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Behavioral Characteristics of MRIO-Based Global AGE Models with Variable Elasticity of Substitution between Varieties

Kazuhiko OYAMADA*

February, 2023

Abstract

This paper explores the indirect spillover effects of trade-related policies that affect welfare gains/losses via variety adjustments mentioned as by Fujita, Krugman, and Venables (2000), where access to a greater variety of intermediate commodities may reduce the costs of production using those intermediates. Using an applied general equilibrium model that incorporate direct cross-border linkages between producers and importing agents, we examine what happens when the elasticity of substitution between varieties from different sources is endogenized. Experimental simulations using the model reveal that the efficiency-enhancing effects of smoother resource allocations (substitution) may work more effectively than the cost-reducing effects of variety adjustments suggested by Fujita et al. (2000). A production sector that exhibits increasing returns to scale under monopolistic competition may serve as the main engine for accelerating the efficiency-enhancing effects to remarkable levels.

Keywords: variable elasticity of substitution, firm heterogeneity, monopolistic competition, multi-regional input-output, applied general equilibrium

JEL classification: C68, D58, F12, L11

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1. Introduction

In the field of international economics, there has been debates on the contribution of introducing heterogeneous firms to the aggregate 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). Also, in the applied general equilibrium (AGE) research community, comparison of simulation results obtained with different theoretical foundations may be important and informative for policy evaluations. Acquiring knowledge on the relationships between the characteristics of simulation results and certain settings of a model may be very helpful in analyzing and interpreting the obtained calculation results. Thus, a supermodel that can comprehensively handle three types of trade models with product differentiation, respectively based on Armington (1969), Krugman (1980), and Melitz (2003), within a common framework has been developed and used to examine the magnitudes of calculated changes in welfare levels or various economic indicators in response to a certain shock, such as trade liberalization (Oyamada, 2015, 2019, and 2020).

Oyamada (2020), the first study that forms the basis of this series of research, explores the role of the importer's love of variety (LoV) using a model with a relatively simple structure, to answer the question of whether heterogeneous firm models definitely generate greater welfare gains than homogeneous firm models if we retain the values of preference parameters used across the aforementioned three types of trade models. The focus on LoV was motivated by the results of an empirical study carried out by Ardelean (2006), which reported that the observed LoV is between 40 to 60 percent weaker than assumed in theoretical models. The simulation experiments with the model revealed the following points. First, the reallocation of resources based on the endogenous productivity changes among heterogeneous firms in the Melitz-type model does not necessarily enhance the effectiveness of trade policy beyond the level predicted by the homogeneous firm models when LoV is weaker than assumed in many theoretical and applied models. Second, whether the Melitz-type heterogeneous firm model generates greater welfare gains than those obtained by the Krugman-type homogeneous firm model is determined by the relationship between the value of the intensity of LoV and a critical value defined by a combination of the elasticity of substitution between varieties and the Pareto shape parameter for the productivity distribution of firms. Third, when LoV intensifies in the Krugman- and Melitz-type models, the ties between the countries/regions involved in trade liberalization tend to strengthen and promote the formation of a trading bloc separated from the countries/regions that are not directly involved.

The supermodel used in Oyamada (2020) has two shortcomings: (a) it cannot separately analyze the indirect channels that affect welfare gains/losses via variety adjustments as mentioned by Fujita, Krugman, and Venables (2000), where access to a greater variety of intermediate commodities may reduce the costs of production using those intermediates; and (b) the markup rates are kept constant because the model assumes constant elasticity of substitution between varieties from different sources, so it cannot consider the empirical evidence that larger, better performing firms set higher markups (De Loecker and Warzynski, 2012; Feenstra and Weinstein, 2017). Work has been ongoing to address these weaknesses.

To address shortcoming (a), Oyamada (2015) extended the "sourcing at border" (SaB)-type model developed for Oyamada (2020), which assumes that varieties from different sources are aggregated at the border of every destination country/region so that the composition ratio of imports by the producing country in the demand of every economic agent in the model becomes identical. This resulted in the creation of the "sourcing by agent" (SbA)-type, which incorporates direct cross-border linkages between economic agents both on the supply and demand sides so that the process of variety adjustments in intermediate transactions can be analyzed in detail. The simulation experiments with the SbA-type model revealed that the extra adjustment margin (endogenous productivity changes among heterogeneous firms) in the Melitz-type model may enhance both supplemental cost-reducing effects based on the increase in variety of intermediate goods and supplemental price-lifting effects rooted in strong LoV, if and only if an imperfectly competitive production sector is included in the scope of analysis. Without the cost-reducing effects generated by variety adjustments through intermediate transactions, welfare effects of removing price distortions (e.g., trade liberalization) will no longer be substantial.

To cope with flaw (b), Oyamada (2019) endogenized the elasticity of substitution between varieties as an increasing function of the total number of varieties available in each destination country/region, inspired by the intuition addressed by Dixit and Stiglitz (1977) that an additional variety reduces the distance between varieties filling in the gaps between existing varieties. Utilizing relatively simple and straight-forward functional form for the elasticity of substitution, simulation experiments using the model with endogenous elasticity revealed that a more efficient environment may emerge when the influence of the total number of varieties on the substitution elasticity becomes stronger, whereas economic agents will comply with circumstances that are more inefficient when LoV intensifies with constant elasticity.

The present study is positioned at the intersection of Oyamada (2015) and Oyamada

(2019) to explore whether a model that incorporates monopolistic competition among firms has any further notable features. The reminder of this paper is organized as follows. Section 2 presents a brief note on the analytical model developed for this study. In Section 3, we perform experimental simulations to clarify the behavioral characteristics of the model and verify the results. Section 4 concludes the study.

2. Introduction of Variable Elasticity of Substitution to a Sourcing-by-Agent-Type Applied General Equilibrium Model

The model used in this study is a version of the SbA-type AGE model that can flexibly switch among the Armington-, Krugman-, and Melitz-type specifications of product differentiation within a single framework. It has been extended to endogenize substitution elasticity for the commodity produced by monopolistically competitive industry that exhibits increasing returns to scale (IRTS).

The main parameters and exogenous variables are calibrated to multi-regional input-output (MRIO) data compiled from the Global Trade Analysis Project (GTAP) 9.2 Data Base for 2011 (Hertel, 1997; Aguiar, Narayanan, and McDougall, 2016) by applying a simple procedure presented by Walmsley, Hertel, and Hummels (2014), here with the assumption that the Pareto shape parameter is set to 5.0. The global economy is divided into three countries/regions indexed r (source) and s (destination) that are linked through trade flows: (r01) the United States (US), (r02) China, and (r03) the rest of the world (RoW). Commodities and activities indexed i and j are categorized into (i01) primary industries, (i02) manufacturing, and (i03) services, respectively. The manufacturing sector (i02) is assumed to be imperfectly competitive with IRTS, while the other two are characterized by constant returns to scale (CRTS). The primary industries (i01) use sector specific factors, such as land and natural resources, in addition to capital, labor, and intermediate goods in the production process. The service sector (i03) provides a fraction of its output as the international transportation supply.

An important feature of the model is that firms in the manufacturing sector (i02) with IRTS technology are divided into two segments, namely, firms engaged in production and those engaged in sales. In the production process, the production segment of firms (which we call "representative producers") collectively determines sector-wide input levels of intermediate goods and primary factors, and the output volume, based on CRTS technologies. Then, the product is wholesaled to the sales segment. The sales segment consists of many dealers/merchants (which we call "firms" hereinafter), which have the market power to determine the marked-up sales price of the commodity in every domestic and international market. Economies of scale enter here.

The base model is the one utilized in Oyamada (2015) that includes an SbA-type trade module. Here, the elasticity of substitution for the manufactured product (i = i02) is defined as an increasing function of the total number of varieties that are available for each economic agent in the destination country/region s:

$$\sigma_{ijs}^{TX} = \rho_{ijs}^{X}\left(N_{ijs}^{DX} + \sum_r N_{ijrs}^{QX}\right)^{\nu_{ijs}^{X}}, \tag{1}$$

and

$$\sigma_{is}^{TC} = \rho_{is}^{C}\left(N_{is}^{DC} + \sum_r N_{irs}^{QC}\right)^{\nu_{is}^{C}}, \tag{2}$$

where

$\sigma_{ijs}^{TX} > 1$ is the elasticity of substitution between varieties of commodity i for the representative producers of industry j in country/region s,

$\sigma_{is}^{TC} > 1$ is the elasticity of substitution between varieties of commodity i for the representative consumers in country/region s,

N_{ijs}^{DX} is the number of domestic firms dealing in commodity i active in country/region s doing business with industry j,

N_{is}^{DC} is the number of domestic firms dealing in commodity i active in country/region s doing business with final consumers,

N_{ijrs}^{QX} is the number of international firms dealing in commodity i active on the r-s link doing business with industry j,

N_{irs}^{QC} is the number of international firms dealing in commodity i active on the r-s link doing business with final consumers,

$\nu_{ijs}^{X} \in [0,1]$ is the parameter that prescribes the influence of the total number of varieties available for the representative producers of industry j in country/region s on the elasticity of substitution,

$\nu_{is}^{C} \in [0,1]$ is the parameter that prescribes the influence of the total number of varieties available for the representative consumers in country/region s on the elasticity of substitution,

ρ_{ijs}^{X} is the unit coefficient given by $\rho_{ijs}^{X} \equiv \frac{\sigma 0_{ijs}^{TX}}{\left(N0_{ijs}^{DX} + \sum_r N0_{ijrs}^{QX}\right)^{\nu_{ijs}^{X}}}$,

ρ_{is}^{C} is the unit coefficient given by $\rho_{is}^{C} \equiv \frac{\sigma 0_{is}^{TC}}{\left(N0_{is}^{DC} + \sum_r N0_{irs}^{QC}\right)^{\nu_{is}^{C}}}$,

$\sigma 0^{TX}_{ijs}$ and $\sigma 0^{TC}_{is}$ are the initial levels of the elasticity of substitution between varieties,

$N0^{DX}_{ijs}$ and $N0^{DC}_{is}$ are the initial numbers of domestic firms active in country/region s, and

$N0^{QX}_{ijrs}$ and $N0^{QC}_{irs}$ are the initial numbers of international firms active on the r-s link.

When $\nu^{X}_{ijs} = 0$, σ^{TX}_{ijs} will not change. This is similar for the case of ν^{C}_{is} and σ^{TC}_{is}. Note that σ^{TX}_{ijs} and σ^{TC}_{is} have suffixes that distinguish economic agent on the demand side as well as suffix s because the number of available varieties differs by destination country/region and by importer agent. σ^{TX}_{ijs} and σ^{TC}_{is} replace all of the σ^{T}_{i} that enters the previous version used in Oyamada (2015).

The equations/inequalities in addition to (1) and (2) that form the Melitz-type trade module becomes as follows:

$$\eta^{X}_{ijs} = -1/\sigma^{TX}_{ijs}, \tag{3}$$

$$\eta^{C}_{is} = -1/\sigma^{TC}_{is}, \tag{4}$$

$$X_{ijs} \leq \theta^{TX}_{ijs} \begin{Bmatrix} \left(1 - \sum_r \alpha^{TX}_{ijrs}\right)\left(N^{DX}_{ijs}\right)^{\left(\sigma^{TX}_{ijs}-1\right)/\sigma^{TX}_{ijs}} \left(D^{X}_{ijs}\right)^{\left(\sigma^{TX}_{ijs}-1\right)/\sigma^{TX}_{ijs}} \\ + \sum_r \alpha^{TX}_{ijrs}\left(N^{QX}_{ijrs}\right)^{\left(\sigma^{TX}_{ijs}-1\right)/\sigma^{TX}_{ijs}} \left(Q^{X}_{ijrs}\right)^{\left(\sigma^{TX}_{ijs}-1\right)/\sigma^{TX}_{ijs}} \end{Bmatrix}^{\sigma^{TX}_{ijs}/\left(\sigma^{TX}_{ijs}-1\right)} \perp p^{X}_{ijs}, \tag{5}$$

$$C_{is} \leq \theta^{TC}_{is} \begin{Bmatrix} \left(1 - \sum_r \alpha^{TC}_{irs}\right)\left(N^{DC}_{is}\right)^{\left(\sigma^{TC}_{is}-1\right)/\sigma^{TC}_{is}} \left(D^{C}_{is}\right)^{\left(\sigma^{TC}_{is}-1\right)/\sigma^{TC}_{is}} \\ + \sum_r \alpha^{TC}_{irs}\left(N^{QC}_{irs}\right)^{\left(\sigma^{TC}_{is}-1\right)/\sigma^{TC}_{is}} \left(Q^{C}_{irs}\right)^{\left(\sigma^{TC}_{is}-1\right)/\sigma^{TC}_{is}} \end{Bmatrix}^{\sigma^{TC}_{is}/\left(\sigma^{TC}_{is}-1\right)} \perp p^{C}_{is}, \tag{6}$$

$$p^{X}_{ijs}\left(\theta^{TX}_{ijs}\right)^{\left(\sigma^{TX}_{ijs}-1\right)/\sigma^{TX}_{ijs}} \left(1 - \sum_r \alpha^{TX}_{ijrs}\right)\left(N^{DX}_{ijs}\right)^{-1/\sigma^{TX}_{ijs}} \left(\frac{X_{ijs}}{D^{X}_{ijs}}\right)^{1/\sigma^{TX}_{ijs}} \leq p^{DX}_{ijs} \perp D^{X}_{ijs}, \tag{7}$$

$$p^{C}_{is}\left(\theta^{TC}_{is}\right)^{\left(\sigma^{TC}_{is}-1\right)/\sigma^{TC}_{is}} \left(1 - \sum_r \alpha^{TC}_{irs}\right)\left(N^{DC}_{is}\right)^{-1/\sigma^{TC}_{is}} \left(\frac{C_{is}}{D^{C}_{is}}\right)^{1/\sigma^{TC}_{is}} \leq p^{DC}_{is} \perp D^{C}_{is}, \tag{8}$$

$$p^{X}_{ijs}\left(\theta^{TX}_{ijs}\right)^{\left(\sigma^{TX}_{ijs}-1\right)/\sigma^{TX}_{ijs}} \alpha^{TX}_{ijrs}\left(N^{QX}_{ijrs}\right)^{-1/\sigma^{TX}_{ijs}} \left(\frac{X_{ijs}}{Q^{X}_{ijrs}}\right)^{1/\sigma^{TX}_{ijs}} \leq \left(1+\tau^{MX}_{ijrs}\right)\left(1+\tau^{TX}_{ijrs}\right)\left(1+\tau^{EX}_{ijrs}\right)p^{QX}_{ijrs} \perp Q^{X}_{ijrs}, \tag{9}$$

$$p^{C}_{is}\left(\theta^{TC}_{is}\right)^{\left(\sigma^{TC}_{is}-1\right)/\sigma^{TC}_{is}} \alpha^{TC}_{irs}\left(N^{QC}_{irs}\right)^{-1/\sigma^{TC}_{is}} \left(\frac{C_{is}}{Q^{C}_{irs}}\right)^{1/\sigma^{TC}_{is}}$$

$$\leq \left(1+\tau_{irs}^{MC}\right)\left(1+\tau_{irs}^{TC}\right)\left(1+\tau_{irs}^{EC}\right)p_{irs}^{QC} \qquad \perp Q_{irs}^{C}, \quad (10)$$

$$p_{ijr}^{DX} = \left(\frac{1}{1+\eta_{ijr}^{X}}\right)\frac{p_{ir}^{w}}{\varphi_{ijr}^{DX}}, \qquad (11)$$

$$p_{ir}^{DC} = \left(\frac{1}{1+\eta_{ir}^{C}}\right)\frac{p_{ir}^{w}}{\varphi_{ir}^{DC}}, \qquad (12)$$

$$p_{ijrs}^{QX} = \left(\frac{1}{1+\eta_{ijs}^{X}}\right)\frac{p_{ir}^{w}}{\varphi_{ijrs}^{QX}}, \qquad (13)$$

$$p_{irs}^{QC} = \left(\frac{1}{1+\eta_{is}^{C}}\right)\frac{p_{ir}^{w}}{\varphi_{irs}^{QC}}, \qquad (14)$$

$$\sum_j N_{ijr}^{DX}\frac{D_{ijr}^{X}}{\varphi_{ijr}^{DX}} + N_{ir}^{DC}\frac{D_{ir}^{C}}{\varphi_{ir}^{DC}} + \sum_j\sum_s N_{ijrs}^{QX}\frac{Q_{ijrs}^{X}}{\varphi_{ijrs}^{QX}} + \sum_s N_{irs}^{QC}\frac{Q_{irs}^{C}}{\varphi_{irs}^{QC}} + \Omega_{ir}$$
$$\leq Z_{ir} - \begin{pmatrix} N_{ir}H_{ir} + \sum_j N_{ijr}^{DX}F_{ijr}^{DX} + N_{ir}^{DC}F_{ir}^{DC} \\ +\sum_j\sum_s N_{ijrs}^{QX}F_{ijrs}^{QX} + \sum_s N_{irs}^{QC}F_{irs}^{QC} \end{pmatrix} \qquad \perp p_{ir}^{W}, \quad (15)$$

$$\mu_{ijr}^{DX} = \left(\frac{\gamma_i}{\gamma_i-\sigma_{ijr}^{TX}+1}\right)^{\gamma_i/\left(\sigma_{ijr}^{TX}-1\right)}\left(\varphi_{ijr}^{DX}\right)^{-\gamma_i}, \qquad (16)$$

$$\mu_{ir}^{DC} = \left(\frac{\gamma_i}{\gamma_i-\sigma_{ir}^{TC}+1}\right)^{\gamma_i/\left(\sigma_{ir}^{TC}-1\right)}\left(\varphi_{ir}^{DC}\right)^{-\gamma_i}, \qquad (17)$$

$$\mu_{ijrs}^{QX} = \left(\frac{\gamma_i}{\gamma_i-\sigma_{ijs}^{TX}+1}\right)^{\gamma_i/\left(\sigma_{ijs}^{TX}-1\right)}\left(\varphi_{ijrs}^{QX}\right)^{-\gamma_i}, \qquad (18)$$

$$\mu_{irs}^{QC} = \left(\frac{\gamma_i}{\gamma_i-\sigma_{is}^{TC}+1}\right)^{\gamma_i/\left(\sigma_{is}^{TC}-1\right)}\left(\varphi_{irs}^{QC}\right)^{-\gamma_i}, \qquad (19)$$

$$\varphi_{ijr}^{DX} = \frac{\gamma_i-\sigma_{ijr}^{TX}+1}{\gamma_i\left(\sigma_{ijr}^{TX}-1\right)}\left(\frac{D_{ijr}^{X}}{F_{ijr}^{DX}}\right), \qquad (20)$$

$$\varphi_{ir}^{DC} = \frac{\gamma_i-\sigma_{ir}^{TC}+1}{\gamma_i\left(\sigma_{ir}^{TC}-1\right)}\left(\frac{D_{ir}^{C}}{F_{ir}^{DC}}\right), \qquad (21)$$

$$\varphi_{ijrs}^{QX} = \frac{\gamma_i-\sigma_{ijs}^{TX}+1}{\gamma_i\left(\sigma_{ijs}^{TX}-1\right)}\left(\frac{Q_{ijrs}^{X}}{F_{ijrs}^{QX}}\right), \qquad (22)$$

$$\varphi_{irs}^{QC} = \frac{\gamma_i-\sigma_{is}^{TC}+1}{\gamma_i\left(\sigma_{is}^{TC}-1\right)}\left(\frac{Q_{irs}^{C}}{F_{irs}^{QC}}\right), \qquad (23)$$

and

$$p_{ir}^{w}\left(N_{ir}H_{ir} + \sum_j N_{ijr}^{DX}F_{ijr}^{DX} + N_{ir}^{DC}F_{ir}^{DC} + \sum_j\sum_s N_{ijrs}^{QX}F_{ijrs}^{QX} + \sum_s N_{irs}^{QC}F_{irs}^{QC}\right)$$
$$= -\begin{pmatrix} \sum_j \eta_{ijr}^{X}p_{ijr}^{DX}N_{ijr}^{DX}D_{ijr}^{X} \\ +\eta_{ir}^{C}p_{ir}^{DC}N_{ir}^{DC}D_{ir}^{C} \end{pmatrix} - \sum_s \begin{pmatrix} \sum_j \eta_{ijs}^{X}p_{ijrs}^{QX}N_{ijrs}^{QX}Q_{ijrs}^{X} \\ +\eta_{is}^{C}p_{irs}^{QC}N_{irs}^{QC}Q_{irs}^{C} \end{pmatrix}, \qquad (24)$$

where

η_{ijs}^{X} is a parameter introduced for convenience,

η_{is}^{C} is another parameter introduced for convenience,
X_{ijs} is the intermediate demand for composite commodity i in industry j of country/region s,
C_{is} is the final demand for composite commodity i in country/region s,
Z_{ir} is the gross output of commodity i in country/region r,
D_{ijs}^{X} is the average domestic trade flow quantity of commodity i for the intermediate input to industry j per active firm operating in country/region s,
D_{is}^{C} is the average domestic trade flow quantity of commodity i for the final consumption per active firm operating in country/region s,
Q_{ijrs}^{X} is the average international trade flow quantity of commodity i for the intermediate input to industry j per active firm operating on the r-s link,
Q_{irs}^{C} is the average international trade flow quantity of commodity i for the final consumption per active firm operating on the r-s link,
p_{ijs}^{X} is the price index for the composite commodity X_{ijs},
p_{is}^{C} is the price index for the composite commodity C_{is},
p_{ijs}^{DX} is the differentiated sales price of intermediate commodity i for domestic market s sold to industry j,
p_{is}^{DC} is the differentiated sales price of consumption commodity i for domestic market s,
p_{ijrs}^{QX} is the differentiated sales price of intermediate commodity i for international market s sold to industry j by firms in country/region r excluding the transportation margin and import tariff,
p_{irs}^{QC} is the differentiated sales price of consumption commodity i for international market s sold by firms in country/region r excluding the transportation margin and import tariff,
p_{ir}^{W} is the wholesale price (producer price) of commodity i,
$\mu_{ijr}^{DX} \in (0, 1]$ is the proportion of firms established in country/region r that are able to sell intermediate commodity i to industry j in the domestic market,
$\mu_{ir}^{DC} \in (0, 1]$ is the proportion of firms established in country/region r that are able to sell consumption commodity i in the domestic market,
$\mu_{ijrs}^{QX} \in (0, 1]$ is the proportion of firms established in country/region r that are able to sell intermediate commodity i to industry j in the international market s,
$\mu_{irs}^{QC} \in (0, 1]$ is the proportion of firms established in country/region r that are able to sell consumption commodity i in the international market s,
φ_{ijr}^{DX} is the average productivity level of domestic firms dealing in commodity i

active in country/region r doing business with industry j,

φ_{ir}^{DC} is the average productivity level of domestic firms dealing in commodity i active in country/region r doing business with final consumer,

φ_{ijrs}^{QX} is the average productivity level of international firms dealing in commodity i active on the r-s link doing business with industry j,

φ_{irs}^{QC} is the average productivity level of international firms dealing in commodity i active on the r-s link doing business with final consumer,

N_{ir} is the overall number of firms dealing in commodity i established in country/region r,

F_{ijr}^{DX} is the fixed overhead costs necessary to make sales to industry j in the domestic market r as measured in units of gross output (composite input),

F_{ir}^{DC} is the fixed overhead costs necessary to make sales to final consumers in the domestic market r as measured in units of gross output (composite input),

F_{ijrs}^{QX} is the fixed overhead costs necessary to make sales to industry j in the international market on the r-s link as measured in units of gross output (composite input),

F_{irs}^{QC} is the fixed overhead costs necessary to make sales to final consumers in the international market on the r-s link as measured in units of gross output (composite input),

H_{ir} is the fixed entry costs necessary to establish a firm dealing in commodity i in country/region r as measured in units of gross output (composite input),

α_{ijrs}^{TX} is a weight parameter in the intermediate commodity aggregator that reflects the preference of the representative producers of industry j in country/region s for the commodity supplied by country/region r,

α_{irs}^{TC} is a weight parameter in the consumption commodity aggregator that reflects the preference of the representative consumers in country/region s for the commodity supplied by country/region r,

θ_{ijs}^{TX} is a scaling factor in the intermediate commodity aggregator,

θ_{is}^{TC} is a scaling factor in the consumption commodity aggregator,

γ_i is the Pareto shape parameter related to the distribution of productivity such that satisfies $\gamma_i > \sigma_{ijs}^{TX} - 1$ and $\gamma_i > \sigma_{is}^{TC} - 1$,

τ_{ijrs}^{EX} is the export duty/subsidy rate levied by the government of country/region r on intermediate commodity i for industry j,

τ_{irs}^{EC} is the export duty/subsidy rate levied by the government of country/region r on consumption commodity i,

τ^{TX}_{ijrs} is the transportation margin rate on intermediate commodity i for industry j,

τ^{TC}_{irs} is the transportation margin rate on consumption commodity i,

τ^{MX}_{ijrs} is the import tariff rate levied by the government of country/region s on intermediate commodity i for industry j,

τ^{MC}_{irs} is the import tariff rate levied by the government of country/region s on consumption commodity i, and

Ω_{ir} is international transportation supply defined with a national/regional share parameter ω_{ir} as

$$\Omega_{ir} \equiv \frac{\omega_{ir}}{p^W_{ir}} \sum_{i'} \sum_{r'} \sum_s \left\{ \begin{array}{c} \sum_j \tau^{TX}_{i'jr's}\left(1+\tau^{EX}_{i'jr's}\right) N^{QX}_{i'jr's} p^{QX}_{i'jr's} Q^X_{i'jr's} \\ +\tau^{TC}_{i'r's}\left(1+\tau^{EC}_{i'r's}\right) N^{QC}_{i'r's} p^{QC}_{i'r's} Q^C_{i'r's} \end{array} \right\}.$$

The perpendicular symbol "⊥" shows the complementarity relationships between positive variables and inequalities. Note that the parameters that define the intensity of the importer's LoV no longer enters the model. Instead of using the LoV-related parameters, ν^X_{ijs} and ν^C_{is} are introduced, which define the influence of the total number of varieties available in the destination country-region on the substitution elasticity. Ω_{ir} is included in (15) if and only if i corresponds to the service sector in order to satisfy the special treatment concerning the supply of international shipping by the transportation service sector required in the GTAP Data Base.

Equations (1) through (4) are for the IRTS sector only. Thus, these equations are not used under the Armington-type specification. Inequalities (5) and (6) are the commodity aggregators for the goods produced by the IRTS sector when we assume the Melitz- and the Krugman-type specifications. For the CRTS sectors, N^{DX}_{ijr}, N^{DC}_{ir}, N^{QX}_{ijrs}, and N^{QC}_{irs} are fixed to unity, respectively. Note that these inequalities imply that sourcing is done directly by economic agents on the demand side. The following Inequalities (7) through (10) are the first-order conditions for minimizing the costs of producing composite commodities, which determine the levels of D^X_{ijs}, D^C_{is}, Q^X_{ijrs}, and Q^C_{irs}, respectively. Equations (11) through (14) define the markup prices set by firms in the IRTS sector. Note that the markup rates are now endogenous and differentiated specific to the economic agents in the destination country/region because of the endogenized elasticity of substitution. Similar to the case of Inequalities (5) and (6), φ^{DX}_{ijr}, φ^{DC}_{ir}, φ^{QX}_{ijrs}, and φ^{QC}_{irs} are fixed to unity and the expression in parentheses is ignored when the production sector exhibits CRTS technology. Inequality (15) represents the transformation of the gross output Z_{ir}, which determines the level of the wholesale price p^W_{ir}. The expressions in parenthesis on the right-hand side of Inequality (15) apply if and only if i is the IRTS sector, which implies that the fractions of Z_{ir} are foregone as fixed costs of establishing firms and entering markets. Equations (16) through (24) are only for the IRTS sector. Equations (16) through (23) define the proportions of active firms and their average levels of productivity. On the other hand, Equation (24) is the zero-profit condition based on monopolistic competition that determines the overall number of firms established in country/region r, N_{ir}. Once a firm is established in country/region r by paying the fixed entry costs H_{ir}, the firm draws productivity and verifies if its level meets the minimum requirement to enter a link-specific market and make sales. The least required level of productivity is such that it covers the fixed overhead costs of operations, F_{ijr}^{DX}, F_{ir}^{DC}, F_{ijrs}^{QX}, or F_{irs}^{QC}. Those who do not have sufficient levels of productivity become inactive even though they were once established.

Then, the Melitz-, Krugman-, and Armington-type specifications of product differentiation are switched by the following choices of equations/inequalities and parameter settings.

Melitz-type Specification: In the Melitz-type specification, the following settings apply, in addition to Equations/Inequalities (1) through (24):

$N_{ijr}^{DX} = \mu_{ijr}^{DX} N_{ir}$,

$N_{ir}^{DC} = \mu_{ir}^{DC} N_{ir}$,

$N_{ijrs}^{QX} = \mu_{ijrs}^{QX} N_{ir}$,

and

$N_{irs}^{QC} = \mu_{irs}^{QC} N_{ir}$.

Krugman-type Specification: In the Krugman-type, the following settings apply, in addition to Equations/Inequalities (1) through (15), and (24):

$F_{ijr}^{DX} = F_{ir}^{DC} = F_{ijrs}^{QX} = F_{irs}^{QC} = 0$,

$\varphi_{ijr}^{DX} = \varphi_{ir}^{DC} = \varphi_{ijrs}^{QX} = \varphi_{irs}^{QC} = 1$,

and

$N_{ir} = N_{ijr}^{DX} = N_{ir}^{DC} = N_{ijrs}^{QX} = N_{irs}^{QC}$ $\quad (\therefore \mu_{ijr}^{DX} = \mu_{ir}^{DC} = \mu_{ijrs}^{QX} = \mu_{irs}^{QC} = 1)$.

Armington-Type Specification: In the Armington-type, the following settings apply, in addition to (5) through (15):

$H_{ir} = F_{ijr}^{DX} = F_{ir}^{DC} = F_{ijrs}^{QX} = F_{irs}^{QC} = 0$,

$\varphi_{ijr}^{DX} = \varphi_{ir}^{DC} = \varphi_{ijrs}^{QX} = \varphi_{irs}^{QC} = 1$,

$N_{ir} = N_{ijr}^{DX} = N_{ir}^{DC} = N_{ijrs}^{QX} = N_{irs}^{QC} = 1$ $\quad (\therefore \mu_{ijr}^{DX} = \mu_{ir}^{DC} = \mu_{ijrs}^{QX} = \mu_{irs}^{QC} = 1)$, and

$\eta^X_{ijs} = \eta^C_{is} = 0.$

3. Experiments

We next verify the results of the simulation experiments performed with the three-region three-sector AGE model with the SbA-type trade module that endogenizes elasticity of substitution between varieties from different sources. Assuming that the US (r01) permanently removes tariffs on manufactured products (i02) imported from China (r02), we examine how the calculated values of selected economic indicators change when the influence of the total number of varieties on the elasticity of substitution in the manufacturing sector ($\nu^X_{"i02"js}$ and $\nu^C_{"i02"s}$) takes different values from zero to unity. The main scenario is expressed by setting the import tariff rate $\tau^M_{"i02""r02""r01"} = 0$, which is 2.967% initially.

3.1 Basic Effects

The basic effects of the US import liberalization of Chinese manufactured products are expected to be as follows. Once the market price of the manufactured commodity imported from China declines in the US due to the removal of tariff, the demand for Chinese products relatively increases in the US, so that the wholesale price of the manufactured commodity rises in China. In the US, the increased demand for imports from China partially replaces the demand for the manufactured substitutes produced domestically, so the wholesale price drops in the US. While demand for imports from the RoW also shrinks in the US, China increases imports from the RoW to substitute for its relatively expensive domestic products, so the direction of change in the wholesale price in the RoW is ambiguous. Here, the price slightly falls from its pre-liberalization level. These basic effects are mainly captured by the Armington-type specification.

In the post-liberalization environment noted above, the effects of the US import liberalization of Chinese manufactured products in both international and domestic trade flows by importer agents are as shown in Tables 1 to 4. Table 1 corresponds to the imports by the representative consumers in each country/region listed at the top of the table from the country/region shown on the left. In a similar manner, Tables 2 through 4 show the imports by the representative producer of the primary industries, manufacturing, and services, respectively. The effects are measured as percentage deviations from the initial levels of endogenous variables.

In the US, demand in the manufacturing and service sectors as well as final consumer demand increases for imported Chinese products in exchange for reducing demand for both commodities produced domestically and those imported from the RoW, as expected (see column-wise across Tables 1, 3, and 4 along the "r01" headings on the top). On the other hand, primary industries in the US expand intermediate inputs of domestic products in addition to the inputs imported from China (see Table 2 column-wise along the "r01" headings on the top). The magnitude of the expansion of demand for Chinese products is greatest in the US primary industries (9.860%) compared with the other agents (9.206%, 9.342%, and 9.360%). This implies that the relative volume of the primary industries grows more than that in the other production sectors in the US after trade liberalization. Thus, the manufacturing sector shrinks in the US and the service sector follows.

China expands imports from the US and RoW, the prices of which are now relatively cheap (see column-wise across Tables 1 through 4 along the "r02" headings on the top). Enjoying the income increase brought by the improvement in the terms of trade, demand in the manufacturing and service sectors as well as final consumer demand also increases for the domestic products even though their prices have become expensive. In contrast, the primary sector reduces intermediate input of manufactured goods. Because the magnitude of the expansion of demand for US products in primary industries is the least (2.283%) compared with the other agents (2.265%, 2.688%, and 2.657%), the relative volume of the primary sector shrinks more than that of the other sectors in China. Hence, the manufacturing and service sectors expand in China.

The RoW increases imports of the relatively cheap US manufactured products reducing imports from China (see column-wise across Tables 1 through 4 along the "r03" headings on the top). On the other hand, reactions of economic agents in this region to the domestic and intra-regionally traded products differ. While demand in the primary and service sectors as well as final consumer demand increases (Tables 1, 2, and 4), demand in the manufacturing sector decreases (Table 3). The magnitude of the expansion of demand for US products in the manufacturing sector is the least (1.201%) compared with the other agents (1.216%, 1.253%, and 1.215%) suggesting that the relative volume of the manufacturing sector shrinks most in the RoW. Then, the service sector follows.

The removal of trade protection against China by the US makes it easier for Chinese firms to enter the US market. Then, competition among firms to do business in the US market escalates, making it difficult for non-Chinese firms to enter. On the other hand, the hurdles (cut-off level of productivity) to enter non-US markets becomes lower for non-Chinese firms that sell a commodity cheaper than before. Therefore, Chinese firms withdraw from those non-US markets. On the other hand, the availability of cheaper imported intermediates enables Chinese firms to make profits easier than before, as the manufactured products can now be wholesaled at lower prices in China. Consequently, the barriers to Chinese firms entering the US market dramatically fall. The changes in the average sales quantity per active firm also follow the same pattern, whereas the proportion of active firms operating in each trade link shows completely opposite changes.

3.2 Effects of Changing the Influence of the Total Number of Varieties on the Elasticity of Substitution

Let us turn to see how the effects of liberalizing trade by the US for China on selected economic indicators change with different values of $\nu^{X}_{"i02"js}$ (for the representative producers) and $\nu^{C}_{"i02"s}$ (for the representative consumer), which control the influence of the total number of varieties on the elasticity of substitution. In the experiments, the values of one or both of these parameters are changed from zero to unity, with a step width of 0.05. Note that the intensive margin represented by the sales quantity per firm and the extensive margin represented by the number of active firms are accounted for by the same weight throughout the experiments.

3.2.1 Simultaneous Changes in the Parameters for All Agents

When the influence of the total number of varieties on the elasticity of substitution ($\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$) is changed simultaneously for all agents, the model does not necessarily generate results similar to those with an SaB-type model such as that used in Oyamada (2019). The main differences come from the existence of the agent-specific items that enable finer adjustments in the SbA-type model utilized in this study. For instance, the endogenous elasticity of substitution $\sigma^{TX}_{"i02"js}$ and $\sigma^{TC}_{"i02"s}$ can vary independently among agents in an SbA-type model while the elasticity remains identical for all agents as $\sigma^{T}_{"i02"s}$ in an SaB-type model. Thus, the SbA-type environment is more efficient in allocating resources compared with the SaB-type environment.

Figure 1 depicts the effects of the US liberalizing imports of Chinese manufactured products on national/regional welfare in each country/region: the US (r01), China (r02), and the RoW (r03). The effects are captured as percentage deviations from the pre-liberalization levels of endogenous variables. In each panel, the red, blue, and green lines correspond to the

Melitz-, Krugman-, and Armington-type specifications. Welfare changes on the leftmost side, where $\nu^X_{"i02"js} = \nu^C_{"i02"s} = 0$, correspond to changes in total consumption quantity. The Armington lines capture the size of basic effects on the terms of trade. The differences between the blue Krugman line and green Armington line show the magnitudes of effects based on cost reductions brought by economies of scale. On the other hand, the differences between the red Melitz and blue Krugman lines capture the volumes of effects amplified through the productivity growth among heterogeneous firms.

When the values of $\nu^X_{"i02"js}$ and $\nu^C_{"i02"s}$ for all agents simultaneously change from zero to unity, all of the countries/regions largely gain because of the efficiency-enhancing effects of smoother resource reallocation led by international trade in an environment with less distortion thanks to the removal of tariffs. The Melitz-type model, which may inflate effects through the productivity growth among heterogeneous firms, tends to generate much a larger impact on welfare compared with the Krugman-type model, which captures only the gains brought by economies of scale. In addition, welfare gains of the US are much larger with the Melitz-type specification in the SbA-type environment than those in the SaB-type environment (red line in the top panel of Figure 1). In the SaB-type environment, welfare gains of the US under the Melitz-type model are about half of the present levels generated in the SbA-type environment. In contrast, welfare gains of the RoW projected by the Melitz-type model, which consistently maintains the highest levels among the three types of specifications regardless of the values of $\nu_{"i02"s}$ in the SaB-type environment, became less than those projected by the Krugman-type in the present SbA-type setting (bottom panel of Figure 1). This suggests that the presence of agent-specific adjustable items in the SbA-type model works more favorably for a country that liberalize imports compared with a third country excluded from trade liberalization under the Melitz-type specification. The drop in the range where $\nu^X_{"i02"js}$ and $\nu^C_{"i02"s}$ take small values, which is observed for the RoW with the Melitz-type model (red line in the bottom panel of Figure 1), will be explained later when we verify the results of independently changing $\nu^X_{"i02"js}$ by producer agent.

Figure 7 shows the effects of import liberalization by the US on the wholesale price in each country/region. It is clear that the price falls in all countries/regions through the efficiency-enhancing effects of smoother substitution, as the values of $\nu^X_{"i02"js}$ and $\nu^C_{"i02"s}$ increase for all agents. As if reflecting the larger welfare effects for the US generated by the Melitz-type model in the SbA-type environment, the sizes of price reductions in all of the countries/regions are also larger than those in the SaB-type model. This again suggests that the SbA-type model tends to magnify efficiency-enhancing effects of smoother resource allocation utilizing its extra adjustment items.

3.2.2 Independent Changes in the Parameters by Importer Agent

Now, let us examine the results of changing the values of $\nu^{X}_{"i02"js}$ (for the representative producers) and $\nu^{C}_{"i02"s}$ (for the representative consumer) independently by agent. The scenario that the US unilaterally liberalize imports of Chinese manufactured products remains unchanged. Before delving into the details, we compare the results when $\nu^{C}_{"i02"s}$ is changed with the case where $\nu^{X}_{"i02"js}$ for all producers shifts simultaneously. For convenience, let us start verifying the price effects first. Figures 8 and 9 respectively show the effects of the US import liberalization on the wholesale price of manufactured products when $\nu^{C}_{"i02"s}$ and $\nu^{X}_{"i02"js}$ for all producers are each changed from zero to unity. The value of the parameter for the agent not being targeted is fixed to zero.

At first glance, the effects captured in Figure 8 completely differ from those depicted in Figures 7 and 9. On the other hand, Figures 7 and 9 appear similar in terms of both form and magnitude. These results suggest that intermediate transactions play an important role in the price effects. In the case where $\nu^{C}_{"i02"s}$ alone changes, efficiency-enhancing effects of smoother substitution work for only consumption goods. Then, an increase in the value of $\nu^{C}_{"i02"s}$ just promotes substitution for more expensive Chinese manufactured goods with cheaper commodities produced in the US and RoW. Thus, the wholesale price of manufactured products falls in China and rises in the US as the value of $\nu^{C}_{"i02"s}$ grows (top and middle panels of Figure 8). The reason why the price drops in the RoW is that the region replaces a fraction of its domestic products with the US-made commodity (bottom panel of Figure 8). One point to note is that the effects generated with the Melitz-type specification are relatively large compared to those generated with the Krugman-type specification in both Figure 8 and Figure 9.

Figures 2 and 3 respectively show the effects of the US import liberalization on national/regional welfare in each country/region when $\nu^{C}_{"i02"s}$ and $\nu^{X}_{"i02"js}$ for all producers are respectively changed from zero to unity. Although the wholesale price of manufactured products falls both in China and the RoW when $\nu^{C}_{"i02"s}$ alone changes, the changes in welfare in the case with the Melitz-type model show contrasts (red lines in the middle and bottom panels of Figure 2). In China, income increases because of the expansion of final demand in the US for Chinese products, so welfare improves. In the RoW, reallocation of resources from the primary and service sectors to the manufacturing sector to increase production for China reduces income and therefore worsens welfare in the case where cost reductions through the efficiency-enhancing effects are not large. The Melitz-type specification potentially reinforces this negative impact. The expanded exports to China by a raised value of $\nu^{C}_{"i02"s}$ improve the terms of trade for the US and thus also its welfare (top panels of Figure 2). In turn, Figure 3 depicts very similar patterns to Figure 1, although the magnitudes are discounted especially for the US because this case captures only the effects working through intermediate transactions alone, discarding those through final consumption. Considering that the role of intermediate transactions seems to be significant, let us next look at the cases of independently changing $\nu^{X}_{"i02"js}$ by production sector.

Figures 10 to 12 depict the effects of the US import liberalization for Chinese manufactured products on the wholesale price when $\nu^{X}_{"i02""i01"s}$, $\nu^{X}_{"i02""i02"s}$, or $\nu^{X}_{"i02""i03"s}$ is independently shifted from zero to unity. Note that efficiency-enhancing effects of smoother substitution work just as in the primary industries, manufacturing, or services that correspond to the chosen sector j in $\nu^{X}_{"i02"js}$. The effects captured in Figures 11 and 12 show patterns relatively similar to those in Figures 9 and 8, respectively. On the other hand, Figure 10 differs from all the others. These results suggest that the manufacturing sector, which exhibits IRTS under monopolistic competition, must be the main engine for accelerating the efficiency-enhancing effects of smoother substitution to remarkable levels. Given that this tendency was not obvious in the SaB-type environment, especially for changes in the wholesale price of manufactured products, a hypothesis arises that efficiency-enhancing effects of smoother substitution work more effectively than the cost-reducing effects of variety adjustments suggested by Fujita *et al.* (2000). Although the effects generated by items that differ in terms of the power of influence cannot be directly compared, this point is worth exploring further. A possible reason why the price drop is smaller in the range where $\nu^{X}_{"i02""i02"s}$ takes a large value close to unity for the Melitz-type model compared with the Krugman-type model in the RoW is that the number of active firms increased greatly when additional adjustments take place in the Melitz-type specification, causing the sector-wide fixed-cost burden to become too great (red and blue lines in the bottom panel of Figure 11).

When $\nu^{X}_{"i02""i01"s}$ alone is changed, the efficiency-enhancing effects of smoother substitution work for only the primary industries. Then, an increase in the value of $\nu^{X}_{"i02""i01"s}$ promotes an increase in the intermediate demand of the primary sector for the manufactured products sold mainly in the domestic market.[3] Thus, the wholesale price of manufactured products increases in all of the countries/regions as the value of $\nu^{X}_{"i02""i01"s}$

[3] The input shares of the primary products, manufactured products, and services in the production of the primary sector are 15.324%, 35.141%, and 49.535% in the US, 25.714%, 48.966%, and 25.320% in China, and 20.549%, 36.232%, and 43.219% in the RoW.

grows (Figure 10)

As in the case of shifting $\nu^{C}_{"i02"s}$, the same account can be applied to the case where $\nu^{X}_{"i02""i03"s}$ alone changes. In this case, efficiency-enhancing effects of smoother substitution work for services only. An increase in the value of $\nu^{X}_{"i02""i03"s}$ encourages substitution for more expensive Chinese manufactured goods with cheaper commodities produced in the US and RoW. Then, the wholesale price of manufactured products falls in China and rises in the US as the value of $\nu^{X}_{"i02""i03"s}$ increases (top and middle panels of Figure 12). The price drops in the RoW because this region replaces a fraction of its domestic products with the US made commodity (bottom panel of Figure 12).

Let us now examine welfare effects in the cases where $\nu^{X}_{"i02""i01"s}$, $\nu^{X}_{"i02""i02"s}$, or $\nu^{X}_{"i02""i03"s}$ is independently shifted from zero to unity (Figures 4 to 6). We begin with the case of changing $\nu^{X}_{"i02""i02"s}$ because the captured effects show patterns similar to those we saw when $\nu^{C}_{"i02"s}$ and $\nu^{X}_{"i02"js}$ for all agents or $\nu^{X}_{"i02"js}$ for all producers was shifted simultaneously (Figures 1, 3 and 5). As in the case of changing only $\nu^{X}_{"i02"js}$ for all producers, the magnitudes of effects are discounted especially for the US, because shifting only $\nu^{X}_{"i02""i02"s}$ captures only the effects working in the manufacturing sector and hence the synergetic combination of efficiency-enhancing effects among economic agents is lost. The reason why the elimination of this synergetic combination among economic agents most strongly affects the US might be that the presence of agent-specific adjustable items in the SbA-type model is more favorable to a country that liberalizes imports. A possible reason for the deterioration of welfare when $\nu^{X}_{"i02""i02"s}$ is small, as observed for the RoW under the Melitz-type model, conforms to the reason we mentioned for the case when $\nu^{C}_{"i02"s}$ alone changes. Reallocating resources from the primary and service sectors to the manufacturing sector to increase production for China reduces income and therefore worsens welfare in the range with a small value of $\nu^{X}_{"i02""i02"s}$ where the efficiency-enhancing effects do not work substantially (red line in the bottom panel of Figure 5).

When $\nu^{X}_{"i02""i01"s}$ alone changes, an increase in the value of $\nu^{X}_{"i02""i01"s}$ promotes expansion of intermediate demand in the primary industry mainly for its own products.[4] Thus, cost reductions work relatively well in the primary industry, so more consumption is possible with the same amount of income. On the other hand, China can be better off if the country increases the allocation of resources to the manufacturing sector because of the import liberalization by the US. This implies that augmenting resource reallocation to the

[4] The demand shares of the primary sector for the primary products, manufactured, and services are 5.216%, 1.572%, and 0.911% in the US, 8.465%, 3.092%, and 2.106% in China, and 7.354%, 2.696%, and 1.741% in the RoW.

primary sector in response to an increase in the value of $\nu^{X}_{"i02""i01"s}$ is regressive in the post-liberalization environment. While the former prevails in most cases (Figure 4), the latter dominantly appears in China under the Melitz-type specification (red line in the middle panel of Figure 4).

When $\nu^{X}_{"i02""i03"s}$ alone changes, the same account as the one we considered for the case of shifting $\nu^{C}_{"i02"s}$ may apply. In China, income increases because of the expansion of intermediate demand in the US for Chinese products, so welfare improves. In the RoW, reallocation of resources from the primary and service sectors to the manufacturing sector to increase production for China reduces income and therefore worsens welfare when cost reductions through the efficiency-enhancing effects may not be large. The Melitz-type specification potentially reinforces this negative impact. The expanded exports to China by a raised value of $\nu^{X}_{"i02""i03"s}$ improve the terms of trade of the US and thus also its welfare (top panels of Figure 6).

Finally, the effects generated by the Krugman-type specification, which mainly captures the gains brought by economies of scale, tend to be linearly correlated with the changes in the influence of the total number of varieties on the elasticity of substitution ($\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$), particularly for the price effects. Although no extra valuation on the changes in varieties is accounted for in the effects, the intensive- and extensive-margin effects are still working in opposite directions (on the same weight) in the Melitz-type environment, so the working direction of the total effects may not be definitively projected.

4. Concluding Remarks

To assess the efficiency-enhancing effects of international trade in more detail, we utilized an MRIO-based AGE model of global trade that endogenizes the elasticity of substitution as an increasing function of the total number of varieties available to each economic agent on the demand side. Considering the case where the US unilaterally liberalizes imports of Chinese manufactured products as an example, simulation experiments with a three-region three-sector model that can be flexibly switched among the Armington-, Krugman-, and Melitz-type specifications of product differentiation within a single framework revealed the following results.

1. The Melitz-type model, which may inflate effects through the productivity growth among heterogeneous firms, tends to generate a much larger impact on welfare

compared with the Krugman-type model, which captures only the gains brought by economies of scale, in the presence of agent-specific adjustable items (variable elasticity) in the SbA-type model.

2. A production sector that exhibits IRTS under monopolistic competition may serve as the main engine for accelerating the efficiency-enhancing effects of smoother substitution to remarkable levels.

3. The efficiency-enhancing effects of smoother substitution may work more effectively than the cost-reducing effects of variety adjustments suggested by Fujita *et al.* (2000).

4. The effects generated by the Krugman-type model, which mainly capture the gains brought by the economies of scale, tend to be linearly correlated with the changes in the influence of the total number of varieties on the elasticity of substitution, particularly for the price effects.

The cost-reducing effects generated by changing the influence of the total number of varieties on the elasticity of substitution capture the same process of variety adjustments that Fujita *et al.* (2000) noted as the forward linkage created through access to a greater variety of intermediate commodities from a different angle. Smoother access to a greater variety enables producers the costs of production to be further reduced, expanding opportunities to produce higher quality products. Thus, additional research is needed on the relationships between the number of varieties and the elasticity of substitution, including estimations of the values of ν_{ijs}^{X} and ν_{is}^{C} as well as the pursuit of its functional form.

Endogenizing elasticity of substitution in an SbA-type AGE model may further expand the possibilities of analysis. While AGE models that incorporate direct cross-border linkages between producers and importing agents enable us to assess the effects of economic policies on trade in intermediate goods, the way that the behaviors of economic agents are differentiated strongly affects the properties of simulation results (Carrico, 2017). To maximize the utility of this kind of AGE model, reactions of agents to an external shock must differ in simulations. One approach to differentiate agents' behavior is to calibrate a model to MRIO data that contain information on agent-specific trade costs such as transportation margins and composite tariff rates. In that case, behaviors of agents are characterized by the share parameters in the demand aggregator functions. In another approach, it will be straight forward to re-estimate or collect information on agent-specific elasticities of substitution between commodities supplied by different sources. However, the task is not easy and relatively time-consuming especially for a global trade model, since the data set for estimation itself might be limited. The present study shows an idea for differentiating the elasticity of substitution among economic agents. Since producers and importing agents are directly connected by cross-border trade flows in our model, the entry/exit of firms to/from a market on a trade link also becomes specific with respect to producers and importers, so the endogenous elasticities of substitution independently vary across importer agents. We hope this study provides an interesting perspective to the researchers working on global trade analysis.

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Table 1. Changes in Trade Flows of Manufactured Products (%, Armington, Final Demand)

	r01	r02	r03
r01	-0.322	2.675	1.216
r02	9.206	0.076	-1.346
r03	-1.512	1.450	0.008

Source: Calculations by the author.

Table 2. Changes in Trade Flows of Manufactured Products (%, Armington, Intermediate – Primary)

	r01	r02	r03
r01	0.274	2.283	1.253
r02	9.860	-0.305	-1.310
r03	-0.923	1.063	0.045

Source: Calculations by the author.

Table 3. Changes in Trade Flows of Manufactured Products (%, Armington, Intermediate - Manufacturing)

	r01	r02	r03
r01	-0.198	2.688	1.201
r02	9.342	0.088	-1.361
r03	-1.389	1.462	-0.007

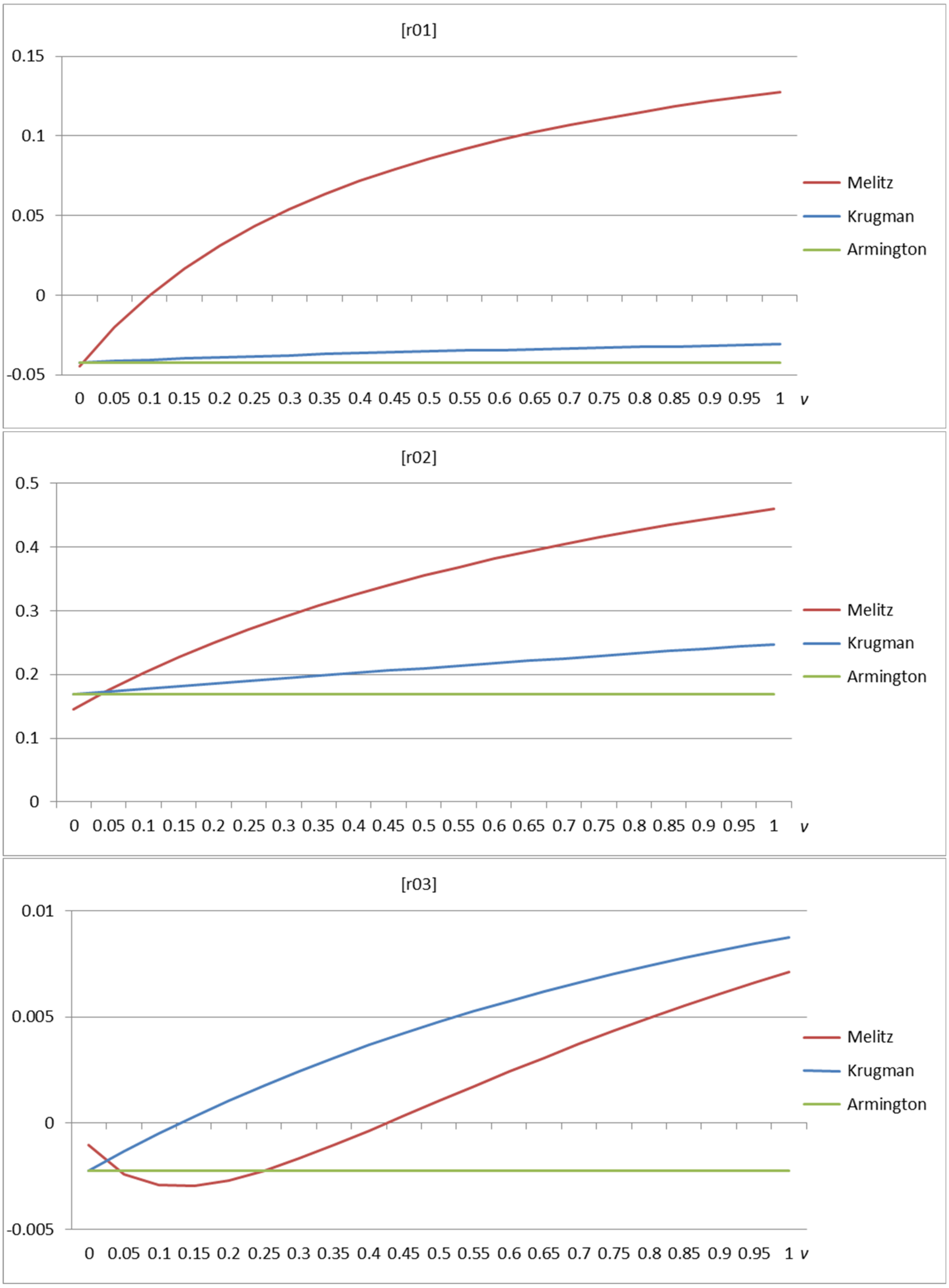
Source: Calculations by the author.

Table 4. Changes in Trade Flows of Manufactured Products (%, Armington, Intermediate - Services)

	r01	r02	r03
r01	-0.182	2.657	1.215
r02	9.360	0.059	-1.347
r03	-1.373	1.432	0.007

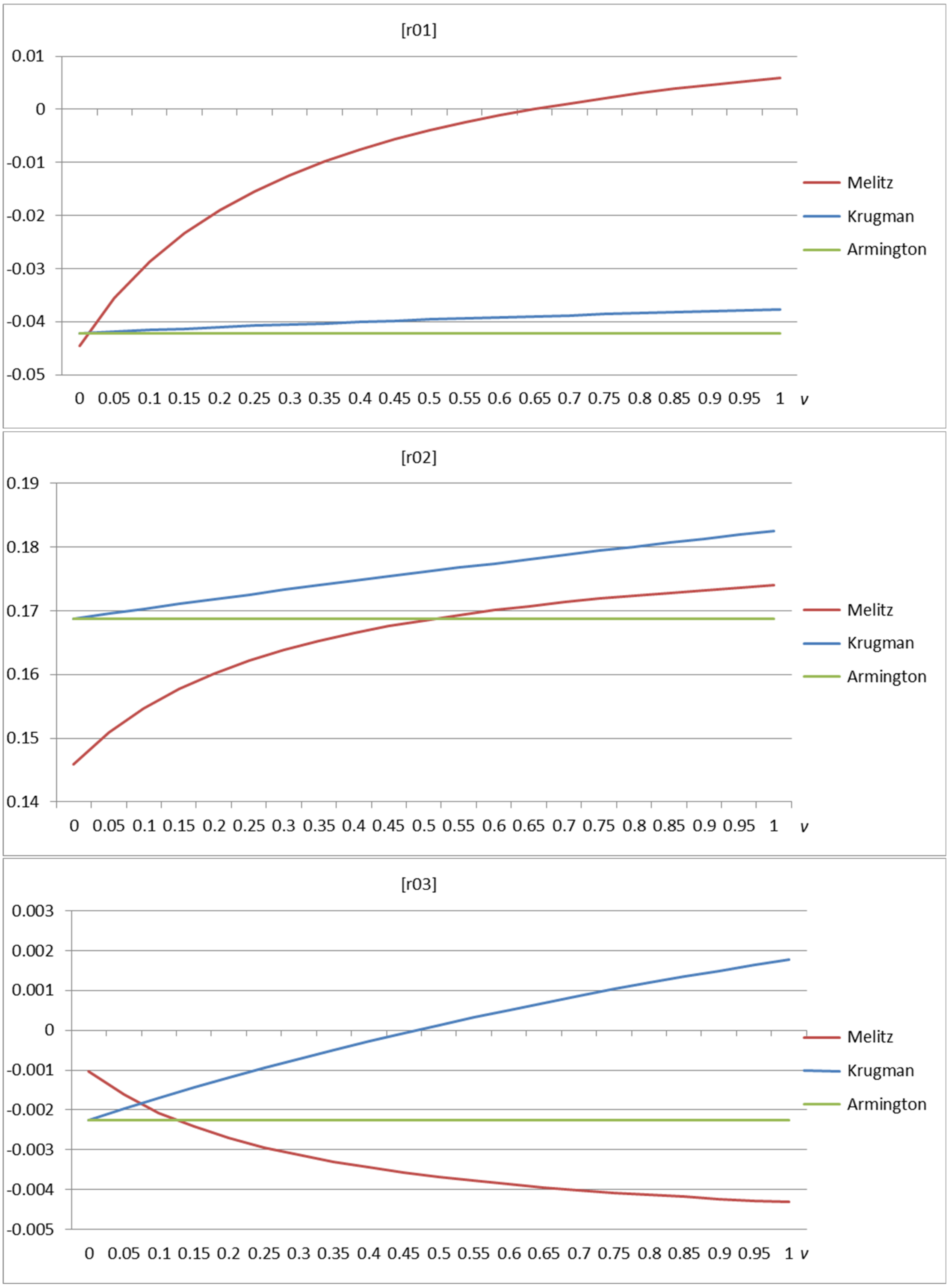
Source: Calculations by the author.

Figure 1. Welfare Effects (%, All Agents)



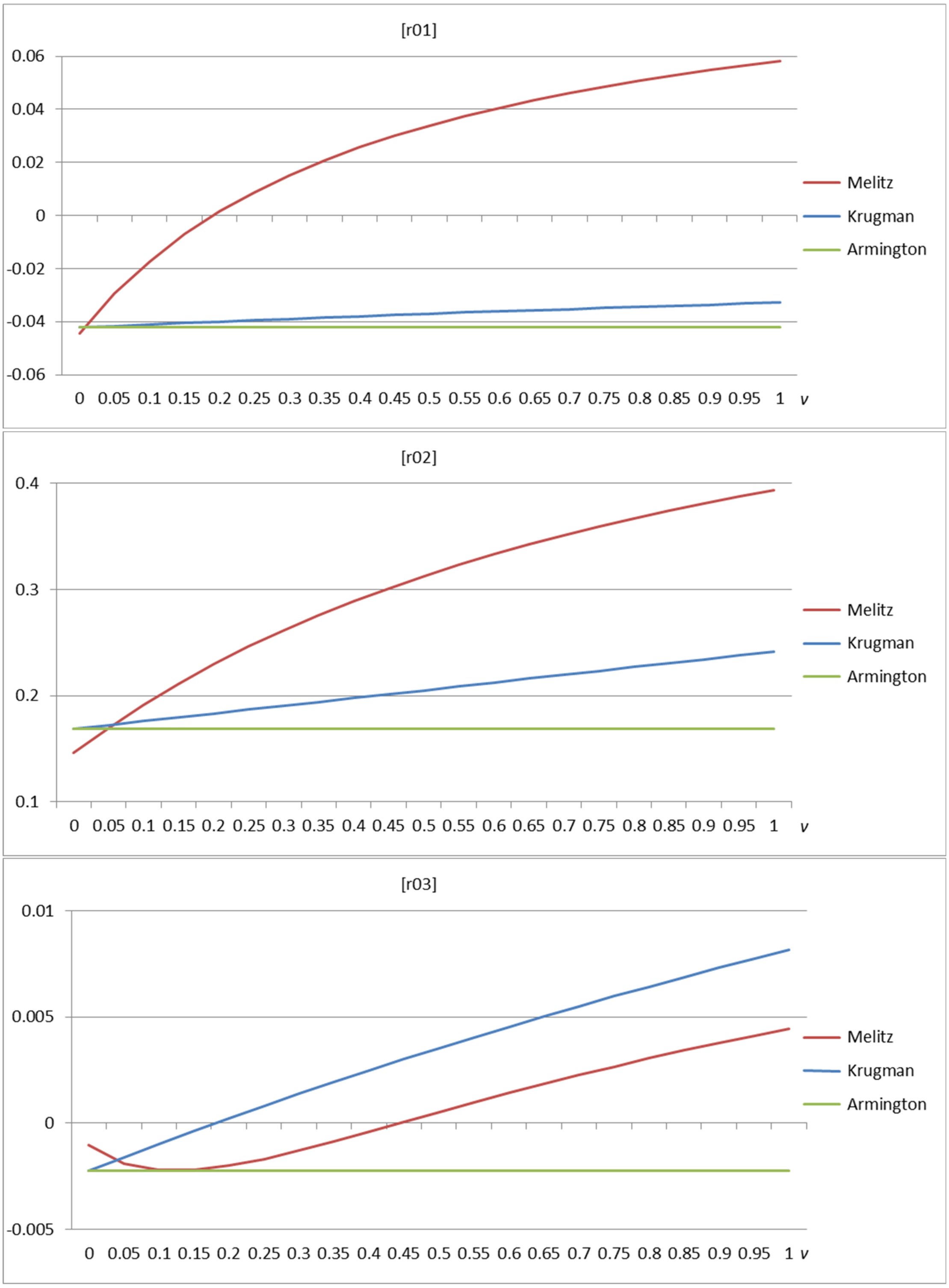
Source: Calculations by the author.

Figure 2. Welfare Effects (%, Final Demand)



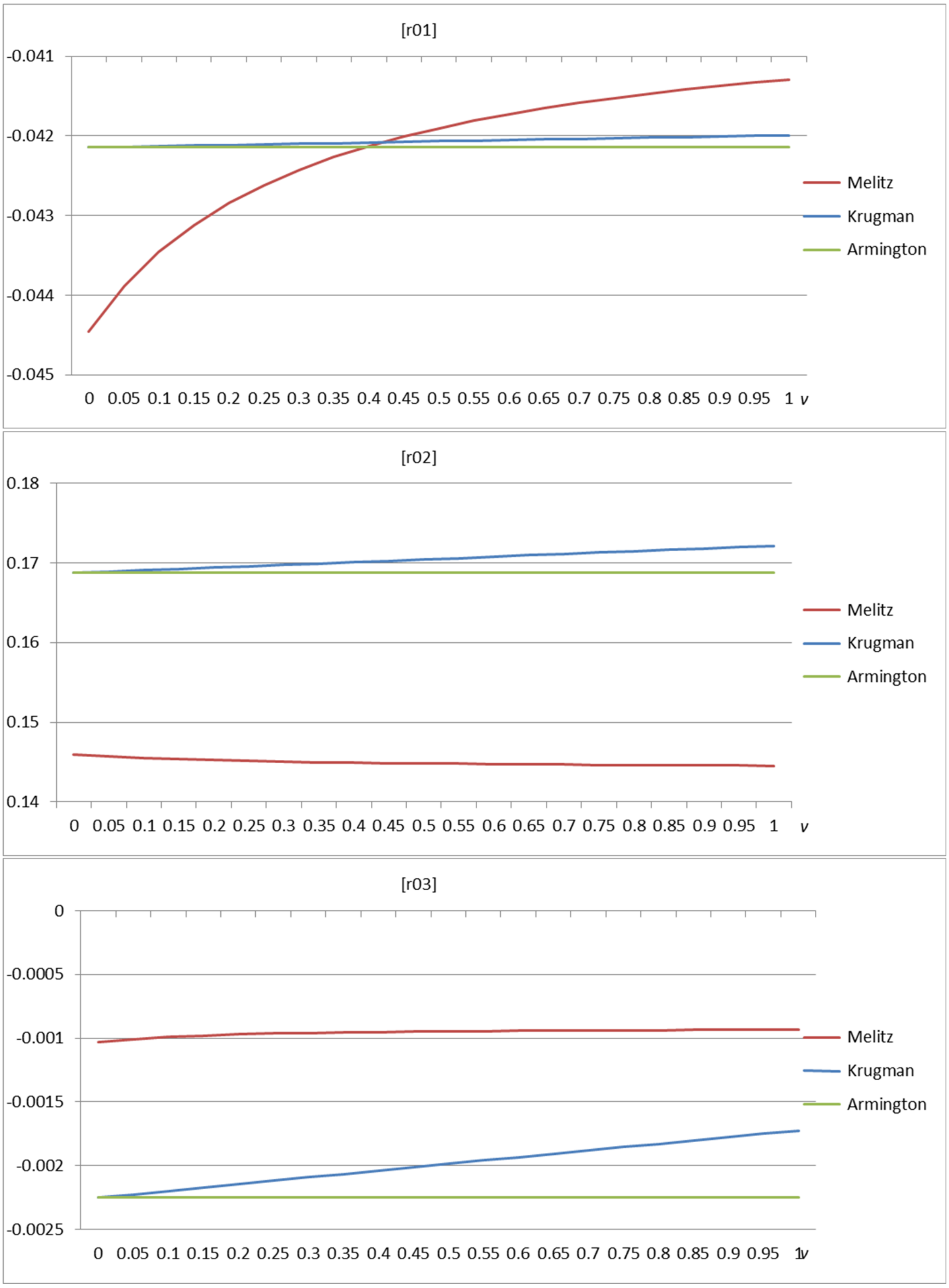
Source: Calculations by the author.

Figure 3. Welfare Effects (%, All Intermediates)



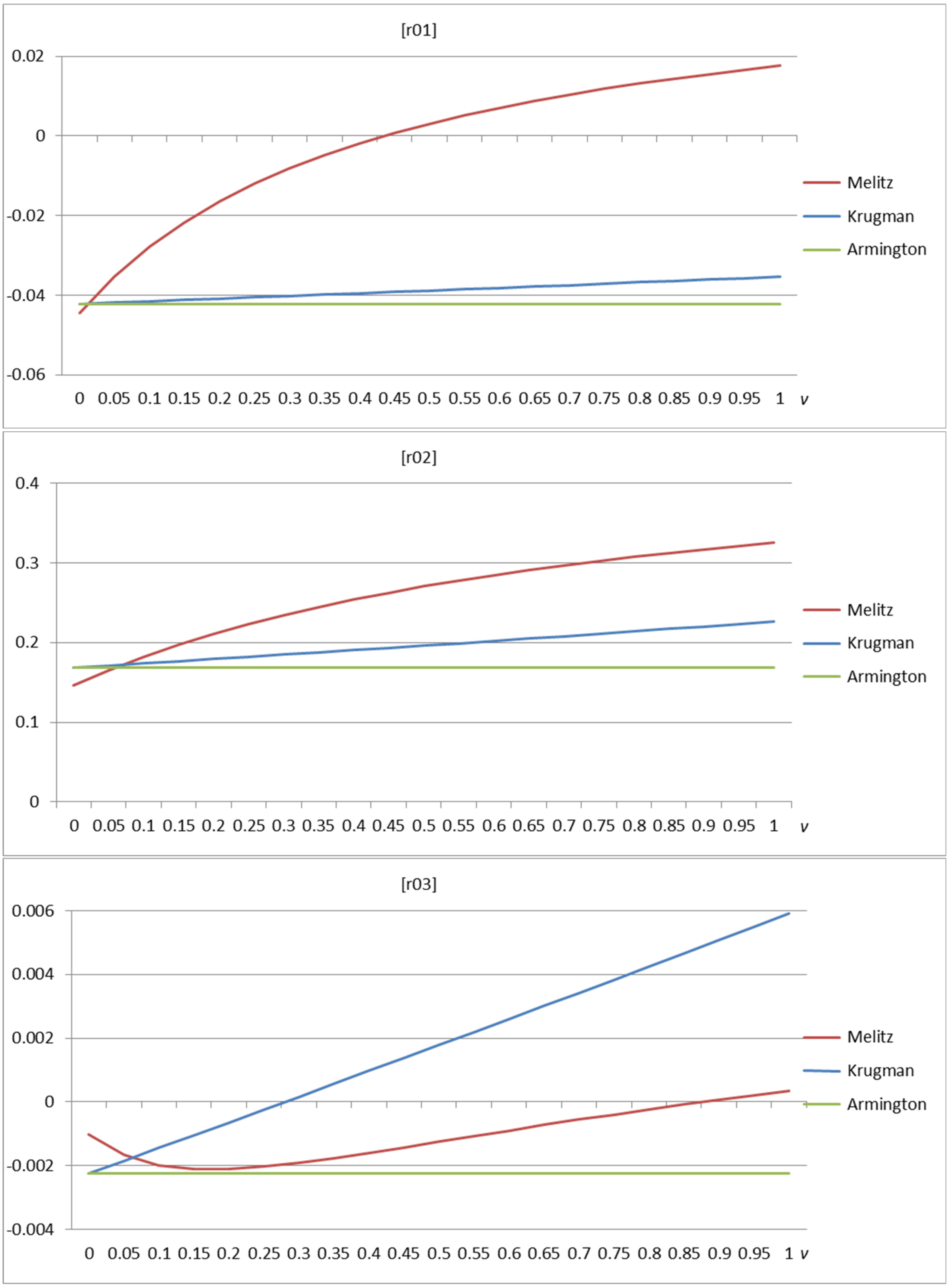
Source: Calculations by the author.

Figure 4. Welfare Effects (%, Intermediate - Primary)



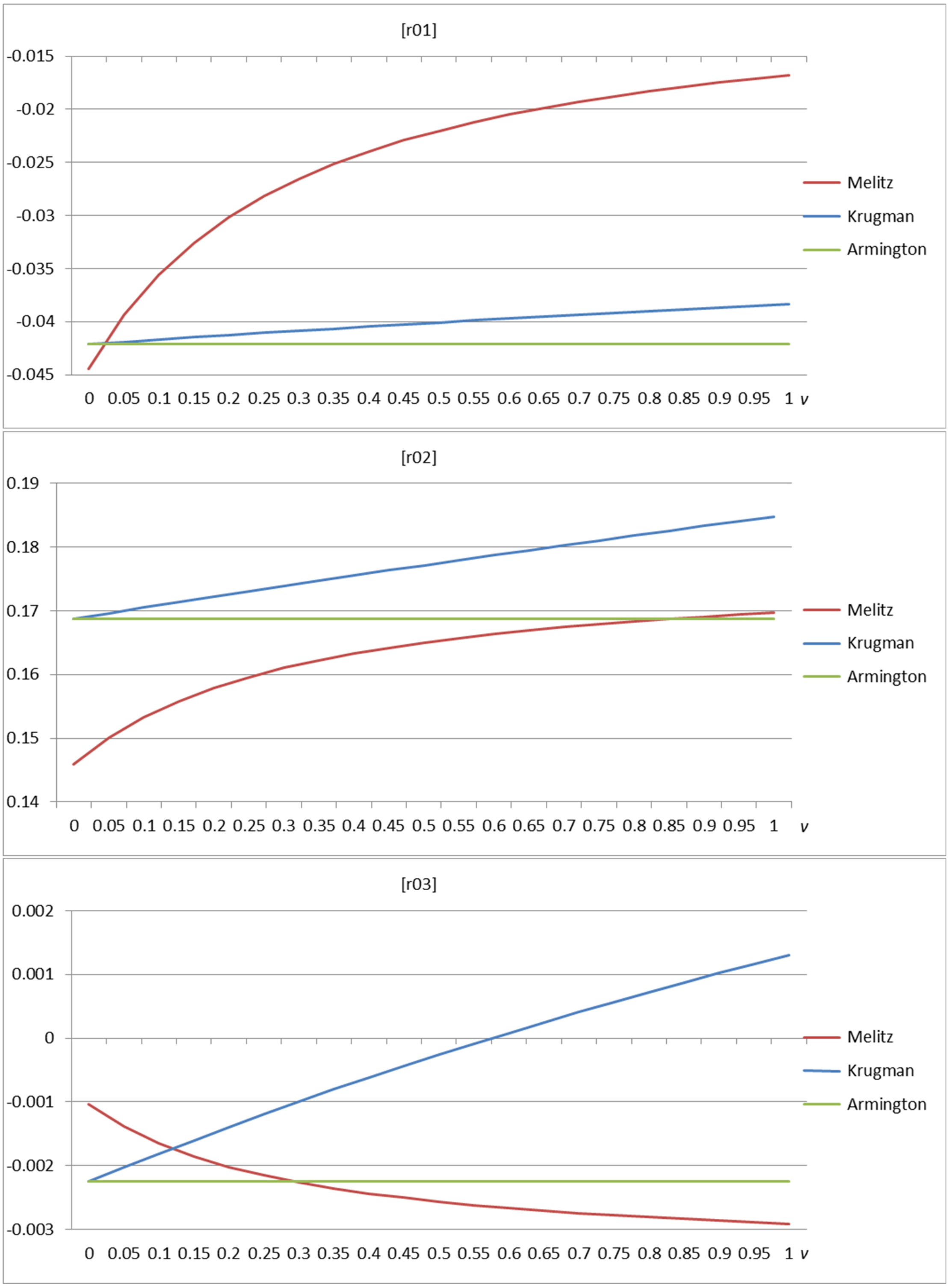
Source: Calculations by the author.

Figure 5. Welfare Effects (%, Intermediate - Manufacturing)



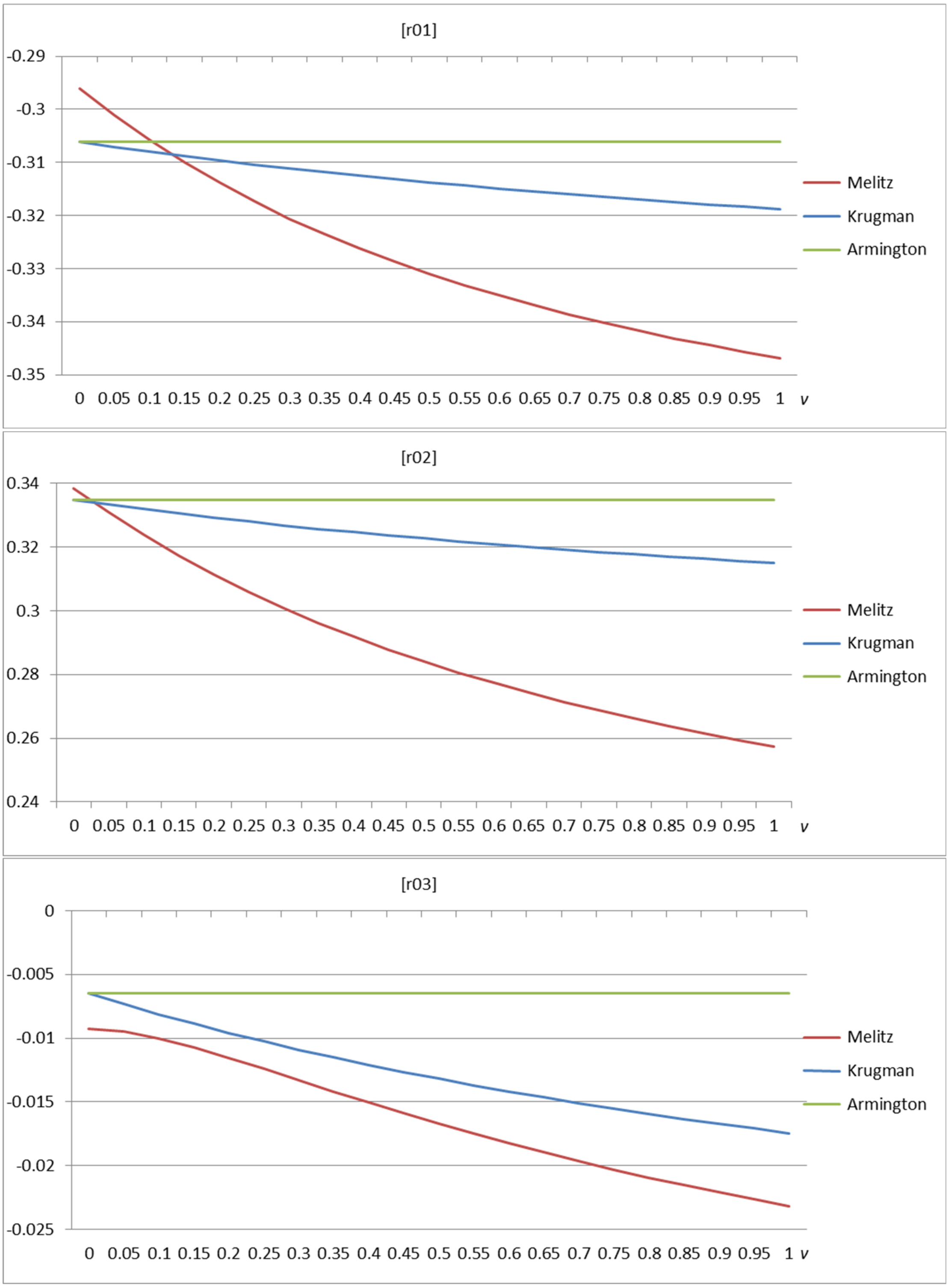
Source: Calculations by the author.

Figure 6. Welfare Effects (%, Intermediate - Services)



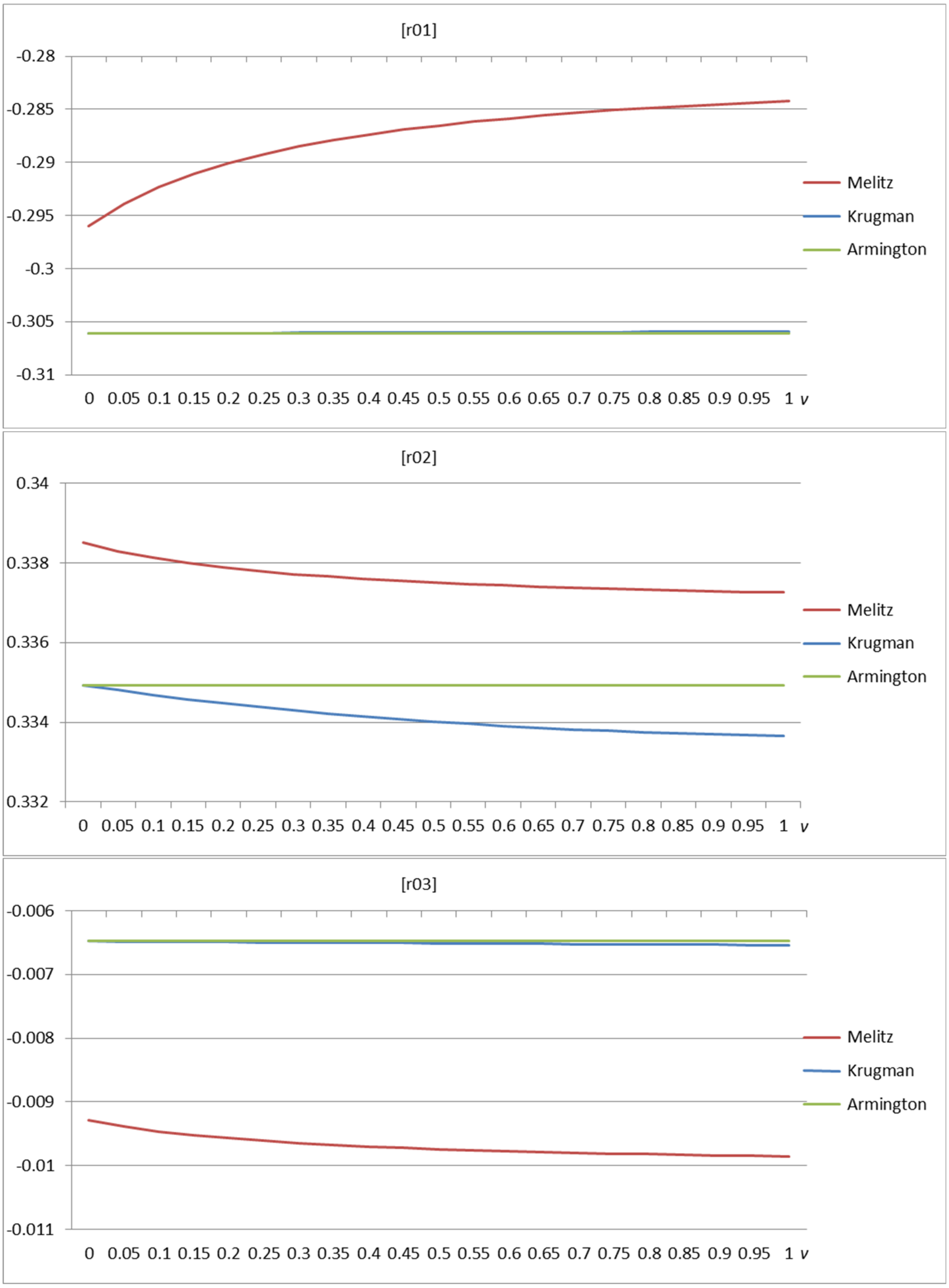
Source: Calculations by the author.

Figure 7. Effects on Wholesale Price of Manufactured Products (%, All Agents)



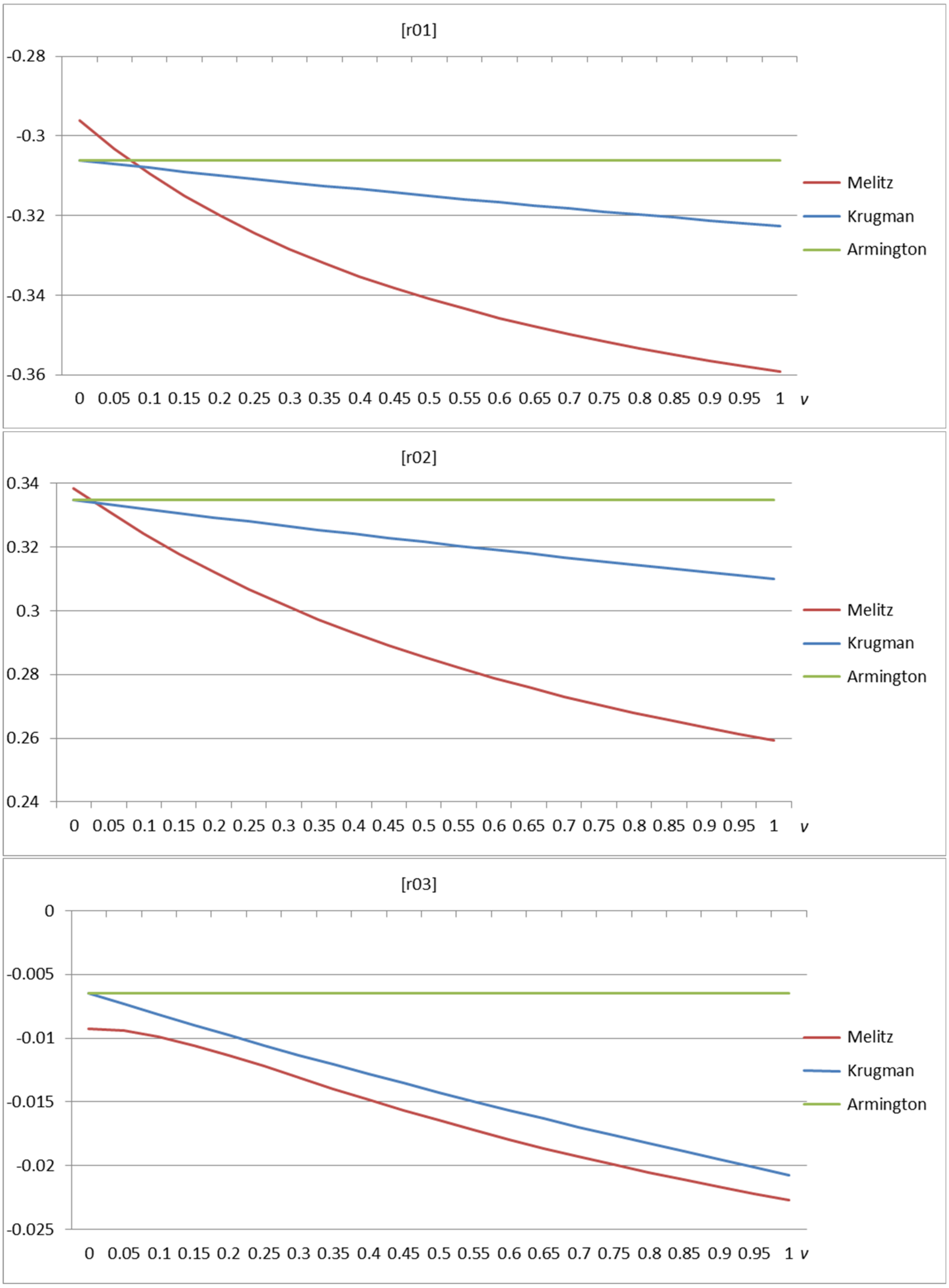
Source: Calculations by the author.

Figure 8. Effects on Wholesale Price of Manufactured Products (%, Final Demand)



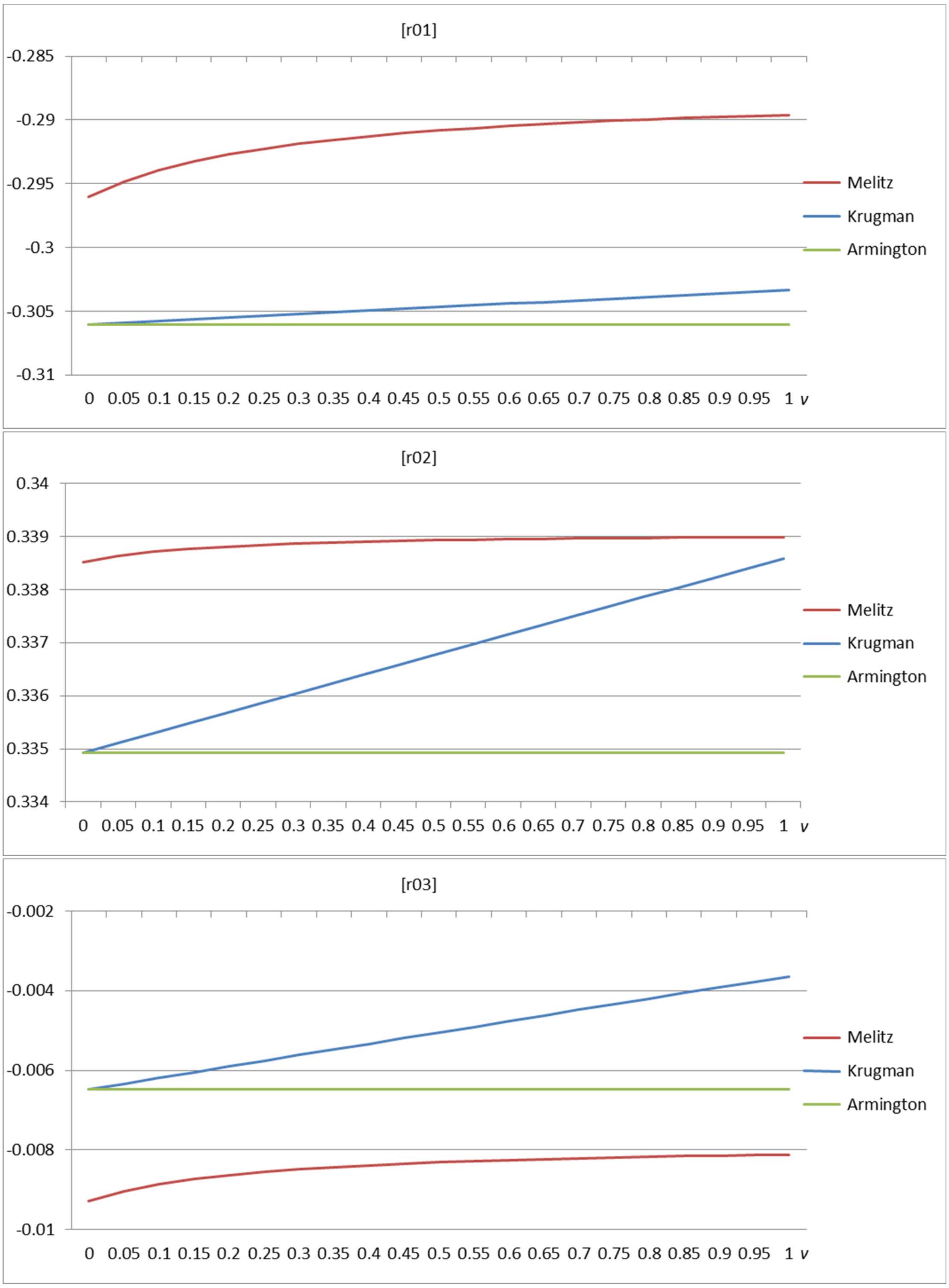
Source: Calculations by the author.

Figure 9. Effects on Wholesale Price of Manufactured Products (%, All Intermediates)



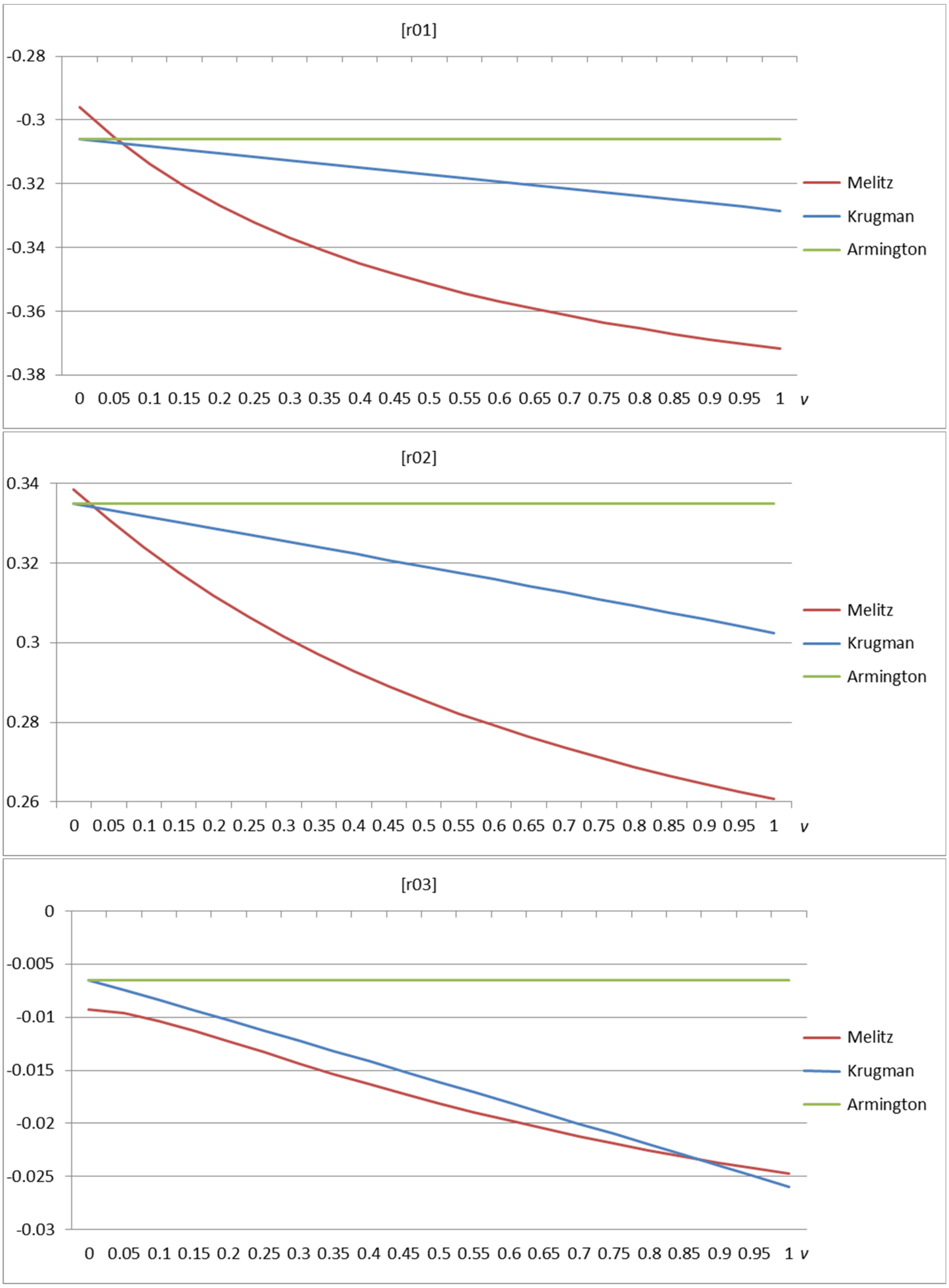
Source: Calculations by the author.

Figure 10. Effects on Wholesale Price of Manufactured Products (%, Intermediate - Primary)



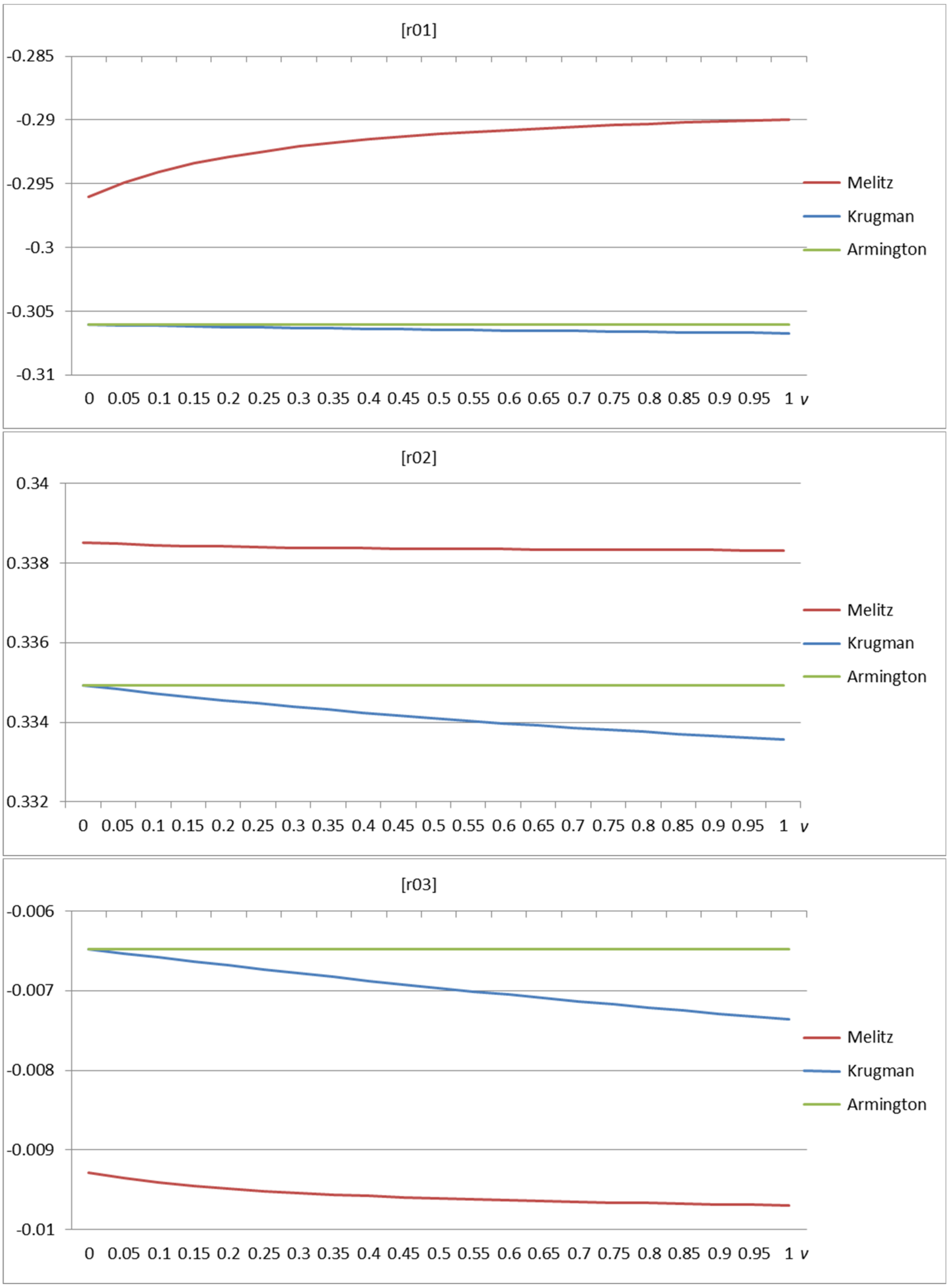
Source: Calculations by the author.

Figure 11. Effects on Wholesale Price of Manufactured Products (%, Intermediate - Manufacturing)



Source: Calculations by the author.

Figure 12. Effects on Wholesale Price of Manufactured Products (%, Intermediate - Services)



Source: Calculations by the author.