison et al. (1996).

1. First, as in the case of model CD, fixed cost is calibrated, given exogenous CDR.
2. Second, the number of firms n_{ir} is determined exogenously.
3. Third, we calibrate μ_{ir}^D, μ_{irs}^X, ϕ_{ir}^D, ϕ_{irs}^X by solving an optimization problem with constraints (76), (79)–(80).

In step 2, we assume that the number of firms is 50 for all IRTS sectors in all regions. As the objective function in step 3, we assume the following function.

$$\mathrm{Loss}_i = \sum_{s,r,r'} \xi_{ir'r} X_{isr} (\phi_{isr} - \phi_{ir'r})^2 \tag{81}$$

where

$$\begin{aligned}\phi_{isr} &= \begin{cases} \phi_{ir}^D & s = r \\ \phi_{isr}^X & s \neq r \end{cases} \\ X_{isr} &= \begin{cases} p_{ir}^{\mathrm{AD}} \mathrm{AD}_{ir} & s = r \\ \tilde{p}_{isr}^M M_{isr} & s \neq r \end{cases} \\ \theta_{isr} &= X_{isr} / \sum_{r'} X_{ir'r} \\ \xi_{isr} &= \begin{cases} 1 & \text{if } \theta_{isr} = \arg\max_{s'} \{\theta_{is'r}\} \\ 0 & \text{Otherwise.} \end{cases}\end{aligned}$$

ξ_{irs} is a variable which takes unity if supply from region r has the largest share in total supply to regions s and takes zero otherwise.[22] In the calibration, we determine μ_{ir}^D, μ_{irs}^X, and ϕ_{irs} so that the loss function (81) is minimized.

[21] Of course, the absolute value of variables depend on choice of the number of firms. However, in the simulation, we only see rates of change in variables.

[22] In total supply to region r, own supply usually has the largest share. Thus, we usually have $\xi_{irr} = 1$ and $\xi_{isr} = 0$ $(s \neq r)$. However, $\xi_{irr} = 0$ sometimes holds. For example, since the domestic supply of MIN is quite small in Japan, we have $\xi_{\mathrm{MIN,JPN,JPN}} = 0$.

4.3 Elasticity of demand for Armington goods

In models except for model LGMC, elasticity of demand for Armington goods (ε_{ir}^{A}) are included in markup formula. Using notations defined so far, ε_{ir}^{A} is represented as

$$\varepsilon_{ir}^{A} = \frac{C_{ir}}{A_{ir}} \tag{82}$$

We can prove (82) as follows. First, ε_{ir}^{A} is defined as

$$\varepsilon_{ir}^{A} \equiv -\frac{\partial A_{ir}}{\partial p_{ir}^{A}} \frac{p_{ir}^{A}}{A_{ir}}$$

Demand for Armington goods are the sum of final demand C_{ir}^{D} and intermediate demand I_{ir}^{D}. Thus, ε_{ir}^{A} becomes

$$\varepsilon_{ir}^{A} = -\left[\frac{\partial C_{ir}^{D}}{\partial p_{ir}^{A}} + \frac{\partial I_{ir}^{D}}{\partial p_{ir}^{A}}\right] \frac{p_{ir}^{A}}{A_{ir}}$$

Since intermediate demand are derived from Leontief production technology, $\partial I_{ir}^{D} / \partial p_{ir}^{A} = 0$ holds. Thus, we have

$$\varepsilon_{ir}^{A} = -\frac{\partial C_{ir}^{D}}{\partial p_{ir}^{A}} \frac{p_{ir}^{A}}{A_{ir}} = -\frac{\partial C_{ir}^{D}}{\partial p_{ir}^{A}} \frac{p_{ir}^{A}}{C_{ir}} \frac{C_{ir}^{A}}{A_{ir}} \tag{83}$$

On the other hand, final demand are derived from Cobb-Douglas utility function. Thus, uncompensated demand is given by

$$C_{ir}^{D} = \frac{\theta_{ir}^{C} H_{r}}{(1 + t_{ir}^{C}) p_{ir}^{A}}$$

This leads to

$$\frac{\partial C_{ir}^{D}}{\partial p_{ir}^{A}} \frac{p_{ir}^{A}}{C_{ir}^{D}} = 1 \tag{84}$$

From (83) and (84), we can confirm that (82) holds. (82) shows that ε_{ir}^{A} is the variable which takes values from 0 to 1.

It is desirable to incorporate (82) into the simulation. However, there is one problem for it. That is, if we determine ε_{ir}^{A} by (82), ε_{ir}^{A} for sectors which has no final demand becomes zero. Since ε_{ir}^{A} enters into markup formula as the denominator, markup formula cannot be defined if ε_{ir}^{A} is zero. Moreover, even if ε_{ir}^{A} is not zero, small values of ε_{ir}^{A} make the model quite unstable. To avoid this problem, we assume $\varepsilon_{ir}^{A} = 0.5$ for $\forall i$ in the simulation.

5 Model for the simulation

I have already explained model structure in Section 2. However, in programs for the simulation, the model is described by different notations. Here, I present the model in accordance with simulation programs.

1. In the program, all functions are basically written in calibrated share form (Rutherford, 1998). Thus, we describe the model by calibrated share form below.

2. Representation by calibrated-share form actually includes references prices. However, in the following, reference prices are omitted for notational simplification.

3. Variables given in parentheses on the right end are slack variables associated to each equation.

4. Variables with hat indicate value at the benchmark equilibrium.

5.1 Notations

First, let us define necessary notations. The last column shows variable name used in GAMS program.

Activity level

Notation	Description	Program
Y_{ir}	Output of CRTS sector ($i \in C$)	`y(i,r)`
Y_{ir}^{XT}	IRTS sector supply to transport sector ($i \in K$)	`y_xt(i,r)`
A_{ir}	Armington activity of goods i	`a(i,r)`
AD_{ir}	Aggregation of domestic varieties ($i \in K$)	`ad(i,r)`
AM_{ir}	Aggregation of imports from different region	`am(i,r)`
M_{isr}	Aggregation of import varieties ($i \in K$)	`m(i,s,r)`
U_r	Utility	`u(r)`
T	International transport service	`yt`

Variables related to IRTS sectors

Notation	Description	Program
π_{ir}	Profit of a firm in IRTS sector ($i \in K$)	`ep(i,r)`
q_{ir}^{D}	Domestic supply of a firm in IRTS sector ($i \in K$)	`q_d(i,r)`
q_{irs}^{X}	Export supply to region s of a firm in IRTS sector in region r ($i \in K$)	`q_x(i,r,s)`
μ_{ir}^{D}	Markup rate for domestic supply ($i \in K$)	`mu_d(i,r)`
μ_{irs}^{X}	Markup rate for export supply ($i \in K$)	`mu_x(i,r,s)`
$\tilde{\mu}_{irs}^{X}$	Markup rate for export supply (adjusted by transport cost) ($i \in K$)	`mu_xx(i,r,s)`
β_{irs}	($i \in K$)	`beta(i,r,s)`
n_{ir}	The number of firms in IRTS sector ($i \in K$)	`n(i,r)`
q_{ir}^{T}	Total output of a firm in IRTS sector ($i \in K$)	`q_tt(i,r)`
S_{ir}^{AD}	Share of domestic supply in Armington aggregation ($i \in K$)	`s_ad(i,r)`
S_{ir}^{AM}	Share of import supply in Armington aggregation ($i \in K$)	`s_am(i,r)`
S_{isr}^{M}	Share of import from region s in total import of region r ($i \in K$)	`s_m(i,s,r)`
δ_{ir}^{D}	Share of domestic supply in total supply ($i \in K$)	`delta_d(i,r)`
δ_{irs}^{X}	Share of export supply in total supply ($i \in K$)	`delta_x(i,r,s)`
AC_{ir}	Average cost ($i \in K$)	`ac(i,r)`
p_{ir}^{COM}	Price in the integrated market model ($i \in K$)	`p_com(i,r)`

Unit cost and price index

Notation	Description	Program
c_{ir}^{Y}	Unit cost of sector i	c_y(i,r)
c_{ir}^{A}	Unit cost of Armington aggregation	c_a(i,r)
c_{ir}^{AD}	Unit cost of aggregation of domestic varieties	c_ad(i,r)
c_{r}^{U}	Unit cost of utility	c_u(r)
c_{ir}^{AM}	Unit cost of import aggregation	c_am(i,r)
c_{isr}^{M}	Unit cost of aggregation of import varieties	c_m(i,s,r)
c^{T}	Unit cost of international transport service	c_t
p_{ir}^{PF}	Price index of the primary factor composite	p_pf(i,r)
p_{r}^{I}	Price index of investment	p_inv(r)
p_{ir}^{Y}	Price of output of CRTS sector	p_y(i,r)
p_{ir}^{D}	Price of a domestic variety ($i \in K$)	p_d(i,r)
p_{irs}^{X}	Price of an export variety ($i \in K$)	p_x(i,r,s)
$\tilde{p}_{irs}^{X}$	CIF price of an export variety	p_x_(i,r,s)
p_{ir}^{AD}	Price index of aggregated domestic variety ($i \in K$)	p_ad(i,r)
p_{ir}^{AM}	Price index of aggregated import	p_am(i,r)
p_{isr}^{M}	CIF price of import from region s	p_m(i,s,r)
$\tilde{p}_{isr}^{M}$	Price of import including tariff	?
p^{T}	Price of international transport service	p_t
p_{ir}^{A}	Price of Armington goods	p_a(i,r)
p_{fr}^{F}	Price of primary factor f	p_f(f,r)
p_{r}^{U}	Price index of utility	p_u

Demand functions

Notation	Description	Program
a_{fir}^{F}	Unit demand for primary factor f in sector i	a_f(f,i,r)
a_{ir}^{C}	Unit final demand for goods i	a_c(i,r)
a_{ir}^{AD}	Unit demand for domestic goods in Armington aggregation	a_ad(i,r)
a_{ir}^{AM}	Unit demand for aggregated import in Armington aggregation	a_am(i,r)
a_{isr}^{M}	Region r's unit demand for import from region s	a_m(i,s,r)
a_{ir}^{DD}	Unit demand for a domestic variety	a_dd(i,r)
a_{isr}^{MM}	Region r's unit demand for a variety from region s	a_mm(i,s,r)
a_{ir}^{T}	Unit demand for input of transport sector	a_t(i,r)

Share parameters

Share parameters are constant at the benchmark level.

Notation	Description	Program
θ_{ir}^{C}	Share of goods i in final demand	sh_c(i,r)
θ_{fir}^{F}	Share of primary factor f in production	sh_f(f,i,r)
θ_{jir}^{I}	Share of intermediate goods j in production	sh_i(j,i,r)
θ_{ir}^{PF}	Share of the primary factor composite in production	sh_pf(i,r)
θ_{ir}^{AD}	Share of domestic goods in Armington aggregation	sh_ad(i,r)
θ_{ir}^{AM}	Share of import goods in Armington aggregation	sh_am(i,r)
θ_{isr}^{M}	Share of import from region s in total import of region r	sh_m(i,s,r)
θ_{ir}^{T}	Share of each input in transport sector	sh_t(i,r)

Elasticity of substitution (EOS)

Notation	Description	Program
σ_i^A	EOS between domestic and import goods in Armington aggregation	`sig_a(i,r)`
σ_i^M	EOS among imports from different region	`sig_m(i,r)`
σ_i^{PF}	EOS among primary factors	`sig_pf(i,r)`
σ_i^D	EOS among domestic varieties	`sig_dd(i,r)`
σ_i^F	EOS among import varieties	`sig_ff(i,r)`

Tax rates

Notation	Description	Program
t_{ir}^Y	Production tax rate for goods i	`ty(i,r)`
t_{jir}^I	Tax rate for intermediate input j in sector i	`ti(j,i,r)`
t_{fir}^F	Tax rate for primary factor f in production	`tf(f,i,r)`
t_{irs}^X	Subsidy rate for export	`tx(i,r,s)`
t_{irs}^M	Tariff rate	`tm(i,r,s)`
t_{ir}^C	Tax rate for final demand	`tc(i,r)`

Variables for integrated market models

Notation	Description	Program
μ_{ir}	Overall markup rate ($i \in K$)	`mu(i,r)`

Parameters for model QCV

Notation	Description	Program
$\phi_{ir}^D, \phi_{irs}^X$	Conjectural variation parameter for supply from region r to region s ($i \in K$) (exogenous)	`phi0(i,r,s)`

Variables for model IC

Notation	Description	Program
$\hat{q}_{vir}^T$	Change in own total supply ($i \in K$)	`h_qtv(i,r)`
$\hat{q}_{vir}^D$	Change in own domestic supply ($i \in K$)	`h_qdv(i,r)`
$\hat{q}_{virs}^X$	Change in own export supply ($i \in K$)	`h_qxv(i,r,s)`
$\hat{p}_{it}^r$	Conjectured change in rival firm's price ($i \in K$)	`h_p(r,i,t)`
$\hat{q}_{it}^{D,r}$	Conjectured change in rival firm's domestic supply ($i \in K$)	`h_qd(r,i,t)`
$\hat{q}_{its}^{X,r}$	Conjectured change in rival firm's export supply ($i \in K$)	`h_qx(r,i,t,s)`
$\hat{p}_{is}^{\text{AD},r}$	Conjectured change in p_{is}^{AD} ($i \in K$)	`h_pad(r,i,s)`
$\hat{p}_{its}^{M,r}$	Conjectured change in p_{its}^M ($i \in K$)	`h_pmu(i,r)`
$\hat{p}_{is}^{\text{AM},r}$	Conjectured change in p_{is}^{AM} ($i \in K$)	`h_pam(r,i,s)`
$\hat{p}_{is}^{A,r}$	Conjectured change in p_{is}^A ($i \in K$)	`h_pa(r,i,s)`
$\hat{p}_{virs}^X$	Change in own export price ($i \in K$)	
$\hat{p}_{its}^{X,r}$	Conjectured change in p_{its}^X ($i \in K$)	

Other variables and parameters

Notation	Description	Program
M_r	Income of the representative household	`inc_ra(r)`
a^I_{jir}	Input coefficient for intermediate goods j in sector i	`vafm(j,i,r)`
E^F_{fr}	Endowment of primary factor f (exogenous)	`evoa(f,r)`
INV_r	Investment (exogenous)	`inv(r)`
BOP_r	Capital inflow (exogenous)	`vb(r)`
τ_{irs}	The amount of transport service required to ship one unit of goods i from region r to region s (exogenous)	`tau(i,r,s)`
fc_{ir}	Fixed input in IRTS sector ($i \in K$) (exogenous)	
ε^A_{ir}	Demand elasticity of Armington goods (exogenous)	`eod(i,r)`

5.2 Imperfectly competitive model (model CD)

In this section, equilibrium conditions related to IRTS sectors are presented. First, we explain conditions for model CD. As to other imperfectly competitive models, we present explanation in the last place.

5.2.1 Profit maximization

Profit of a firm in IRTS sector i in region r: Profit of a firm in IRTS sector i in region r is defined as follows:

$$\pi_{ir} = (1 - t^Y_{ir}) \left[p^D_{ir} q^D_{ir} + \sum_s p^X_{irs} q^X_{irs} \right] - c^Y_{ir} \left[q^D_{ir} + \sum_s q^X_{irs} + \text{fc}_{ir} \right] \qquad \{\pi_{ir}\}_{i \in K}$$

FOCs for profit maximization: FOCs for profit maximization is given by

$$(1 - t^Y_{ir}) p^D_{ir} \left[1 - \mu^D_{ir} \right] = c^Y_{ir} \qquad \{q^D_{ir}\}_{i \in K}$$
$$(1 - t^Y_{ir}) p^X_{irs} \left[1 - \mu^X_{irs} \right] = c^Y_{ir} \qquad \{q^X_{irs}\}_{i \in K}$$

Since all markets are segmented, conditions for profit maximization are distinguished according to destination. The LHS represents marginal revenue and the RHS represents marginal cost.

Zero profit condition: Model CD assumes free entry–exit. Thus, the number of firms (varieties) is determined so that zero profit condition is satisfied.

$$\pi_{ir} = 0 \qquad \{n_{ir}\}_{i \in K}$$

Total ouput of a firm: Total ouput of a firm (q^T_{ir}) is given by[23]

$$q^T_{ir} = q^D_{ir} + \sum_s q^X_{irs} + \text{fc}_{ir} \qquad \{q^T_{ir}\}_{i \in K}$$

[23]Strictly speaking, q^T_{ir} is sum of total output and fixed input

5.2.2 Markup rates

Markup rates Markup rates are represented as follows:

$$\mu^D_{ir} = \frac{1}{\sigma^D_i} + \left\{ \frac{1}{\sigma^A_i} - \frac{1}{\sigma^D_i} + \left[\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i} \right] S^{\text{AD}}_{ir} \right\} \frac{1}{n_{ir}} \qquad \{\mu^D_{ir}\}_{i\in K}$$

$$\tilde{\mu}^X_{isr} = \frac{1}{\sigma^F_i} + \left\{ \frac{1}{\sigma^M_i} - \frac{1}{\sigma^F_i} + \left[\frac{1}{\sigma^A_i} - \frac{1}{\sigma^M_i} + \left(\frac{1}{\varepsilon^A_{ir}} - \frac{1}{\sigma^A_i} \right) S^{\text{AM}}_{ir} \right] S^M_{isr} \right\} \frac{1}{n_{is}} \qquad \{\tilde{\mu}^X_{irs}\}_{i\in K}$$

$$\mu^X_{irs} = \tilde{\mu}^X_{irs} / \beta_{irs} \qquad \{\mu^X_{irs}\}_{i\in K}$$

$$\beta_{irs} = \frac{(1 - t^X_{irs}) p^X_{irs}}{(1 - t^X_{irs}) p^X_{irs} + p^T \tau_{irs}} \qquad \{\beta_{irs}\}_{i\in K}$$

As FOCs for profit maximization, markup rates are distinguished according to destination.

Share variables: Share variables in markup rates are defined as follows:

$$S^{\text{AD}}_{ir} = \frac{p^{\text{AD}}_{ir} \text{AD}_{ir}}{p^A_{ir} A_{ir}} \qquad \{S^{\text{AD}}_{ir}\}_{i\in K}$$

$$S^{\text{AM}}_{ir} = \frac{p^{\text{AM}}_{ir} \text{AM}_{ir}}{p^A_{ir} A_{ir}} \qquad \{S^{\text{AM}}_{ir}\}_{i\in K}$$

$$S^M_{irs} = \frac{\tilde{p}^M_{irs} M_{irs}}{p^{\text{AM}}_{is} \text{AM}_{is}} \qquad \{S^M_{irs}\}_{i\in K}$$

5.3 Unit cost and price index

In this section, unit cost and price index are defined.

Price index of the primary factor composite: Price index of the primary factor composite in sector i is given by

$$p^{\text{PF}}_{ir} = \left[\sum_f \theta^F_{fir} [(1 + t^F_{fir}) p^F_{fr}]^{1-\sigma^{\text{PF}}_i} \right]^{\frac{1}{1-\sigma^{\text{PF}}_i}} \qquad \{p^{\text{PF}}_{ir}\}$$

Unit cost of production: Unit cost of sector i is given by

$$c^Y_{ir} = \sum_j \theta^I_{jir} (1 + t^I_{jir}) p^A_{jr} + \theta^{\text{PF}}_{ir} p^{\text{PF}}_{ir} \qquad \{c^Y_{ir}\}$$

Since production technology is Leontief type, unit cost is the linear combination of prices of intermediate inputs and the primary factor composite.

Unit cost of Armington aggregation: Unit cost of Armington aggregation is

$$c^A_{ir} = \left[\theta^{\text{AD}}_{ir} (p^Y_{ir})^{1-\sigma^A_i} + \theta^{\text{AM}}_{ir} (p^{\text{AM}}_{ir})^{1-\sigma^A_i} \right]^{\frac{1}{1-\sigma^A_i}} \qquad \{c^A_{ir}\}_{i\in C}$$

$$c^A_{ir} = \left[\theta^{\text{AD}}_{ir} (p^{\text{AD}}_{ir})^{1-\sigma^A_i} + \theta^{\text{AM}}_{ir} (p^{\text{AM}}_{ir})^{1-\sigma^A_i} \right]^{\frac{1}{1-\sigma^A_i}} \qquad \{c^A_{ir}\}_{i\in K}$$

Unit cost of Armington aggregation differs across CRTS goods and IRTS goods.

Unit cost of aggregation of domestic varieties: In IRTS goods, different varieties are aggregated through CES function. Thus, unit cost of aggregation of domestic varieties is given by

$$c_{ir}^{\mathrm{AD}} = \left[\frac{n_{ir}}{\bar{n}_{ir}}\right]^{\frac{1}{1-\sigma_i^D}} p_{ir}^D \qquad \{c_{ir}^{\mathrm{AD}}\}_{i\in K}$$

Unit cost of utility: Since utility function is Cobb-Douglas type, unit cost of utility (unit expenditure function) is given by

$$c_r^U = \prod_i \left[\tilde{p}_{Cir}^A\right]^{\theta_{ir}^C} \qquad \{c_r^U\}$$

where $\tilde{p}_{Cir}^A \equiv (1+t_{ir}^C)p_{ir}^A$.

Unit cost of import aggregation: Imports from different regions are aggregated into the import composite through a CES function. Thus, unit cost of import aggregation is given by

$$c_{ir}^{\mathrm{AM}} = \left[\sum_s \theta_{isr}^M (\tilde{p}_{isr}^M)^{1-\sigma_i^M}\right]^{\frac{1}{1-\sigma_i^M}} \qquad \{c_{ir}^{\mathrm{AM}}\}$$

where $\tilde{p}_{isr}^M = (1+t_{isr}^M)p_{isr}^M$.

Unit cost of aggregation of import variety: Import varieties are aggregated through CES function. c_{irs}^M represents unit cost of aggregation of varieties imported from region r to region s.

$$c_{irs}^M = \left[\frac{n_{ir}}{\bar{n}_{ir}}\right]^{\frac{1}{1-\sigma_i^F}} \tilde{p}_{irs}^X \qquad \{c_{irs}^M\}_{i\in K}$$

CIF price of import goods: CIF price of import goods is the price which includes export tax and transport cost.

$$\tilde{p}_{irs}^X = (1-t_{irs}^X)p_{irs}^X + p^T\tau_{irs} \qquad \{\tilde{p}_{irs}^X\}_{i\in K}$$
$$\tilde{p}_{irs}^X = (1-t_{irs}^X)p_{ir}^Y + p^T\tau_{irs} \qquad \{\tilde{p}_{irs}^X\}_{i\in C}$$

Unit cost of international transport sector: International transport service is created through Cobb-Douglas function. Thus, its unit cost is given by

$$c^T = \prod_{i\in C,r} \left[p_{ir}^Y\right]^{\theta_{ir}^T} \qquad \{c^T\}$$

Price of investment goods: Price of investment goods (p_r^I) is equal to the price of goods CGD.

$$p_r^I = p_{\mathrm{CGD},r}^Y \qquad \{p_r^I\}$$

5.3.1 Zero profit condition

Production activity:

$$c_{ir}^Y \geq (1-t_{ir}^Y)p_{ir}^Y \qquad \{Y_{ir}\}_{i\in C}$$

Unit cost of production of inputs to transport sector:

$$c_{ir}^Y \geq (1-t_{ir}^Y)p_{ir}^Y \qquad \{Y_{ir}^{\mathrm{XT}}\}_{i\in K}$$

Armington aggregation:

$$c_{ir}^{A} \geq p_{ir}^{A} \qquad \{A_{ir}\}$$

Aggregation of domestic varieties:

$$c_{ir}^{\mathrm{AD}} \geq p_{ir}^{\mathrm{AD}} \qquad \{\mathrm{AD}_{ir}\}_{i \in K}$$

Aggregation of imports from different regions:

$$c_{ir}^{\mathrm{AM}} \geq p_{ir}^{\mathrm{AM}} \qquad \{\mathrm{AM}_{ir}\}$$

Aggregation of import varieties:

$$c_{irs}^{M} \geq p_{irs}^{M} \qquad \{M_{irs}\}_{i \in K}$$

Utility:

$$c_{r}^{U} \geq p_{r}^{U} \qquad \{U_{r}\}$$

International transport sector:

$$c^{T} \geq p^{T} \qquad \{Y^{T}\}$$

5.3.2 Unit compensated demand

Demand for primary factor:

$$a_{fir}^{F} = \bar{a}_{fir}^{F} \left[\frac{p_{ir}^{\mathrm{PF}}}{\tilde{p}_{fir}^{F}} \right]^{\sigma_i^{\mathrm{PF}}} \qquad \{a_{fir}^{F}\}$$

Final demand :

$$a_{ir}^{C} = \bar{a}_{ir}^{C} \frac{c_r^U}{\tilde{p}_{Cir}^{A}} \qquad \{a_{ir}^{C}\}$$

Demand for domestic goods from Armington aggregation:

$$a_{ir}^{\mathrm{AD}} = \bar{a}_{ir}^{\mathrm{AD}} \left[\frac{c_{ir}^{A}}{p_{ir}^{Y}} \right]^{\sigma_i^{A}} \qquad \{a_{ir}^{\mathrm{AD}}\}_{i \in C}$$

$$a_{ir}^{\mathrm{AD}} = \bar{a}_{ir}^{\mathrm{AD}} \left[\frac{c_{ir}^{A}}{p_{ir}^{\mathrm{AD}}} \right]^{\sigma_i^{A}} \qquad \{a_{ir}^{\mathrm{AD}}\}_{i \in K}$$

Demand for import composite from Armington aggregation:

$$a_{ir}^{\mathrm{AM}} = \bar{a}_{ir}^{\mathrm{AM}} \left[\frac{c_{ir}^{A}}{p_{ir}^{\mathrm{AM}}} \right]^{\sigma_i^{A}} \qquad \{a_{ir}^{\mathrm{AM}}\}$$

Demand for import:

$$a_{irs}^{M} = \bar{a}_{irs}^{M} \left[\frac{c_{is}^{\mathrm{AM}}}{\tilde{p}_{irs}^{M}} \right]^{\sigma_i^M} \qquad \{a_{irs}^{M}\}$$

Demand for each variety: a_{ir}^{DD} is demand for domestic variety and a_{irs}^{MM} is demand for import variety.

$$a_{ir}^{\mathrm{DD}} = \bar{q}_{ir}^{D} \left[\frac{n_{ir}}{\bar{n}_{ir}} \right]^{\frac{\sigma_i^D}{1-\sigma_i^D}} \qquad \{a_{ir}^{\mathrm{DD}}\}$$

$$a_{irs}^{\mathrm{MM}} = \bar{q}_{irs}^{X} \left[\frac{n_{ir}}{\bar{n}_{ir}} \right]^{\frac{\sigma_i^F}{1-\sigma_i^F}} \qquad \{a_{irs}^{\mathrm{MM}}\}$$

Demand for input of transport sector:

$$a_{ir}^{T} = \bar{a}_{ir}^{T} \frac{c^{T}}{p_{ir}^{Y}} \qquad \{a_{ir}^{T}\}_{i \in C}$$

5.3.3 Market clearing conditions

Below, we present market clearing conditions. Basically, the LHS represents supply and the RHS represents demand.

Market of output of CRTS sector ($i \in C$, $i \neq$ CGD): Supply is Y_{ir} and demand is the sum of domestic demand, export demand, and demand from transport sector.

$$Y_{ir} \geq a_{ir}^{\mathrm{AD}} A_{ir} + \sum_{s} a_{irs}^{M} \mathrm{AM}_{is} + a_{ir}^{T} Y^{T} \qquad \{p_{ir}^{Y}\}$$

Market of investment goods ($i \in C$, $i =$ CGD):

$$Y_{ir} \geq I_r \qquad \{p_{ir}^{Y}\}$$

Market of domestic variety ($i \in K$): Supply of a variety is q_{ir}^{D} and demand for it is $a_{ir}^{\mathrm{DD}} \mathrm{AD}_{ir}$.

$$q_{ir}^{D} \geq a_{ir}^{\mathrm{DD}} \mathrm{AD}_{ir} \qquad \{p_{ir}^{D}\}$$

Market of export variety ($i \in K$): Supply of a variety is q_{irs}^{X} and demand for it is $a_{irs}^{\mathrm{MM}} M_{irs}$.

$$q_{irs}^{X} \geq a_{irs}^{\mathrm{MM}} M_{irs} \qquad \{p_{irs}^{X}\}$$

Market for inputs to transport sector ($i \in K$):

$$Y_{ir}^{\mathrm{XT}} \geq a_{ir}^{T} Y^{T} \qquad \{p_{ir}^{Y}\}$$

Market of domestic goods: Market of aggregated domestic variety. Supply is AD_{ir} and demand for it is $a_{ir}^{\mathrm{AD}} A_{ir}$.

$$\mathrm{AD}_{ir} \geq a_{ir}^{\mathrm{AD}} A_{ir} \qquad \{p_{ir}^{\mathrm{AD}}\}$$

Market of import composite: Supply of import composite is AM_{ir} and demand is $a^{\text{AM}}_{ir} A_{ir}$.

$$\text{AM}_{ir} \geq a^{\text{AM}}_{ir} A_{ir} \qquad \{p^{\text{AM}}_{ir}\}$$

Market of import goods: Supply is M_{irs} and demand is $a^{M}_{irs}\text{AM}_{is}$. In the case of CRTS goods ($i \in C$), the next relation defines CIF price of import goods.

$$\begin{aligned} & M_{irs} \geq a^{M}_{irs}\text{AM}_{is} \qquad \{p^{M}_{irs}\}_{i \in K} \\ & p^{M}_{irs} = (1 - t^{X}_{irs}) p^{Y}_{ir} + p^{T} \tau_{irs} \qquad \{p^{M}_{irs}\}_{i \in C} \end{aligned}$$

Market of transport service: Supply is Y^T and demand is the sum of demand from transport of CRTS goods ($\tau_{isr} a^{M}_{isr}\text{AM}_{ir}$) and demand from transport of IRTS goods ($\tau_{isr} n_{is} a^{\text{MM}}_{isr} M_{isr}$).

$$Y^T \geq \sum_{i \in C, s, r} \tau_{isr} a^{M}_{isr}\text{AM}_{ir} + \sum_{i \in K, s, r} \tau_{isr} n_{is} a^{\text{MM}}_{isr} M_{isr} \qquad \{p^T\}$$

Market of Armington goods: Supply is A_{ir} and demand consists of intermediate demand and final demand.

$$A_{ir} \geq \sum_{j \in C} a^{I}_{ijr} Y_{jr} + \sum_{j \in K} a^{I}_{ijr} (Y^{\text{XT}}_{jr} + n_{jr} q^{T}_{jr}) + a^{C}_{ir} U_r \qquad \{p^{A}_{ir}\}$$

Market of primary factors:

$$\bar{E}^{F}_{f} \geq \sum_{i \in C} a^{F}_{fir} Y_{ir} + \sum_{i \in K} a^{F}_{fir} (Y^{\text{XT}}_{ir} + n_{ir} q^{T}_{ir}) \qquad \{p^{F}_{fr}\}$$

Utility: This is the condition that income is equal to expenditure.

$$M_r \geq p^{U}_{r} U_r \qquad \{p^{U}_{r}\}$$

5.3.4 Income of the representative household

Income: Income spent on consumption is the sum of factor income, tax revenue, and capital inflow minus investment expenditure.

$$\begin{aligned} M_r = & \sum_{f} p^{F}_{fr} E^{F}_{fr} \\ & + \sum_{i \in C} t^{Y}_{ir} p^{Y}_{ir} Y_{ir} + \sum_{i \in K} t^{Y}_{ir} p^{Y}_{ir} Y^{\text{XT}}_{ir} + \sum_{i \in K} t^{Y}_{ir} n_{ir} \left[p^{D}_{ir} q^{D}_{ir} + \sum_{s} p^{X}_{irs} q^{X}_{irs} \right] \\ & + \sum_{j} \left[\sum_{i \in C} t^{I}_{jir} p^{A}_{jr} a^{I}_{jir} Y_{ir} + \sum_{i \in K} t^{I}_{jir} p^{A}_{jr} a^{I}_{jir} (Y^{\text{XT}}_{ir} + n_{ir} q^{T}_{ir}) \right] \\ & + \sum_{f} \left[\sum_{i \in C} t^{F}_{fir} p^{F}_{fr} a^{F}_{fir} Y_{ir} + \sum_{i \in K} t^{F}_{fir} p^{F}_{fr} a^{F}_{fir} (Y^{\text{XT}}_{ir} + n_{ir} q^{T}_{ir}) \right] \\ & - \sum_{i \in C, s \in R} t^{X}_{irs} p^{Y}_{ir} a^{M}_{irs} \text{AM}_{is} - \sum_{i \in K, s \in R} t^{X}_{irs} p^{X}_{irs} n_{ir} q^{X}_{irs} \\ & + \sum_{i \in C, s \in R} t^{M}_{isr} p^{M}_{isr} a^{M}_{isr} \text{AM}_{ir} + \sum_{i \in K, s \in R} t^{M}_{isr} [(1 - t^{X}_{isr}) p^{X}_{isr} + \tau_{isr} p^{T}] n_{is} q^{X}_{isr} \\ & + \sum_{i} t^{C}_{ir} p^{A}_{ir} a^{C}_{ir} U_r - p^{I}_{r} I_r + p^{U}_{\text{USA}} \text{BOP}_r \end{aligned}$$

5.4 Other imperfectly competitive models

So far, we assume model CD as the imperfectly competitive model. In this section, we explain how equilibrium conditions are modified under different models.

5.4.1 Model CH

First, we consider model CH. In model CH, it is assumed that varieties in an industry are homogeneous. Since aggregation of varieties is not included in model CH, variables c_{ir}^{AD}, c_{irs}^{M}, a_{ir}^{DD}, and a_{irs}^{MM} do not disappear in model CH.

Markup rates: Markup rates are modified as follows:

$$\mu_{ir}^{D} = \left[\frac{1}{\sigma_i^A} + \left(\frac{1}{\varepsilon_{ir}^A} - \frac{1}{\sigma_i^A}\right) S_{ir}^{\mathrm{AD}}\right] \frac{1}{n_{ir}} \qquad \{\mu_{ir}^{D}\}_{i\in K}$$

$$\tilde{\mu}_{irs}^{X} = \left\{\frac{1}{\sigma_i^M} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^M} + \left(\frac{1}{\varepsilon_{ir}^A} - \frac{1}{\sigma_i^A}\right) S_{is}^{\mathrm{AM}}\right] S_{irs}^{M}\right\} \frac{1}{n_{ir}} \qquad \{\tilde{\mu}_{irs}^{X}\}_{i\in K}$$

Demand for domestic goods:

$$\mathrm{AD}_{ir} = a_{ir}^{\mathrm{AD}} A_{ir} \qquad \{\mathrm{AD}_{ir}\}_{i\in K}$$

Demand for import goods:

$$M_{irs} = a_{irs}^{M} \mathrm{AM}_{is} \qquad \{M_{irs}\}_{i\in K}$$

Domestic variety: Total domestic supply is sum of supply of each variety.

$$n_{ir} q_{ir}^{D} \geq \mathrm{AD}_{ir} \qquad \{p_{ir}^{D}\}_{i\in K}$$

Price of export goods:

$$p_{irs}^{M} = \tilde{p}_{irs}^{X} \qquad \{p_{irs}^{X}\}_{in\in K}$$

Price of domestic goods:

$$p_{ir}^{\mathrm{AD}} = p_{ir}^{D} \qquad \{p_{ir}^{D}\}_{i\in K}$$

Export variety: Total export supply is sum of supply of each variety.

$$n_{ir} q_{irs}^{X} \geq M_{irs} \qquad \{p_{irs}^{M}\}_{i\in K}$$

5.4.2 Model CF

Model CF assumes that the number of firms (n_{ir}) is exogenously constant.

The number of firms: The number of firms ($\bar{n}$) is constant at the benchmark value.

$$n_{ir} = \bar{n}_{ir} \qquad \{n_{ir}\}_{i\in K}$$

Utility:

$$\tilde{M}_r \geq p_r^U U_r \qquad \{p_r^U\}$$

Income of the representative household: Profit is added to income of the household.

$$\tilde{M}_r = M_r + \sum_{i \in K} \pi_{ir} \qquad \{\tilde{M}_r\}$$

5.4.3 Model LGMC

Model LGMC is the large group monopolistic competition model.

Markup rates: Since each firm conjectures $n_{ir} \to \infty$, markup rates are modified as follows:

$$\mu_{ir}^D = 1/\sigma_i^D \qquad \{\mu_{ir}^D\}_{i \in K}$$
$$\tilde{\mu}_{irs}^X = 1/\sigma_i^F \qquad \{\tilde{\mu}_{irs}^X\}_{i \in K}$$

5.4.4 Model QCV

Model QC assumes non-zero conjectural variation. Thus, form of markup rates are modified.

Markup rates:

$$\mu_{ir}^D = \frac{1}{\sigma_i^D} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^D}\right] \frac{1 + (n_{ir} - 1)\phi_{ir}^D}{n_{ir}} + \left[\frac{1}{\varepsilon_{ir}^A} - \frac{1}{\sigma_{ir}^A}\right] \frac{S_{ir}^{\mathrm{AD}} + (n_{ir} - S_{ir}^{\mathrm{AD}})\phi_{ir}^D}{n_{ir}} \qquad \{\mu_{ir}^D\}_{i \in K}$$
$$\begin{aligned}\tilde{\mu}_{irs}^X = {} & \frac{1}{\sigma_i^F} + \left[\frac{1}{\sigma_i^M} - \frac{1}{\sigma_i^F}\right] \frac{1 + (n_{ir} - 1)\phi_{irs}^X}{n_{ir}} + \left[\frac{1}{\sigma_i^A} - \frac{1}{\sigma_i^M}\right] \frac{S_{irs}^M + (n_{ir} - S_{irs}^M)\phi_{isr}^X}{n_{ir}} \\ & + \left[\frac{1}{\varepsilon_{is}^A} - \frac{1}{\sigma_i^A}\right] \frac{S_{irs}^M S_{is}^{\mathrm{AM}} + (n_{ir} - S_{irs}^M S_{is}^{\mathrm{AM}})\phi_{isr}^X}{n_{ir}} \qquad \{\tilde{\mu}_{irs}^X\}_{i \in K}\end{aligned}$$

5.4.5 Model BD

Model BD assumes Bertrand competition.

Markup rate:

$$1/\mu_{ir}^D = \varepsilon_{ir}^D = \sigma_i^D + [\sigma_i^A - \sigma_i^D + (\varepsilon_{ir}^A - \sigma_i^A)S_{ir}^{\mathrm{AD}}]\frac{1}{n_{ir}} \qquad \{\mu_{ir}^D\}_{i \in K}$$
$$1/\tilde{\mu}_{irs}^X = \sigma_i^F + \{\sigma_i^M - \sigma_i^F + [\sigma_i^A - \sigma_i^M + (\varepsilon_{is}^A - \sigma_i^A)S_{is}^{\mathrm{AM}}]S_{irs}^M\}\frac{1}{n_{ir}} \qquad \{\tilde{\mu}_{irs}^X\}_{i \in K}$$

5.4.6 Model IC

Model IC assumes Cournot competition and integrated market.

FOC for profit maximization:

$$(1 - t_{ir}^Y) p_{ir}^{\mathrm{COM}} (1 - \mu_{ir}) = c_{ir}^Y \qquad \{q_{ir}^T\}_{i \in K}$$

Overall markup rate:

$$\mu_{ir} = -\frac{\hat{p}_{vir}}{\hat{q}_{vir}^T} \qquad \{\mu_{ir}\}_{i \in K}$$

Change in own quantity of firm v in region r: Superscript r indicates that changes in variables are conjectured by a firm in region r.

$$\hat{q}^{T}_{vir} = \delta^{D}_{ir}\hat{q}^{D}_{vir} + \sum_{s}\delta^{X}_{irs}\hat{q}^{X}_{virs} \qquad \{\hat{q}^{T}_{vir}\}_{i\in K}$$
$$\hat{q}^{D}_{vir} = -\sigma^{D}_{r}\hat{p}_{vir} + (\sigma^{D}_{r} - \sigma^{A}_{r})\hat{p}^{\text{AD},r}_{ir} + (\sigma^{A}_{r} - \varepsilon^{A}_{ir})\hat{p}^{A,r}_{ir} \qquad \{\hat{q}^{D}_{vir}\}_{i\in K}$$
$$\hat{q}^{X}_{virs} = -\sigma^{F}_{s}\hat{p}^{X}_{virs} + (\sigma^{F}_{s} - \sigma^{M}_{s})\hat{p}^{M,r}_{irs} + (\sigma^{M}_{s} - \sigma^{A}_{s})\hat{p}^{\text{AM},r}_{is} + (\sigma^{A}_{s} - \varepsilon^{A}_{is})\hat{p}^{A,r}_{is} \qquad \{\hat{q}^{X}_{virs}\}_{i\in K}$$

Changes in quantity of rival firms implied by Cournot conjecture: $t = r$ means the domestic rival firm and $t \neq r$ means the foreign rival firm.

$$\delta^{D}_{it}\hat{q}^{D,r}_{it} + \sum_{s}\delta^{X}_{its}\hat{q}^{X,r}_{its} = 0 \qquad \{\hat{p}^{r}_{it}\}_{i\in K}$$
$$\hat{q}^{D,r}_{it} = -\sigma^{D}_{t}\hat{p}^{r}_{it} + (\sigma^{D}_{t} - \sigma^{A}_{t})\hat{p}^{\text{AD},r}_{it} + (\sigma^{A}_{t} - \varepsilon^{A}_{it})\hat{p}^{A,r}_{it} \qquad \{\hat{q}^{D,r}_{it}\}_{i\in K}$$
$$\hat{q}^{X,r}_{its} = -\sigma^{F}_{s}\hat{p}^{X,r}_{its} + (\sigma^{F}_{s} - \sigma^{M}_{s})\hat{p}^{M,r}_{its} + (\sigma^{M}_{s} - \sigma^{A}_{s})\hat{p}^{\text{AM},r}_{is} + (\sigma^{A}_{s} - \varepsilon^{A}_{is})\hat{p}^{A,r}_{is} \qquad \{\hat{q}^{X,r}_{its}\}_{i\in K}$$

Conjectured changes in prices:

$$\hat{p}^{\text{AD},r}_{is} = \begin{cases} \dfrac{1}{n_{is}}[\hat{p}_{vis} + (n_{is}-1)\hat{p}^{r}_{is}] & s = r \\ \\ \hat{p}^{r}_{is} & s \neq r \end{cases} \qquad \{\hat{p}^{\text{AD},r}_{is}\}_{i\in K}$$
$$\hat{p}^{M,r}_{its} = \begin{cases} \dfrac{1}{n_{it}}[\hat{p}^{X}_{vits} + (n_{it}-1)\hat{p}^{X,r}_{its}] & t = r \\ \\ \hat{p}^{X,r}_{its} & t \neq r \end{cases} \qquad \{\hat{p}^{M,r}_{its}\}_{i\in K}$$
$$\hat{p}^{\text{AM},r}_{is} = \sum_{t}\delta^{M}_{its}\hat{p}^{M,r}_{its} \qquad \{\hat{p}^{\text{AM},r}_{is}\}_{i\in K}$$
$$\hat{p}^{A,r}_{is} = \delta^{\text{AD}}_{is}\hat{p}^{\text{AD},r}_{is} + \delta^{\text{AM}}_{is}\hat{p}^{\text{AM},r}_{is} \qquad \{\hat{p}^{A,r}_{is}\}_{i\in K}$$
$$\hat{p}^{X}_{virs} = \beta_{irs}\hat{p}_{vir} \qquad \{\hat{p}^{X}_{virs}\}_{i\in K}$$
$$\hat{p}^{X,r}_{its} = \beta_{its}\hat{p}^{r}_{it} \qquad \{\hat{p}^{X,r}_{its}\}_{i\in K}$$

Normalization:

$$\hat{p}_{vir} = 1 \qquad \{\hat{p}_{vir}\}_{i\in K}$$

Markets for outputs:

$$q^{T}_{ir} \geq a^{\text{DD}}_{ir}\text{AD}_{ir} + \sum_{s}a^{\text{MM}}_{irs}M_{irs} \qquad \{p^{\text{COM}}_{ir}\}_{i\in K}$$

Price of outputs:

$$p^{D}_{ir} = p^{\text{COM}}_{ir} \qquad \{p^{D}_{ir}\}_{i\in K}$$
$$p^{X}_{irs} = p^{\text{COM}}_{ir} \qquad \{p^{X}_{irs}\}_{i\in K}$$

Supply for each market:

$$q^{D}_{ir} = a^{\text{DD}}_{ir}\text{AD}_{ir} \qquad \{q^{D}_{ir}\}_{i\in K}$$
$$q^{X}_{irs} = a^{\text{MM}}_{irs}M_{irs} \qquad \{q^{X}_{irs}\}_{i\in K}$$

5.4.7 Model IB

Model IB assumes Bertrand competition and integrated market.

FOC for profit maximization: Each firm determines total output so as to maximize profit.

$$(1 - t_{ir}^{Y}) p_{ir}^{\mathrm{COM}} (1 - \mu_{ir}) = c_{ir}^{Y} \qquad \{q_{ir}^{T}\}_{i \in K}$$

Overall markup rate:

$$1/\mu_{ir} = \sum_{s} \delta_{irs}^{X} / \mu_{irs}^{X} + \delta_{ir}^{D} / \mu_{ir}^{D} \qquad \{\mu_{ir}\}_{i \in K}$$

where δ_{ir}^{D} and δ_{irs}^{X} are supply shares defined as follows

$$\delta_{irs}^{X} = q_{irs}^{X} / q_{ir}^{T} \qquad \{\delta_{irs}^{X}\}_{i \in K}$$
$$\delta_{ir}^{D} = q_{ir}^{D} / q_{ir}^{T} \qquad \{\delta_{ir}^{D}\}_{i \in K}$$

Markup rates for each market:

$$1/\mu_{ir}^{D} = \varepsilon_{ir}^{D} = \sigma_{i}^{D} + [\sigma_{i}^{A} - \sigma_{i}^{D} + (\varepsilon_{ir}^{A} - \sigma_{i}^{A}) S_{ir}^{\mathrm{AD}}] \frac{1}{n_{ir}} \qquad \{\mu_{ir}^{D}\}_{i \in K}$$
$$1/\tilde{\mu}_{irs}^{X} = \sigma_{i}^{F} + \{\sigma_{i}^{M} - \sigma_{i}^{F} + [\sigma_{i}^{A} - \sigma_{i}^{M} + (\varepsilon_{is}^{A} - \sigma_{i}^{A}) S_{is}^{\mathrm{AM}}] S_{irs}^{M}\} \frac{1}{n_{ir}} \qquad \{\tilde{\mu}_{irs}^{X}\}_{i \in K}$$

Markets for outputs:

$$q_{ir}^{T} \geq a_{ir}^{\mathrm{DD}} \mathrm{AD}_{ir} + \sum_{s} a_{irs}^{\mathrm{MM}} M_{irs} \qquad \{p_{ir}^{\mathrm{COM}}\}_{i \in K}$$

Price of outputs:

$$p_{ir}^{D} = p_{ir}^{\mathrm{COM}} \qquad \{p_{ir}^{D}\}_{i \in K}$$
$$p_{irs}^{X} = p_{ir}^{\mathrm{COM}} \qquad \{p_{irs}^{X}\}_{i \in K}$$

Supply for each market:

$$q_{ir}^{D} = a_{ir}^{\mathrm{DD}} \mathrm{AD}_{ir} \qquad \{q_{ir}^{D}\}_{i \in K}$$
$$q_{irs}^{X} = a_{irs}^{\mathrm{MM}} M_{irs} \qquad \{q_{irs}^{X}\}_{i \in K}$$

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Table 1: The case with no tariff on services trade (EV, billion US$)

Scenario		PC	CD	LGMC	CH	CF	QCV	BD	IC	IB	AVR(A)	STD(B)	100*A/B
SG	OCE	1.9	2.3	2.8	1.8	2.1	2.6	2.2	3.0	2.6	2.4	0.4	17.7
	CHN	7.4	6.5	8.8	6.4	5.6	8.6	5.5	10.5	6.9	7.4	1.7	22.5
	JPN	9.3	11.0	10.9	10.7	10.0	11.3	12.0	13.4	12.9	11.3	1.3	11.5
	KOR	12.3	13.4	14.2	12.9	13.2	14.1	11.9	14.6	12.1	13.2	1.0	7.4
	ASE	4.8	5.7	6.4	5.4	5.3	6.3	6.1	7.5	7.2	6.1	0.9	14.6
	XAS	2.1	2.3	3.3	1.9	2.0	3.1	3.1	5.7	4.7	3.1	1.3	41.6
	CAN	-0.1	-0.5	-0.3	-0.4	-0.9	-0.4	-0.5	-0.3	-0.4	-0.4	0.2	-50.0
	USA	6.4	4.8	6.9	4.6	1.3	5.5	4.7	9.4	6.7	5.6	2.2	39.0
	MEX	-0.2	-0.3	-0.5	0.1	-0.7	-0.6	0.0	-0.2	-0.3	-0.3	0.2	-80.8
	XCS	0.3	-1.3	-0.5	-0.8	-1.6	-0.8	-1.4	0.1	-0.7	-0.7	0.6	-84.5
	MER	4.3	2.5	3.5	3.0	2.0	3.2	2.0	4.1	2.6	3.0	0.8	27.4
	EUR	15.5	15.3	15.9	16.3	11.2	15.8	15.9	20.0	18.1	16.0	2.4	14.8
	XER	6.1	2.2	4.3	2.6	0.6	3.7	2.3	5.1	3.8	3.4	1.7	49.0
	ROW	-0.1	-1.4	1.0	-1.9	-2.5	0.3	-0.4	3.3	2.6	0.1	2.0	1969.8
	World	69.9	62.7	76.6	62.4	47.7	72.8	63.3	96.0	78.8	70.0	13.5	19.3
SF1	CAN	-0.1	-0.1	-0.2	-0.1	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	-18.5
	USA	4.0	3.8	4.2	3.9	3.5	4.1	3.9	4.6	4.3	4.0	0.3	7.5
	MEX	0.1	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.3	0.1	35.2
	XCS	0.5	0.6	1.0	0.4	0.6	0.9	0.8	1.6	1.3	0.9	0.4	46.9
	World	1.2	0.4	1.2	0.6	-0.2	1.0	0.6	2.6	1.6	1.0	0.8	78.3
SF2	MER	1.3	1.1	1.7	0.8	1.0	1.5	1.0	2.1	1.4	1.3	0.4	30.0
	EUR	2.0	2.2	2.2	2.3	2.1	2.2	2.6	2.7	3.0	2.4	0.3	13.9
	World	1.1	0.9	1.4	0.9	0.6	1.2	1.1	1.8	1.4	1.2	0.4	31.4
SF3	CHN	0.6	-1.1	0.0	-0.7	-2.5	-0.3	-0.9	1.2	0.3	-0.4	1.1	-279.1
	JPN	6.1	6.1	6.4	6.3	5.9	6.5	6.4	7.6	7.2	6.5	0.5	8.3
	KOR	7.3	8.2	8.7	7.8	8.2	8.6	7.5	9.1	8.0	8.2	0.6	7.2
	ASE	3.7	4.5	4.7	4.1	4.1	4.6	5.5	5.5	6.2	4.7	0.8	16.7
	World	9.9	9.5	11.1	9.2	7.1	10.5	9.9	13.3	11.9	10.3	1.7	17.0

AVR is the average of EV, and STD is the standard deviation of EV.

Table 2: The case with an alternative calibration method (EV, billion US$)

Scenario		PC	CD	LGMC	CH	CF	QCV	BD	IC	IB	AVR(A)	STD(B)	100*A/B
SG	OCE	3.0	3.8	4.1	3.0	3.8	3.8	4.1	4.2	4.1	3.8	0.4	11.8
	CHN	15.5	15.6	17.4	15.0	15.1	16.3	17.4	17.7	17.2	16.3	1.1	6.7
	JPN	9.8	10.8	11.6	9.9	9.8	11.6	11.6	12.4	11.5	11.0	0.9	8.6
	KOR	12.8	14.4	14.8	12.9	14.0	14.6	14.7	14.8	14.7	14.2	0.8	5.7
	ASE	8.0	8.9	9.8	7.9	8.6	9.0	9.7	9.7	9.6	9.0	0.7	8.1
	XAS	3.2	3.4	4.3	3.0	3.5	3.8	4.3	4.5	4.2	3.8	0.6	14.6
	CAN	1.7	1.1	1.5	1.6	0.8	1.1	1.5	1.8	1.5	1.4	0.3	22.7
	USA	13.4	10.6	13.5	12.5	7.4	10.4	13.4	16.2	13.3	12.3	2.5	20.5
	MEX	0.4	0.0	0.1	0.3	-0.4	-0.1	0.1	0.3	0.1	0.1	0.2	315.3
	XCS	1.6	0.3	0.8	1.4	0.0	0.3	0.8	1.0	0.8	0.8	0.5	67.8
	MER	5.2	3.9	4.5	5.0	3.5	4.1	4.4	4.6	4.4	4.4	0.5	11.9
	EUR	35.2	31.5	36.1	34.1	28.4	31.2	35.9	38.9	36.0	34.2	3.2	9.4
	XER	8.4	5.3	6.5	7.7	4.3	5.4	6.5	6.8	6.5	6.4	1.3	19.7
	ROW	2.7	2.4	4.0	2.3	1.5	2.7	4.0	4.2	3.8	3.1	0.9	30.9
	World	121.0	112.0	129.2	116.5	100.6	114.1	128.6	136.9	127.5	120.7	11.1	9.2
SF1	CAN	1.2	1.1	1.3	1.2	1.1	1.0	1.3	1.4	1.3	1.2	0.1	9.8
	USA	5.6	5.3	5.7	5.5	5.3	5.3	5.7	6.1	5.7	5.6	0.3	4.8
	MEX	0.5	0.7	0.7	0.5	0.6	0.7	0.7	0.8	0.7	0.7	0.1	14.2
	XCS	1.5	1.8	2.1	1.4	1.7	1.8	2.1	2.2	2.1	1.9	0.3	15.5
	World	3.0	2.3	3.3	2.7	1.8	2.4	3.2	3.9	3.1	2.9	0.6	21.9
SF2	MER	1.5	1.6	2.0	1.4	1.5	1.7	2.0	2.0	1.9	1.7	0.2	14.6
	EUR	15.9	13.7	16.1	15.1	13.5	13.1	16.0	16.3	16.1	15.1	1.3	8.6
	World	7.7	6.1	8.3	7.1	5.1	6.1	8.2	7.9	8.2	7.2	1.2	16.2
SF3	CHN	3.0	1.6	2.6	2.6	1.2	1.8	2.5	2.6	2.5	2.3	0.6	26.8
	JPN	6.6	6.6	7.0	6.6	6.4	6.9	7.0	7.2	6.9	6.8	0.2	3.4
	KOR	7.6	8.8	9.0	7.7	8.6	8.9	9.0	9.0	9.0	8.6	0.6	6.6
	ASE	5.1	5.8	6.1	5.0	5.6	5.8	6.1	6.1	6.0	5.7	0.4	7.4
	World	11.0	10.7	12.2	10.6	9.2	11.0	12.2	12.3	12.0	11.2	1.0	9.1

AVR is the average of EV, and STD is the standard deviation of EV

Table 3: The case with larger elasticity of substitution (EV, billion US$)

Scenario		PC	CD	LGMC	CH	CF	QCV	IC	IB	AVR(A)	STD(B)	100*A/B
SG	OCE	3.6	3.7	4.8	3.2	3.3	4.6	5.7	NA	4.1	0.9	22.2
	CHN	27.3	24.9	30.2	25.5	19.0	29.5	39.3	NA	28.0	6.2	22.2
	JPN	13.2	15.5	15.0	15.6	11.4	15.8	27.6	NA	16.3	5.2	32.1
	KOR	19.3	20.0	22.1	19.9	19.0	21.9	22.7	NA	20.7	1.5	7.2
	ASE	10.9	11.2	12.5	11.0	8.0	12.1	18.3	NA	12.0	3.1	26.0
	XAS	6.9	6.3	8.0	5.9	3.2	7.8	17.0	NA	7.9	4.4	55.2
	CAN	3.0	1.6	2.9	1.8	0.1	2.5	5.3	NA	2.5	1.6	64.9
	USA	21.4	16.1	21.8	17.2	4.0	19.4	46.4	NA	20.9	12.8	61.0
	MEX	2.2	2.2	2.1	2.5	0.4	1.9	4.7	NA	2.3	1.3	55.6
	XCS	3.5	0.7	2.6	1.6	-1.0	2.1	6.8	NA	2.3	2.4	104.9
	MER	8.1	5.6	7.5	6.5	3.5	7.2	13.0	NA	7.4	2.9	39.7
	EUR	48.2	39.5	49.6	41.5	19.5	46.0	77.3	NA	45.9	17.1	37.3
	XER	14.7	7.3	13.2	7.8	2.4	11.8	18.7	NA	10.8	5.4	50.3
	ROW	7.5	4.3	9.5	3.9	0.7	8.5	19.5	NA	7.7	6.0	78.1
	World	189.7	158.9	201.7	163.8	93.6	191.2	322.4	NA	188.8	69.0	36.6
SF1	CAN	1.7	0.9	1.8	0.9	0.6	1.5	3.2	NA	1.5	0.9	57.1
	USA	6.0	4.9	6.0	5.2	3.7	5.7	9.5	NA	5.9	1.8	30.5
	MEX	1.1	1.1	1.3	1.2	0.8	1.3	2.8	NA	1.4	0.7	48.6
	XCS	2.2	1.9	2.9	1.8	1.4	2.7	5.3	NA	2.6	1.3	51.3
	World	4.9	2.9	5.1	3.4	-0.9	4.6	14.9	NA	5.0	4.8	97.0
SF2	MER	2.4	2.0	3.1	1.8	1.3	3.0	6.6	3.1	2.9	1.6	55.5
	EUR	20.1	13.4	20.1	13.5	7.3	17.4	20.2	16.5	16.1	4.5	28.2
	World	12.0	7.9	12.7	8.3	1.4	11.0	12.1	15.2	10.1	4.2	41.9
SF3	CHN	4.9	1.6	4.5	2.1	-2.5	3.9	9.4	NA	3.4	3.6	106.8
	JPN	7.0	6.9	7.3	7.2	5.6	7.5	11.8	NA	7.6	2.0	25.8
	KOR	12.7	13.3	14.8	13.0	13.2	14.7	15.2	NA	13.8	1.0	7.4
	ASE	6.4	7.3	7.5	6.6	5.4	7.3	10.5	NA	7.3	1.6	21.9
	World	19.0	17.4	21.1	17.4	10.0	20.2	29.6	NA	19.2	5.8	30.2

AVR is the average of EV, and STD is the standard deviation of EV

NA indicates the case where the model cannot be solved.

Table 4: The case with different CDR (EV, billion US$)

Scenario		PC	CD	LGMC	CH	CF	QCV	IC	IB	AVR(A)	STD(B)	100*A/B
SG	OCE	3.0	3.1	4.1	2.5	3.0	4.0	4.8	NA	3.5	0.8	22.4
	CHN	15.5	13.0	17.4	12.7	9.8	16.8	23.7	NA	15.5	4.5	28.7
	JPN	9.8	11.9	11.6	11.6	9.0	12.1	20.1	NA	12.3	3.6	29.4
	KOR	12.8	13.7	14.8	13.4	13.5	14.8	16.6	NA	14.2	1.3	9.0
	ASE	8.0	8.4	9.8	7.7	6.5	9.5	14.1	NA	9.1	2.5	26.9
	XAS	3.2	3.0	4.3	2.4	1.2	4.2	10.8	NA	4.1	3.1	75.8
	CAN	1.7	0.5	1.5	0.4	-0.5	1.2	2.8	NA	1.1	1.1	97.0
	USA	13.4	8.0	13.5	7.4	-0.5	11.6	28.9	NA	11.8	8.9	76.1
	MEX	0.4	0.5	0.1	0.7	-0.8	-0.1	1.3	NA	0.3	0.6	215.8
	XCS	1.6	-0.9	0.8	-0.6	-2.1	0.5	3.6	NA	0.4	1.9	425.9
	MER	5.2	2.8	4.5	3.3	1.4	4.2	8.0	NA	4.2	2.1	49.8
	EUR	35.2	28.0	36.1	27.1	14.9	33.3	54.7	NA	32.8	12.1	36.8
	XER	8.4	2.1	6.5	2.4	-0.9	5.6	9.9	NA	4.9	3.8	78.6
	ROW	2.7	-0.4	4.0	-1.2	-2.4	3.2	11.2	NA	2.5	4.6	185.6
	World	121.0	93.5	129.2	89.8	52.3	120.8	210.5	NA	116.7	49.0	42.0
SF1	CAN	1.2	0.6	1.3	0.5	0.5	1.1	1.9	NA	1.0	0.5	49.7
	USA	5.6	4.8	5.7	4.8	4.0	5.5	7.6	NA	5.4	1.1	20.7
	MEX	0.5	0.7	0.7	0.6	0.5	0.7	1.6	NA	0.8	0.4	51.5
	XCS	1.5	1.3	2.1	1.0	1.1	2.0	4.0	NA	1.8	1.0	55.9
	World	3.0	1.4	3.3	1.2	-1.0	2.9	9.4	NA	2.9	3.2	111.9
SF2	MER	1.5	1.0	2.0	0.7	0.6	1.9	4.2	2.1	1.7	1.1	64.9
	EUR	15.9	10.5	16.1	8.9	6.9	14.1	16.1	12.7	12.6	3.6	28.2
	World	7.7	4.4	8.3	3.2	0.4	7.0	9.4	9.1	6.2	3.2	52.1
SF3	CHN	3.0	0.0	2.6	0.1	-2.7	2.0	5.6	NA	1.5	2.7	177.2
	JPN	6.6	6.5	7.0	6.7	5.7	7.1	10.1	NA	7.1	1.4	19.4
	KOR	7.6	8.3	9.0	8.0	8.5	9.0	9.9	NA	8.6	0.8	8.9
	ASE	5.1	5.8	6.1	5.2	4.8	6.0	8.4	NA	5.9	1.2	20.4
	World	11.0	9.3	12.2	8.9	4.8	11.6	18.3	NA	10.9	4.1	37.7

AVR is the average of EV, and STD is the standard deviation of EV

NA indicates the case where the model cannot be solved.