Behavioral Characteristics of Applied General Equilibrium Models with Variable Elasticity of Substitution between Varieties from Different Sources*

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Abstract

Based on an intuition that additional varieties reduce distance between varieties filling in gaps between existing varieties, this study explores the behavioral characteristics of the Melitz-type heterogeneous and the Krugman-type homogeneous firm models endogenizing the substitution elasticity as an increasing function of the total number of varieties that are available in the destination country/region. Choosing the case of the U.S. President Donald Trump's anti-China tariff as an example, simulations with the 3-region, 3-sector applied general equilibrium model revealed the following results: the impact of the efficiency enhancing effect brought by international trade becomes larger for the Melitz-type than the Krugman case; and the efficiency enhancing effect works negative for the regional welfare as the value of the parameter that controls the influence of the total number of varieties to the substitution elasticity gets large.

Keywords: applied general equilibrium; variable elasticity of substitution; preference for variety; heterogeneous firms.

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1. Introduction

As the recent developments in applied general equilibrium (AGE) analysis enabled us to incorporate the Melitz-type monopolistic competition and heterogeneous firms (Zhai, 2008; Balistreri and Rutherford, 2013; Dixon, Jerie, and Rimmer, 2016; Akgul, Villoria, and Hertel, 2016), people's attention is now directed to the re-estimation of the elasticity of substitution between varieties from different sources, which fits to an estimated value of the Pareto shape parameter for the productivity distribution of firms. In this situation, a controversy arises on the question whether the incorporation of endogenous changes in productivity might bring significantly large welfare gains from trade (Balistreri, Hillberry, and Rutherford, 2011; Arkolakis, Costinot, and Rodriguez-Clare, 2012; Melitz and Trefler, 2012; Melitz and Redding, 2013 and 2015). While Dixon, *et al.* (2016) emphasized that the Melitz-type trade specification may not lead to a substantial revision of the welfare estimates obtained with the models such that based on pure competition and the Armington-type specification, our previous studies (Oyamada, 2015; Itakura and Oyamada, 2016) suggest that intensity of the importer's preference for variety (PfV), which might be exaggerated in most of the theoretical as well as applied models with the Krugman- and Melitz-type specifications (Ardelean, 2006), plays a significant and crucial role in determining the magnitude of welfare effects.

Our previous experiments show that the allocation of resources based on the endogenous productivity growth among heterogeneous firms that enters the Melitz-type trade specification does not always enhance effectiveness of a certain policy change more than the level predicted by the homogeneous firm models including not only the Krugman-type but also the Armington-type, in the environment where the PfV is weaker than the one assumed in the theory. The extra adjustment margin (the set of the productivity effect that appears as a change in the sales quantity per exporting firm and the supplemental variety effect as a change in the proportion of exporting firms) in the Melitz-type heterogeneous firm model works favorable to member countries of a free trade agreement (FTA) and unfavorable to non-members if the intensity of the importer's PfV is strong because the supplemental variety effect works stronger than the productivity effect, whereas the extra adjustment margin works unfavorable to FTA members and favorable to non-members if the intensity of the PfV is weak since the productivity effect works stronger than the supplemental variety effect.[1] If we assume weaker intensity of the PfV following

[1] We call the variety effect related to the changes in the number of firm entry as "fundamental variety effect," and the one based on the proportion of exporting firms as "supplemental variety effect." When we

the results from the empirical investigations by Ardelean (2006) to make the analysis more realistic and practical, the homogeneous firm models may generate larger welfare gains than the Melitz-type heterogeneous firm model.

The purpose of this study is to present another approach to handle the variety effect, based on an intuition that additional varieties reduce distance between varieties filling in gaps between existing varieties. Endogenizing the substitution elasticity as an increasing function of the total number of varieties that are available in the destination country/region, we explore the behavioral characteristics of the Melitz-type heterogeneous and the Krugman-type homogeneous firm models as we did with the intensity of the PfV. Although the Krugman's original model with monopolistic competition allows changes in the elasticity of demand (Krugman, 1979), the feature have often been discarded in the process of pursuing simplicity following Krugman (1980). Meanwhile, Feenstra (1994) proposed a model that incorporates new product varieties into a constant-elasticity-of-substitution (CES) aggregate of import prices. Under his specification, the introduction of new or upgraded varieties lowers the international price index through reduction in the markup rate. Arkolakis, Costinot, Donaldson, and Rodoriguez-Clare (2015) introduced variable markups into a model with monopolistic competition and firm-level heterogeneity, and found that gains from trade liberalization predicted by models with variable markups are slightly lower than those predicted by models with constant markups. Our approach is in line with those attempts.

The reminder of this paper is organized as follows. Section 2 presents a brief note on the analytical model used in this study. In Section 3, we perform experimental simulations to clarify the behavioral characteristics of the model and verify the results. Then, Section 4 concludes this paper.

2. The Model

In this section, we overview the AGE model with the Melitz- and Krugman-type trade specifications used in this study. The model is calibrated to the GTAP 9A Data Base for 2011 (Hertel, 1997) with the author's assumption that the Pareto shape parameter is set to 5.0. This time, the global economy is divided into three countries/regions indexed r (source) and s (destination), which are linked through trade flows: (r01) the United States

simply use "variety effect," it includes only the former under the Krugman-type trade specification, whereas it implies the merger of the both fundamental and supplementary effects under the Melitz-type.

of America (USA); (r02) China; and (r03) the Rest of the World (ROW). Commodities and activities respectively indexed i and j are categorized into three: (i01) the primary industries; (i02) manufacturing; and (i03) services. Sectors i02 is assumed to be imperfectly competitive with increasing-returns-to-scale (IRTS), while the other two are characterized by constant-returns-to-scale (CRTS). Sector i01 uses a sector specific factor, such as land and natural resources, in addition to capital, labor, and intermediate goods in its production process. Sector i03 provides a fraction of its output as the inter-regional transportation supply.

An important feature of the model is that firms in Sector i02 that exhibits IRTS are divided into two segments that respectively take charge of production and sales. In the production process, the production segment of firms collectively determines sector-wide input levels of intermediate goods and primary factors, and the output volume, based on the CRTS technologies. Then, the product is wholesaled to the sales segment. The sales segment consists of many dealers/merchants, those who have market power to determine the marked-up sales price of the commodity in local markets. The scale economy enters here.

The base model is a SaB-type trade model with the Armington-Krugman-Melitz encompassing (AKME) module introduced in Oyamada (2016) based on Balistreri and Rutherford (2013) and Dixon *et al.* (2016). The equations that form the Melitz-type trade module are summarized as follows:

$$\sum_j X_{ijs} + C_{is} = \theta_{is}^T \left\{ \begin{array}{l} (1-\sum_r \alpha_{irs}^T) N_{is}{}^{(\beta_{is}+\sigma_i^T-1)/\sigma_i^T} D_{is}^{(\sigma_i^T-1)/\sigma_i^T} \\ +\sum_r \alpha_{irs}^T \widetilde{N}_{irs}{}^{(\beta_{is}+\sigma_i^T-1)/\sigma_i^T} Q_{irs}^{(\sigma_i^T-1)/\sigma_i^T} \end{array} \right\}^{\sigma_i^T/(\sigma_i^T-1)} \perp p_{is}; \quad (1)$$

$$p_{is}^D = (1-\sum_r \alpha_{irs}^T)(\theta_{is}^T)^{(\sigma_i^T-1)/\sigma_i^T} N_{is}{}^{(\beta_{is}-1)/\sigma_i^T} p_{is} \left(\frac{\sum_j X_{ijs}+C_{is}}{D_{is}}\right)^{1/\sigma_i^T} \perp D_{is}; \quad (2)$$

$$(1+\tau_{irs}^M)(1+\tau_{irs}^T)(1+\tau_{irs}^E) p_{irs}^Q = \alpha_{irs}^T (\theta_{is}^T)^{(\sigma_i^T-1)/\sigma_i^T} \widetilde{N}_{irs}{}^{(\beta_{is}-1)/\sigma_i^T} p_{is} \left(\frac{\sum_j X_{ijs}+C_{is}}{Q_{irs}}\right)^{1/\sigma_i^T} \perp Q_{irs}; \quad (3)$$

$$p_{ir}^D = \left(\frac{\sigma_i^T}{\sigma_i^T-1}\right) p_{ir}^w \perp p_{ir}^D; \quad (4)$$

$$p_{irs}^Q = \left(\frac{\sigma_i^T}{\sigma_i^T-1}\right) \frac{p_{ir}^w}{\varphi_{irs}} \perp p_{irs}^Q; \quad (5)$$

$$N_{ir}D_{ir} + \sum_s \widetilde{N}_{irs}\frac{Q_{irs}}{\varphi_{irs}} + \Omega_r = Z_{ir} - N_{ir}H_{ir} - \sum_s \widetilde{N}_{irs}F_{irs} \qquad \perp p_{ir}^{W}; \quad (6)$$

$$E_{irs} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)} {\varphi_{irs}}^{-\gamma_i} \qquad \perp E_{irs}; \quad (7)$$

$$\varphi_{irs} = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{Q_{irs}}{F_{irs}}\right) \qquad \perp \varphi_{irs}; \quad (8)$$

and

$$p_{ir}^{w}\left(N_{ir}H_{ir} + \sum_s \widetilde{N}_{irs}F_{irs}\right) = \frac{1}{\sigma_i^T}\left(p_{ir}^{D}N_{ir}D_{ir} + \sum_s p_{irs}^{Q}\widetilde{N}_{irs}Q_{irs}\right)$$

$$\perp N_{ir}, \quad (9)$$

where

C_{is} is the final demand for commodity i in region s,

D_{is} is the domestic (intra-national) trade flow of commodity i sold in region s,

Q_{irs} is the inter- and intra-regional (not intra-national but inter-national) trade flow of commodity i sold by exporting firms in region r to region s,

p_{is}^{D} is the differentiated sales price for domestic market s,

p_{irs}^{Q} is the differentiated sales price for inter-regional market s sold by firms in region r excluding the transportation margin and the import tariff,

p_{ir}^{w} is the wholesale price of the products,

$E_{irs} \in (0,1)$ is the proportion of exporting firms in region r that sell products to region s,

φ_{irs} is the average productivity of exporting firms,

N_{ir} is the number of firms entered in region r,

$\widetilde{N}_{irs}$ is the number of exporting firms active on the r-s link,

F_{irs} is the fixed exporting cost as measured in units of gross output (composite input) and necessary to make sales on the r-s link,

H_{ir} is the fixed entry cost as measured in units of gross output (composite input) and necessary to establish a firm in region r,

$\beta_{is} \in [0,1]$ is the intensity of the importer's PfV,

$\sigma_i^T > 1$ is the elasticity of substitution between the varieties from different sources,

α_{irs}^{T} is the weight parameter that reflects the preference of region s for the region of origin r,

θ_{is}^{T} is the scaling factor,

γ_i is a shape parameter related to productivity such that $\gamma_i > \sigma_i^T - 1$,

τ_{irs}^E is the rate of export duty/subsidy,

τ_{irs}^T is the rate of transportation margin,

τ_{irs}^M is the import tariff rate, and

Ω_r is inter-regional transportation supply defined with a regional share parameter ω_r as

$$\Omega_r \equiv \frac{\omega_r}{p_{"i03"r}^W} \sum_{i'} \sum_{r'} \sum_s \tau_{i'r's}^T \left(1 + \tau_{i'r's}^E\right) E_{i'r's} N_{i'r'} p_{i'r's}^Q Q_{i'r's}.$$

Ω_r is included in Equation (6) if and only if i is the services sector (i03). Furthermore, the second and the third terms in the right-hand side of Equation (6) enter if and only if i is the manufacturing sector (i02). Similarly, φ_{irs} enters Equation (5) only when i is the manufacturing sector. Equations (7) through (9) are only for the manufacturing sector.

In addition to Equations (1) through (9), the substitution elasticity for the manufactured product (i = i02) is now defined as follows as an increasing function of the total number of varieties which are available in the destination country/region s:

$$\sigma_{is}^T = \mu_{is}\left(N_{is} + \sum_r \widetilde{N}_{irs}\right)^{\nu_i}, \qquad (10)$$

where

μ_{is} is the unit coefficient given by $\mu_{is} \equiv \frac{\sigma 0_{is}^T}{(N0_{is} + \sum_r \widetilde{N0}_{irs})^{\nu_i}}$,

$\nu_i \in [0,1]$ is the parameter that prescribes the influence of the total number of varieties to the substitution elasticity,

$\sigma 0_{is}^T$ is the initial level of the elasticity of substitution between varieties,

$N0_{is}$ is the initial number of firms entered in region s, and

$\widetilde{N0}_{irs}$ is the initial number of exporting firms active on the r-s link.

When $\nu_i = 0$, σ_{is}^T will not change. Notice that σ_{is}^T now has the suffix s because the number of available varieties differs by destination country/region. σ_{is}^T replaces all of the σ_i^T that appears in Equations (1) through (9).

Then, the module switches the Melitz- and Krugman-type specifications by applying different parameter settings as follows.

Melitz-type Specification: In the Melitz-type specification, the following setting applies, in addition to Equations (1) through (10):

$$\widetilde{N}_{irs} = E_{irs} N_{ir}.$$

Krugman-type Specification: In the Krugman-type specification, the following three

relations apply, in addition to Equations (1) through (6), (9), and (10):

$F_{irs} = 0;$

$\varphi_{irs} = 1;$

and

$\widetilde{N}_{irs} = N_{ir} \qquad (\therefore E_{irs} = 1).$

3. Experiments

In this section, we report on the results of simulation experiments performed with the three-region, three-sector AGE model that includes the AKME trade module introduced in the previous section. Taking the case of the Donald Trump's anti-China tariff as an example, we examine how the calculated values of endogenous variables change when the influence of the total number of varieties to the substitution elasticity (ν_i) take different values from zero to unity. To highlight the effects of changing ν_i, we also consider the case of changing the levels of β_{is} for all countries/regions, and compare the results. The Trump's anti-China tariff is expressed by the permanent increase in the rate of import tariff ($\tau^{M}_{"i02""r02""r01"}$) levied on the manufactured products (i02) exported from China (r02) to USA (r01) by 400% (raised from 2.967% to 14.824%). Although the U.S. President Trump has threatened to raise the duty to 45%, the model is unable to converge in one round of iterations with such high tariff rate. Thus, we stopped to pursue realism.

3.1 Basic Effects

Since the model solves for an equilibrium where every kind of adjustments has completed, it needs to entangle the complex mixture of economic effects into several aspects in interpreting simulation results. We deal here with the basic effects directly elicited by raising the import tariff levied on a specific trade link (trade in manufactured products i02 from China r02 to USA r01) and followed by sectoral adjustments.

Once the market price of the manufactured products imported from China (r02) appreciates in USA (r01) due to the increase of import tariff, the demand for the commodity relatively shrinks compared to the demand for the substitutable goods respectively produced domestically in USA (r01) and imported from ROW (r03). It may lower the wholesale price (producer price) of the commodity manufactured in China (r02). On the other hand, the demand in USA (r01) for the substitutable produced domestically or

imported from ROW (r03) replaces a part of the shrunk demand for the Chinese (r02) products so that the wholesale prices of the former appreciate in both r01 and r03. Based on these changes in the wholesale price in every country/region, the volumes of trade flow on each link can also be roughly predicted: (in r01) the demand expands for both domestically produced commodity and imports from r03 whereas the demand for imports from r02 shrinks; (in r02) the demand increases for domestically produced commodity because of its depreciated price whereas the demand for imports from both r01 and r03 reduces because of their appreciated prices; and (in r03) the demand for imports from r02 inflates because of its cheaper price whereas changing directions of the demand for domestically produced commodity and imports from r01 are ambiguous because of the appreciated price of the commodity produced in r01 and r03. Anyway, the terms-of-trade of r02 tends to worsen while that of r01 and r03 improves, respectively.

The raising protection by USA (r01) against China (r02) brings firms in r02 to make profits relatively difficult because imported intermediate goods become more expensive so that the number of entered firms tends to reduce in r02. Although it is unable to predict clearly, the increased demand in r01 for the goods produced in r01 and r03 may increase the number of firm entry in r01 and r03. Under the Melitz-type trade specification, the proportion of exporting firms active on each trade link tends to show the same changing directions as the volumes of trade flow mentioned above. On the other hand, the hurdle to enter the international market (the cut-off level of productivity) and the sales quantity per firm show completely opposite changes to the proportion of exporting firms. One point to note is that the replacement of the shrunk demand in r01 for the r02 products will not be fully recovered by the increased demand for the commodity produced in r01 and r03. Therefore, the total number of varieties respectively available in r01 and r02 definitely reduces from the level before the policy change, because of the enlarged distortion in the global economy. The total number of varieties available in r03 also tends to decrease due to the shrunk exports from r03 to r02.

3.2 Effects of Changing the Value of ν_i on the Simulation Results

We now turn to see how the effects of the anti-China tariff placed by USA change with different values of ν_i, which controls the influence of the total number of varieties to the substitution elasticity. The value of ν_i is changed from zero to unity, with the step width of 0.05. For reference, the levels of β_{is} for all countries/regions also are simultaneously changed from zero to unity in a similar manner.

Figure 1 shows the effects of the anti-China tariff implemented by USA (r01) on the total number of varieties available in every country/region, when ν_i and β_{is} respectively and independently take the values between zero and unity under the Melitz-type trade specification. In the figure, three panels from the top to the bottom show the effects in r01 through r03. Let us call the panel on the top "Panel 1T," the one in the middle "Panel 1M," and the one at the bottom "Panel 1B," respectively. As we noted previously, the total number of varieties tends to reduce from the level before the policy implementation. Then, larger level of ν_i increases the total number of varieties available in r01, whereas varieties reduce as β_{is} takes larger value (Panel 1T). The reason for the former is because larger value of ν_i enables smoother substitution between varieties so that the efficiency enhancing effect of international trade intensifies. Thus, the number of firm entry in r01, number of firms in r03 exporting to r01 increase, while reduction in the number of firms in r02 exporting to r01 becomes less. In contrast, stronger PfV (larger value of β_{is}) tends to increase the domestic transaction and imports from r03 so that the reduction in the number of firms in r02 porting to r01 expands. Similar effects are captured in Panel 1M. Reductions in the number of firm entry in r02, and the firms in r01 and r03 exporting to r02 become smaller as ν_i grows. Meanwhile, the number of those firms reduces as β_{is} grows, based on the worse terms-of-trade for r02.

Panel 1B shows an interesting pattern. When smoother substitution is enabled by larger value of ν_i, r03 expands international trade within the region replacing imports from r01 and r02. In consequence, the total number of variety reduces in r03 when ν_i takes a large value. If PfV is strong (larger value of β_{is}), r02 basically increases imports from r02 reducing those from r01, since the former is cheaper than before whereas the latter is now expensive. The imports from r02 will not increase enough to offset the reduction in the imports from r01. The intra-regional international trade expands only if substitution is more smooth (large ν_i). Thus, the total number of available varieties increases only if ν_i takes a large value.

Welfare effects partly reflect the changes in the total number of varieties. Figure 2 depicts welfare changes elicited by the anti-China tariff implemented by r01 when ν_i and β_{is} respectively and independently take the values between zero and unity with the Melitz-type trade specification. Since the total number of varieties reduces from the level before the policy implementation in most cases, the regional welfare tends to deteriorate in every country/region. Along with the changes in the total number of varieties, welfare effects also reflect the changes in the sales quantity per firm. One of the most important rules in the Melitz-type trade specification is that the per firm transactions shrink when

available varieties grow, and *vice versa*. In addition, the changes in the total number of varieties are not much accounted for in the welfare if the importer's PfV is not so strong (β_{is} is set small). In Panels 2T and 2M, reductions in the total number of varieties brought by small values of ν_i is not much considered whereas the expansion in the sales quantity is fully accounted for when β_{is} is zero. Thus, the welfare levels become highest when $\nu_i = \beta_{is} = 0$. If the value of ν_i is increased holding $\beta_{is} = 0$, sales quantity decreases so that welfare levels deteriorate. As the PfV intensifies (larger β_{is}), the effects of the reduction in the total number of varieties are added so that welfare levels get worse, again.

In the case of r03, expansion in the total number of varieties led by small values of ν_i is fully accounted for compared to reduction in the sales quantity when β_{is} is set to unity. Hence, the welfare levels become highest when $\nu_i = 0$ and $\beta_{is} = 1$. If the value of ν_i is increased holding $\beta_{is} = 1$, available varieties reduces so that welfare levels deteriorate. As the PfV weakens (smaller β_{is}), the effects of the changes in the total number of varieties are subtracted so that welfare level gets worse around $\nu_i = \beta_{is} = 0$. One exception is that welfare does not improve when the value of ν_i grows under the condition $\beta_{is} = 0$. This requires further investigation.

Let us go ahead to see the case under the Krugman-type trade specification. Figure 1 captures the effects of the anti-r02 tariff implemented by r01 on the total number of varieties available in every country/region, when ν_i and β_{is} respectively and independently take the values between zero and unity under the Krugman-type trade specification. This time, the total number of varieties increases with larger value of ν_i, and decreases with larger value of β_{is} in all of the country/region.

Welfare effects show totally similar patterns as we have seen in the case of the Melitz-type (Figure 4). Since Panel 4B shows different pattern compared to Panels 4T and 4M, we need deeper investigation as in the previous case.

3.3 Comparison of Welfare Effects between the Melitz- and Krugman-type trade specification

In this subsection, we are going to compare the results obtained by the AGE model with different trade specifications, namely, the Melitz- and Krugman-types. Figures 5 and 6 capture the welfare effects we have seen previously in a two-dimensional format when the value of either ν_i or β_{is} is fixed to 0.0, 0.5, and 1.0. Notice that the effects of changing the value of either ν_i or β_{is} show relatively straight curvatures and flat slopes if the Krugman-type trade specification applies. The difference between the Melitz and Krugman

lines implies the total volume of the supplemental variety effect which appears as a change in the proportion of exporting firms and the productivity effect as a change in the sales quantity per exporting firm. Those two kinds of effect, which are specific to the Melitz-type heterogeneous firm model, work opposite and partially offset each other as suggested by Dixon *et al.* (2016:56). Then, the difference between the lines corresponding to different values of β_{is} captured by Figure 5 shows the magnitude of the variety effect. In turn, the difference between the lines corresponding to different values of ν_i captured by Figure 6 shows the volume of the efficiency enhancing effect brought by international trade. One point to note is that the impact of the efficiency enhancing effect is larger for the Melitz-type than the Krugman case.

Since the introduction of anti-China tariff basically increases distortion in the global economy, the effects are negative for both USA (r01) and China (r02). Thus, the variety effect (and the productivity effect if the Melitz-type applies) and the efficiency enhancing effect led by international trade work negative for r01 and r02 (Panels 5T, 5M, 6T, and 6M). The red lines take the top position followed by blue and green, and welfare levels falls as the value of ν_i or β_{is} grow. In contrast, the effects on the welfare level of the non-party r03 show different patterns. In Panel 5B, the variety effect (and the productivity effect if the Melitz-type applies) contributes to improve welfare (the green lines take the top), although its contribution reduces as the value of ν_i grows. In the case of efficiency enhancing effect, it increases as the value of β_{is} grows, while the order of the lines are the same as the ones for r01 and r02 (Panel 6B).

Next, Figure 7 directly compares the variety effect (and the productivity effect if the Melitz-type applies) with the efficiency enhancing effect brought by international trade. This time, the green line corresponds to the effects given by a model with the conventional Armington-type trade specification. Note that the model with the Krugman-type specification yields exactly the same results as the ones obtained with the Armington-type when the values of both ν_i and β_{is} are set to zero. Thus, the Krugman and Armington lines overlap at the far left ($\nu_i = \beta_{is} = 0$). In addition, the welfare gains/losses at $\nu_i = \beta_{is} = 0$ show just the changes in the total consumption quantity, without any extra effect added, calculated under the Meliz- or Krugman-type trade specification. Therefore, the difference between the Melitz and Krugman (or Armington) lines at $\nu_i = \beta_{is} = 0$ can be regarded as the extra adjustment margin (the supplemental variety effect with the productivity effect) encapsulated in the Melitz-type specification.

Since the unfavorable supplemental variety effect which appears as reductions in the number of exporting firms is not accounted for when $\beta_{is} = 0$, the favorable productivity

effect as an expansion in the sales quantity per exporting firm contribute to improve welfare in r01 (Panel 7T). Then, the welfare deteriorates as the unfavorable variety effect is added to the welfare aggregation as the value of β_{is} grows (Panels 7T and 7M). In contrast to r01 and r02, the variety effect works favorable for the non-party r03 (Panel 7B). The efficiency enhancing effect brought by international trade also works negative for the regional welfare as the value of ν_i gets large (Panels 7T though 7B).

Finally, let us think about the case of trade liberalization. Suppose r01 liberalize trade for r02. In this case, the effects are completely reversed from the case of imposing the anti-r02 tariff. Thus, the regional welfare of r01 and r02 increases as the values of ν_i and β_{is} grow in the following manner:

$$\frac{\mathrm{d}WEL_s}{\mathrm{d}\nu_i} > 0;\ \frac{\mathrm{d}^2WEL_s}{\mathrm{d}\nu_i^2} < 0;\ \frac{\mathrm{d}WEL_s}{\mathrm{d}\beta_{is}} > 0;\ \text{and}\ \frac{\mathrm{d}^2WEL_s}{\mathrm{d}\beta_{is}^2} > 0.$$

Note that the Melitz-type model will generate negative welfare effects around $\nu_i = \beta_{is} = 0$, even for case when the country under examination tends to better off with the Armington-type trade model. Under the Melitz-type specification, the main player of a free-trade agreement may suffer from welfare losses if the variety effect is not fully valued in the situation when PfV is not so strong . The reason why it occurs is because the reduction in the volume of consumption quantity (unfavorable productivity effect), which is brought by the decline in the cut-off productivity in the source country/region, is mainly reckoned on while the increase in the number of varieties (favorable variety effect) is not fully accounted for in the utility function when the value of β_s is set small. An important point is that the extra adjustment margin in the Melitz-type heterogeneous firm model basically (and implicitly when the importer's PfV is strong) yields additional reduction in the volume of consumption quantity when the cut-off productivity is lowered and poorly productive small-scale firms come into operation, whereas the fundamental variety effect, which is more explicit in the Krugman-type homogeneous firm model, always is positive when the number of firm entry expands. On the other hand, the efficiency enhancing effect will contribute to bring maximum welfare gains in the condition when PfV is strong enough as the original theory assumes.

5. Concluding Remarks

Based on an intuition that additional varieties reduce distance between varieties filling in gaps between existing varieties, this study explores the behavioral characteristics of the

Melitz-type heterogeneous and the Krugman-type homogeneous firm models endogenizing the substitution elasticity as an increasing function of the total number of varieties that are available in the destination country/region. Choosing the case of the U.S. President Donald Trump's anti-China tariff as an example, simulations with the 3-region, 3-sector applied general equilibrium model revealed the following results in comparison with the case when intensity of the importer's PfV changes.

1. The impact of the efficiency enhancing effect brought by international trade becomes larger for the Melitz-type than the Krugman case.

2. The variety effect (and the productivity effect if the Melitz-type applies) and the efficiency enhancing effect led by international trade work negative for USA and China, since the introduction of anti-China tariff basically increases distortion in the global economy.

3. In contrast, the variety effect (and the productivity effect if the Melitz-type applies) contributes to improve welfare of the non-party ROW, although its contribution reduces as the value of the parameter, which prescribes the influence of the total number of varieties to the substitution elasticity, grows.

4. While the favorable productivity effect as an expansion in the sales quantity per exporting firm contribute to improve welfare in USA when the intensity of the importer's PfV is relatively weak.

5. Welfare levels deteriorates in USA and China as the unfavorable variety effect is added to the welfare aggregation as the PfV gets stronger, whereas the variety effect works favorable for the non-party ROW.

6. The efficiency enhancing effect brought by international trade also works negative for the regional welfare as the value of the parameter that controls the influence of the total number of varieties to the substitution elasticity gets large.

Since the present results may heavily be affected by the form of the substitution elasticity function, we would like to continue this research trying to use other functional forms.

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Figure 1. Changes in Total Number of Varieties (%) - Anti-China Tariff by USA on Manufactured Products (Melitz)

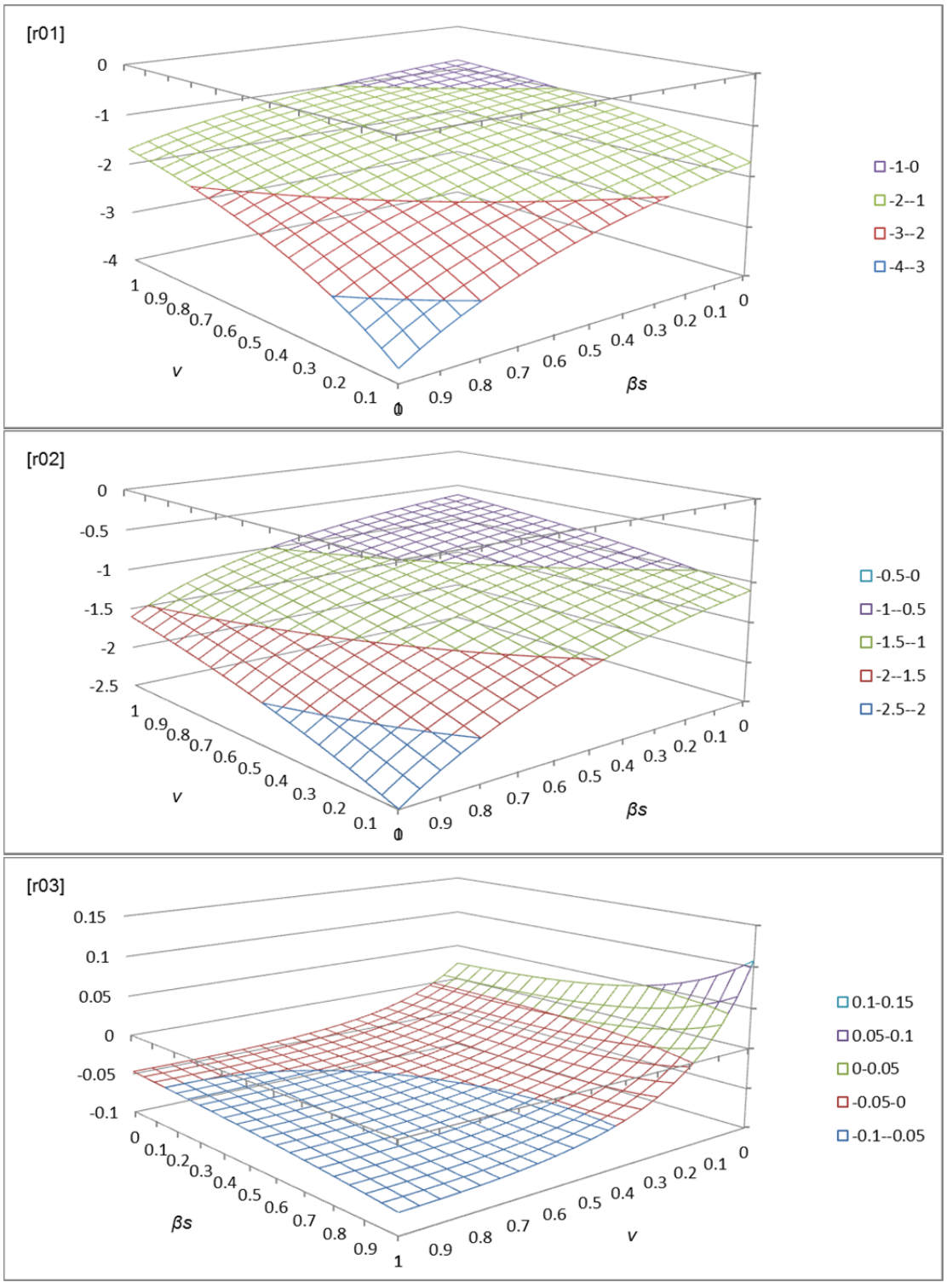

Figure 2. Changes in Welfare (%) - Anti-China Tariff by USA on Manufactured Products (Melitz)

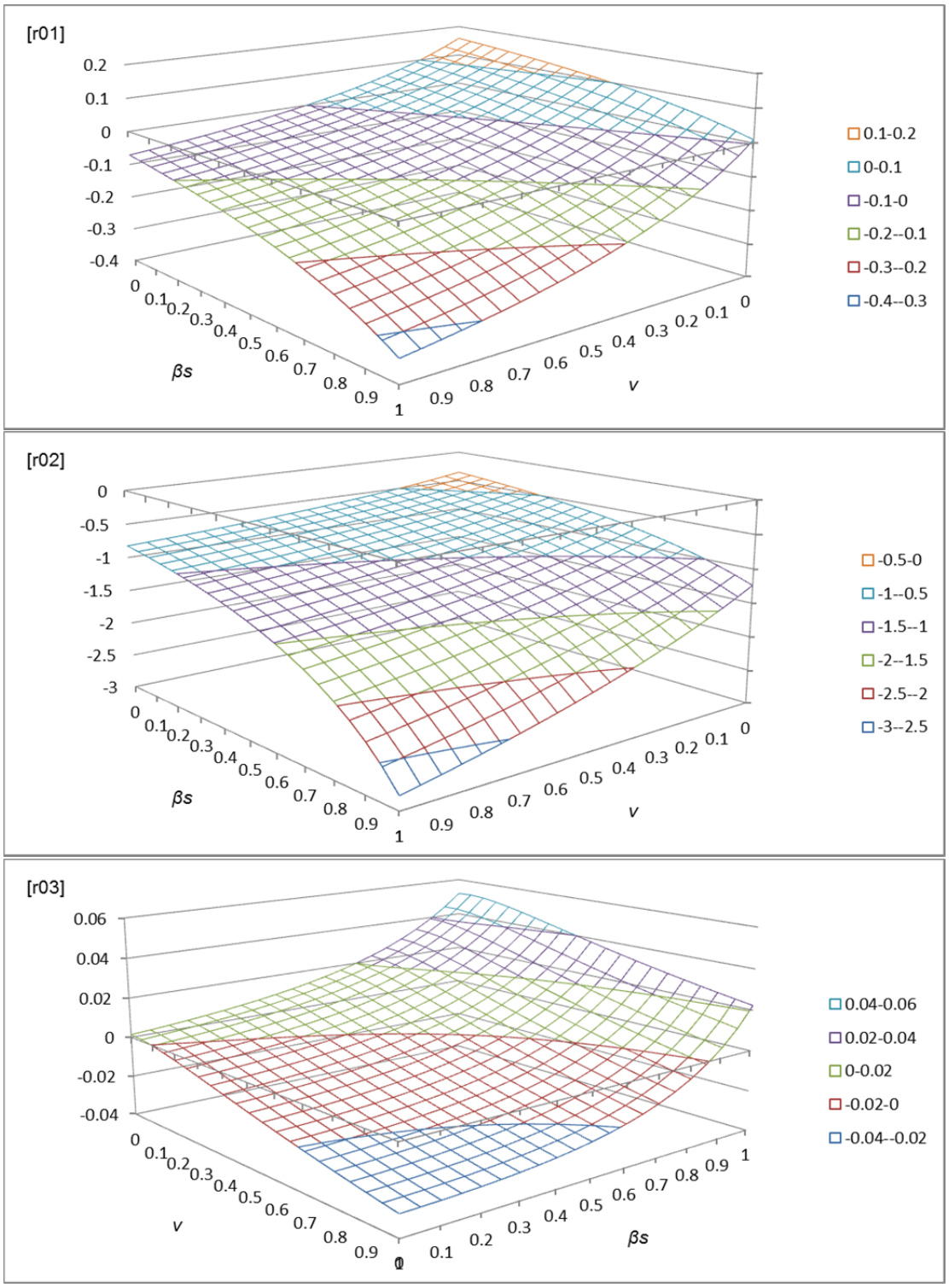

Figure 3. Changes in Total Number of Varieties (%) - Anti-China Tariff by USA on Manufactured Products (Krugman)

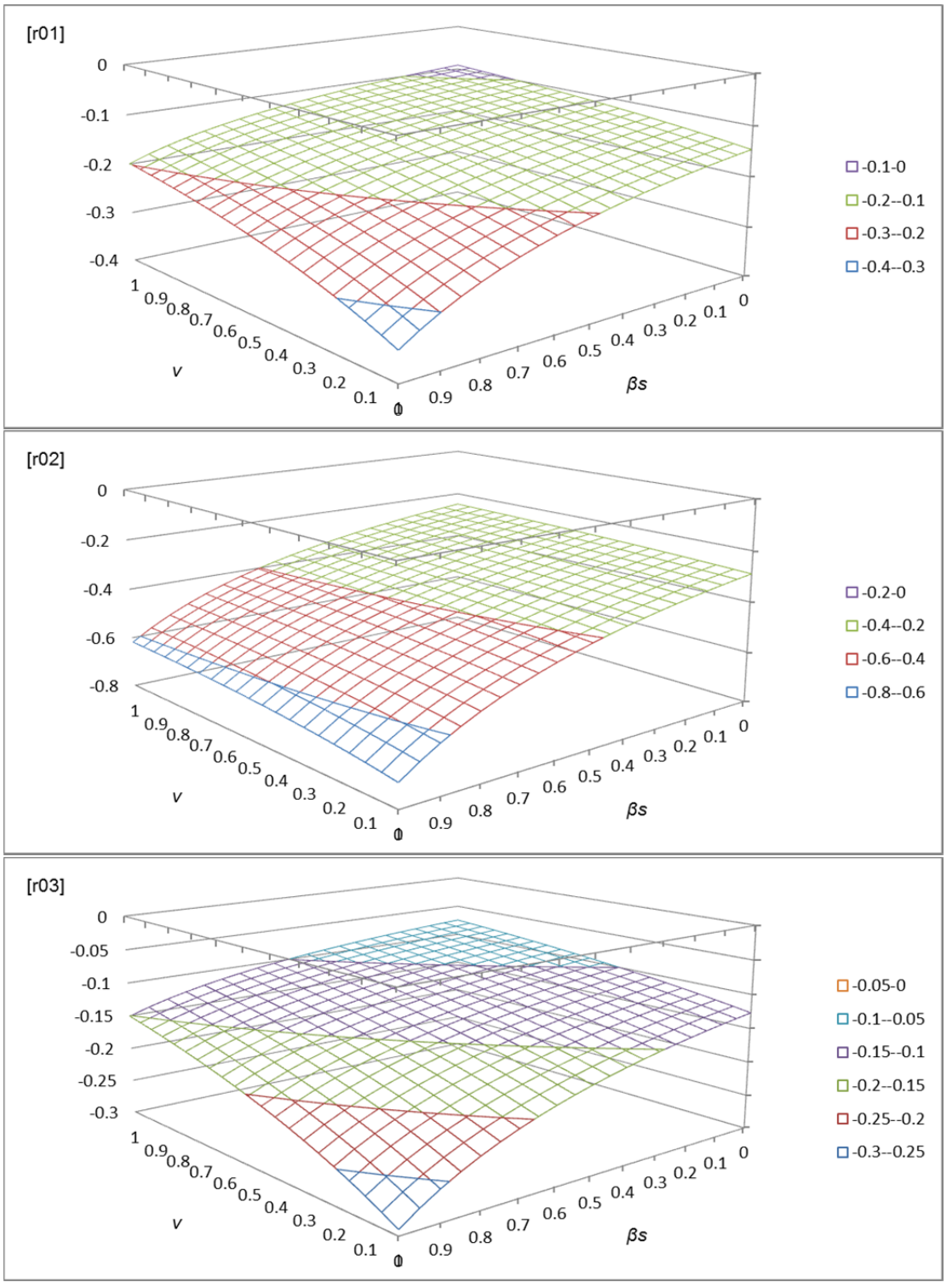

Figure 4. Changes in Welfare (%) - Anti-China Tariff by USA on Manufactured Products (Krugman)

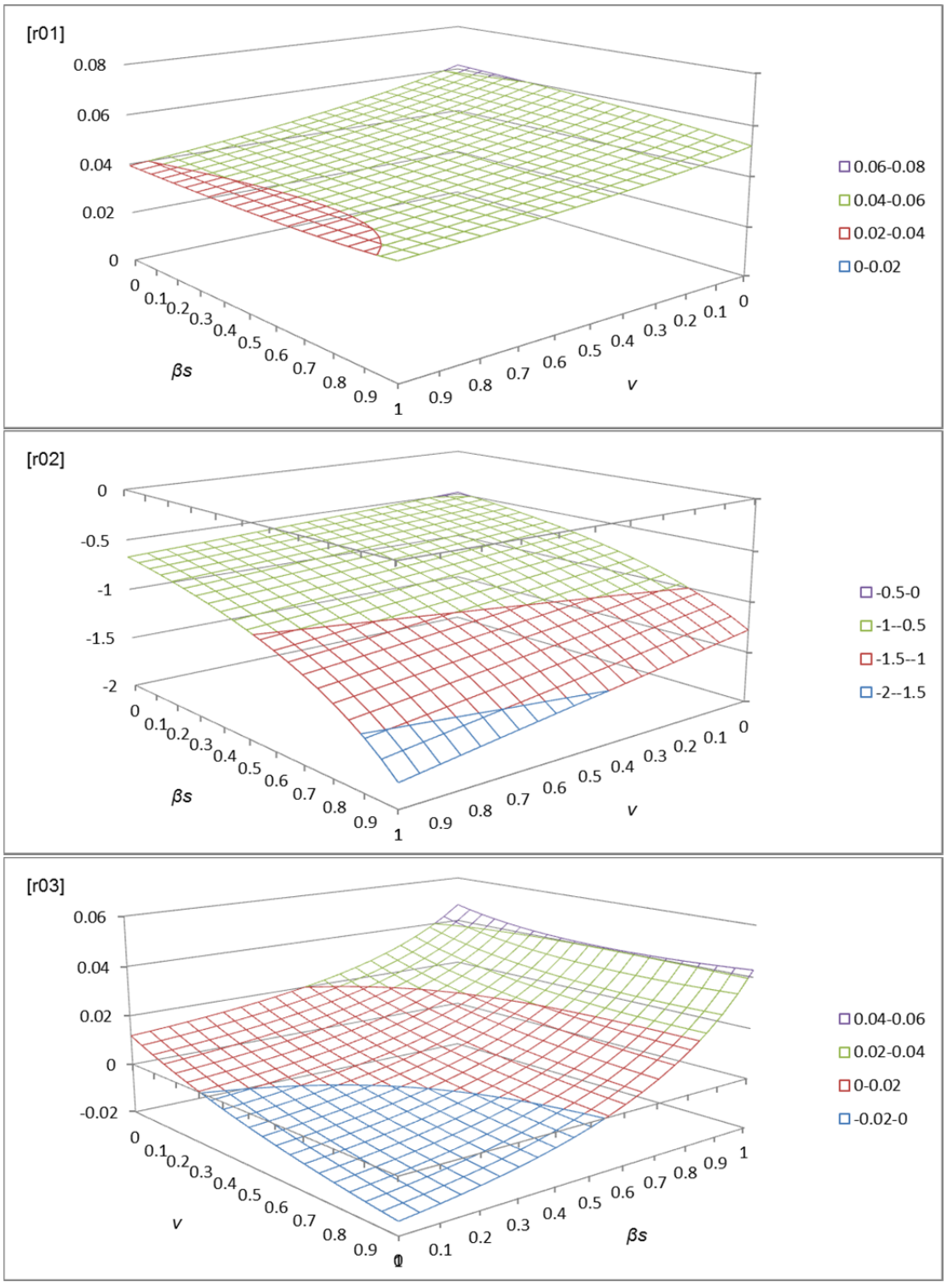

Figure 5. Changes in Welfare (%) - Anti-China Tariff by USA on Manufactured Products (Melitz and Krugman, Fixed β_{is})

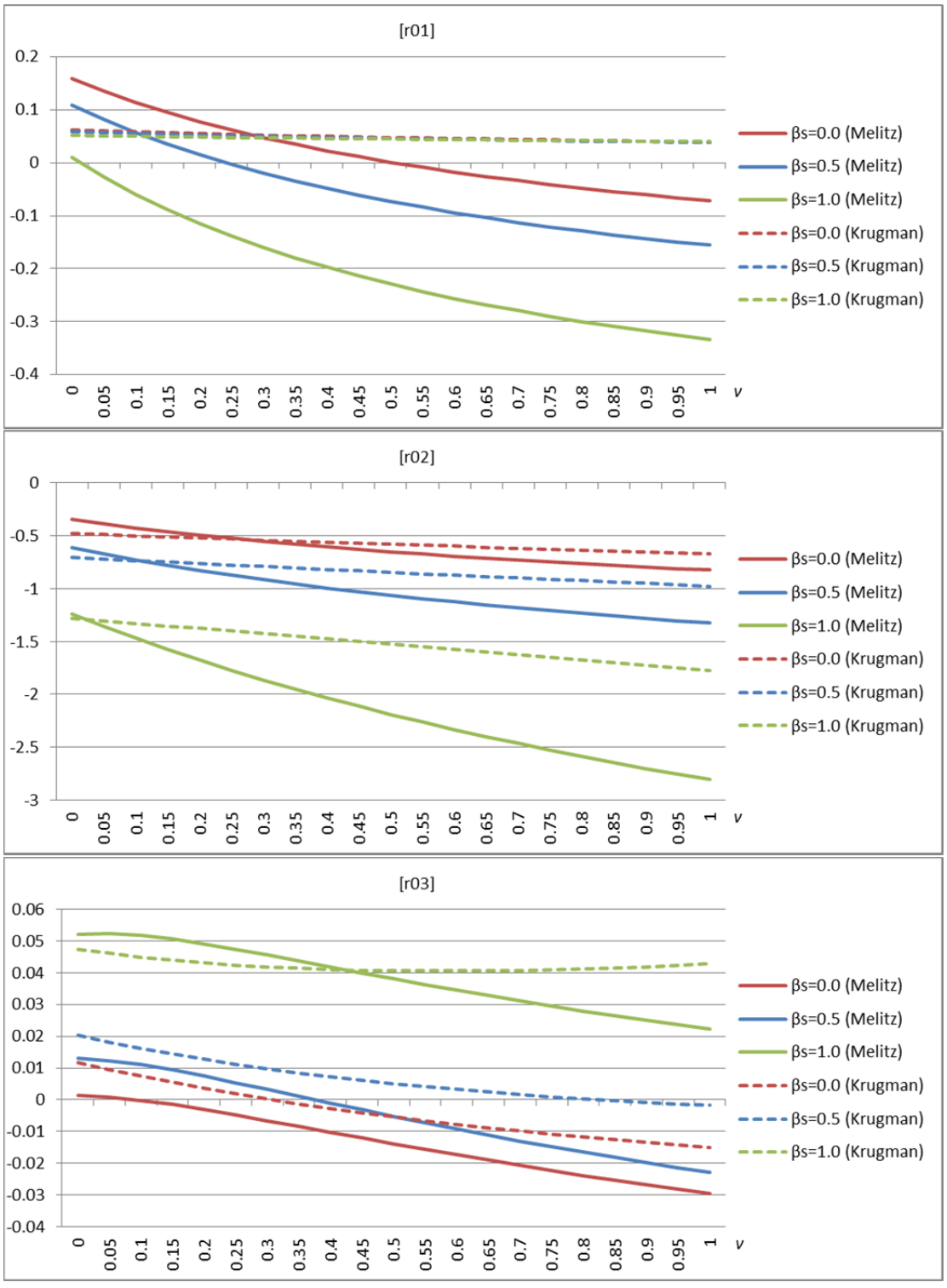

Figure 6. Changes in Welfare (%) - Anti-China Tariff by USA on Manufactured Products (Melitz and Krugman, Fixed ν_i)

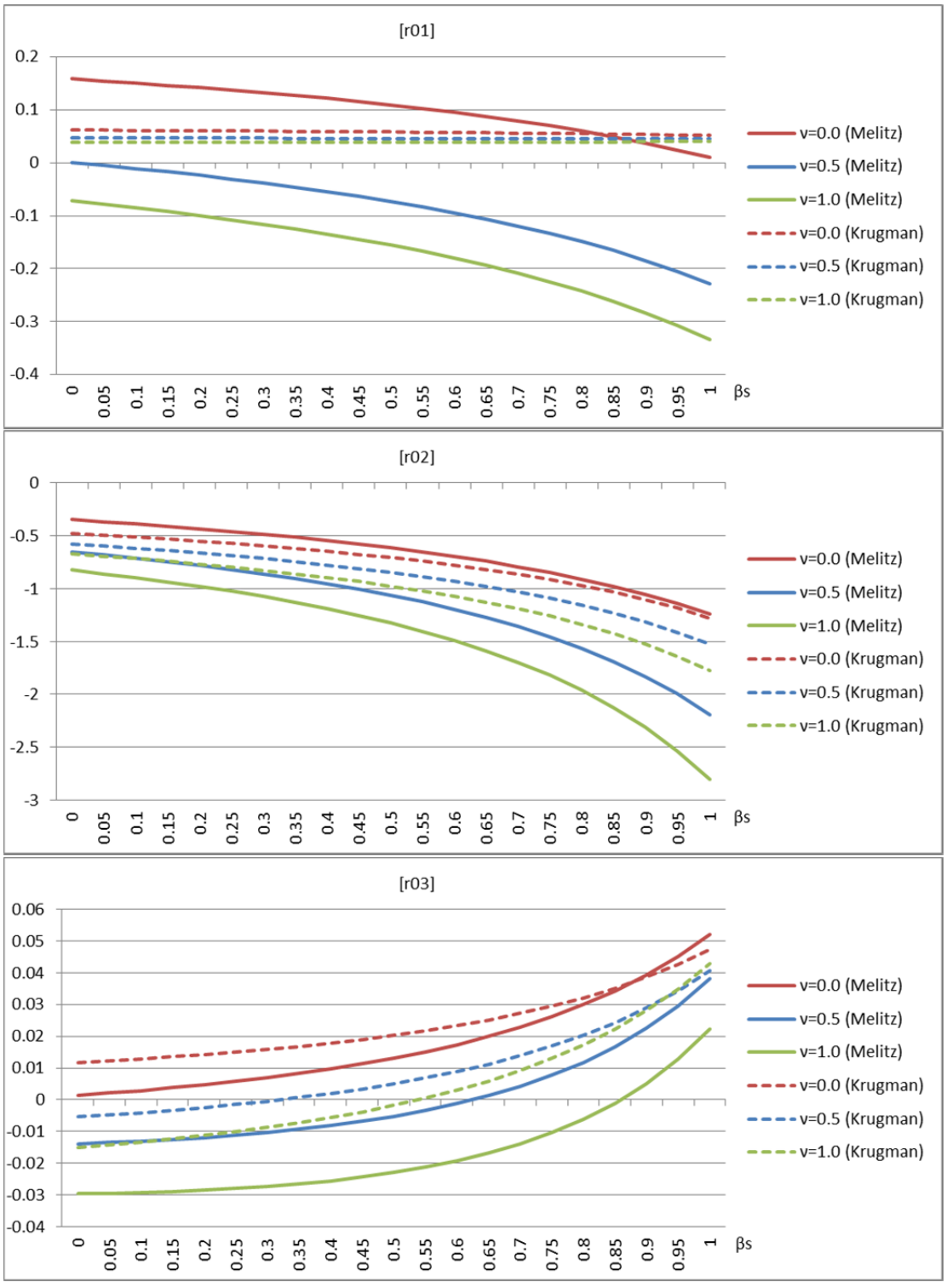

Figure 7. Changes in Welfare (%) - Anti-China Tariff by USA on Manufactured Products (Melitz and Krugman, $\beta_{is} = 0$ or $\nu_i = 0$)