Examining Trade Response of Armington-Krugman-Melitz Encompassing Module in a CGE Model

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Abstract

This paper examines how trade flows respond to liberalization shocks within a framework of recently implemented Armington-Krugman-Melitz Encompassing (AKME) module in the GTAP model. We follow the modeling strategy in Dixon and Rimmer (2012) and Oyamada (2013). We modify the comparative static GTAP model, which is a global CGE model widely used by researchers for quantifying policy impact. We redefine trade flow information stored in the benchmark GTAP Data Base, and implement a calibration procedure established in Oyamada (2013) and Oyamada (2014b). We run simulation of trade liberalization to draw a comparison between different trade specifications, decomposing the trade response in detail. Since there exits only a handful of attempts to compare the trade effects by examining the AKME module, we provide another results for further insights.

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1. Introduction

Computable General Equilibrium (CGE) models have been widely used for quantifying economic impacts of free trade agreements and economic partnership agreements. For the recent examples, it is estimated that Trans-Pacific Partnership (TPP) will increase Japanese real GDP by 0.66%, according to Cabinet Secretariat (2013) in Japan. Pacific Economic Cooperation Council (2012) also estimated that the impact of TPP on Japanese real GDP would be 2.0% higher by 2020. Both of the estimates are based on simulation results obtained from global CGE model; the former uses the GTAP model (Hertel, (1997), and McDougall (2003)), and the latter develops their own global CGE model (Zhai (2008), and Petri *et al*. (2012)). The difference in the estimated economic effects seems to be large, however, it is not surprising since the components taken into their estimates are different. Petri *et al*. (2012) considers exhaustive components of liberalization; such as removing tariffs, reducing non-tariff barriers, liberalizing trade in services and foreign direct investment. On the other hand, Cabinet Secretariat (2013) estimates the impact of removing tariffs, thereby resulted in the lower estimate.

Beside the difference in the components of liberalization, it is more interesting for us to ponder the difference in trade specification used in their global CGE model. Petri *et al*. (2012) define their trade module by following Melitz (2003) based on product differentiation at the firm level. The GTAP model has been using the conventional Armington (1969) specification based on product differentiation at the country level. Thus, we are interested in comparing different trade specifications in global CGE model and its implications for resulting estimates of economic impacts of trade liberalization.

Dixon and Rimmer (2012) proposes an encompassing model of different trade specifications, overarching Armington (1969), Krugman (1980), and Melitz (2003), hereafter referred as AKME module. Although Dixon and Rimmer (2012) does not completely implement the AKME module into a global CGE model, it is a remarkable progress for other CGE modelers. Stimulated by their work, Oyamada (2013) develops a prototype global CGE model incorporating the AKME module. It also explains how the necessary parameters for the AKME module can be calibrated, by offering the source code of the model written in General Algebraic Modeling System (GAMS, Brook *et al*. (1992)). More recently, Dixon *et al*. (2014) conducts thorough analysis on their AKME module and provides the source code in GEMPACK (Harrison and Pearson, (1996)). They find that it is possible to have equivalent economic effects of liberalization on trade and welfare both in Armington and in Melitz specification, once the substitution elasticity meets a certain condition. Oyamada (2014a) investigates properties in a global CGE model with the AKME module by running a set of simulations, targeting at preference parameter on product variety. It identifies that the preference parameter significantly influences the welfare effect of trade liberalization. Depending on the value of preference parameter, welfare gains from trade liberalization can be larger in Melitz specification than in Krugman specification, or vice versa. Dixon *et al*. (2014) and Oyamada (2014a) are among a few studies comparing Armington, Krugman, and Melitz trade specifications in CGE model, except for Balistreri and Rutherford (2012).

This paper introduces the AKME module following the modeling strategy in Dixon and Rimmer (2012) and Oyamada (2013). We modify the GTAP model (Hertel, 1997), which is a global CGE model widely used by researchers for quantifying policy impact. We redefine trade flow information stored in the benchmark GTAP Data Base, and implement a calibration procedure established in Oyamada (2013) and Oyamada (2014b). We run simulation of trade liberalization to draw a comparison between different trade specifications, decomposing the trade response in detail. Since there exits only a handful of attempts to compare the trade effects by examining the AKME module, we provide another results for further insights.

The reminder of this paper is organized as follows. Section 2 highlights the key equations of the AKME trade module implemented in the standard GTAP model as an extension. Section 3 describes the database and the simulation design, and we report simulations results in Section 4, focusing on trade variables. Section 5 provides a summary.

2. Key Equations in AKME Trade Specification

We extend the standard comparative static GTAP model (Hertel, 1997) by incorporating a set of equations derived in Oyamada (2013) and Oyamada (2014b) for the AEME module. In this section, we highlight the key equations used in Armington, Krugman, and Melitz specifications. We assumed that the global economy consists of 10 regions and 10 traded goods (see Table 1).[1] The regions are indexed r (source) and s (destination), while the goods and production activities are indexed i and j. Among the 10 production activities, two manufacturing sectors (LightMnfc and HeavyMnfc) are assumed to be imperfectly competitive with increasing returns to scale production

[1] We used the default 10 regions and 10 sectors aggregation in the GTAP Database version 9 (Narayanan et al. (2014)), which has 140 regions and 57 sectors at disaggregate level.

technology, when we consider Krugman and Melitz trade specifications. The other sectors are assumed to be under perfect competition with constant returns to scale. Capital, labor and intermediate inputs are used in all production activities. Land and natural resources are the specific factor of production employed in agricultural sectors and extraction. One services sector (TransComm) provides a fraction of its output as the inter-regional shipping supply. There are three types of agents who generate demands for goods, private household, governments and firms. The private household and government consume goods produced in home and foreign regions. The firms use intermediate inputs for their production activities.

The system of equations and calibration procedures set out by Oyamada (2013) and Oyamda (2014b) are written in the GAMS programming language. We translate and modify the GAMS source code into the GEMPACK programming language, because the GTAP model is formulated in the GEMAPCK. In the process of translation and modification, we convert the system of equations into percentage change format. Thus, it should be noted that all the variables in the following part of this paper are expressed in percentage change except for the parameters and shares. We begin describing the key equations of the AKME module.

Standard GTAP specification (Double-nests Armington):

Regional import demand in the standard GTAP model is defined as follows,

$$qxs_{irs} = qim_{is} - \sigma_i(pms_{irs} - pim_{is}) \tag{1}$$

where

- qxs_{irs} is good i from source region r to destination region s, $(r \neq s)$.
- pms_{irs} is market price of qxs_{irs}, including tariffs.
- qim_{is} is CES aggregate of imported good i in destination region s.
- pim_{is} is price index for qim_{is}.
- σ_i is parameter for elasticity of substitution between goods i.

Equation (1) states that percentage change in imports of good i from region r to region s is determined by the expansion effect of the CES aggregate, qim_{is}, and the substitution effect of change in relative price. Equation (1) applies to all the imported goods.

Notice that the imports from the source region r are aggregated at the border of destination region s. Then, this CES aggregate of imported good i is further aggregated with domestically produced good i by another CES function in the standard GTAP model, thereby forming a composite of good i in destination regions s. This "double-nesting" of

CES aggregators are commonly used in conventional Armington trade models.

Armington specification (Single-nest Armington):

Unlike the standard GTAP which aggregates imports with "sourcing-at-border," we introduce "sourcing-by-agent" to distinguish the import demands across economic agents, such as private household, government, and firms. By utilizing this "sourcing-by-agent", we can decompose regional trade response, qxs_{irs}, by each agent. This can be seen in the following equations. We use intermediate input demand by firms in sector j for example.

At regional level,

$$qxs_{irs} = S^G_{irs} qgs_{irs} + S^P_{irs} qps_{irs} + \sum_j S^F_{ijrs}\, qfs_{ijrs} \tag{2}$$

At firms level

$$qfs_{ijrs} = qff_{ijrs} \tag{3}$$

At a firm level,

$$qff_{ijrs} = qf_{ijs} - \sigma_i (pmfs_{ijrs} - pf_{ijs}) \tag{4}$$

where

- S^G_{irs} is share of government demand, qgs_{irs}, in regional imports, qxs_{irs}.
- S^P_{irs} is share of private household demand, qps_{irs}, in qxs_{irs}.
- S^F_{ijrs} is share of firms' intermediate inputs demand in qxs_{irs}.
- qfs_{ijrs} is total amount of good i from firms active on the r-s trade route.
- qff_{ijrs} is good i from a firm active on the r-s trade route.
- $pmfs_{ijrs}$ is market price of qff_{ijrs}, including tariffs .
- qf_{ijs} is CES aggregate of qff_{ijrs} used by firms in destination region s.
- pf_{ijs} is price index for qf_{ijs}.

Equation (2) decomposes changes in the regional imports into each agent's demand. For the case of firms in sector j in destination region s, Equation (3) shows the change in demand for intermediate inputs i from firms in source region r. In the Armington specification, number of firms is exogenous and we set it to be one. Therefore, the left hand side of Equation (3) coincides with the right hand side. Demand at the firm level is expressed in CES form in Equation (4). We applied this Armington specification for all the sectors.

Krugman specification:

At regional level,

$$qxs_{irs} = S^G_{irs} qgs_{irs} + S^P_{irs} qps_{irs} + \sum_j S^F_{ijrs}\, qfs_{ijrs}.$$

At firms level

$$qfs_{ijrs} = nfirm_{ir} + qff_{ijrs} \tag{5}$$

At a firm level,

$$\beta_{ijs} qff_{ijrs} = qf_{ijs} - \sigma_i (pmfs_{ijrs} - pf_{ijs}) + (\beta_{ijs} - 1)\, qfs_{ijrs} \tag{6}$$

where

$nfirm_{ir}$ is number of firms in source region r .

β_{ijs} is parameter for importer's preference on variety, $0 \le \beta_{ijs} \le 1$.

Krugman specification introduces the variable for number of firms, which is endogenously determined in the model. Equation (5) means that change in total amount of good i from firms active on the r-s trade route can be explained by change in number of firms in source region and change in supply at a firm level. β_{ijs} controls the strength of firm's preference for variety expansion. Private household and government also have this preference parameter in their CES demand function. If we set $\beta_{ijs} = 0$, then the agent does not place importance on variety expansion, and effectively Equation (6) will become the Armington specification. We set $\beta_{ijs} = 1$ to have the agents value at the most of variety expansion. This is consistent with the theoretical implication by Krugman (1980) and Melitz (2003). However, Ardelean (2006) empirically explore the degree of the preference, and estimates β to be about 0.6. This implies that theoretical models may overstate the effect of variety expansion.

Melitz specification:

At regional level,

$$qxs_{irs} = S^G_{irs} qgs_{irs} + S^P_{irs} qps_{irs} + \sum_j S^F_{ijrs}\, qfs_{ijrs}.$$

At firms level

$$qfs_{ijrs} = -S^R_{irs} rfirm_{irs} + nfirm_{ir} + qff_{ijrs} - avprod_{irs} \tag{7}$$

At a firm level,

$$\beta_{ijs} qff_{ijrs} = qf_{ijs} - \sigma_i (pmfs_{ijrs} - pf_{ijs}) + (\beta_{ijs} - 1)(qfs_{ijrs} + avprod_{irs}) \tag{8}$$

where

S^R_{irs} is share of registered but inactive firms in r that sell products to *s*.

$rfirm_{ir}$ is number of firms registered but inactive in r that sell products to *s*.

$avprod_{irs}$ is average productivity of active firms.

Melitz specification adds two variables. One is on the number of firms registered in source region r but inactive on selling their product on the r-s trade route. The more firms become inactive on the r-s trade route, then total amount of goods being traded will be smaller as Equation (7) explicitly shows. The other variable is on average productivity of active firms on the r-s trade route. If average productivity of active firms improves, then we can interpret that the total amount of good to be shipped can be saved.

We highlighted key equations of the AKME module as well as the specification in the standard GTAP model. We will use them in the following section as we compare and decompose the simulation results on trade effects of liberalization.

3. Database and Simulation Design

We use the GTAP Database version 9 (Narayanan *et al*., 2014) for this study with 10 regions and 10 sectors aggregation. Following the calibration procedure of Oyamada (2013) and Oyamada (2014b), we calibrated the AKME module with the GTAP Database. We assume that there are two sectors exhibit increasing returns to scale, LightMnfc and HeavyMnfc. Parameters for the import substitution elasticities, σ_i, are taken from the default values in the GTAP Database. Preference parameters are set to be one for all agents, and initial value for the proportion of registered but inactive firms are 0.8, while the extensive margin for calibration is set at 0.6. Pareto shape parameters are 6.7 and 7.3 for LightMnfc and HeavyMnfc, respectively. Initial mass of firms is set to be unity. All the values used in the calibration process are by no means based on empirical estimation, and they are meant only for our rudiment experiments. We need more empirically estimated parameter values for the AKME module.

Simulation Design:

(S1) Bilateral tariff eliminations between East Asia and EU with different trade specifications; the standard GTAP, Armington, Krugman, Melitz ($\beta = 1$)

(S2) (S1) with Melitz ($\beta = 0$) [Under revision]

(S3) (S1) with Melitz ($\beta = 0.5$) [Under revision]

Table 2 reports import share and bilateral tariff rates for East Asia and EU. From the third column in the upper panel, we can see that about 60% of East Asia's imports are concentrated in manufactured goods (LightMnfc and HeavyMnfc). East Asia's imports from EU account for 13.6% of total imports. Imports of manufactured goods from EU stand out as compared to the other sectoral imports; such as 6.7% of HeavyMnfc and 3.2% of LightMnfc. They are subject to import tariffs of 3.9% on HeavyMnfc and 10% on LightMnfc. Similar patterns are observed for EU's imports from East Asia. In EU, import of HeavyMnfc from East Asia amounts to 5.7% in total imports, and relatively lower tariffs (1.9%) are imposed. LightMnfc from East Asia accounts for 2.5% of total imports, subject to 3.8% bilateral tariffs. We conduct simulations of trade liberalization by removing these bilateral tariffs on the manufactured goods between East Asia and EU. Also, we remove tariffs on intra-regional trade if there exits any.

4. Simulation Results

We begin examining the (S1) simulation results on regional imports, qxs_{irs}, and its decomposition by agents. Table 3 reports the trade response from the liberalization between East Asia and EU on LightMnfc and HeavyMnfc. First, results on regional imports of manufactured goods are larger in East Asia's import from EU than EU's from East Asia. This reflects the fact that East Asia imposes relatively higher tariff rates than EU, leading to more trade responses. Secondly, effects on regional imports increase by changing the trade specification from the standard GTAP, Armington, Krugman, and to Melitz, except for two cases Krugman specification. Thirdly, by looking at the trade response by agents, increase in firms import demands dominates other agents under all of the specifications for both directions of trade. This result can be interpreted as that firms are massively trading intermediate inputs between the regions, forming stronger production networks. It is even clearer as we check share of firms' intermediate inputs demand, S^F_{ijrs}. The share of intra-industry trade of intermediate inputs ($i = j$) is significantly larger; 34% for LightMnfc and 55% for HeavyMnfc from EU to East Asia, and 30% and 36% from East Asia to EU, respectively.

Table 4 decomposes simulation results on regional imports into intra-industry trades. Since the standard GTAP does not break the regional imports into agents, there is nothing to report here. The decompositions correspond to Equation (3) in Armington, Equation (5) in Krugman, and Equation (7) in Melitz specification. Starting from the Armington, intra-LightMnfc import from EU to East Asia is 26.1%, and which is decomposed from the percent change in total regional imports of 77.1% shown previously in Table 3. We can grasp the significant change caused by intra-manufactured imports. This is true for Krugman and Melitz specifications, which provide more interesting decomposition in Table 4. In Krugman, changes in intra-manufactured imports are explained by changes in firm level supply. This indicates that, for the case of Krugman specification, intensive margin trade effects dominate extensive margin effects since the number of firms doesn't show significant changes. Contrastingly, for the Melitz specification, inactive firms become active on the routes between East Asia and EU, leading to more varieties available on the trade routes. These extensive margin trade effects are the dominant explanation of the changes observed in intra-manufactured imports Because the tariff elimination lowers the level of productivity required to enter, less productive firms can enter the trade routes, bringing down the average productivity, and resulted in fall in firm level supply. These decompositions clearly enrich our interpretation of trade liberalization.

Table 5 reports the results on decomposing the intra-industry import demand at firm level, which correspond to Equation (4) in Armington, Equation (6) in Krugman, and Equation (8) in Melitz specification. They are CES demand functions at the firm level expressed in terms of percent change format. Armington and Krugman specifications agree in decomposed results where substitution effects generate positive response to the demands. Trade liberalization abolishes the tariffs, thereby reducing relative price for more demands. In Melitz specification, however, intra-manufactured import demands at firm level exhibit negative responses. Because worsening changes in average productivity raise relative prices, the substitution effects result in negative directions. This decomposition concludes our analysis on the trade responses to the liberalization.
[Revising welfare comparison table]

5. Summary

We introduced the Armington, Krugman, and Melitz module into the standard comparative static GTAP model, and calibrated to the GTAP Database following Oyamada (2013) and Oyamada (2014b). We run illustrative simulations of trade liberalization to draw a comparison between different trade specifications, focusing on trade and welfare effects. Our key findings from the simulation experiments are summarized as follows:

Impacts of liberalization on regional trade are amplified as we switch trade specification from the standard GTAP model to Armington, Krugman, and Melitz in turn.

By introducing "sourcing-by-agent", we can decompose the simulation results on regional imports into agent specific demands, which is not available in the standard GTAP model. Also with the sourcing-by-agent, we can identify the intra-manufactured trade flows as the largest share. Further decomposition reveals that intensive margin trade effects are more pronounced in Krugman specification, whereas extensive margin trade effects are significant in Melitz specification. These decompositions clearly enrich our interpretation of trade liberalization.

These findings may have policy implications for evaluating free trade agreement. However, We need more empirically estimated parameter for the AKME module to become realistic. Since there exits only a few of attempts to compare the welfare and trade effects by testing the AKME module, our contribution by this paper is to add another test results for further insights.

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Table 1. Regions and Sectors

	Regions	Sectors
1	Oceania	GrainsCrops
2	EastAsia	MeatLstk
3	SEAsia	Extraction
4	SouthAsia	ProcFood
5	NAmerica	TextWapp
6	LatinAmer	LightMnfc
7	EU_25	HeavyMnfc
8	MENA	Util_Cons
9	SSA	TransComm
10	RestofWorld	OthServices

(Source) Narayanan *et al*. (2014)

Table 2. Import Share (%) and Tariff Rate (%) for East Asia and EU

East Asia	Import Share (%)		Tariff rate (%)	
	From EU_25	World	From EU_25	Average
GrainsCrops	0.0	3.6	7.1	22.9
MeatLstk	0.2	1.4	25.6	22.0
Extraction	0.1	18.1	1.1	0.5
ProcFood	0.5	3.4	16.7	12.9
TextWapp	0.3	3.2	7.8	5.7
LightMnfc	3.2	10.4	10.0	6.6
HeavyMnfc	6.7	49.5	3.9	2.8
Util_Cons	0.2	0.5	0.0	0.0
TransComm	1.3	5.0	0.0	0.0
OthServices	1.2	4.7	0.0	0.0
Total	13.6	100	5.2	3.7

EU_25	Import Share (%)		Tariff rate (%)	
	From EastAsia	World	From EastAsia	Average
GrainsCrops	0.0	2.1	5.3	1.2
MeatLstk	0.0	1.2	3.0	4.2
Extraction	0.0	7.3	0.1	0.0
ProcFood	0.1	4.8	10.9	1.8
TextWapp	1.2	4.2	10.1	3.6
LightMnfc	2.5	19.4	3.8	0.7
HeavyMnfc	5.7	41.8	1.9	0.4
Util_Cons	0.1	1.1	0.0	0.0
TransComm	0.7	7.2	0.0	0.0
OthServices	0.6	10.8	0.0	0.0
Total	11.0	100	3.0	0.6

(Source) Narayanan *et al*. (2014)

Table 3. Simulation Results on Regional Imports, qxs_{irs}, and Decomposition by Agents (%)

	East Asia Imports from EU		EU Imports from East Asia	
	LightM	HeavyM	LightM	HeavyM
Std.GTAP	53.8	20.5	24.7	12.6
Armington	77.1	26.2	30.0	16.3
government	0.0	0.0	0.0	0.2
private h.h.	13.4	1.7	9.6	2.1
firms	63.6	24.6	20.4	14.1
Krugman	72.6	28.5	31.3	15.4
government	0.0	0.0	0.0	0.2
private h.h.	12.3	1.9	10.5	1.9
firms	60.2	26.6	20.8	13.3
Melitz	105.2	30.6	34.9	21.0
government	0.0	0.0	0.0	0.2
private h.h.	19.1	2.0	11.4	2.7
firms	86.1	28.6	23.5	18.1

Table 4. Simulation Results on Decomposition into Intra-industry Imports (%)

	East Asia Imports from EU		EU Imports from East Asia	
	intra-LightM	intra-HeavyM	intra-LightM	intra-HeavyM
Armington:				
qfs	26.1	14.5	9.1	5.7
Krugman:				
qfs	26.9	14.8	7.9	6.3
number of firms	−1.3	1.2	0.7	−0.4
firm level supply	28.2	13.6	7.2	6.7
Melitz:				
qfs	35.5	16.9	10.5	7.6
entry on r-s route	35.3	16.5	10.5	7.4
number of firms	0.3	0.2	−0.1	0.2
firm level supply	−3.5	−1.8	−1.2	−0.8
average productivity	3.4	1.9	1.3	0.9

Table 5. Simulation Results on Decomposition into Intra-industry Import Demand at Firm Level (%)

	East Asia Imports from EU		EU Imports from East Asia	
	intra-LightM	intra-HeavyM	intra-LightM	intra-HeavyM
Armington:				
qff: firm level supply	26.1	14.5	9.1	5.7
expansion effect	−0.3	0.3	0.3	−0.1
substitution effect	26.4	14.3	8.8	5.8
Krugman:				
qff: firm level supply	28.2	13.6	7.2	6.7
expansion effect	1.2	−0.6	−1.3	0.9
substitution effect	27.0	14.2	8.5	5.8
Melitz:				
qff: firm level supply	−3.5	−1.8	−1.2	−0.8
expansion effect	−0.1	0.3	0.2	0.2
substitution effect	−3.4	−2.0	−1.4	−0.9