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

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Abstract

This study explores the behavioral characteristics of an applied general equilibrium model with the Melitz-type heterogeneous and Krugman-type homogeneous firms, which endogenizes substitution elasticity as an increasing function of the total number of varieties with the assumption of agent-specific sourcing of imported and domestically produced commodities. Simulation experiments with the model revealed that inter-sector and international spillovers of the effects of smoother substitution through intermediate transactions among countries/regions amplify the efficiency-enhancing effect of international trade to bring significantly large welfare gains to all countries in the global economy. The production sector, which is assumed in the model to differentiate outputs under monopolistic competition, plays an important role as the key agent that effectively transmits the favorable effect to the global economy.

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

JEL Classification Numbers: C68, D58, F12, L11.

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1. Introduction

While applied general equilibrium (AGE) models that incorporate direct cross-border linkages between producers and importing agents enable us to assess effects of economic policies on trade in intermediate goods, the way how behaviors of economic agents are differentiated affects very much the properties of simulation results (Carrico, 2017). To maximize the utilities of this kind of AGE models, reactions of agents to an external shock must differ in simulations. One approach to differentiate agents' behavior is to calibrate a model to multi-regional input-output (MRIO) data that contain information on agent-specific composite tariff rates. In this case, behaviors of agents are characterized by the share parameters in the demand aggregator functions. Another approach is straight-forward to re-estimate or collect information on agent-specific elasticities of substitution between commodities from different sources. However, this work is not easy and relatively time-consuming especially for a global trade model, since the data set for estimation itself might be difficult to find. The purpose of this research is to present an idea to differentiate the elasticity of substitution among economic agents, based on an intuition that an additional variety reduces distance between varieties filling in gaps between existing varieties, and explore what kind of behavioral characteristics a MRIO-based model with the Melitz-type monopolistic competition and heterogeneous firms may show. 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 that the endogenize substitution elasticities independently vary across importer agents. In addition, our approach is in line with the previous attempts to incorporate variable markups rooted in the evidence that larger, better performing firms set higher markups (Feenstra, 1994; Arkolakis, Costinot, Donaldson, and Rodoriguez-Clare, 2019).

This research positions at the intersection of our two previous works. The first study, Oyamada (2015), examined how simulation results change when an analytical model based on the theoretical framework of Melitz (2003) or Krugman (1980) is extended to assume agent-specific sourcing of imported and domestically produced commodities, and then the intensity of economic agents' preference for variety (PfV) changes independently. Focusing on the forward linkage created through the access to a greater variety of intermediate commodities (we call this process "quality adjustment") that may reduce the price index and hence the costs of production of firms (Fujita, Krugman, and Venables, 2000), it showed the potential utilities of MRIO-based models that can control the degree of quality adjustment by production sector. The second study, Oyamada (2019), explored the behavioral characteristics of relatively simple Melitz-type heterogeneous and Krugman-type homogeneous firm models, assuming that sourcing of imported and domestically produced commodities take place at the border. Presenting an alternative approach to handle effects on the extensive margin of trade, which endogenizes the substitution elasticity between varieties instead of changing the intensity of PfV, it demonstrated that smoother adjustments will be possible with variable elasticity of substitution so that the efficiency-enhancing effect of international trade may become prominent to recover welfare levels in all countries. Thus, this study tries to present more detailed analysis how and through which channel the efficiency-enhancing effect grows and spillovers in the global economy.

The reminder of this study 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. Section 4 concludes the study.

2. The Model

In this section, an overview of the AGE model with the Melitz- and Krugman-type trade specifications used in this study is presented. The model is a simple extension of the one introduced in Itakura and Oyamada (2016), which converted a sourcing-at-border (SaB) type global trade model to be a sourcing-by-agent (SbA) type. The main parameters and exogenous variables are calibrated to a MRIO table, which was compiled from the GTAP 9.2 Data Base for 2011 (Hertel, 1997) applying a simple procedure presented by Walmsley, Hertel, and Hummels (2014), with the author's 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), which are linked through trade flows: (r01) the United States (US), (r02) China, and (r03) the Rest of the World (RoW). Commodities and activities that are indexed as i and j are categorized into (i01) primary industries, (i02) manufacturing, and (i03) services, respectively. The manufacturing sector (i02) is assumed imperfectly competitive with increasing returns to scale (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 services 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 exhibit IRTS technology are divided into two segments that respectively assume charge of production and sales. In the production process, firms' production segment 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 every domestic and international market. The scale economy enters here.

Then, the international trade part of the model is replaced by the Armington-Krugman-Melitz encompassing (AKME) module introduced in Oyamada (2015) based on Balistreri and Rutherford (2013) and Dixon, Jerie, and Rimmer (2016). The equations that form the Melitz-type trade module are summarized as follows:

$$X_{ijs} \leq \theta_{ijs}^{TX} \begin{Bmatrix} \left(1-\sum_r \alpha_{ijrs}^{TX}\right)\left(N_{ijs}^{DX}\right)^{\left(\beta_{ijs}^{X}+\sigma_i^T-1\right)/\sigma_i^T}\left(D_{ijs}^{X}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T} \\ +\sum_r \alpha_{ijrs}^{TX}\left(N_{ijrs}^{QX}\right)^{\left(\beta_{ijs}^{X}+\sigma_i^T-1\right)/\sigma_i^T}\left(Q_{ijrs}^{X}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T} \end{Bmatrix}^{\sigma_i^T/\left(\sigma_i^T-1\right)} \quad \perp p_{ijs}^{X}, \quad (1)$$

$$C_{is} \leq \theta_{is}^{TC} \begin{Bmatrix} \left(1-\sum_r \alpha_{irs}^{TC}\right)\left(N_{is}^{DC}\right)^{\left(\beta_{is}^{C}+\sigma_i^T-1\right)/\sigma_i^T}\left(D_{is}^{C}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T} \\ +\sum_r \alpha_{irs}^{TC}\left(N_{irs}^{QC}\right)^{\left(\beta_{is}^{C}+\sigma_i^T-1\right)/\sigma_i^T}\left(Q_{irs}^{C}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T} \end{Bmatrix}^{\sigma_i^T/\left(\sigma_i^T-1\right)} \quad \perp p_{is}^{C}, \quad (2)$$

$$\left(1-\sum_r \alpha_{ijrs}^{TX}\right)\left(\theta_{ijs}^{TX}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T}\left(N_{ijs}^{DX}\right)^{\left(\beta_{ijs}^{X}-1\right)/\sigma_i^T} p_{ijs}^{X}\left(\frac{X_{ijs}}{D_{ijs}^{X}}\right)^{1/\sigma_i^T} \leq p_{ijs}^{DX} \quad \perp D_{ijs}^{X}, \quad (3)$$

$$\left(1-\sum_r \alpha_{irs}^{TC}\right)\left(\theta_{is}^{TC}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T}\left(N_{is}^{DC}\right)^{\left(\beta_{is}^{C}-1\right)/\sigma_i^T} p_{is}^{C}\left(\frac{C_{is}}{D_{is}^{C}}\right)^{1/\sigma_i^T} \leq p_{is}^{DC} \quad \perp D_{is}^{C}, \quad (4)$$

$$\alpha_{ijrs}^{TX}\left(\theta_{ijs}^{TX}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T}\left(N_{ijrs}^{QX}\right)^{\left(\beta_{ijs}^{X}-1\right)/\sigma_i^T} p_{ijs}^{X}\left(\frac{X_{ijs}}{Q_{ijrs}^{X}}\right)^{1/\sigma_i^T} \leq \left(1+\tau_{ijrs}^{MX}\right)\left(1+\tau_{ijrs}^{TX}\right)\left(1+\tau_{ijrs}^{EX}\right)p_{ijrs}^{QX} \quad \perp Q_{ijrs}^{X}, \quad (5)$$

$$\alpha_{irs}^{TC}\left(\theta_{is}^{TC}\right)^{\left(\sigma_i^T-1\right)/\sigma_i^T}\left(N_{irs}^{QC}\right)^{\left(\beta_{is}^{C}-1\right)/\sigma_i^T} p_{is}^{C}\left(\frac{C_{is}}{Q_{irs}^{C}}\right)^{1/\sigma_i^T} \leq \left(1+\tau_{irs}^{MC}\right)\left(1+\tau_{irs}^{TC}\right)\left(1+\tau_{irs}^{EC}\right)p_{irs}^{QC} \quad \perp Q_{irs}^{C}, \quad (6)$$

$$p_{ijr}^{DX} = \left(\frac{\sigma_i^T}{\sigma_i^T - 1}\right)\frac{p_{ir}^w}{\varphi_{ijr}^{DX}}, \tag{7}$$

$$p_{ir}^{DC} = \left(\frac{\sigma_i^T}{\sigma_i^T - 1}\right)\frac{p_{ir}^w}{\varphi_{ir}^{DC}}, \tag{8}$$

$$p_{ijrs}^{QX} = \left(\frac{\sigma_i^T}{\sigma_i^T - 1}\right)\frac{p_{ir}^w}{\varphi_{ijrs}^{QX}}, \tag{9}$$

$$p_{irs}^{QC} = \left(\frac{\sigma_i^T}{\sigma_i^T - 1}\right)\frac{p_{ir}^w}{\varphi_{irs}^{QC}}, \tag{10}$$

$$\begin{aligned}&\sum_j N_{ijr}^{DX}\frac{D_{ijr}^X}{\varphi_{ijr}^{DX}} + N_{ir}^{DC}\frac{D_{ir}^C}{\varphi_{ir}^{DC}} + \sum_j\sum_s N_{ijrs}^{QX}\frac{Q_{ijrs}^X}{\varphi_{ijrs}^{QX}} + \sum_s N_{irs}^{QC}\frac{Q_{irs}^C}{\varphi_{irs}^{QC}} + \Omega_r \\ &\le Z_{ir} - \begin{pmatrix} N_{ir}H_{ir} + \sum_j N_{ijr}^{DX}F_{ijr}^{DX} + N_{ir}^{DC}F_{ir}^{DC} \\ + \sum_j\sum_s N_{ijrs}^{QX}F_{ijrs}^{QX} + \sum_s N_{irs}^{QC}F_{irs}^{QC}\end{pmatrix} \quad \perp p_{ir}^W,\end{aligned} \tag{11}$$

$$\mu_{ijr}^{DX} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)}\left(\varphi_{ijr}^{DX}\right)^{-\gamma_i}, \tag{12}$$

$$\mu_{ir}^{DC} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)}\left(\varphi_{ir}^{DC}\right)^{-\gamma_i}, \tag{13}$$

$$\mu_{ijrs}^{QX} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)}\left(\varphi_{ijrs}^{QX}\right)^{-\gamma_i}, \tag{14}$$

$$\mu_{irs}^{QC} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)}\left(\varphi_{irs}^{QC}\right)^{-\gamma_i}, \tag{15}$$

$$\varphi_{ijr}^{DX} = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{D_{ijr}^X}{F_{ijr}^{DX}}\right), \tag{16}$$

$$\varphi_{ir}^{DC} = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{D_{ir}^C}{F_{ir}^{DC}}\right), \tag{17}$$

$$\varphi_{ijrs}^{QX} = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{Q_{ijrs}^X}{F_{ijrs}^{QX}}\right), \tag{18}$$

$$\varphi_{irs}^{QC} = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{Q_{irs}^C}{F_{irs}^{QC}}\right), \tag{19}$$

and

$$\begin{aligned}&p_{ir}^w\left(N_{ir}H_{ir} + \sum_j N_{ijr}^{DX}F_{ijr}^{DX} + N_{ir}^{DC}F_{ir}^{DC} + \sum_j\sum_s N_{ijrs}^{QX}F_{ijrs}^{QX} + \sum_s N_{irs}^{QC}F_{irs}^{QC}\right) \\ &= \frac{1}{\sigma_i^T}\begin{pmatrix} \sum_j p_{ijr}^{DX}N_{ijr}^{DX}D_{ijr}^X + p_{ir}^{DC}N_{ir}^{DC}D_{ir}^C \\ + \sum_j\sum_s p_{ijrs}^{QX}N_{ijrs}^{QX}Q_{ijrs}^X + \sum_s p_{irs}^{QC}N_{irs}^{QC}Q_{irs}^C\end{pmatrix},\end{aligned} \tag{20}$$

where

X_{ijs} is the intermediate input of composite commodity i by sector j in region s,

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

Z_{ir} is the gross output of sector i in region r,

D_{ijs}^{X} is the domestic (intra-national) trade flow of commodity i for intermediate input sold in region s,

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

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

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

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 sector 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 sector j by firms in region r excluding the transportation margin and the import tariff,

p_{irs}^{QC} is the differentiated sales price of consumption commodity i for international market s sold by firms in region r excluding the transportation margin and the import tariff,

p_{ir}^{W} is the wholesale price of each product,

$\mu_{ijs}^{DX} \in (0,1)$ is the proportion of firms established in region r that are able to sell intermediate commodity for sector j on the domestic market r,

$\mu_{ir}^{DC} \in (0,1)$ is the proportion of firms established in region r that are able to sell consumption commodity on the domestic market r,

$\mu_{ijrs}^{QX} \in (0,1)$ is the proportion of exporting firms in established in region r that are able to sell intermediate commodity for sector j on the international market s,

$\mu_{irs}^{QC} \in (0,1)$ is the proportion of exporting firms in established in region r that are able to sell consumption commodity on the international market s,

φ_{ijr}^{DX} is the average productivity of firms active on the domestic market r doing business with sector j,

φ_{ir}^{DC} is the average productivity of firms active on the domestic market r doing business with final consumer,

φ_{ijrs}^{QX} is the average productivity of exporting firms active on the r-s link doing business with sector j,

φ_{irs}^{QC} is the average productivity of exporting firms active on the r-s link doing business with final consumer,

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

N_{ijr}^{DX} is the number of firms active on the domestic market r doing business with sector j,

N_{ir}^{DC} is the number of firms active on the domestic market r doing business with final consumer,

N_{ijrs}^{QX} is the number of exporting firms active on the r-s link doing business with sector j,

N_{irs}^{QC} is the number of exporting firms active on the r-s link doing business with final consumer,

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

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

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

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

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

$\beta_{ijs}^{X} \in [0,1]$ is the intensity of the sector j's PfV,

$\beta_{is}^{C} \in [0,1]$ is the intensity of the final consumer's PfV,

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

α_{ijrs}^{TX} is the weight parameter that reflects the preference of sector j in region s for the commodity imported from region r,

α_{irs}^{TC} is the weight parameter that reflects the preference of final consumer in region s for the commodity imported from region r,

θ^{TX}_{ijs} is the scaling factor in the intermediate commodity aggregator,

θ^{TC}_{is} is the scaling factor in the consumption commodity aggregator,

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

τ^{EX}_{ijrs} is the rate of export duty/subsidy levied by the government r on intermediate commodity i for sector j,

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

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

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

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

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

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

$$\Omega_r \equiv \frac{\omega_r}{p^W_{\text{"i03"}r}} \sum_{i'} \sum_{r'} \sum_s \left\{ \begin{matrix} \sum_j \tau^{TX}_{i'jr's}\left(1+\tau^{EX}_{i'jr's}\right) N^{QX}_{i'jr's} p^{QX}_{i'jr's} Q^X_{i'jr's} \\ +\tau^{TC}_{i'r's}\left(1+\tau^{EC}_{i'r's}\right) N^{QC}_{i'r's} p^{QC}_{i'r's} Q^C_{i'r's} \end{matrix} \right\}.$$

Ω_r is included in Equation (11) if and only if i is the services sector ($i =$ i03). The perpendicular symbol "$\perp$" shows the complementarity relationships between positive variables and inequalities.

Equations (1) and (2) are the commodity aggregators respectively for the intermediate and consumption goods produced by the IRTS sector. For the CRTS sectors, both β^X_{ijs} and β^C_{is} are set to zero in addition to the fact that all of N^{DX}_{ijr}, N^{DC}_{ir}, N^{QX}_{ijrs}, and N^{QC}_{irs} are fixed to unity. Note that just these equations formulate that the commodities sold both on the domestic and international markets are sourced by each economic agent. Thus, producers and importing agents are directly connected by cross-border trade flows in this model. The following Equations (3) through (6) are the first-order conditions (FOCs) to minimize costs of producing the composite commodities, which determine the levels of D^X_{ijs}, D^C_{is}, Q^X_{ijrs}, and Q^C_{irs}, respectively. Equations (7) through (10) define the markup prices set by dealers in the IRTS sector. Similar to the cases of Equations (1) and (2), φ^{DX}_{ijr}, φ^{DC}_{ir}, φ^{QX}_{ijrs}, and φ^{QC}_{irs} are fixed to unity as well as the expressions in the parentheses are dropped, when the production sector exhibits CRTS technology. Equation (11) formulates the transformation of the gross output Z_{ir}, which determines the level of the wholesale price p_{ir}^{w}. The expression in the parentheses in the right-hand side of Equation (11) enter if and only if i is the IRTS sector, which imply fractions of Z_{ir} forego as fixed costs of establishing a firm and entering a domestic or international market. $\varphi_{ijr}^{DX} = \varphi_{ir}^{DC} = \varphi_{ijrs}^{QX} = \varphi_{irs}^{QC} = 1$ when i is the CRTS sector. Equations (12) through (20) are only for the IRTS sector. The former eight respectively define the proportions of active firms and the average levels of their productivity. On the other hand, Equation (20) is the zero-profit condition based on the monopolistic competition that determines the number of firms established in region r, N_{ir}. Once a firm is successfully established in region r, paying the fixed entry cost H_{ir}, the firm draws her/his own productivity and verifies whether its level meets the minimum requirement to enter a market and make sales. The least required level of productivity is such that covers the fixed overhead cost of operation, F_{ijr}^{DX}, F_{ir}^{DC}, F_{ijrs}^{QX}, or F_{irs}^{QC}. Those who do not have enough level of productivity become inactive even though they are once established.

In addition to Equations (1) through (20), the substitution elasticity for the manufactured product ($i =$ i02) is now defined as follows as increasing functions of the total number of varieties which are available for each economic agents in the destination country/region s:

$$\sigma_{ijs}^{TX} = \rho_{ijs}^{X}\left(N_{ijs}^{DX} + \sum_r N_{ijrs}^{QX}\right)^{\nu_{ijs}^{X}}, \tag{21}$$

and

$$\sigma_{is}^{TC} = \rho_{is}^{C}\left(N_{is}^{DC} + \sum_r N_{irs}^{QC}\right)^{\nu_{is}^{C}}, \tag{22}$$

where

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

$\nu_{ijs}^{X} \in [0,1]$ is the parameter that prescribes the influence of the total number of varieties available for a production sector to the substitution elasticity,

$\nu_{is}^{C} \in [0,1]$ is the parameter that prescribes the influence of the total number of varieties available for the final consumer to the substitution elasticity,

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

$N0_{ijs}^{DX}$ and $N0_{is}^{DC}$ are the initial numbers of firms active on the domestic market r, and

$N0_{ijrs}^{QX}$ and $N0_{irs}^{QC}$ are the initial numbers of exporting firms active on the r-s link.

When $\nu_{ijs}^{X} = 0$, σ_{ijs}^{TX} will not change. It is similar for the case of ν_{is}^{C} and σ_{is}^{TC}. Notice that σ_{ijs}^{TX} and σ_{is}^{TC} now have the suffices that distinguish economic agent as well as suffix s because the number of available varieties differs by destination country/region and by importer agent. σ_{ijs}^{TX} and σ_{is}^{TC} replace all of the σ_{i}^{T} that enters Equations (1) through (20).

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 (22):

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

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

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

and

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

Krugman-type Specification: In the Krugman-type specification, the following three relations apply, in addition to Equations (1) through (11), (20), (21), and (22):

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

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

and

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

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. For computational practice, the model was coded in the General Algebraic Modeling System (GAMS) and solved by its PATH solver, which enables us to easily handle complementary slackness.[1] Assuming that the US (r01) permanently

[1] Brook, Kendrick, and Meeraus (1992) and Ferris and Munson (1998).

removes tariff on the manufactured product (i02) imported from China (r02) for example, we examine how the calculated values of selected economic indicators change when the influence of the total number of varieties to the substitution elasticity for the manufacturing sector ($\nu_{"i02"}$) take different values from zero to unity. To highlight the effects of changing the value of $\nu_{"i02"}$, we also consider the case of simultaneously changing the levels of $\beta_{"i02"s}$ for all countries/regions, and compare the results. The main scenario is expressed by setting the rate of import tariff $\tau^{M}_{"i02""r02""r01"} = 0$, which initially is 2.967%.

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 the removal of import tariff levied in a specific trade link (trade in manufactured product from China to the US) and followed by sectoral adjustments.

Once the market price of the manufactured product imported from China falls in the US, due to the removal of tariff, the demand for the Chinese product relatively increases in the US, so that the wholesale price (producer price) of the manufactured product rises in China. In the US, the increased demand for the imports from China partially replace that for the manufactured substitutable produced domestically, so that its wholesale price falls in the US. While demand for the imports from the RoW also reduces in the US, China increases imports from the RoW to substitute its expensive domestic product, so that the changing direction of the wholesale price in the RoW is ambiguous. In many cases, the price tends to fall from its pre-liberalization level.

Based on these changes in the wholesale price in every country/region, the volumes of trade flow of manufactured products on each link can also be roughly projected. The US mainly consumes the commodity imported from China, so that the demand for the goods both domestically produced and imported from the RoW reduces. Meanwhile, the dealers/merchants in the US expand their exports to both the Chinese and RoW markets, as a substitutable to the relatively expensive Chinese product, although the sector-wide production of manufactured goods relatively reduces. In the same reason, the dealers/merchants in the RoW also increase their exports to China and other countries within the same region. As a result, the effects of liberalizing trade by the US for China on international and domestic trade flows of manufactured products by importer agent become the ones captured by Tables 1 through 4. The case of the Krugman-type with $\beta^{X}_{"i02"js} =$

$\beta^C_{"i02"s} = \nu^X_{"i02"js} = \nu^C_{"i02"s} = 0$, which generates the same results as those obtained by the conventional Armington-type, is chosen to see the basic effects of liberalizing trade for reference. The countries/regions at the left of the tables correspond to the sources while the ones at the top to the destinations. Note that the diagonal parts respectively include both domestic and intra-regional transactions. The changing rates in those two kinds of transactions are identical in the model.

In the US, the manufacturing and services sectors as well as the final consumer increase demand for imported Chinese products in exchange for reducing demand for commodities both domestically produced and 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, the primary industries in the US expands intermediate inputs of domestic products in addition to the one imported from China (see Table 2 column-wise along the "r01" headings on the top). One may notice that the magnitude of the expansion of demand for the Chinese products by the US primary industries is the greatest (9.860%) compared to the other agents (9.206%, 9.342%, and 9.360%). This implies that the relative volume of the primary industries becomes larger than the other production sectors in the US after liberalizing trade. Thus, the manufacturing sector shrinks in the US and the services follow.

China expands imports from the US and RoW, which prices are now relatively cheap (see column-wise across Tables 1 through 4 along the "r02" headings on the top). Except the primary industries, the manufacturing and services sectors as well as the final consumer also increase demand for the domestic products even though its price has been appreciating. The income increase brought by the improvement in terms of trade enabled this. In contrast, the primary sector reduces intermediate input of manufactured goods. Since the magnitude of the expansion of demand for the US products by the primary industries is the least (2.283%) compared to the other agents (2.265%, 2.688%, and 2.657%), one may notice that the relative volume of the primary sector becomes smaller than the other sectors in China. Hence, the manufacturing and services 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 the primary and services sectors as well as the final consumer expand their demand (Tables 1, 2, and 4), the manufacturing sector reduces (Table 3). The fact that the magnitude of the expansion of demand for the US products by the manufacturing sector is the least (1.201%) compared to the other agents (1.216%, 1.253%, and 1.215%) suggests that the relative volume of the manufacturing sector shrinks most in the RoW. Then, the services sector follows.

The removal of protection by the US for China brings firms in China to make profits easier because cheaper imported intermediates are now available so that the number of firm entry in the manufacturing sector tends to increase in China. Although it is difficult to project clearly, the reduced demand in the US for the manufactured commodity produced both in the US and in the RoW may lead reductions in the number of firm entry in those country and region. This time, the US is successful to increase exports to China and the RoW based on its cheapest pricing to the extent that cover the loss in the domestic sales, while the RoW fails to cover the loss in the US market by the increased exports to China and its domestic sales. Consequently, the number of firm entry increases in the US whereas reduces in the RoW. In this situation, the proportion of firms, which are active on each trade-link including the domestic market, shows completely similar changing pattern to the case of trade flows as captured by Tables 5 through 8, when the basic Melitz-type trade specification ($\beta^X_{"i02"js} = \beta^C_{"i02"s} = 1$ and $\nu^X_{"i02"js} = \nu^C_{"i02"s} = 0$) applies. In contrast, the hurdle to enter the domestic and international markets (the cut-off level of productivity) and the sales quantity per firm show completely opposite changes to the proportion of active firms (Tables 9 through 12). It is because there is a definitive rule in the Melitz-type trade specification that a higher/lower level of the cut-off productivity (also the average productivity) always decreases/increases the number of varieties and expands/shrinks the sales quantity per firm. This rule can be confirmed respectively differentiating Equations (14) and (18) with respect to φ^{QX}_{ijrs}:

$$\frac{\mathrm{d}\mu^{QX}_{ijrs}}{\mathrm{d}\varphi^{QX}_{ijrs}} = -\gamma_i \left(\frac{\gamma_i}{\gamma_i - \sigma^T_i + 1}\right)^{\gamma_i/(\sigma^T_i - 1)} \left(\varphi^{QX}_{ijrs}\right)^{-\gamma_i - 1} < 0,$$

and

$$\frac{\mathrm{d}Q^X_{ijrs}}{\mathrm{d}\varphi^{QX}_{ijrs}} = \frac{\gamma_i(\sigma^T_i - 1)}{\gamma_i - \sigma^T_i + 1} F^{QX}_{ijrs} > 0.$$

Analogous results can be obtained for the cases of consumption commodity and domestic firms differentiating Equations (12), (13), (15), (16), (17), and (19) with respect to the corresponding average productivity.

3.2 Effects of Changing Values of $\boldsymbol{\beta^X_{ijs}}$, $\boldsymbol{\beta^C_{is}}$, $\boldsymbol{\nu^X_{ijs}}$, and $\boldsymbol{\nu^C_{is}}$ on the Simulation Results

Next, let us see how the effects of liberalizing trade by the US for China on economic indicators change with different values of $\beta^X_{"i02"js}$, $\beta^C_{"i02"s}$, $\nu^X_{"i02"js}$, and $\nu^C_{"i02"s}$, which respectively controls the intensity of importer's PfV and the influence of the total number of varieties to the substitution elasticity. In the experiments, the values of one or a set of those four parameters changes from zero to unity, with the step width of 0.05.[2] Note that when the values of parameters categorized in the β-type (intensity of importer's PfV) are changed, those that in the ν-type (influence of the total number of varieties to the substitution elasticity) remains zero, and *vice versa*. When the β-type is set to zero, the intensive-margin represented by the sales quantity per firm and the extensive margin by the number of (active) firms are accounted for on the same weight. On the other hand, extra valuation on the changes in varieties is added when the β-type takes positive values. In many theoretical and applied models, the β-type parameters are (implicitly) set to unity so that those models draw maximum possible valuation from the extensive margin. In the following, we will see first the cases of changing parameters for all importer agents at the same time. Then, we see the cases of changing the β-type parameters by agent. Finally, we examine the effects of changing the ν-type by agent in comparisons with the earlier two cases of all agents or importer's PfV.

3.2.1 Simultaneous Changes in Parameters for All Agents

When the intensity of importer's PfV ($\beta^X_{"i02"js}$ and $\beta^C_{"i02"s}$) or the influence of the total number of varieties to the substitution elasticity ($\nu^X_{"i02"js}$ and $\nu^C_{"i02"s}$) are changed simultaneously for all agents, the model generates similar results to the ones we obtained in Oyamada (2019), which utilized a SaB-type model. The main differences come from the existence of the agent-specific items that enable finer adjustments in the SbA-type model used in this study. For instance, the endogenous substitution elasticity $\sigma^{TX}_{"i02"js}$ and $\sigma^{TC}_{"i02"s}$ can vary independently among agents in a SbA-type model while the elasticity is identical for all agents as $\sigma^{T}_{"i02"s}$ in a SaB-type. Thus, the SbA-type environment enables modelled economies to reallocate resources more efficiently compared to the cases in the SaB-type.

Figures 1 and 7 depict the effects of liberalizing imports of Chinese manufactured products by the US on regional welfare in each country/region: the US (r01), China (r02), and the RoW (r03). The effects are captured as percentage deviations from the base case. In Figure 1, the values of $\beta^X_{"i02"js}$ and $\beta^C_{"i02"s}$ are changed simultaneously from zero to unity keeping the values of $\nu^X_{"i02"js}$ and $\nu^C_{"i02"s}$ bound to zero. On the other hand, the values of

[2] Since there is no substantial difference was found for the values of $\nu^X_{"i02"js}$, and $\nu^C_{"i02"s}$ set greater than unity, we just focus on the range between zero and unity.

$\nu_{"i02"js}^{X}$ and $\nu_{"i02"s}^{C}$ are changed at the same time from zero to unity in Figure 7 keeping the values of $\beta_{"i02"js}^{X}$ and $\beta_{"i02"s}^{C}$ fixed to zero. In each figure, the red, blue, and green lines correspond to the Melitz-, Krugman-, and Armington-type trade specifications, respectively. The green Armington lines are presented to show the volumes of basic effects elicited mainly by changes in the terms of trade.

In Figures 1 and 7, welfare changes on the leftmost side, where $\beta_{"i02"js}^{X} = \beta_{"i02"s}^{C} = \nu_{"i02"js}^{X} = \nu_{"i02"s}^{C} = 0$, correspond to changes in total consumption quantity. Then, the differences between the blue Krugman and green Armington lines show the magnitudes of the fundamental extensive-margin effect that appear as changes in the number of firm entries.[3] Since there is no extra valuation on the changes in varieties, the effects calculated under the Krugman- and Armington-type specification become identical at $\beta_{"i02"js}^{X} = \beta_{"i02"s}^{C} = \nu_{"i02"js}^{X} = \nu_{"i02"s}^{C} = 0$. In turn, the differences between the red Melitz and blue Krugman lines imply the total volumes of the supplemental extensive- and intensive-margin effects. The former appears as changes in the proportion of active firms, whereas the latter appears as changes in the sales quantity per active firm. These two types of effects offset each other in the Melitz-type model by the aforementioned rule.

When the values of $\beta_{"i02"js}^{X}$ and $\beta_{"i02"s}^{C}$ are small and close to zero, the Melitz-type model tends to generate the lowest welfare levels for countries related to trade liberalization, the US and China (top and middle panels of Figure 1), whereas the highest for third countries, the RoW (bottom panel of Figure 1). In contrast, when the values of $\beta_{"i02"js}^{X}$ and $\beta_{"i02"s}^{C}$ are large and close to unity, the Melitz-type generates the highest welfare levels for the countries involved in the trade liberalization, whereas the lowest for countries outside of the framework. Thus, welfare effects projected by the Melitz-type model are more sensitive to changes in the values of $\beta_{"i02"js}^{X}$ and $\beta_{"i02"s}^{C}$. This occurs because the extra adjustment margin in the Melitz-type model basically yields negative intensive-margin effects in a situation when the cut-off productivity is lowered and poorly productive small-scale firms come into operation in the countries involved, while the fundamental extensive-margin effect, which is more explicit in the Krugman-type model, is always positive when the number of firm entries expands. In the top and middle panels of Figure 1, the magnitude of the negative intensive-margin effect excels that of the favorable supplemental extensive-margin effect in the interval when the red Melitz line lies below the blue

[3] We call the extensive-margin effect related to the changes in the number of firm entries as "fundamental extensive-margin effect," and the one based on the proportion of active firms as "supplemental extensive-margin effect." When we simply use the "extensive-margin effect," it includes only the former under the Krugman-type trade specification, whereas it implies the merger of both fundamental and supplementary effects under the Melitz-type.

Krugman line, whereas the positive extensive-margin effect outweighs when the red line lies above the blue line. Thus, homogeneous firm models including not only the Krugman- but also the Armington-types may generate larger welfare gains than the Melitz-type heterogeneous firm model if we assume weaker intensity of the PfV.

When the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ are shifting from zero to unity, the basic characteristics are essentially similar to the previously seen case of $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$ for the countries related to trade liberalization, although the shapes of figures are now diminishing (top and middle panels of Figure 7). If we focus on the third countries excluded from trade liberalization, there is a substantial difference between the cases when the values of the β- and ν-types are respectively changed (bottom panels of both Figures 1 and 7). When the PfV intensifies (by changing $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$), the US tries to expand imports from China without caring very much about price rise because China now has the most efficient environment to increase varieties (firm entries). Since the increase in imported varieties enables the US to reduce production costs through intermediate transactions more than the level that fully covers the appreciated input prices, based on the forward linkage suggested by Fujita *et al.* (2000:242), the US also expands exports to China under the scale economy so as to enable China to produce more varieties. Consequently, the ties between the US and China become strong and promote the formation of a trading bloc separated from the RoW. Thus, welfare worsens in the RoW as the values of $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$ increase (bottom panel of Figure 1). Contrarly, increasing the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ enables smoother resource relocations led by international trade (efficiency enhancing effect) in the environment with less distortion achieved by the removal of tariffs. Hence, welfare improves in the RoW as the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ grow (bottom panel of Figure 7). Note that welfare gains of the US are much larger with the Melitz-type specification in the SbA-type environment than those in the SaB-type. In our previous study (Oyamada, 2019), welfare gains of the US with the Melitz-type model were about half of the present levels generated in the SbA-type environment. In contrast, welfare gains of the RoW, which consistently kept the highest levels among the Armington-, Krugman-, and Melitz-type specifications regardless of the values of $\nu_{"i02"s}$ in the SaB-type environment, the gains of RoW projected by the Melitz-type model tend to be less than those by the Krugman-type in the present SbA-type setting. This suggests that the extra items for adjustment in the SbA-type model work more favorable to a country that liberalize imports compared to a third country that is excluded from trade liberalization when the Melitz-type specification is presumed.

To explore the background of the welfare effects, let us see changes in the wholesale prices of manufactured products. Similar to the case of the welfare effects, Figures 13 and 19 show the effects of liberalizing imports by the US of manufactured products from China on the wholesale price in each country/region. In Figure 13, the values of $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$ are simultaneously changed from zero to unity keeping the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ kept at zero, whereas the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ are changed from zero to unity in Figure 19 keeping the values of $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$ fixed to zero. When the values of $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$ increase, the price tends to rise in China as import demand expands in the US (middle panel of Figure 13). The reason why the price falls in the US when the Melitz-type specification applies is because the cost-reduction effect mentioned earlier is working substantially through intermediate transactions (top panel of Figure 13). In contrast, the cost-reduction effect based on the increase in variety is insufficient when the Krugman-type specification applies to cover the cost-expansion effect based on the increased price of intermediate inputs caused by the strong PfV. On the other hand, the wholesale price of manufactured goods produced in the RoW shows totally opposite reaction to that in the US. The price rises with the Melitz-type specifications whereas falls when the Krugman-type applies (bottom panel of Figure 13). Compared to the case of the PfV, the price tend to depreciates in all countries/regions, by the efficiency-enhancing effect of smoother substitution, when the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ increase (Figure 19). Note that the volumes of price reduction in the US and RoW are much larger with the case of changing the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ compared to the case of $\beta^{X}_{"i02"js}$ and $\beta^{C}_{"i02"s}$ (top and bottom panels of Figures 13 and 19). This brings significantly large welfare gains to the US and RoW when $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ take large values, which revert the welfare losses to positive gains (red line in the top panels as well as red and blue lines in the bottom panels respectively of Figures 1 and 7).

3.2.2 Changes in Parameters Selected from $\boldsymbol{\beta^{X}_{ijs}}$ and $\boldsymbol{\beta^{C}_{is}}$

Next, let us see the cases of changing the β-type parameters by agent. The scenario that the US unilaterally liberalize imports of Chinese manufactured products is the same as before. Figures 2 and 3 depict the effects of trade liberalization by the US on regional welfare in each country/region when $\beta^{C}_{"i02"s}$ (for the representative consumer) and $\beta^{X}_{"i02"js}$ (for producers) are respectively changed from zero to unity keeping the values of $\nu^{X}_{"i02"js}$ and $\nu^{C}_{"i02"s}$ as well as the β-type for the agents being out of focus fixed to zero. Figure 3 show the case when $\beta^{X}_{"i02"js}$ for all producers shift simultaneously.

There are mainly two kinds of differences from Figure 1. First, although it is a matter of course, the volumes of the impact are suppressed because the cost-reduction effect through intermediate transactions is absent in the case of shifting $\beta^{C}_{"i02"s}$ (Figure 2) nor the final consumer's extra valuation on the changes in varieties is not accounted for in the case of changing $\beta^{X}_{"i02"js}$ for all producers (Figure 3). Figures 2 and 3 suggest that the loss of the cost-reduction effect causes relatively heavy damage to welfare levels.[4] The second difference is the decline of welfare in the US when the Melitz-type specification applies in the case of changing $\beta^{C}_{"i02"s}$ (red line in the top panel of Figure 2). This is because the US expands demand for the Chinese manufactured products in exchange for reducing demand for commodities both domestically produced and imported from the RoW, so that the total number of varieties decreases under the condition that no cost-reduction effect works through increased intermediate demand for the imported Chinese products.

Figures 14 and 15 capture the effects on the wholesale price of manufactured products when $\beta^{C}_{"i02"s}$ for final consumers and $\beta^{X}_{"i02"js}$ for all producers are respectively changed from zero to unity. Since the cost-reduction effect through intermediate transactions is absent as noted, the effects shown in Figure 14 just reflect the changes in demand (mainly for final consumption). When the Melitz-type specification applies, for instance, the total demand for Chinese products increases while that for the US and RoW decreases. In turn, the effects shown in Figure 15 capture the synthesis of the cost-reduction effect working through intermediate transactions and the changes in demand (mainly for intermediate inputs). Since producers start purchasing manufactured commodities without caring much about price rise as the value of $\beta^{X}_{"i02"js}$ increases, the cost-reduction effect will be drowned out by expansions in demand. This is the reason why the red Melitz line for China has U-shaped figure (middle panel in Figure 15).

Since the contribution of the cost-reduction effect through intermediate transactions seems to be large in welfare changes, let us see the cases of independently changing $\beta^{X}_{"i02"js}$ by production sector. Figures 4 through 6 respectively depict the effects of trade liberalization by the US on regional welfare in each country/region when $\beta^{X}_{"i02""i01"s}$, $\beta^{X}_{"i02""i02"s}$, or $\beta^{X}_{"i02""i03"s}$ changes from zero to unity. In these cases, the cost-reduction effect through intermediate transactions seems not working substantially in primary industries. The effect in services is not large, either. The reason might be found in the shares of intermediate demand for manufactured commodities in the national/regional total demand: 1.57%, 3.09%, and 2.70% by primary industries, and 24.36%, 19.68%, and

[4] This is partly because the shares of final demand for manufactured commodities in the US (r01), China (r02), and the RoW (r03) are 39.87%, 20.25%, and 35.38% in the total demand.

22.71% by services, respectively in the US, China, and the RoW. Thus, the manufacturing sector, which uses 34.18%, 56.97%, and 39.22% of manufactured commodities as intermediate inputs, can be regarded as the most influential agent in this study.

If we see changes in the wholesale price of manufactured products, the influential position of the manufacturing sector can be confirmed. Figures 16 through 18 show the effects on the wholesale price when $\beta^X_{"i02""i01"s}$, $\beta^X_{"i02""i02"s}$, or $\beta^X_{"i02""i03"s}$ are respectively changed from zero to unity. Notice that the cost-reduction effect is relatively limited or not obvious in the cases of primary industries and services (Figures 16 and 18). Changing $\beta^X_{"i02""i01"s}$ or $\beta^X_{"i02""i03"s}$ tends to just inflate the basic effects we have seen in Section 3.1 that the post-liberalization sizes (so as intermediate demand for manufactured goods) of primary industries expand in the US and RoW and shrinks in China while those of services diminish in the US and RoW and magnifies in China. In contrast, figures for the manufacturing sector show similar patterns to those for the case when $\beta^X_{"i02"js}$ for all producers are changed simultaneously, even though there are differences in magnitudes (Figure 17 compared with Figure 15). Consequently, the manufacturing sector can be considered as the key agent in this case for example that may affect the entire economy effectively especially when the Melitz-type specification fits economic conditions. Implementing an economic policy targeting this agent may work efficiently.

3.2.3 Changes in Parameters Selected from ν^X_{ijs} and ν^C_{is}

Finally, let us move to see the cases of changing the ν-type parameters by agent. As in the previous cases, we presume unilateral liberalization by the US for the imports of Chinese manufactured products. Figures 8 and 9 show the effects on regional welfare in each country/region when $\nu^C_{"i02"s}$ (for the representative consumer) and $\nu^X_{"i02"js}$ (for producers) are respectively changed from zero to unity keeping the values of $\beta^C_{"i02"s}$ and $\beta^X_{"i02"js}$ as well as the ν-type for the agents being out of focus bound to zero. In Figure 9, $\nu^X_{"i02"js}$ for all producers are changed at the same time.

The largest differences from the previously seen cases of changing the ν-type parameters for all agents simultaneously, such that are captured by Figure 7, or changing the β-type parameters by agent, which are shown in Figures 2 and 3, can be found in welfare effects on the RoW when we utilize the Melitz-type model (red lines in the bottom panels of Figures 8 and 9). As we saw earlier, the efficiency-enhancing effect through smoother substitution will germinate when the values of $\nu^C_{"i02"s}$ or $\nu^X_{"i02"js}$ increases, so that even the third countries that are not directory involved in trade liberalization may improve welfare (red and blue lines in the bottom panel of Figure 7). Nevertheless, the RoW fails to improve welfare when the Melitz-type specification applies in the case of changing $\nu^{C}_{"i02"s}$ (red line in the bottom panel of Figure 8). In contrast, the RoW can be better off when the values of $\nu^{X}_{"i02"js}$ for all producers are relatively large in the Melitz-type model (red line in the bottom panel of Figure 9), although the volumes of the impact are smaller than the case that $\nu^{C}_{"i02"s}$ and $\nu^{X}_{"i02"js}$ for all agents shift simultaneously (as captured in Figure 7). This suggests that inter-sector and international spillovers of the effects of soother resource allocations through intermediate transactions among countries/regions amplify the efficiency-enhancing effect in the Melitz-type model to be a sufficiently large level for the third countries to improve welfare.

If we see Figure 20 that captures the effects on the wholesale price of manufactured products when $\nu^{C}_{"i02"s}$ for the representative consumer is changed from zero to unity, a story that is completely different from the cases of changing the β-type parameters comes into shape. As noted, the US tries to expand imports from China without caring very much about price rise when the PfV intensifies by changing $\beta^{C}_{"i02"s}$. On this basic trend, the wholesale price rises in China whereas falls in the US and RoW when the Melitz-type specification applies (red lines in Figure 14). In contrast, the wholesale price appreciates in the US and depreciates in China when $\nu^{C}_{"i02"s}$ increases with the Melitz-type specification (red lines in the top and middle panels in Figure 20). Since the efficiency-enhancing effect expanding through intermediate transactions is absent in this case, the US just increase demand for the domestically produced commodities, which have the cheapest price in the post-liberalization world, reducing imports of expensive Chinese products. Thus, economic agents pursue cheaper commodities in the environment where the influence of the total number of varieties to the substitution elasticity ($\nu^{C}_{"i02"s}$ and/or $\nu^{X}_{"i02"js}$) intensifies while an increase in the number of varieties just is important when economic agents have strong PfV (large $\beta^{C}_{"i02"s}$ and/or $\beta^{X}_{"i02"js}$).

Figure 21, which captures effects on the wholesale price of manufactured products when $\nu^{X}_{"i02"js}$ for all producers are changed simultaneously from zero to unity, show similar patterns to the ones in Figure 19. The price falls in all countries/regions as the values of $\nu^{X}_{"i02"js}$ for all agents grow by the efficiency-enhancing effect of smoother substitution. This also supports the hypothesis that the inter-sector and international connectedness through intermediate transactions play an important role in reinforcing the efficiency-enhancing effect of smoother substitution.

Then, let us see the cases of independently changing $\nu^{X}_{"i02"js}$ by production sector.

Figures 10 through 12 respectively depict the effects of trade liberalization by the US on regional welfare in each country/region when $\nu^{X}_{"i02""i01"s}$, $\nu^{X}_{"i02""i02"s}$, or $\nu^{X}_{"i02""i03"s}$ changes from zero to unity. First, the efficiency-enhancing effect of smoother substitution seems not to be fully amplified through the intermediate inputs of primary industries, as in the case of $\beta^{X}_{"i02""i01"s}$ (Figures 4 and 10). This might be based on the small shares of the sector's intermediate demand for manufactured commodities in the national/regional total demand (1.57%, 3.09%, and 2.70% in the US, China, and the RoW). Next, the welfare effects generated in the case of changing $\nu^{X}_{"i02""i02"s}$ for manufacturing show relatively similar patterns to those obtained in the case of changing $\beta^{X}_{"i02"js}$ for all producers (Figures 9 and 11). On the other hand, the effects obtained by changing $\nu^{X}_{"i02""i03"s}$ for services show similar patterns to those projected in the case of $\nu^{C}_{"i02"s}$ for the representative consumer (Figures 8 and 12). While the reason why the case of changing $\nu^{X}_{"i02""i03"s}$ for services tend to show similar patterns to those of $\nu^{C}_{"i02"s}$ for the representative consumer might be partly because of the shares of intermediate demand by the services sector in the total demand (24.36%, 19.68%, and 22.71% in the US, China, and the RoW), which are much smaller than those by manufacturing (34.18%, 56.97%, and 39.22% in the US, China, and the RoW). An important point here is that the share of intermediate demand by the manufacturing sector in the RoW (39.22%) has closer volume to the share of final demand (35.38%) compared to that of services (22.71%). These results suggests that the manufacturing sector, which differentiates outputs under monopolistic competition, is the key agent to strengthen the efficiency-enhancing effect of smoother substitution to the level that may enable the third countries outside of trade liberalization to also be better off.

Figures 22 through 24 show the effects on the wholesale price when $\nu^{X}_{"i02""i01"s}$, $\nu^{X}_{"i02""i02"s}$, or $\nu^{X}_{"i02""i03"s}$ are respectively changed from zero to unity. Similar to the previously explored cases of $\beta^{X}_{"i02""i01"s}$ or $\beta^{X}_{"i02""i03"s}$, the efficiency-enhancing effect of smoother substitution is relatively small in the cases of primary industries and services (Figures 22 and 24). Thus, changing $\nu^{X}_{"i02""i01"s}$ or $\nu^{X}_{"i02""i03"s}$ tends to simply reflect the trends in intermediate demand. Since Figure 23 shows similar patterns to the case when $\nu^{X}_{"i02"js}$ for all producers are changed simultaneously (captured in Figure 21), and some of the effects are projected even larger, the manufacturing sector can be regarded as the key agent that effectively transmits the efficiency-enhancing effect of smoother substitution to the global economy.

4. Concluding Remarks

Based on an intuition that an additional variety reduces the distance between varieties filling the gaps in existing varieties, this study explored the behavioral characteristics of a MRIO-based AGE model with the Melitz-type heterogeneous and Krugman-type homogeneous firms that operate under monopolistic competition. Choosing the case of unilateral import liberalization of Chinese manufactured products by the US for example, simulation experiments with the three-region, three-sector model of global trade, which endogenizes the substitution elasticity as an increasing function of the total number of varieties that are available for each economic agent on the demand side, revealed the following results.

1. Introducing agent-specific items that enable finer adjustments in a SbA-type model may work more favorable to a country that liberalize imports compared to a third country that are not directory involved in trade liberalization when the Melitz-type trade specification is assumed.

2. Since smoother adjustment will be enabled by variable substitution elasticity, the efficiency-enhancing effect of international trade may bring significantly large welfare gains to all countries in the global economy in an environment with less distortion achieved by removal of tariffs so that even third countries excluded from trade liberalization can recover welfare losses to positive gains.

3. Inter-sector and international spillovers of the effects of smoother resource relocations through intermediate transactions among countries/regions amplify the efficiency-enhancing effect in the Melitz-type model to be a sufficiently large level for third countries to improve welfare.

4. In this study, the manufacturing sector, which differentiates outputs under monopolistic competition, plays an important role as the key agent that effectively transmits the efficiency-enhancing effect of smoother substitution to the global economy. Implementing an economic policy targeting this agent may work efficiently.

5. While economic agents pursue variety increase no matter how much the price

appreciates in the environment with strong PfV, agents just pursue cheaper commodities in more efficient circumstance when the influence of the total number of varieties to the substitution elasticity intensifies.

The simulation experiments demonstrated in this study also embossed that the magnitudes or directions of economic effects can be easily controlled to generate "preferable" results choosing "suitable" values of the β-type or ν-type parameters. Therefore, it must be very important to pursue a reasonable and agreeable way to determine values of those parameters along with estimating values of basic elasticity of substitution and the Pareto shape parameter.

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Table 1. Percentage Changes in Trade Flow of Manufactured Product (Krugman: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, 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

Table 2. Percentage Changes in Trade Flow of Manufactured Product (Krugman: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, 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

Table 3. Percentage Changes in Trade Flow of Manufactured Product (Krugman: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, 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

Table 4. Percentage Changes in Trade Flow of Manufactured Product (Krugman: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, 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

Table 5. Percentage Changes in Proportion of Active Firms (Melitz: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Final Demand)

	r01	r02	r03
r01	-0.603	4.700	2.105
r02	15.147	-0.187	-2.661
r03	-2.596	2.601	0.059

Table 6. Percentage Changes in Proportion of Active Firms (Melitz: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Intermediate - Primary)

	r01	r02	r03
r01	0.068	3.914	2.219
r02	15.924	-0.936	-2.552
r03	-1.938	1.831	0.170

Table 7. Percentage Changes in Proportion of Active Firms (Melitz: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Intermediate - Manufacturing)

	r01	r02	r03
r01	-0.434	4.637	2.049
r02	15.343	-0.247	-2.715
r03	-2.430	2.539	0.003

Table 8. Percentage Changes in Proportion of Active Firms (Melitz: $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Intermediate - Services)

	r01	r02	r03
r01	-0.373	4.612	2.118
r02	15.414	-0.271	-2.349
r03	-2.370	2.515	0.071

Table 9. Percentage Changes in Sales Quantity per Firm (Melitz: $\boldsymbol{\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0}$, Final Demand)

	r01	r02	r03
r01	0.121	-0.914	-0.416
r02	-2.781	0.037	0.541
r03	0.527	-0.512	-0.012

Table 10. Percentage Changes in Sales Quantity per Firm (Melitz: $\boldsymbol{\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0}$, Intermediate - Primary)

	r01	r02	r03
r01	-0.014	-0.765	-0.438
r02	-2.912	0.188	0.518
r03	0.392	-0.362	-0.034

Table 11. Percentage Changes in Sales Quantity per Firm (Melitz: $\boldsymbol{\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0}$, Intermediate - Manufacturing)

	r01	r02	r03
r01	0.087	-0.902	-0.405
r02	-2.814	0.050	0.552
r03	0.493	-0.500	-0.001

Table 12. Percentage Changes in Sales Quantity per Firm (Melitz: $\boldsymbol{\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 1,\ \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0}$, Intermediate - Services)

	r01	r02	r03
r01	0.075	-0.898	-0.418
r02	-2.826	0.054	0.538
r03	0.481	-0.496	-0.014

Figure 1. Welfare Effects (%, $\nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, All Agents)

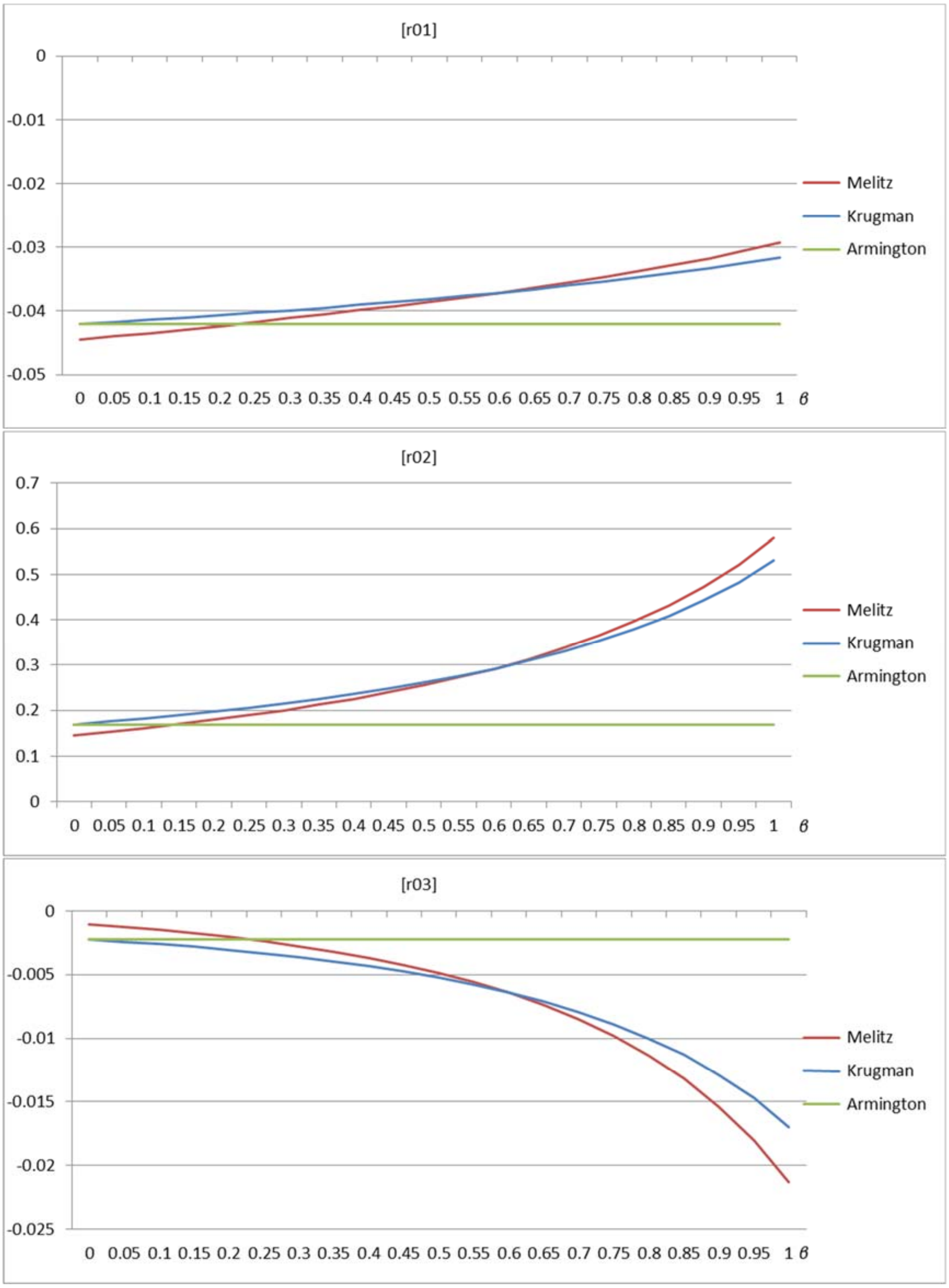

Figure 2. Welfare Effects (%, $\beta^{X}_{"i02"js} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Final Demand)

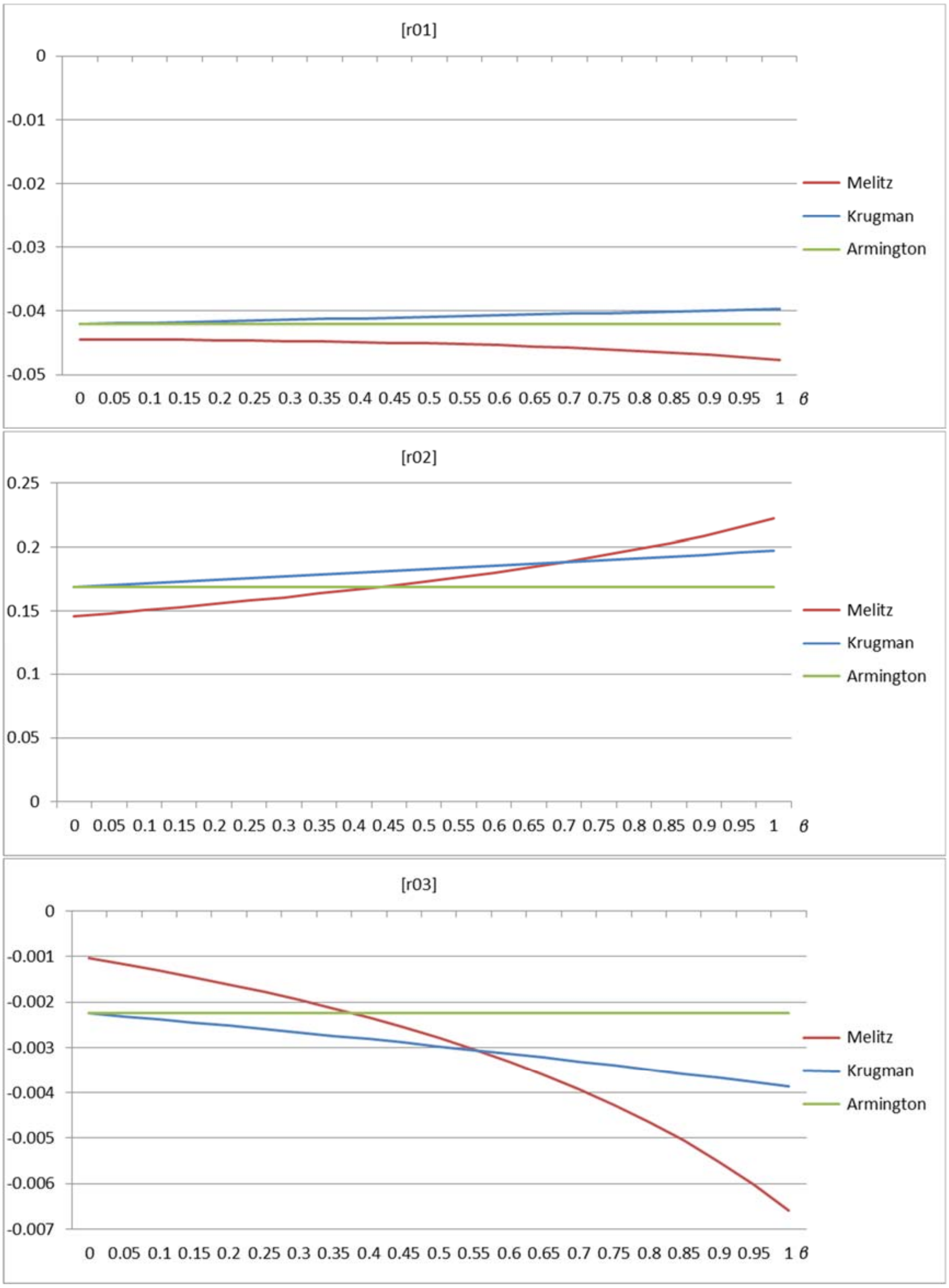

Figure 3. Welfare Effects (%, $\beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, All Intermediates)

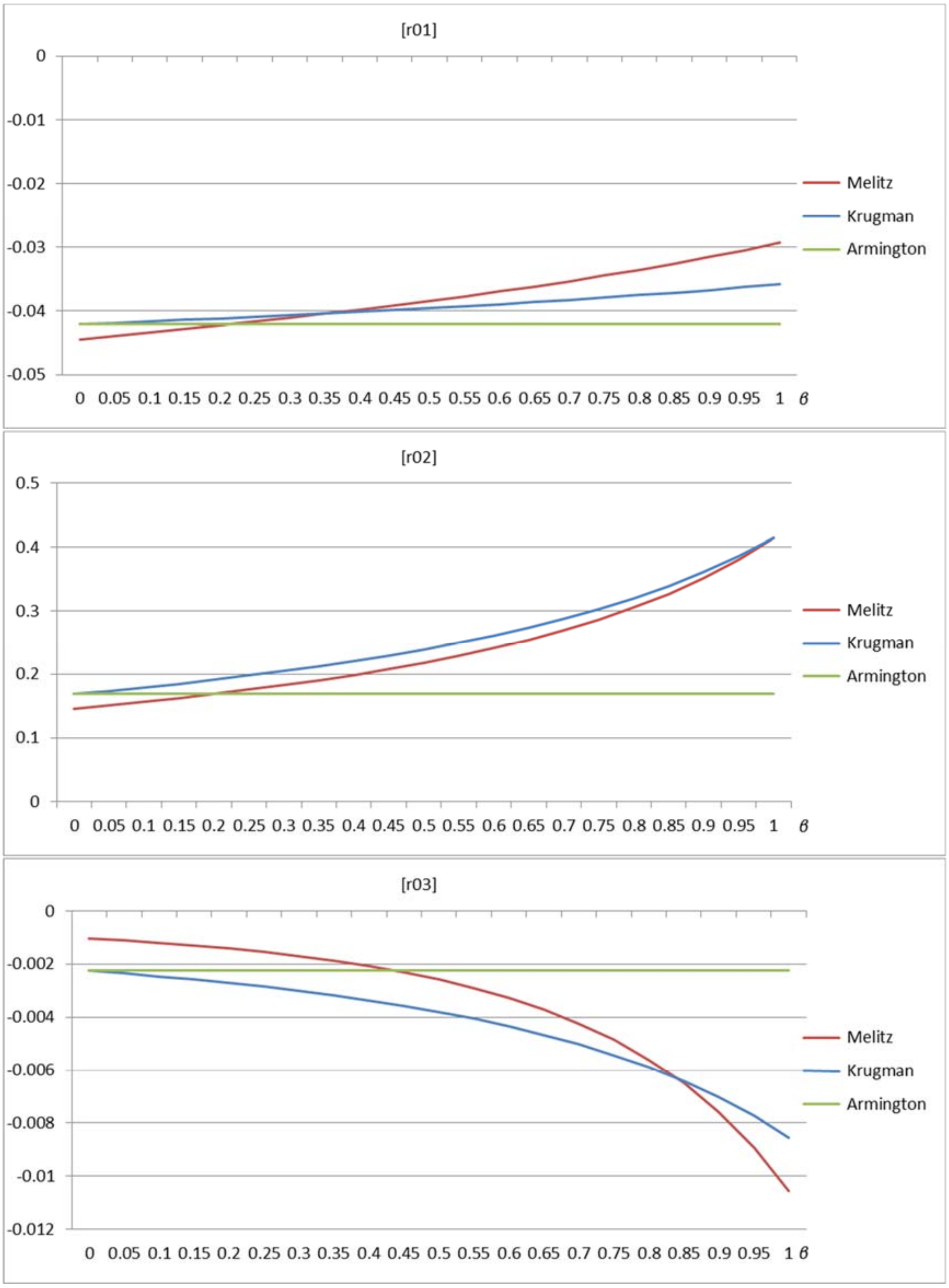

Figure 4. Welfare Effects (%, $\beta^X_{"i02""i02"s} = \beta^X_{"i02""i03"s} = \beta^C_{"i02"s} = \nu^X_{"i02"js} = \nu^C_{"i02"s} = 0$, Intermediate - Primary)

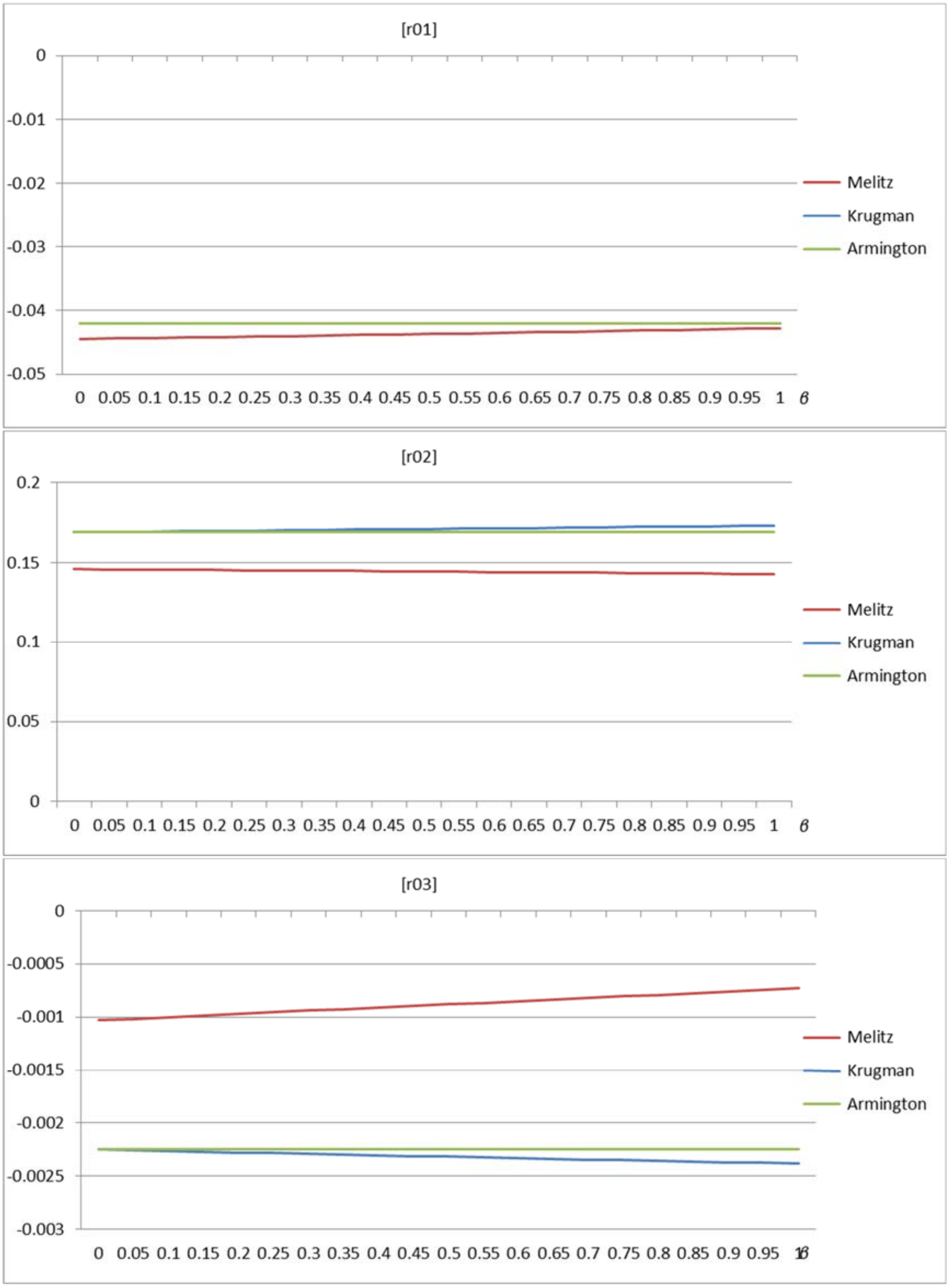

Figure 5. Welfare Effects (%, $\boldsymbol{\beta^{X}_{"i02""i01"s} = \beta^{X}_{"i02""i03"s} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0}$, Intermediate - Manufacturing)

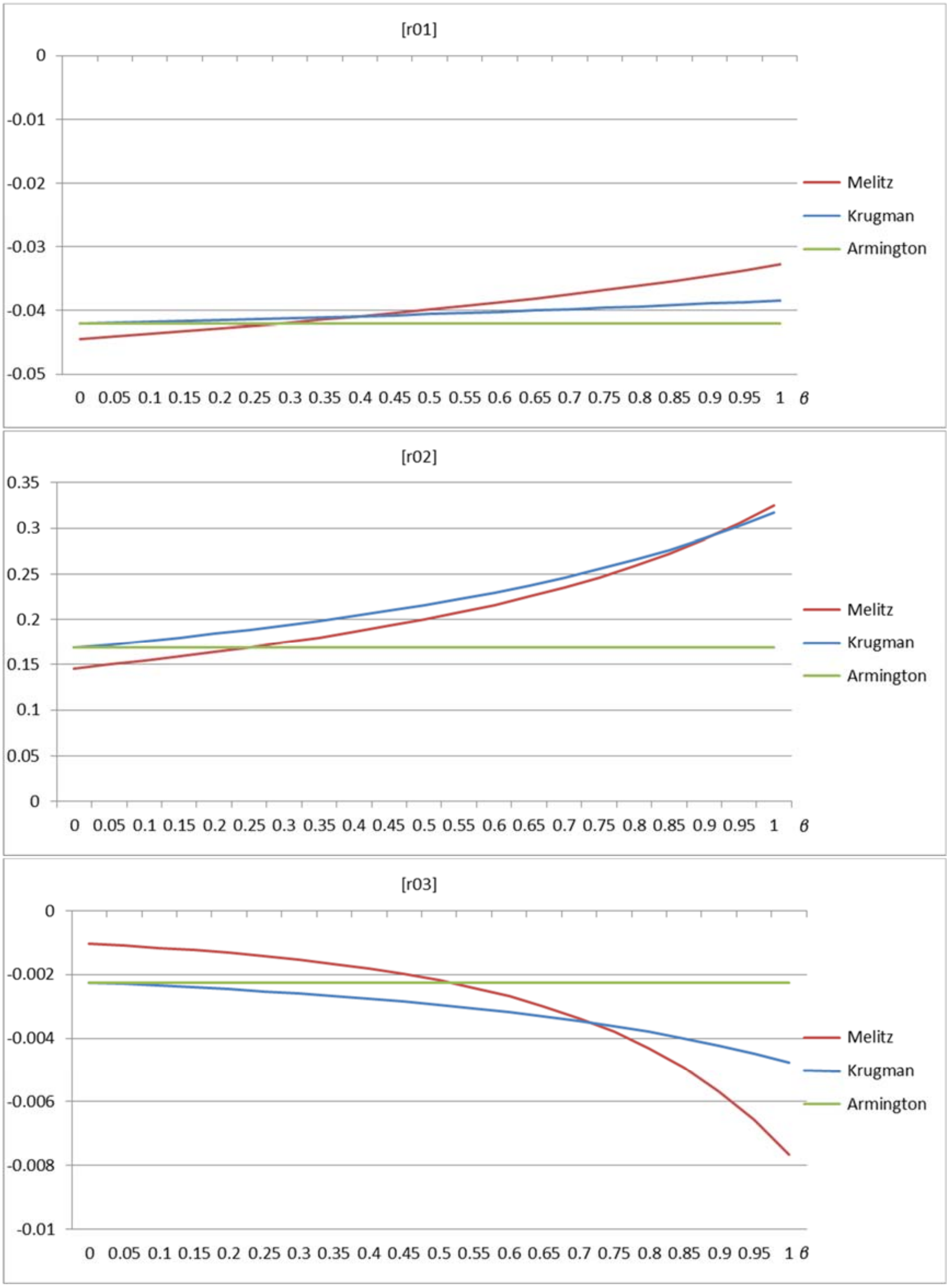

Figure 6. Welfare Effects (%, $\beta^{X}_{"i02""i01"s} = \beta^{X}_{"i02""i02"s} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Intermediate - Services)

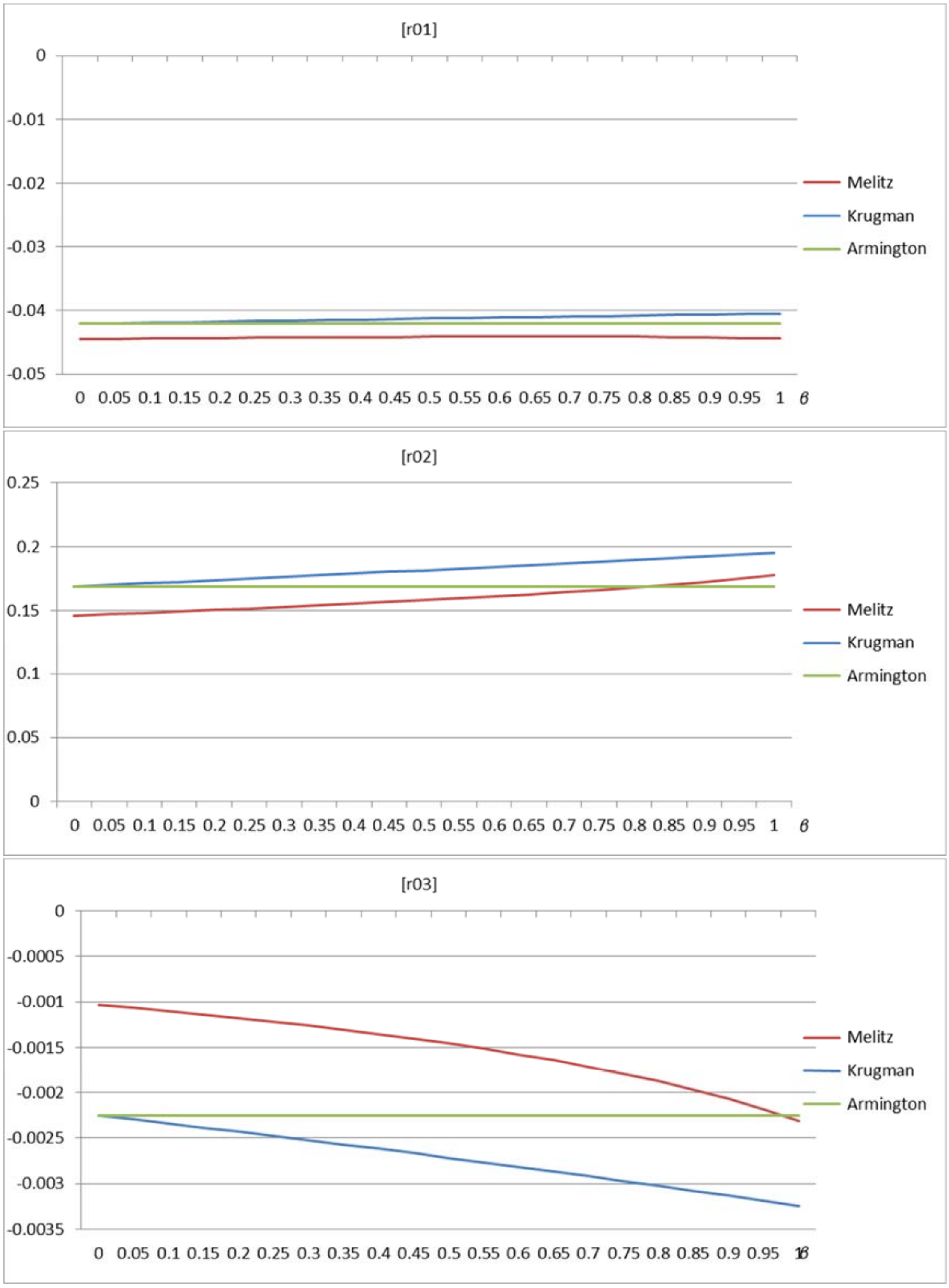

Figure 7. Welfare Effects (%, $\boldsymbol{\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 0}$, All Agents)

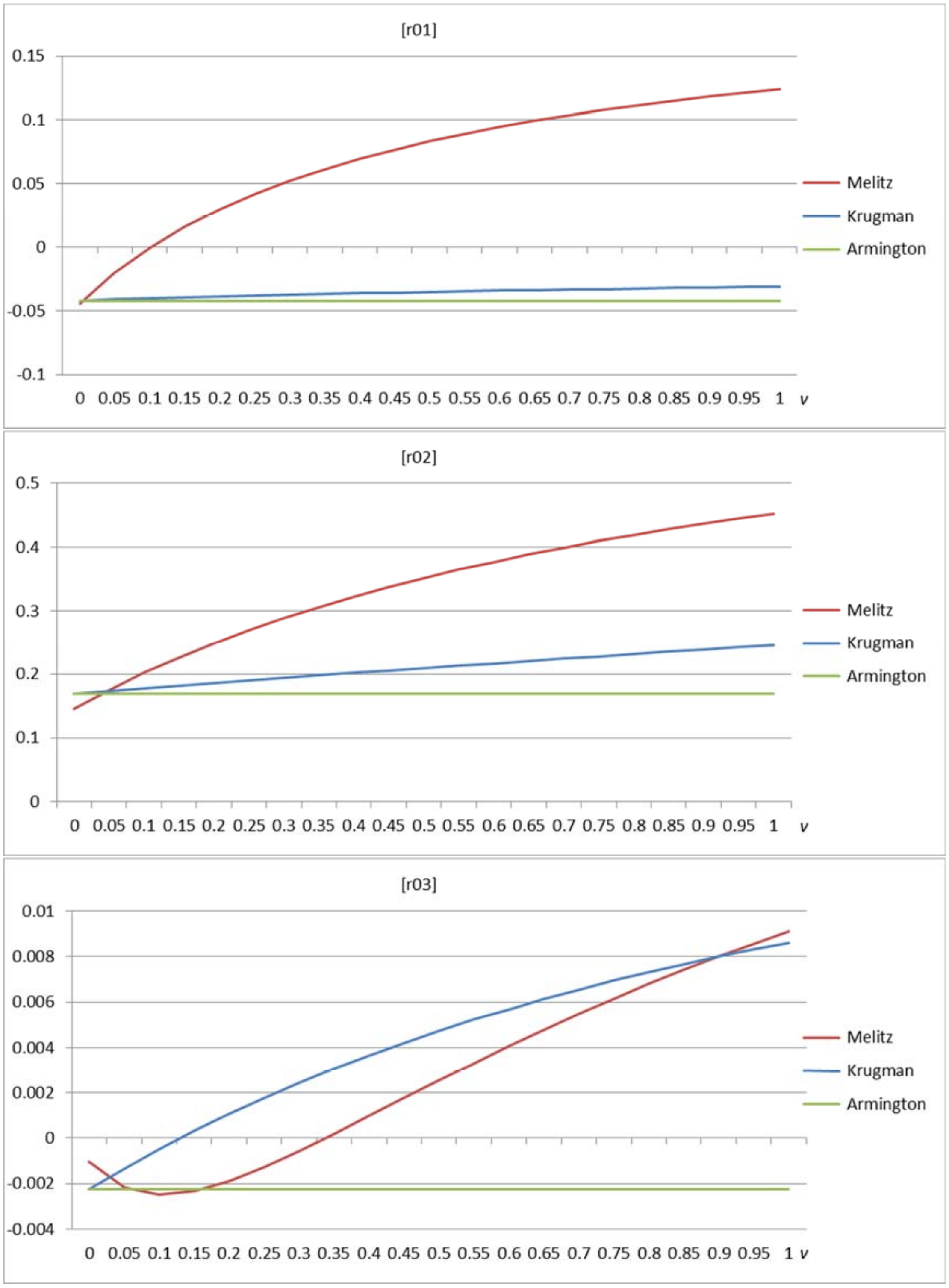

Figure 8. Welfare Effects (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = 0$, Final Demand)

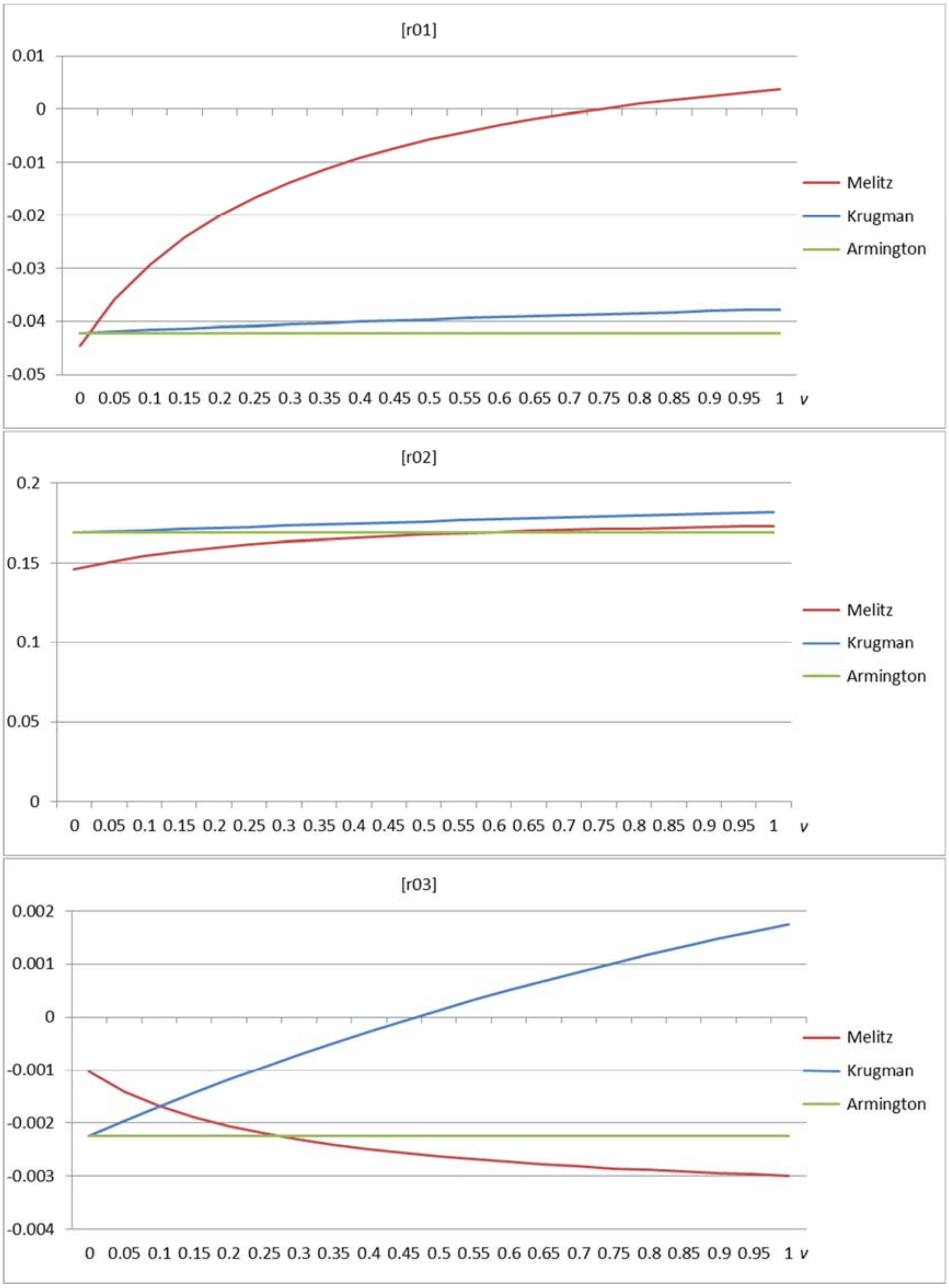

Figure 9. Welfare Effects (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{C}_{"i02"s} = 0$, All Intermediates)

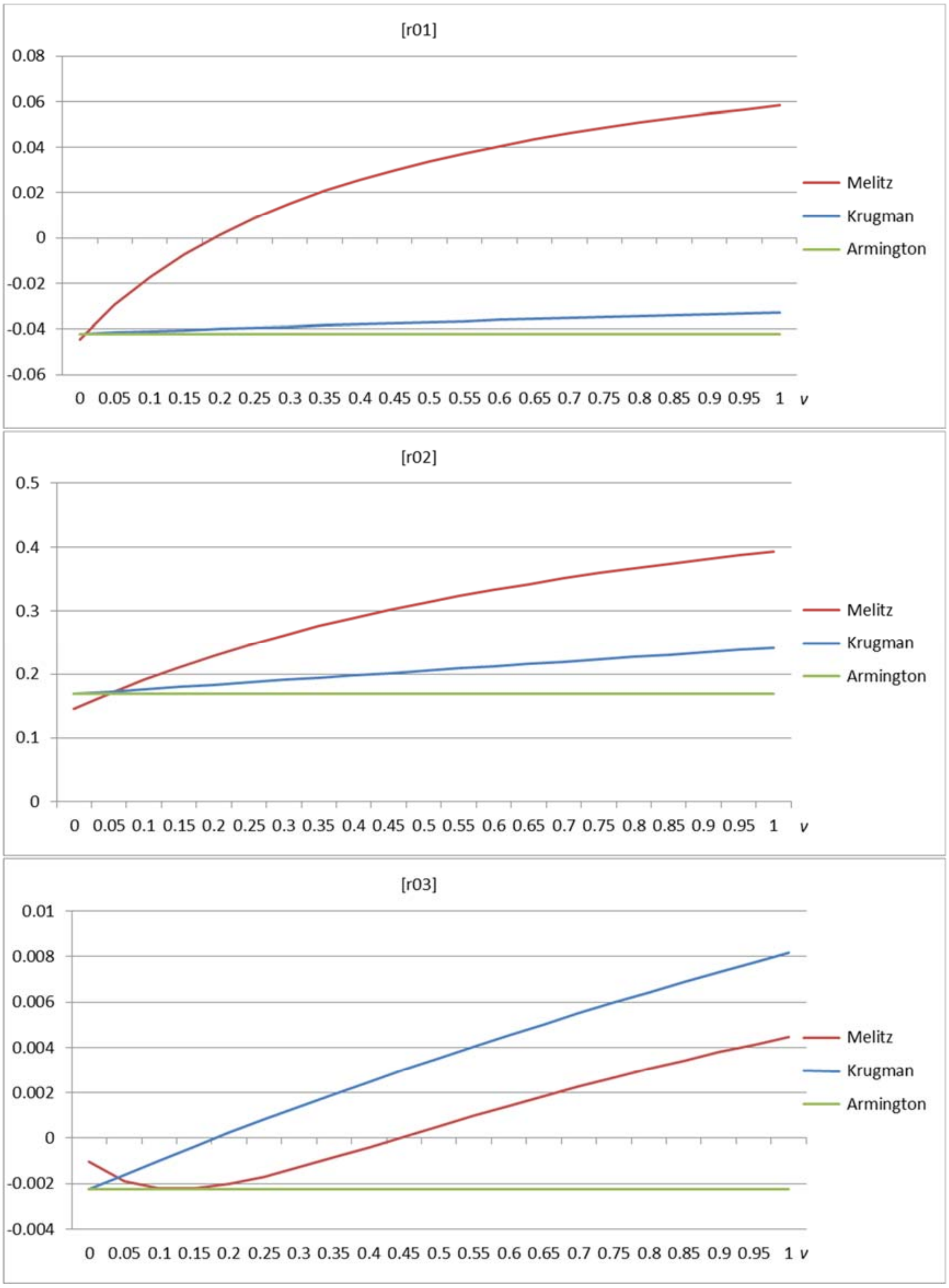

Figure 10. Welfare Effects (%, $\beta^X_{"i02"js} = \beta^C_{"i02"s} = \nu^X_{"i02""i02"s} = \nu^X_{"i02""i03"s} = \nu^C_{"i02"s} = 0$, Intermediate - Primary)

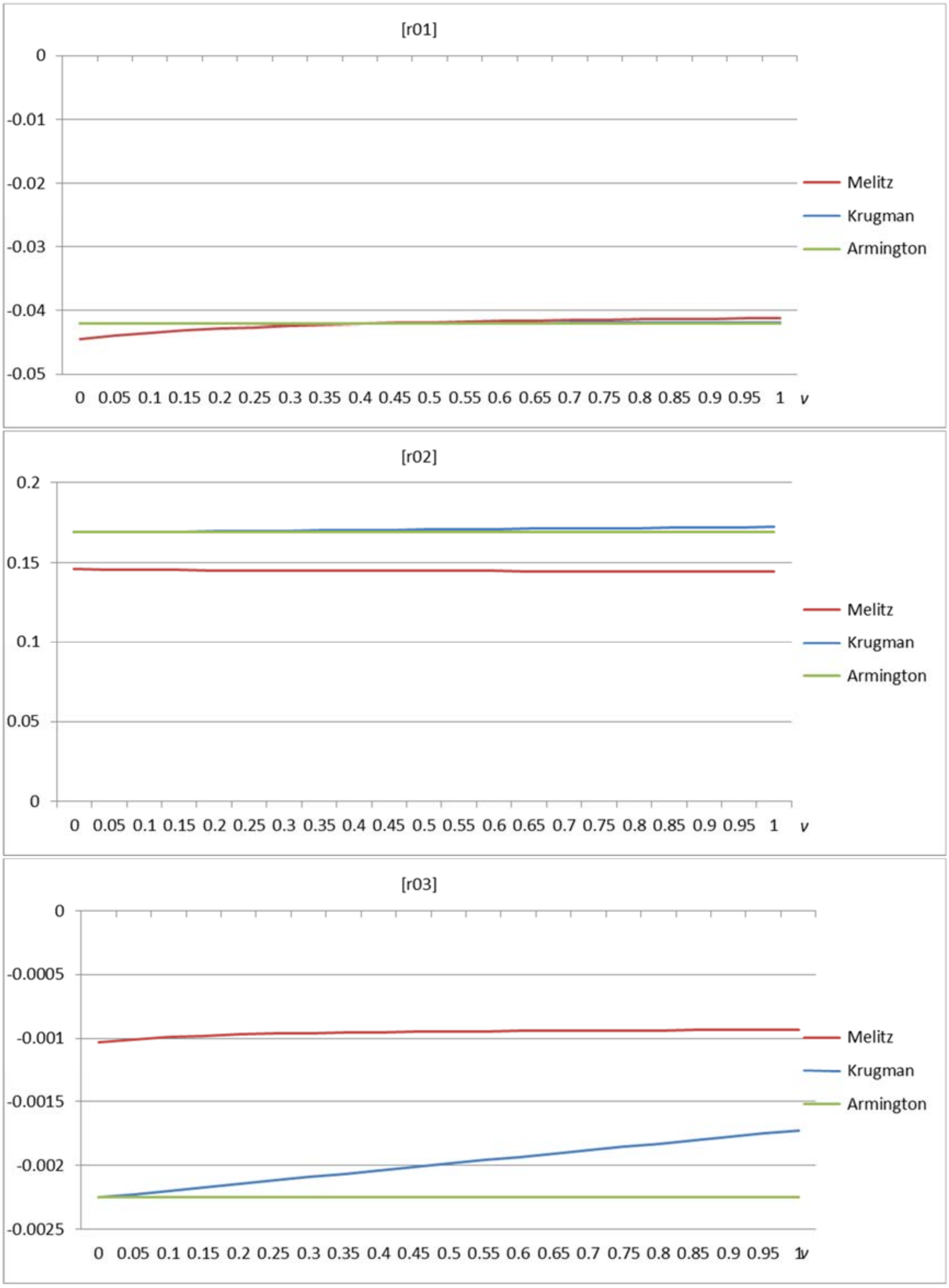

Figure 11. Welfare Effects (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02""i01"s} = \nu^{X}_{"i02""i03"s} = \nu^{C}_{"i02"s} = 0$, Intermediate - Manufacturing)

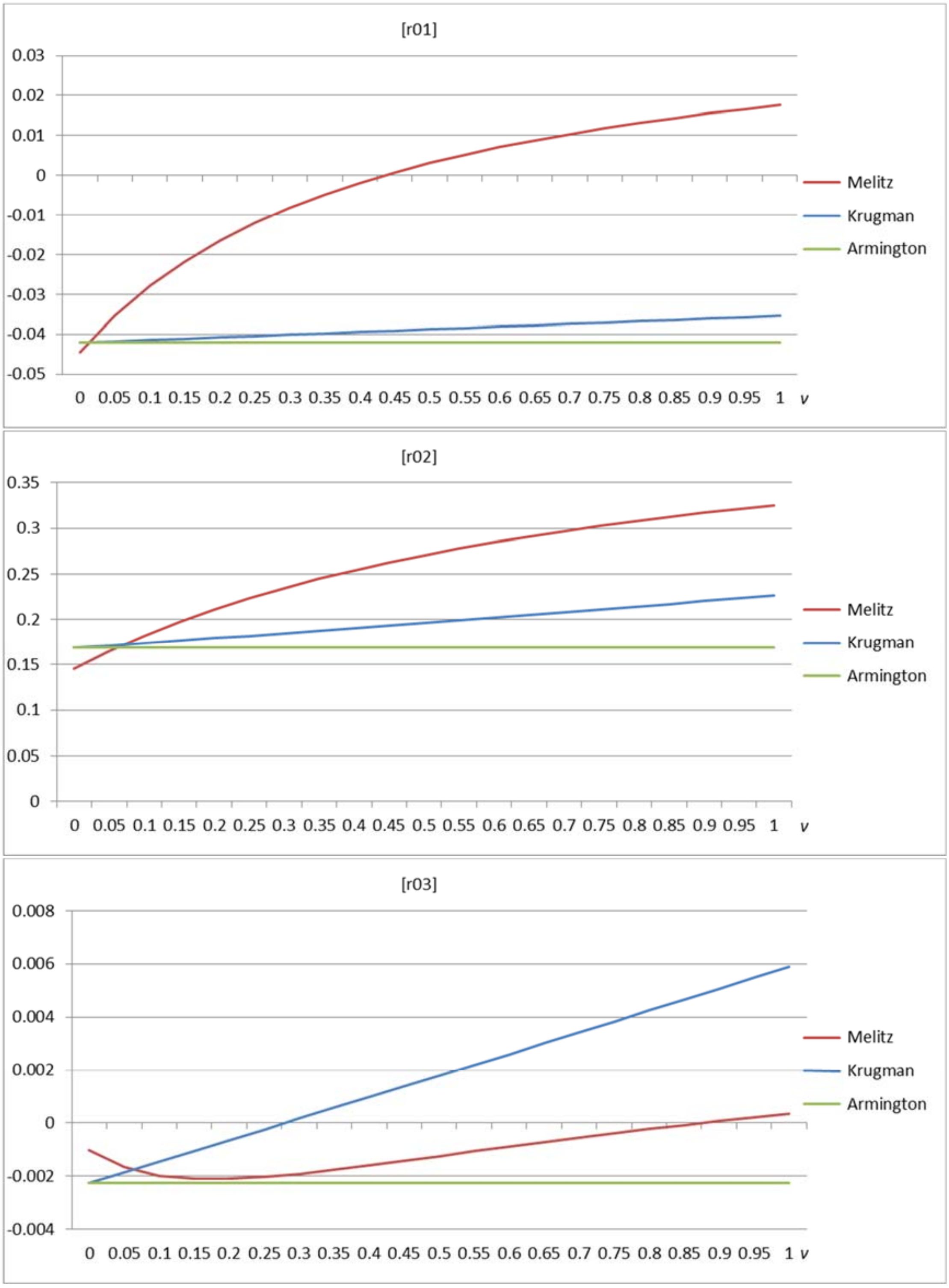

Figure 12. Welfare Effects (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02""i01"s} = \nu^{X}_{"i02""i02"s} = \nu^{C}_{"i02"s} = 0$, Intermediate - Services)

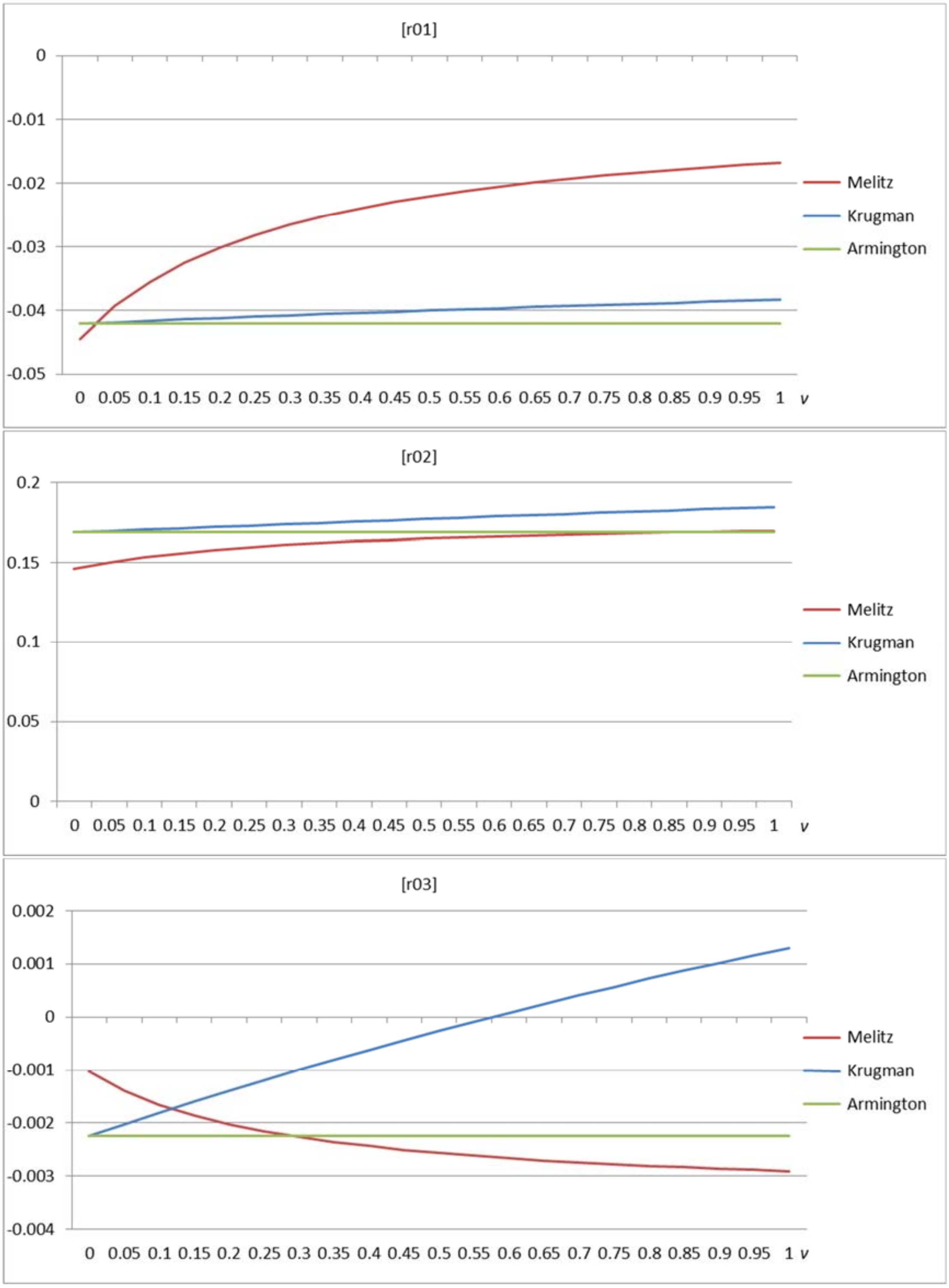

Figure 13. Effects on Wholesale Price of Manufactured Product (%, $\nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, All Agents)

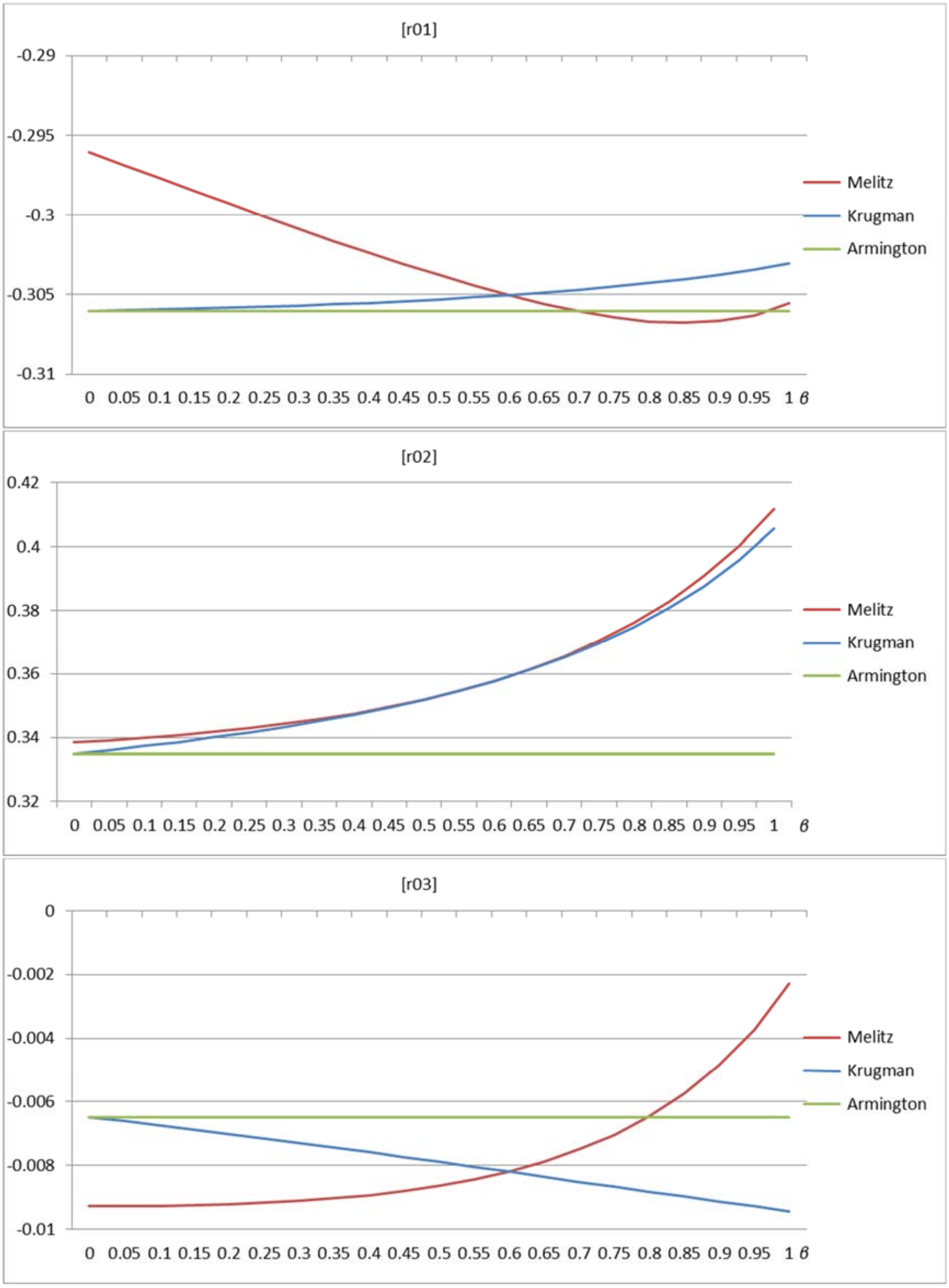

Figure 14. Effects on Wholesale Price of Manufactured Product (%, $\beta^X_{"i02"js} = \nu^X_{"i02"js} = \nu^C_{"i02"s} = 0$, Final Demand)

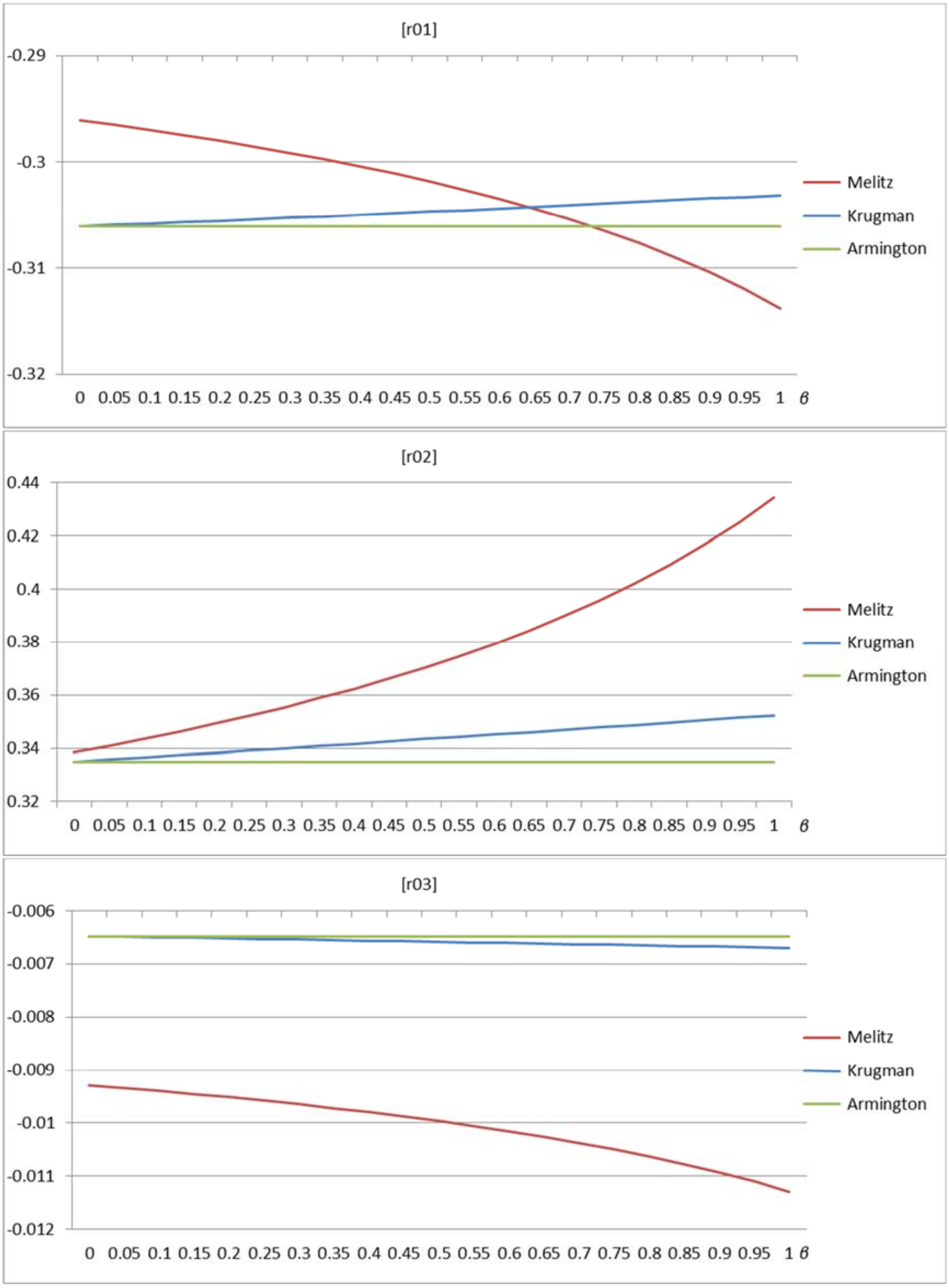

Figure 15. Effects on Wholesale Price of Manufactured Product (%, $\beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, All Intermediates)

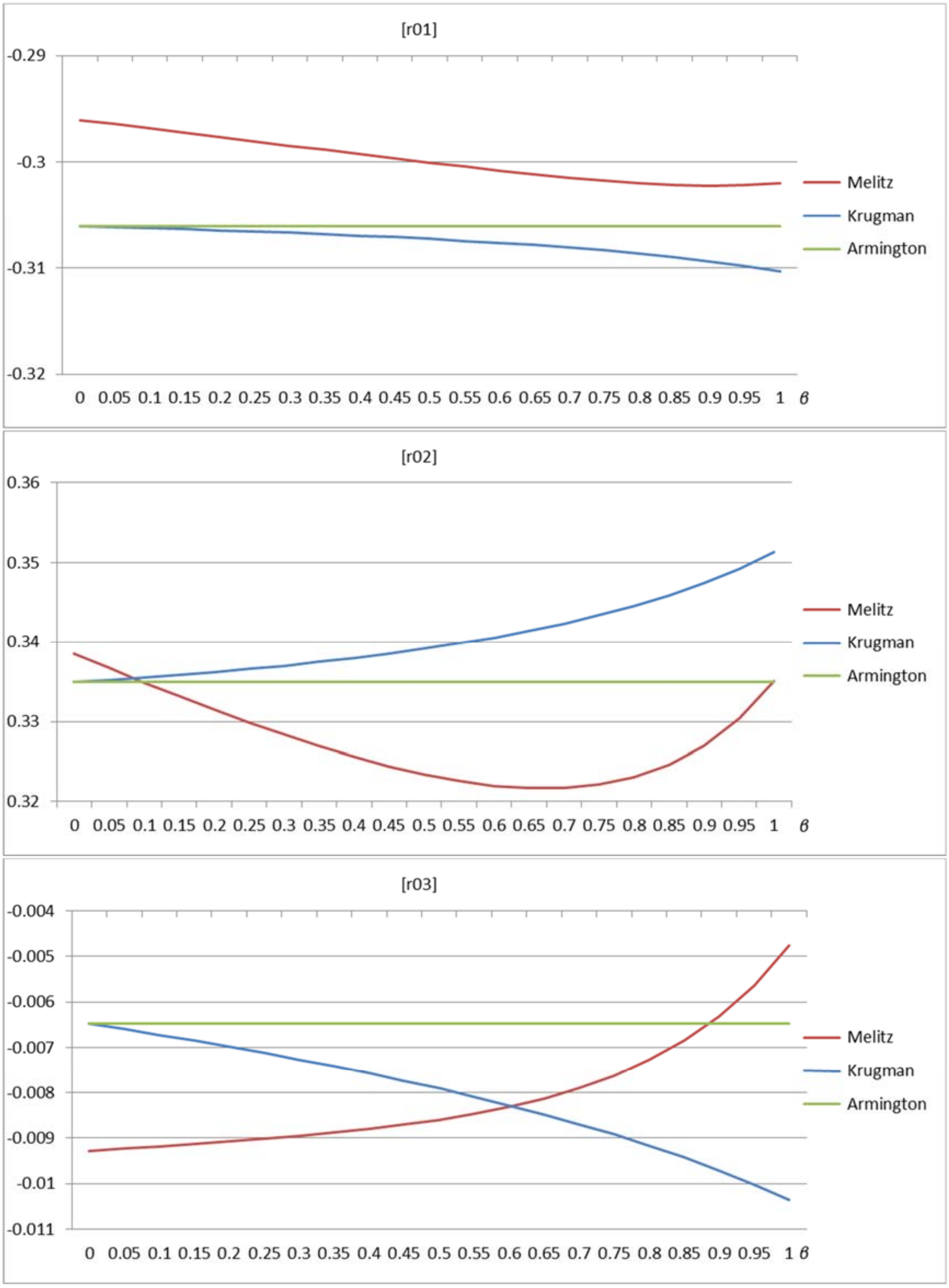

Figure 16. Effects on Wholesale Price of Manufactured Product (%, $\boldsymbol{\beta^X_{"i02""i02"s} = \beta^X_{"i02""i03"s} = \beta^C_{"i02"s} = \nu^X_{"i02"js} = \nu^C_{"i02"s} = 0}$, Intermediate - Primary)

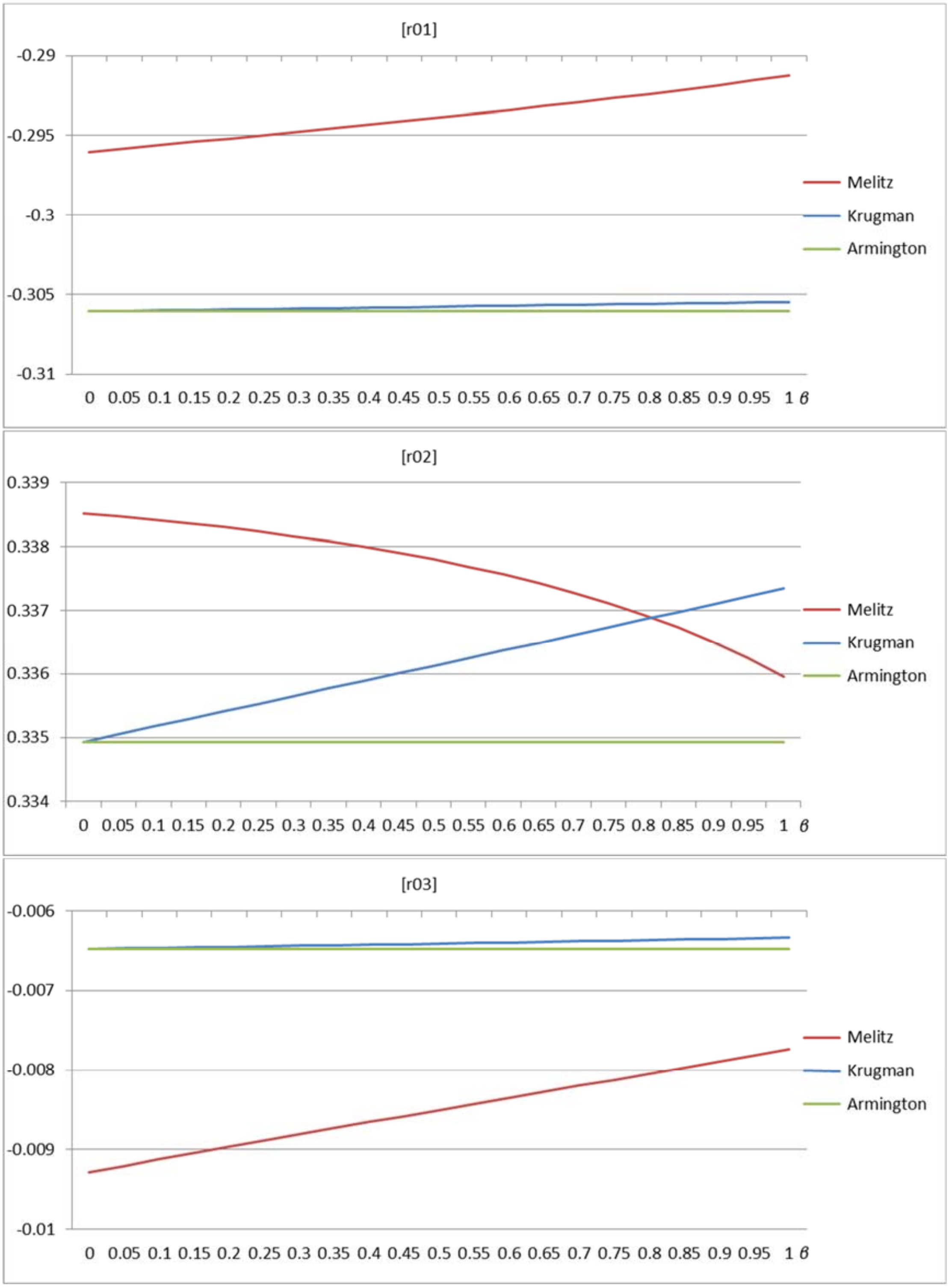

Figure 17. Effects on Wholesale Price of Manufactured Product (%, $\beta^{X}_{"i02""i01"s} = \beta^{X}_{"i02""i03"s} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = \nu^{C}_{"i02"s} = 0$, Intermediate – Manuf.)

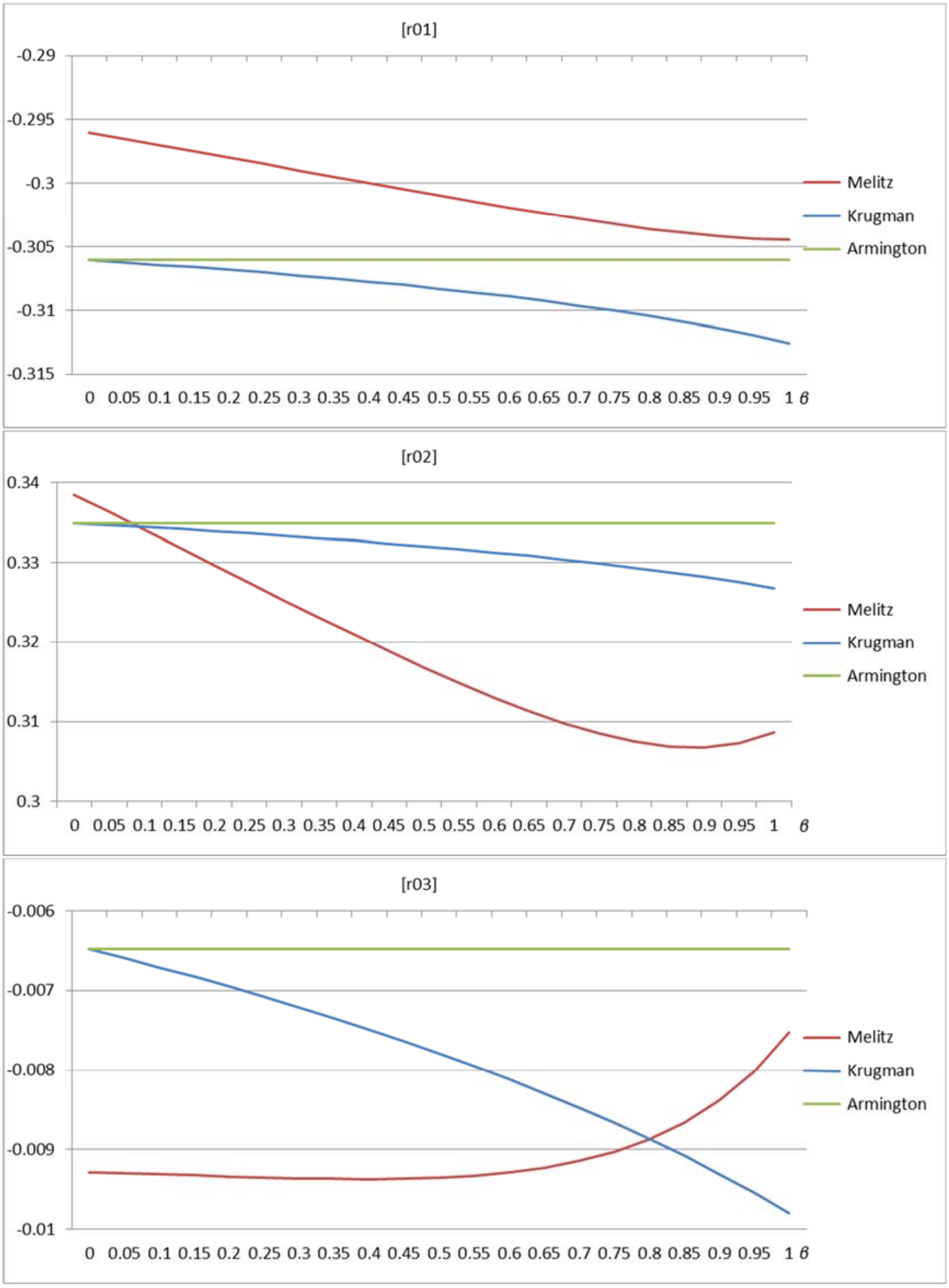

Figure 18. Effects on Wholesale Price of Manufactured Product (%, $\beta^X_{"i02""i01"s} = \beta^X_{"i02""i02"s} = \beta^C_{"i02"s} = \nu^X_{"i02"js} = \nu^C_{"i02"s} = 0$, Intermediate - Services)

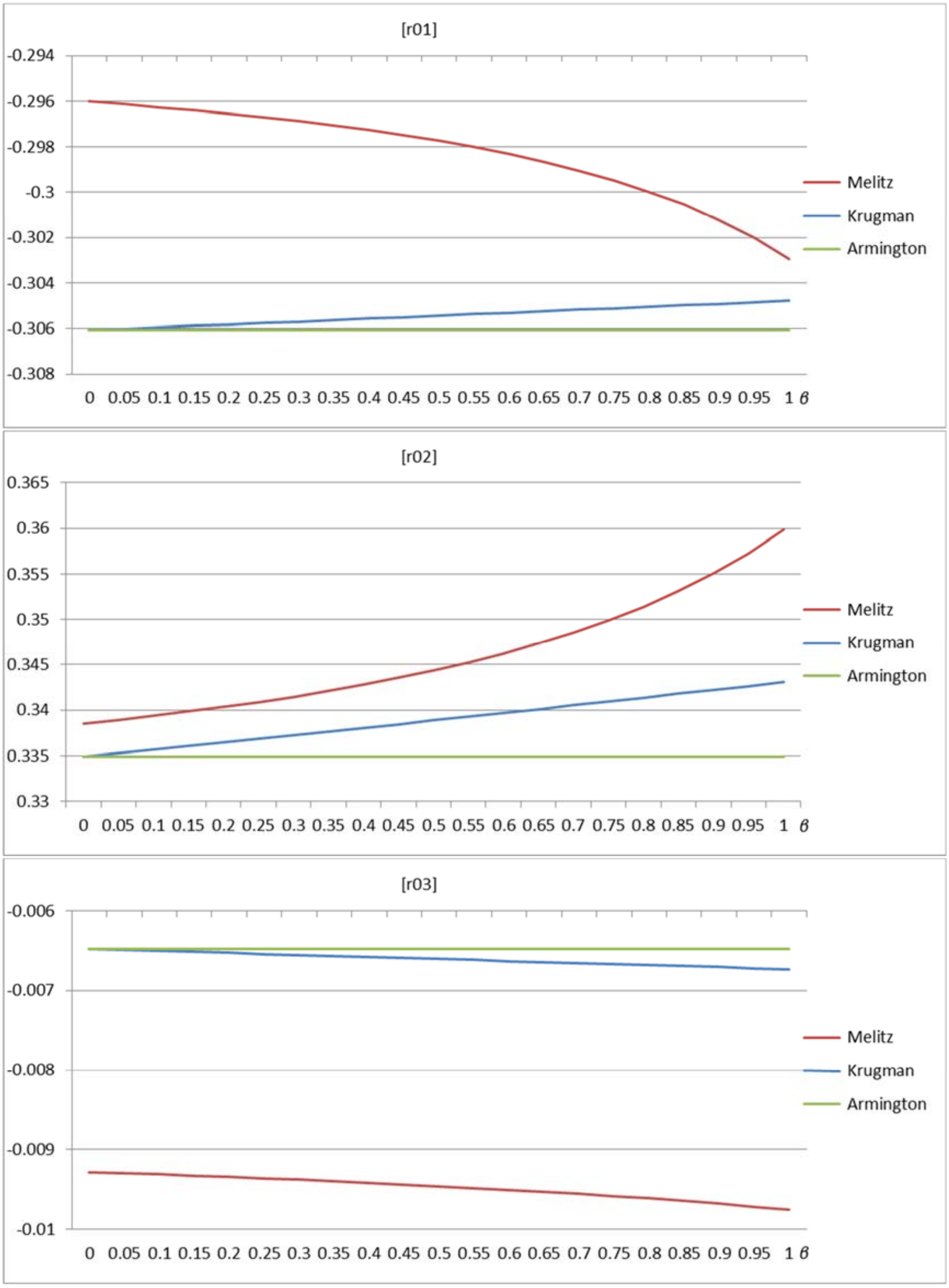

Figure 19. Effects on Wholesale Price of Manufactured Product (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = 0$, All Agents)

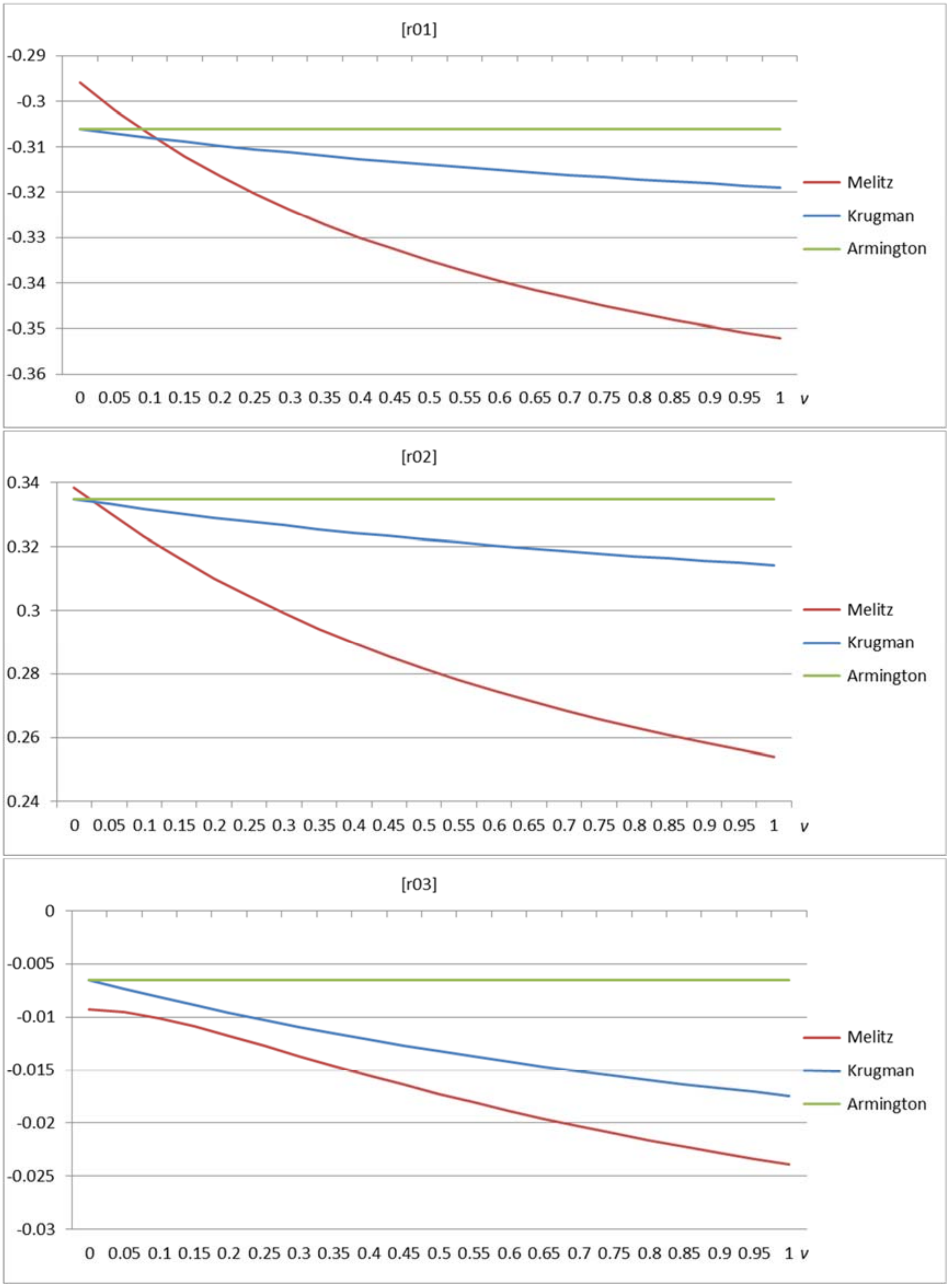

Figure 20. Effects on Wholesale Price of Manufactured Product (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02"js} = 0$, Final Demand)

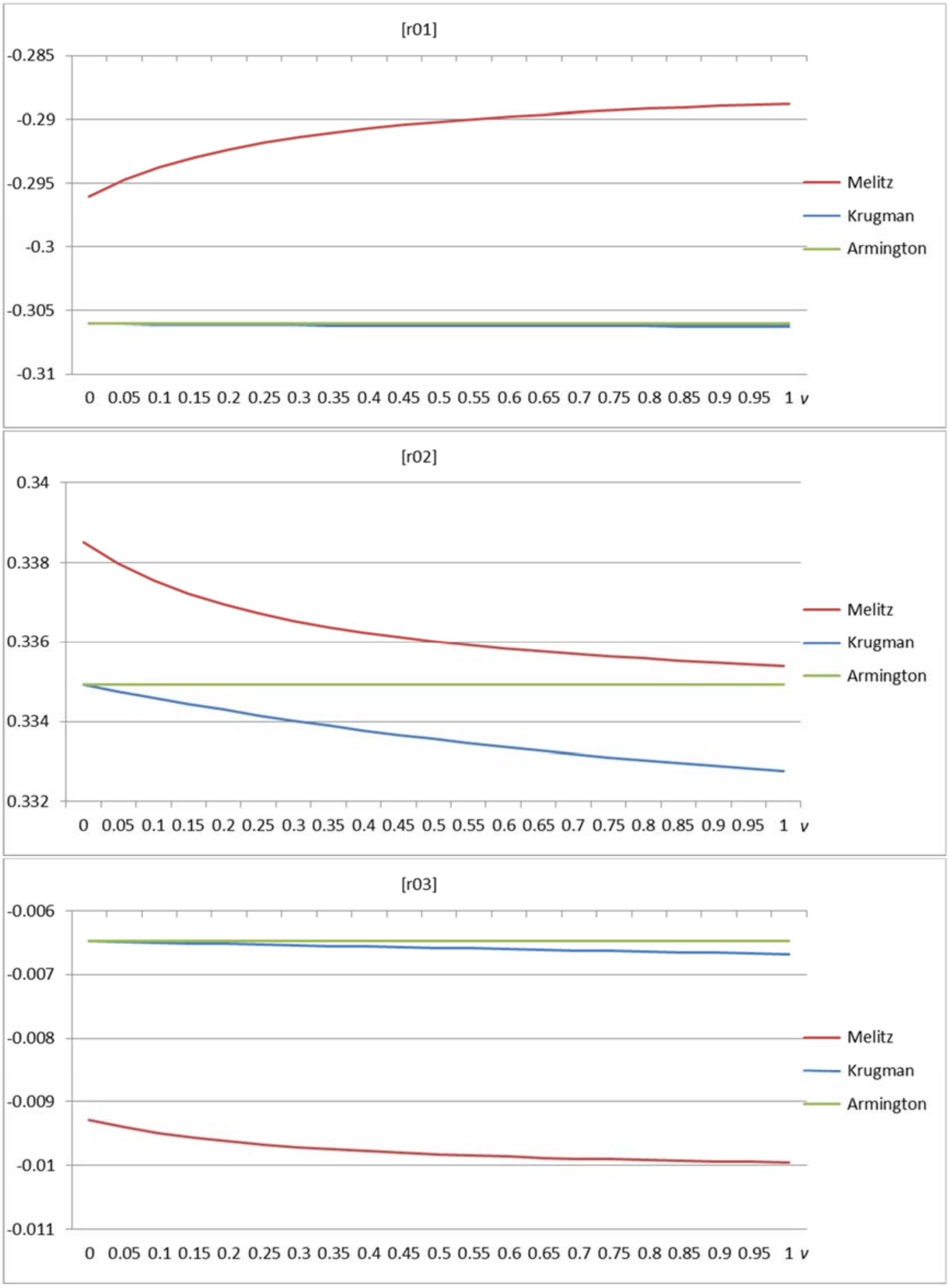

Figure 21. Effects on Wholesale Price of Manufactured Product (%, $\boldsymbol{\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{C}_{"i02"s} = 0}$, All Intermediates)

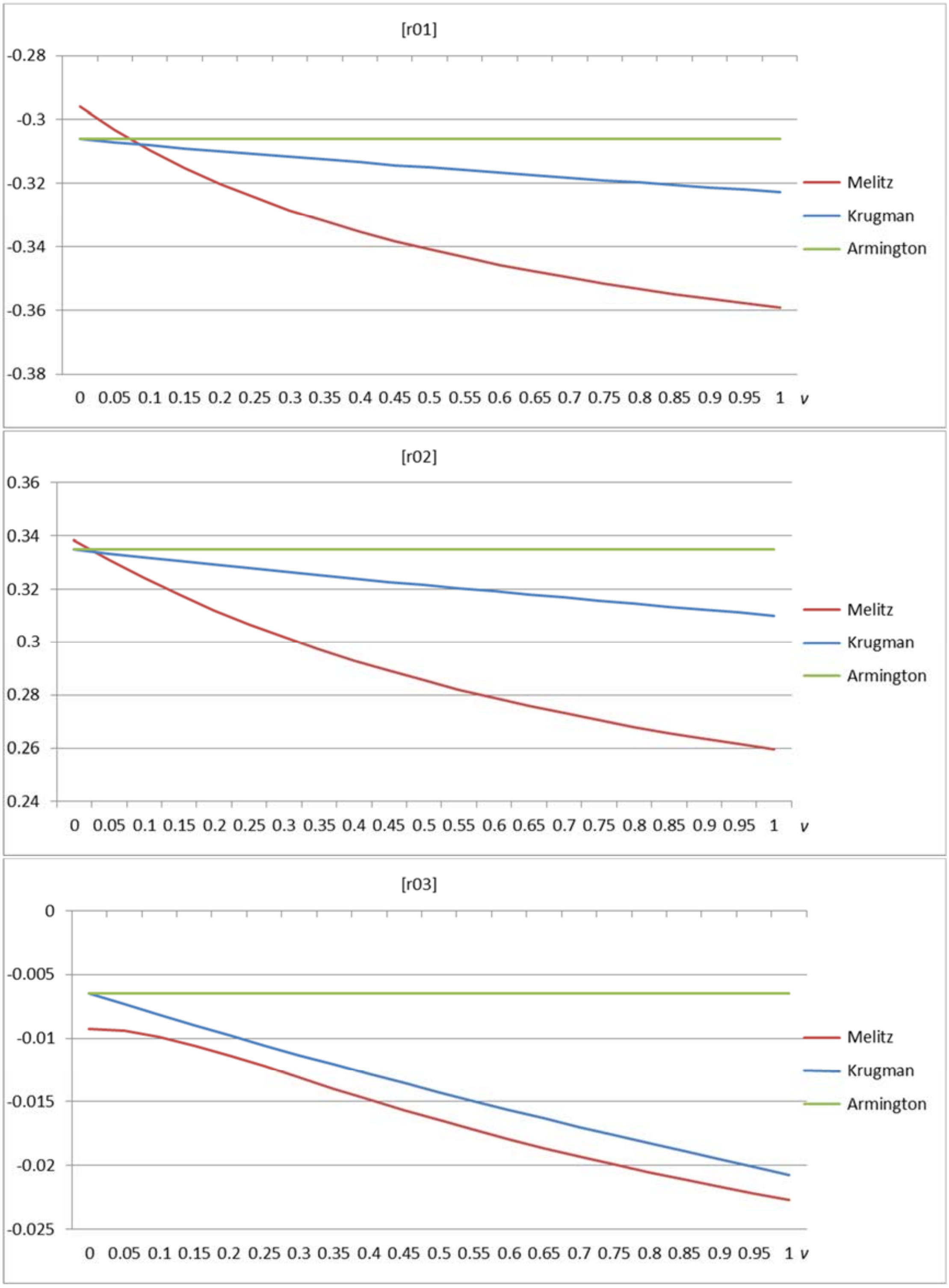

Figure 22. Effects on Wholesale Price of Manufactured Product (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02""i02"s} = \nu^{X}_{"i02""i03"s} = \nu^{C}_{"i02"s} = 0$, Intermediate - Primary)

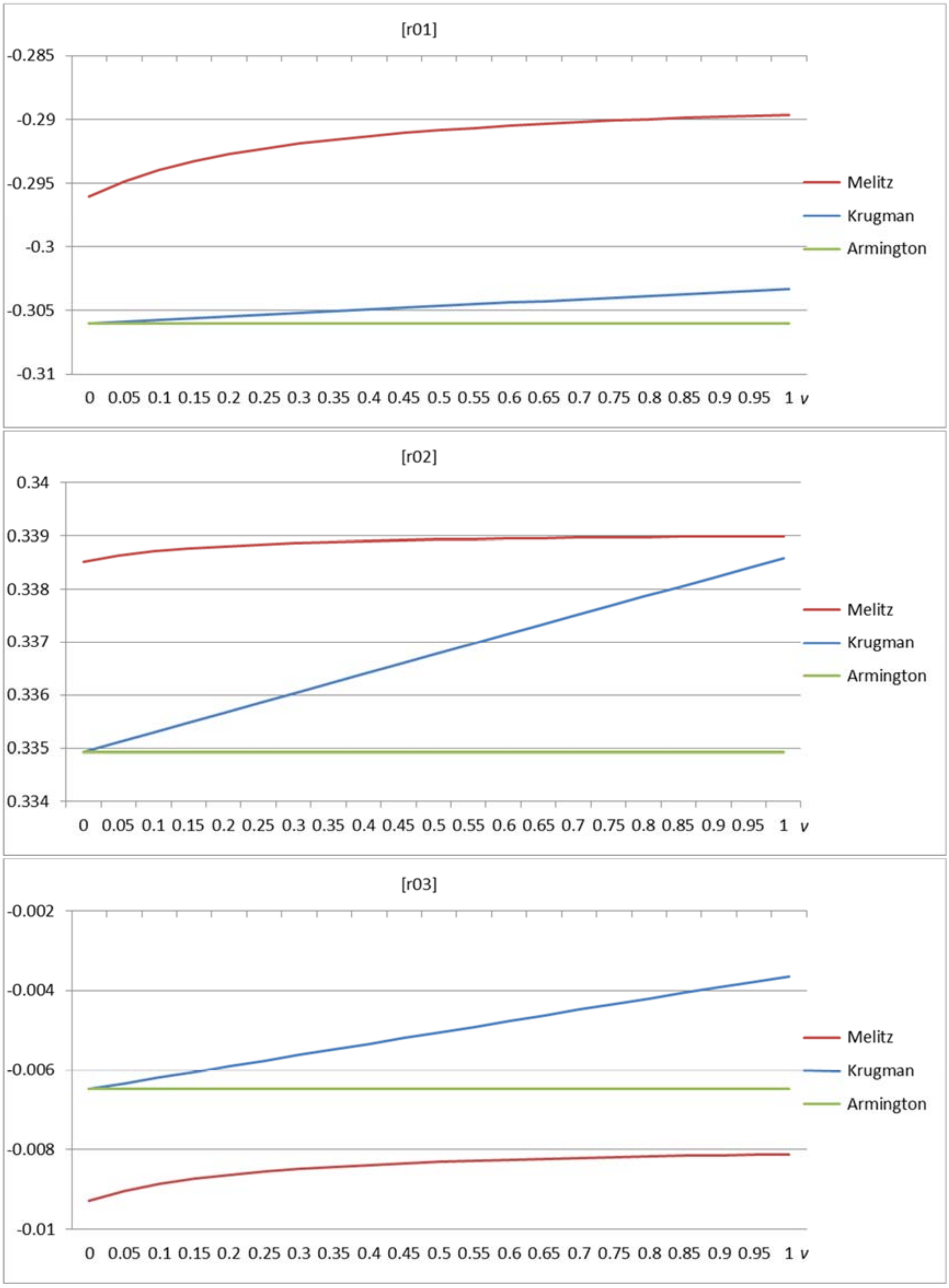

Figure 23. Effects on Wholesale Price of Manufactured Product (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02""i01"s} = \nu^{X}_{"i02""i03"s} = \nu^{C}_{"i02"s} = 0$, Intermediate – Manuf.)

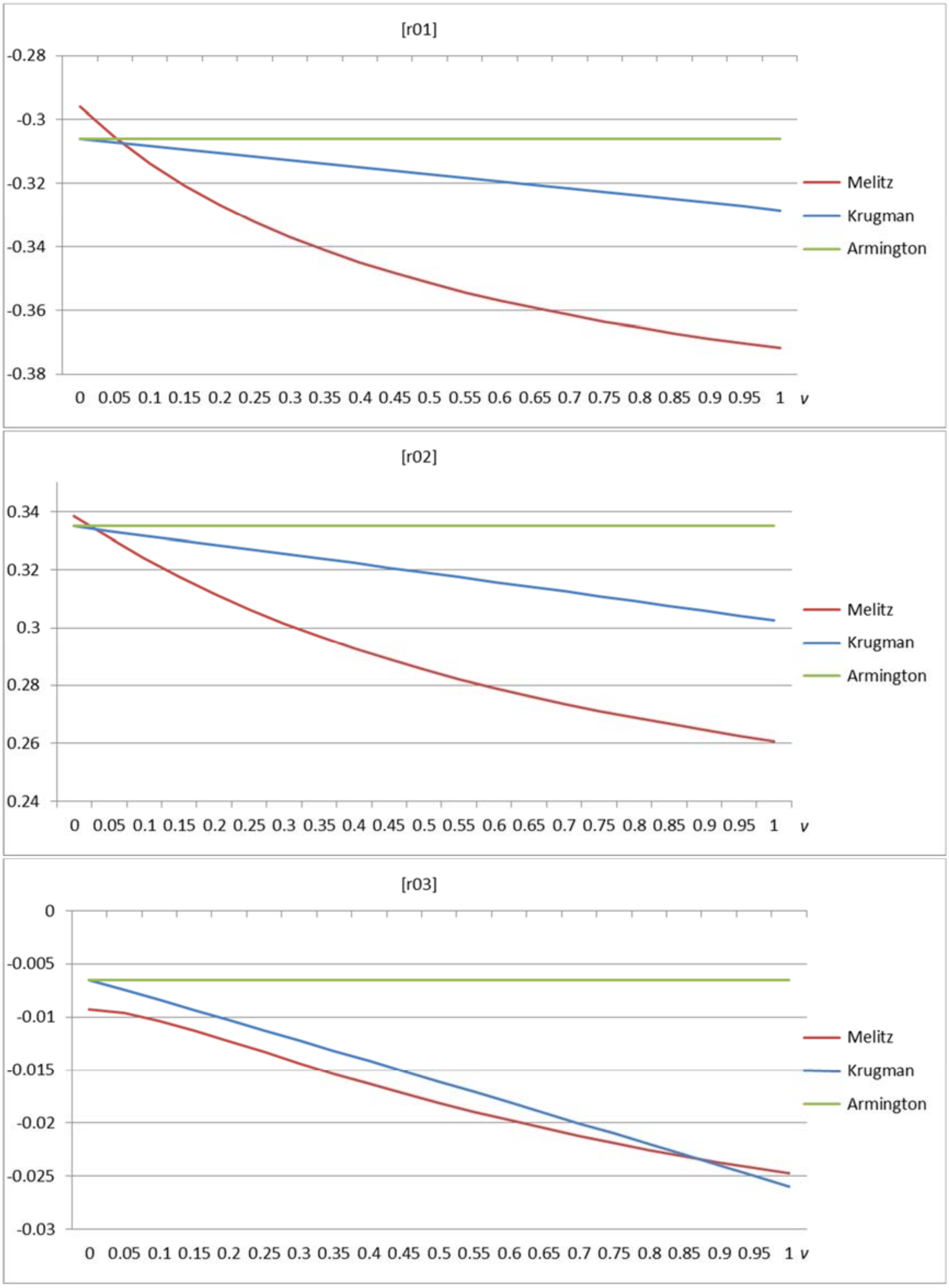

Figure 24. Effects on Wholesale Price of Manufactured Product (%, $\beta^{X}_{"i02"js} = \beta^{C}_{"i02"s} = \nu^{X}_{"i02""i01"s} = \nu^{X}_{"i02""i02"s} = \nu^{C}_{"i02"s} = 0$, Intermediate - Services)