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Measuring Korea's Industry-level Productivity Change Due to Tariff Cuts using a CGE Model*

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Abstract

Purpose – This study examined the effect of tariff cuts on productivity in Korea's manufacturing industries and the effect of initial productivity level before tariff cuts on productivity improvement after tariff cuts. We also attempted to identify whether import-driven or export-driven factors are more important for productivity improvement, especially in low productivity industries.

Design/methodology – Since tariff reduction is a policy decision that can affect cross-industry, its impact is spread across all industries beyond the scope of a single firm through the input and output network of industry structure. Accordingly, we proposed a new method to measure the change in productivity to reflect the impact of tariff cuts across industries. Through an Armington CGE analysis, changes in endogenous variables can be directly measured after the exogenous shock of tariff reduction, and the amount of movements in productivity triggered by tariff cuts can also be calculated. We can thus assess the effectiveness of exogenous policy, such as tariff cuts, through the difference between the benchmark and counterfactual values of endogenous variables.

Findings – This study confirmed that tariff reduction positively affected productivity improvement in Korea's manufacturing industries. It also confirmed that productivity gains occur in Korea's leading export industries. Finally, greater productivity gains were recorded in the group with additional high-export-share or high-import-share conditions for low productivity industries. These results are, in a limited sense, consistent with the existing studies that emphasize the importance of exports and imports on productivity improvement, especially for low productivity industries.

Originality/value – The results of our experiments are different from those of non-CGE studies, which measure the industry-level change in productivity with dummy coefficients, in terms of directly calculating the amount of change in productivity. In addition, we propose that the Armington CGE model is more appropriate than the Melitz CGE model to directly measure the productivity after tariff cuts. This is because the Melitz CGE model assumes the given specific productivity density, which does not change after an overall drop of tariffs. To the best of our knowledge, this approach to directly calculating productivity by reflecting the impact of tariff reduction across industries through CGE analysis, is unprecedented in this literature.

Keywords: Computable General Equilibrium, Free Trade Agreement, Input-output Table, Productivity

JEL Classifications: D57, D58, F15

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1. Introduction

In the international trade field, there have been many studies regarding the impact of free trade on productivity; in particular, after Melitz (2003), interest in productivity has increased. Accordingly, research using micro-data has become mainstream (Amiti and Konings, 2007; Halpern, Koren, and Szeidl, 2015; Olley and Pakes, 1996; Pavcnik, 2002). However, since tariff reduction is a policy decision that can affect cross-industry, analysis by individual firms, ignoring the effects of cross-industry issues, is insufficient. The effect of tariff cuts can be spread across all industries beyond the scope of a single firm through the input and output network of industry structure. If we raise the following questions, micro-level data research does not provide answers: (1) what happens to productivity dynamics in Korea's major industries when tariff cuts occur in Korea? (2) How differently do the high-productivity and low-productivity industries react to external shocks? (3) What factors are important to productivity improvement for low productivity sectors?

To answer these questions effectively, we propose a new way to measure the change in productivity to reflect the impact of tariff cuts across industries by comparing the results of dynamic productivity shifts from the benchmark to the counterfactual equilibrium through a CGE model. This approach differs from that of previous studies, which empirically analyzed the causes of productivity growth by using firm-level productivity calculated using the Olley-Pakes method[1] (Amiti and Konings, 2007; Halpern, Koren, and Szeidl, 2015; Olley and Pakes, 1996; Pavcnik, 2002). Our approach suggests that, through CGE analysis, changes in endogenous variables can be directly measured after the exogenous shock of tariff reduction, and the amount of movement in productivity triggered by tariff cuts can also be calculated. We can thus confirm the effectiveness of exogenous policy, such as tariff cuts through the difference between the benchmark and the counterfactual values of endogenous variables. The results of our experiments are also different from those of non-CGE studies, which measure the industry-level change in productivity with dummy coefficients, in terms of directly calculating the amount of change in productivity. In addition, we propose that the Armington CGE model is more appropriate than the Melitz CGE model to directly measure the productivity after tariff cuts. This is because the Melitz CGE model assumes the given specific productivity density, which does not change after an overall drop of tariffs. To the best of our knowledge, this approach to directly calculating productivity by reflecting the impact of tariff reduction across industries through CGE analysis, is unprecedented in this literature.

Through Armington CGE analysis, this study attempted to confirm Korea's Free Trade Agreement (FTA) performance by analyzing the impact of tariff reduction on productivity. We began with the questions on whether the productivity of Korean manufacturing industries would improve after trade liberalization, as well as how tariff reduction would affect productivity. There are three studies regarding the analysis of FTA effects on firm-level productivity in Korea, all showing that the FTA contributed to firms' productivity gain through export expansion (Bae Chan-Kwon et al., 2012; Jang Yoong-Joon, 2015; Lee Hong-shik et al., 2006). Similarly, we could confirm that productivity gains appeared in Korea's leading export industries. To further analyze this, we sought to identify whether import-

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[1] It was estimated by taking a log of the Cobb-Douglas production function ($Y = B_0 + B_l L + B_k K + B_m M + e$). Using the estimated coefficient values, total factor productivity ($TFP = Y - \widehat{B_l}L - \widehat{B_k}K - \widehat{B_m}M$) was calculated in consideration of the price deflator and the Asian financial crisis(Amiti and Koning, 2007). Bae, Chan-KWon et al. (2012) and Jang et al. (2015) calculated firm-level productivity by calculating M, which is the intermediate effect excluding the value-added portion of total sales.

driven or export-driven factors are more important for productivity improvement, especially in low productivity industries.

Productivity can improve through export-driven or import-driven channels as tariff decreases owing to the spread of FTAs, (Ahn et al., 2019; De Hoyos and Iacovone, 2013). First, more enhanced market competition through trade expansion after trade liberalization can make business activities more efficient, leading to improvement in productivity. The issues of competition and productivity were highlighted by Melitz (2003), who explains the survival of highly productive firms through free trade. Melitz (2003) claims that by introducing firm heterogeneity and trade cost into the theory model, less productive firms will exit and contract after trade liberalization, and the average sector productivity can be improved further as the market shares of highly productive surviving firms rise, which is also shown empirically by Bernard et al. (2007), and Melitz and Ottaviano (2008). Trefler (2004) shows that the deep Canadian tariff cuts raised industry level labor productivity through substantial loss in employment with the exit or contraction of low-productivity plants. Fernandes (2007) [2] show that productivity gains were expected to be stronger for larger Colombian plants and in less competitive industries, and for the least productive Canadian plants through innovation (Lileeva and Trefler, 2010). On the other hand, market opening also enables firms to purchase various types of intermediate goods at lower prices. Recent research shows that the quality and variety of imported inputs increase firm productivity using Hungarian (Halpern, Koren, and Szeidl, 2015), Indonesian (Amiti and Konings, 2007), Canadian (Lileeva and Trefler, 2010), Chilean (Kasahara and Lapham, 2013; Kasahara and Rodrigue, 2008), and Indian data (Goldberg et al., 2010; Topalova and Khandelwal, 2011). Firms can also improve productivity through advanced technology transfer and learning effects through increasing quality and variety of imported intermediate materials (Blalock and Veloso, 2007; Keller, 2004). De Hoyos and Iacovone (2013) show that increase in import competition and access to imported intermediate inputs can be a crucial source of productivity growth for firms. Blalock and Veloso (2007) show that firms in import-intensive sectors have higher productivity growth than other firms through import-driven technology transfers. Halpern, Koren, and Szeidl (2015) show that importing input varieties has a significant effect on firm productivity owing to imperfect substitution between foreign and domestic goods. We show that our study is consistent with previous studies in that it emphasizes the importance of imports or exports for productivity gains.

The paper proceeds as follows. Section 2 presents the research methodology and introduces our new productivity measurement. Section 3 describes the data and grouping, and finally shows the impact of tariff reduction on productivity by case. Section 4 presents the conclusion.

2. Research Method

2.1. CGE Analysis

Computable General Equilibrium (CGE) analysis shows how the total endogenous equilibrium changes with respect to the external impact given by the tariff reduction (Balistreri and Rutherford, 2011). Since tariff reduction is a policy decision that can affect the industry as a whole, its impact can be spread across all sectors through industry structure.

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[2] Fernandes (2007) uses Herfindahl indexes (degree of market share inequality) and turnover rate (sunk costs preventing exit) to measure domestic competition.

Accordingly, we decided to adopt CGE analysis as a research method. Compared to non-CGE research, studies regarding productivity change have not been active in the CGE field due to technical issues.

When selecting CGE methodology, we had to decide whether to follow the Armington (1969) or the Melitz (2003) CGE model. Because the Melitz model assumes the sector-specific productivity density for an industry of interest, we decided to follow the Armington CGE model to reflect the impact across all industries. Then, we proposed a new way to measure dynamic productivity shifts directly from the benchmark to the counterfactual equilibrium in CGE.

2.1.1. CGE Model Based on Armington (1969)

Armington CGE[3] analysis is commonly used to measure policy effects in economics. In this study, we attempt to identify whether tariff reduction affects industry-level productivity in Korea and how tariff reduction affects productivity while considering the impact of tariff cuts across industries.

The Armington CGE model we use is a process that solves the system of equations created and built with equations that describe the composition of each economic agent and market. The equation system includes domestic production, government behavior, investment demand, export and import price and balance of payment equations, Armington composite goods, transformation equations, market- clearance condition equations, and household consumption equations, etc. All equations can be explained mathematically as follows.

Regarding production, equation (1) shows the composite factor function. F_{hj} is the capital and labor used in j industry. β_{hj} is the share of labor and capital in the composition factor function. Importantly, Y_j is the value-added of the j industry. b_j is a scale parameter indicating the increase in value-added by factor input in the value-added production function. This expansion factor is considered as a productivity measurement in this study.

$$Y_j = b_j \prod_h F_{hj}^{\beta_{hj}} \ , \forall j \tag{1}$$

Equation (2) shows the demand function of an intermediate input. It implies that the intermediate inputs of j industries have been used to produce the goods of i industry. ax_{ij} is the minimum intermediate input coefficient for one unit production.

$$X_{ij} = ax_{ij} Z_j \ , \forall i \tag{2}$$

Equation (3) shows the factor demand function. r_h is the price of the h element. $p_j{}^s$ is the price of supply in the j industry. Z_j is production in the j industry.

$$F_{hj} = \frac{\beta_{hj}}{r_h} p_j{}^s Z_j, \ \forall h, j \tag{3}$$

Equation (4) shows the unit cost function.

$$P_j^s = ay_j p_j^y + \sum_i ax_{ij} P_i^q \ , \forall_i \tag{4}$$

On the demand side, equation (5) shows the government demand function. $X_i{}^g$ is public expenditure on goods in the i industry, indicating that the government is spending a certain

[3] The theoretical basis lies in general equilibrium models developed by K. Arrow and G. Debreu (Debreu, 1959). This study is based on Hosoe (2004) and our empirical model was modified from Hosoe (2004).

ratio of tax revenue. $T_j = \tau_j Z_j$, which is the tax amount imposed on product, Z_j.

$$X_i^g = \frac{\mu_i}{p_i^q}\left(\sum_j T_j - S^g\right),\ \forall i \tag{5}$$

Equation (6) shows the investment demand function. S is savings of the private sector, S^g is savings of the government sector, and S^f f is the foreign savings. ε is the exchange rate and λ_i is the share of expenditure on goods in the i industry.

$$X_i^v = \frac{\lambda_i}{p_i^q}\left(S + S^g + \varepsilon S^f\right),\ \forall i \tag{6}$$

Equation (7) shows the household consumption function in the private sector. It implies that some of the income generated from selling the production factor is saved, while some of it is used as demand. α_i is the share of expenditure on goods in the i industry out of income.

$$X_i^p = \frac{\alpha_i}{p_i^q}\left(\sum_h r_h\, FF_h - S\right),\ \forall i \tag{7}$$

Equation (8) shows Armington consumption for composite goods. It is the aggregate of imported and domestically supplied goods. . δm_i and δd_i are the share of imports and domestic goods used for production of composite goods, respectively.

$$Q_i = \gamma_i(\delta m_i M^{\eta_i} + \delta d_i D^{\eta_i})^{\frac{1}{\eta_I}} \tag{8}$$

Equation (9) shows the demand function for domestic goods. It implies goods produced domestically among those used as input materials. γ_i is the share to be used for production, and δd_i is the share of domestic goods.

$$D_i = \left(\frac{\gamma^{\eta_i}\delta d_i p_i^q}{p_i^d}\right)^{\frac{1}{1-\eta_i}} Q_i,\ \forall i \tag{9}$$

Equation (10) shows the demand function for imported goods. It is determined based on elasticity.

$$M_i = \left(\frac{\gamma^{\eta_i}\delta m_i p_i^q}{p_i^m}\right)^{\frac{1}{1-\eta_i}} Q_i,\ \forall i \tag{10}$$

The producer decides whether to export the product or sell it domestically, and, as a result, export volume is determined, based on the transformation function such as equation (11). ξd_i and ξe_i are each share of domestic demand and export supply, respectively.

$$Z_i = \theta_i(\xi e_i E_i^{\varphi_i} + \xi d_i D_i^{\varphi_i})^{\frac{1}{\varphi_i}} \tag{11}$$

Equation (12) shows the supply function for exported goods. ψ_i is the elasticity of production substitution between domestic goods and export goods[4].

$$E_i = \left(\frac{\theta^{\varphi_i}\xi e_i\ (\tau_i + p_i^s)}{p_i^e}\right)^{\frac{1}{1-\varphi_i}} Z_i,\ \forall i.\, i \tag{12}$$

[4] It is assumed that exports are imperfectly transformable with domestic goods, which means that one unit of export can transform with less than one unit of domestic goods.

Based on the equilibrium equation for trade balance, equation (13) shows balance of payment.

$$\sum_i P_i^{W_e} E_i + S^f = \sum_i P_i^{W_m} M_i \tag{13}$$

Finally, the goods' market clearing condition is defined as equation (14). It shows that Armington consumption is determined by the consumption of intermediate and final goods.

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{ij}, \ \forall i \tag{14}$$

Equation (15) shows factors' market clearing conditions. It ensures that the demand and supply of each production factor are matched.

$$\sum_j F_{hj} = FF_h \tag{15}$$

In general, solving the above CGE will find the equilibrium for the variables defined as endogenous variables. They are the values of Y_j, F_{hj}, X_{ij}, Z_j, E_i, M_i, Q_i, P_j^y, P_j^s, P_i^q, and other endogenous variables are found. Then if exogenous variables are changed by imposing a new policy, a new balance equilibrium can be found. In our experiments, this exogenous shock is a tariff cut. The new exogenous variable creates a counterfactual equilibrium with new endogenous variables of $\widehat{F_{hj}}$, $\widehat{X_{ij}}$, $\widehat{Z_j}$, $\widehat{E_j}$, $\widehat{M_j}$, $\widehat{Q_j}$, $\widehat{P_j^y}$, $\widehat{P_j^q}$, etc. We can measure the effectiveness of exogenous policy through the difference between the benchmark and the counterfactual values of endogenous variables.

2.1.2. Productivity Measurement in Our Model

Few studies directly dealt with productivity in Armington-based CGE research. Hanson and Rose (1997) described productivity using augmented technical change. Giesecke (2002) determined that differences in growths between regions are due to labor using dynamic multiregional analysis. Doe et al. (2006) and Harvey and Davis (2018) measured the impact of productivity by changing the exogenous productivity parameters. In their CGE studies, the productivity calculated by initial calibration was not changed, which is different from our model.

In our model, we could obtain the scale parameter, b_j, which indicates the increase in value-added by inputting factors into the value-added production function, from the composite factor aggregation function, equation (1).

$$b_j(Y_j, F_{hj}) = Y_j / \prod_h F_{hj}^{\beta_{hj}} = \frac{ay_j(\frac{T_j}{\tau_j})}{\prod_h F_{hj}^{\beta_{hj}}}, \forall_i \tag{16}$$

The change in productivity can be measured as b_j^o - $\hat{b}_j$. Here, b_j^o ($b_j^o = Y_j^0 / \prod_h F_{hj}^{0\beta_{hj}}$) is the initial level of value-added and $\hat{b}_j$ ($\hat{b}_j = \hat{Y}_j / \prod_h \hat{F}_{hj}^{\beta_{hj}}$) is the new level after the exogenous shock of tariff reduction. After moving from the benchmark to the new counterfactual equilibrium after the exogenous shock of tariff reduction, it is possible to calculate $\hat{b}_j$.

With the development of a simple calculation in equation (16), we can show that changes in taxes (τ_j) can affect changes in productivity (b_j). Here, j means not a specific sector, but all sectors. In addition, using this equation, the change in productivity can be measured from $b_j^o - \hat{b}_j$.

Evidently, all endogenous variables have a new balanced equilibrium. Particularly, the difference between b_j^o and $\hat{b}_j$ as a change in the scale parameter, which implies a change in productivity, can be measured in our approach. This approach to calculating productivity directly through CGE analysis is, to the best of our knowledge, the first attempt in the literature.

Based on the results of the CGE analysis, similar mechanisms can be applied to derive conclusions. When the shock of tariff reduction occurs, it was confirmed that the production factors reallocate to a specific group, resulting in an increase in production and export of that group, and a change in productivity. In general, productivity increases in a group where the production factors move after a tariff cut. Therefore, through CGE analysis for each experiment, it can be seen how tariff reduction affects productivity improvement through which group the production factor moves to.

2.1.3. Productivity Measurement based on Melitz Model using CGE

A representative study embodying the Melitz model in CGE started with Zhai (2008), and a limited number of such studies have since been conducted (Akgul, Villoria and Hertel, 2016; Balistreri and Rutherford, 2011; Balistreri and Rutherford, 2013; Dixon, Jerie and Rimmer, 2016). Roh and Oh (2016) and Roh and Kim (2018) have applied the Melitz CGE model for Korea. Research based on the Melitz model differs in how CGE is implemented among researchers, but in general, productivity and tariff reduction are separate through equations. The Melitz model (2003) assume that equilibrium distribution of productivity is exogenously given and productivity levels remain unchanged by trade.

Balistreri and Rutherford (2011) assume M_r firms choose their form-specific productivity φ from a Pareto distribution with probability density, $g(\varphi) = \frac{a}{\varphi}(\frac{b}{\varphi})^a$ and cumulative distribution, $G(\varphi) = 1 - \left(\frac{b}{\varphi}\right)^a$, where a is the shape parameter and b is the minimum productivity. That is, the production function is determined by the exogenously calibrated parameters b and a, which are independent from other endogenous variables. Empirically, the marginal productivity $\varphi_{rs}^* = b/\left[\frac{N_{rs}}{M_r}\right]^{\frac{1}{a}}$ determines whether to participate or not, and then M_r and N_{rs} (the number of operating firms) are determined. Parameters a, b, M and N are disconnected from other endogenous variables of CGE[5].

Dixon, Jerie, and Rimmer (2016) constructed the AKME model including Armington, Krugman, and Melitz into 10 equations and the formula for firm profit is derived as follows: $\prod_{ksd} = P_{ksd}Q_{ksd} - \left[\frac{W_s T_{sd}}{\Phi_k}\right] Q_{ksd} - F_{sd}W_s, k \in S(s,d)$. This equation is the contribution to the profits of a class-k producer in country s from its sales to d. Q_{ksd} is the quantity of widgets sent from country s to country d by each firm in class k. P_{ksd} is the price. $\frac{W_s T_{sd}}{\Phi_k}$ is a variable cost, and W_s is the cost of a unit of labor to widget markets in country s. T_{sd} is the power of the tariff or possibly transport costs associated with the sale of widgets from s to d. In this case, $W_s T_{sd}$, which includes tariff, and productivity (Φ_k) are separated so that they cannot affect each other. The assumed productivity density leads to an increase in average productivity depending on the level of marginal company participation. Akgul, Villoria, and Hertel (2016) do not distinguish between partial equilibrium and general equilibrium, but productivity is still firm level productivity.

[5] For this reason, Balestrerie (2011, 2013) achieved equilibrium by distinguishing between general equilibrium and partial equilibrium. A general equilibrium including production and production prices, demand and demand prices, and a partial equilibrium regulating the production of individual firms, are made to create a consistent equilibrium with each other iteratively.

Thus, if the Melitz model is to be implemented through actual empirical work, there may be debates related to parameters a and b defining the productivity distribution, number of blueprints (M), and number of firms (N) which should be exogenously set. Considering the Melitz model where productivity and tariff rate are partially separated and not entirely connected, it is not necessary to use the Melitz model to answer how tariff cuts affects productivity change in Korea's major industries.

3. Simulation Results

3.1. Data

Starting with the Korea-Chile FTA of 2004, Korea has signed FTAs with 55 countries through 16 agreements as of September 2020. In addition, the Korea-UK FTA, Korea-Israel FTA, and Korea-Indonesia CEPA were signed or concluded in 2019. Korea has FTA networks with major trading partners, which includes the Korea-EU, Korea-US, Korea-China, and Korea-Vietnam FTAs, accounting for 77% of the world's GDP. As a result, Korea has become the world's seventh-largest export economy with a $ 600 billion vale in 2018, 73% of which are exports to 52 countries whom it has signed an FTA. In addition, 88% of Korean consumers recognize that the range of product choices has been diversified as a result of the FTAs.[6] As such, trade with FTA partner countries has increased and consumer welfare has improved as simultaneous FTAs were promoted after Korea's first, the Korea-Chile FTA. However, there are voices saying that it is necessary to seek a new direction for future development along with an objective evaluation of past achievements.

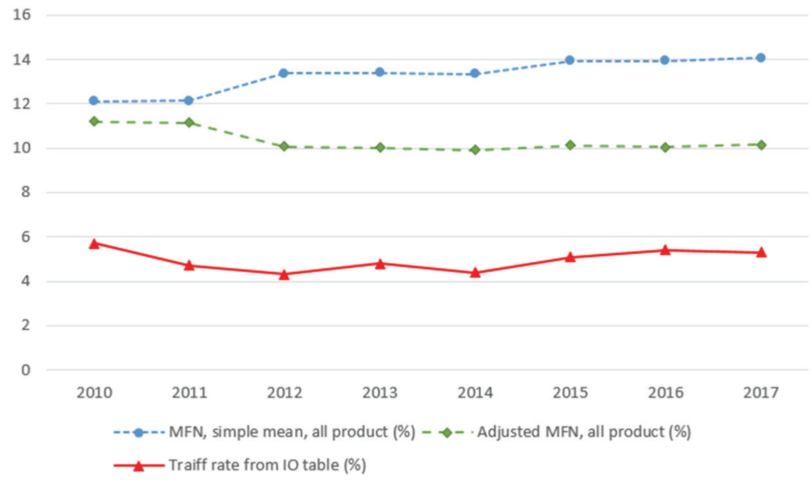
Generally, the economic reasons for signing FTAs are to improve consumer welfare through reductions in import prices and diversification of consumable items. They also include expanding trade, creating employment, securing stable overseas markets, attracting foreign investment, and transferring technology. In addition to these economic incentives, FTA partners are likely to maintain the same stance on various trade issues discussed internationally, which could work in favor of multilateral negotiations. It also has the advantage of cooperation among FTA parties in terms of diplomacy and security. Despite these various effects, if the economic effect of the FTA is evaluated only in terms of increases in trade due to tariff reduction, the effect of FTAs can be underestimated.

Therefore, we examine Korea's FTA performance by analyzing how tariff reduction affects industrial productivity based on CGE analysis. To this end, a social accounting matrix[7] is generated for CGE analysis, based on the input-output table, published annually by the Bank of Korea.

[6] A press release by the Ministry of Trade, Industry and Energy (April 11, 2019) was quoted as saying, "Free Trade Forum: 15 Years, Evaluation and Challenges."

[7] The social accounting matrix consists of production (goods and services), production factors (labor and capital), and institutional sectors (households, firm, government and overseas). Production accounts show transactions between industrial sectors, while production factor accounts show transactions of production factors that are utilized in production activities. In the institutional sector, transactions between households, firms, government, and overseas are recorded. The input-output table is used to record transactions between industrial sectors, and National income statistics are used to record transactions between institutional sectors. Rows and columns represent the receipts and expenditures of each account, and the sum of rows and columns always matche each other.

Fig. 1. Trend of Korea's Tariff Rate from 2010 to 2017



Note: Adjusted MFN is a simple mean of the tariff rate by year under the condition that the tariff rate is zero if Korea has an FTA with an exporting country, and MFN otherwise. The tariff rate from the IO table is a simple mean of the tariff rate which is calculated as the share of tariff revenue out of the total import amount by sector.
Source: Authors' calculation using World Bank Indicator and WTO RTA database.

To find the equilibrium values, imports are used with direct imports that do not include tariff revenue[8] and international margins (wholesale and retail margins and freight rates), as published in the input-output tables. In addition, the tariff rate was calculated as the share of the tariff revenue out of the total import amount.[9] Fig. 1 shows the trend of tariff rates in Korea from 2010 to 2017. Compared to the actual MFN rates, the tariff rates reflecting the effect of tariff reduction with countries that have FTAs is somewhat lower. FTAs seem to have the effect of lowering the average MFN tariff rate that is actually imposed. The tariff rate which is calculated as the share of tariff revenue out of total imports by sector based on the input-output table, is even lower. It seems that the importers actually pay a tariff rate of about 5%, lower than the average MFN rate of 13%. In the actual simulation, the effect that the tariff rate calculated from the input-output table converged to zero was estimated.

3.2. Grouping

This study first examined two questions (1) what happens to productivity dynamics in Korea's major industries when tariff cuts occur in Korea? And, (2) how differently the high-productivity and the low-productivity groups react to external shocks? To answer these two questions, industries were broadly divided into three categories: agriculture, manufacturing, and services. Then, Korean industries were mainly divided into two groups with high-productivity and low-productivity sector.[10] Five industries with relatively higher productivity

[8] Tariff revenue is stated as production taxes (imports) in input-output tables.

[9] As the social accounting matrix includes not only the real sector of the input-output table, but also the financial aspects of taxation, some errors were adjusted on the premise of right and left symmetry to meet market clearing conditions.

[10] The initial productivity for each industry was calculated as the total factor productivity based on the

were classified as group 1, while the rest of the industries are classified as group 2, as shown in the third column of Table1 (Experiment 1). It is possible to infer the effect of initial productivity levels before tariff cuts on productivity gains after tariff cuts. The purpose of this experiment is to find out which of the high or low-productivity groups will be significantly changed by the tariff reduction.

After the first two experiments, we conducted additional experiments to address the next question (3) which are more important for productivity change in low productivity sectors, import-driven or export-driven factors? To answer the third question, two types of experiments were additionally conducted. Note that Korea was found to have a large amount of imports in industries with a large export volume. There are few high-export and low-import or low-export and high-import industries, and only one case of low-export and high-import was 'mining goods'. Therefore, the experiment was conducted with an additional condition of high-export-share or high-import-share for low productivity industries.

First, the manufacturing industries were divided into three types of productivity and exports: H (high), M (middle), and L (low), as shown in the second and forth columns of Table 1. The industries with high productivity and low-export-share were classified as group 1, and the industries with low productivity and high-export-share were classified as group 2, as shown in the 5th column of Table1 (Experiment 2). Food and wood were classified as the former, and the chemical and computer industries were classified as the latter. The rest of the industries, except service, are classified as "others". Note that other possible groups with the combination of initial productivity and export share could not be made because they do not have enough production for the experiment (i.e. (initial productivity, export share) = (High, High) or (Low, Low)).

Table 1. Industry classifications

Industry	Productivity Group	Ex.1 Group	Export Group	Ex.2 Group	Import Group	Ex.3 Group
Agricultural goods	L	A	L	M	L	M
Mining goods	L	G2	L	M	H	G1
Food & beverages	H	G1	L	G1	M	M
Textile and leather	H	G1	M	M	M	M
Wood and paper, printing	H	G1	L	G1	L	M
Petroleum and coal	L	G2	M	M	M	M
Chemical products	L	G2	H	G2	H	G1
Non-metallic mineral	M	G2	L	M	L	M
Basic metal	L	G2	M	M	H	G1
Fabricated metal	H	G1	M	M	L	M
Computer	L	G2	H	G2	H	G1
Electronics	L	G2	M	M	L	M
Machinery	H	G1	H	M	M	M
Transportation	M	G2	H	M	M	M
Other manufacturing	M	G2	L	M	L	M
Manufacturing process	M	G2	L	M	L	M
Service	M	S	H	S	H	S

Source: input output table 2015, released by Bank of Korea (2018).

value-added concept, rather than technology change, considering the input of labor, capital, and intermediate goods.

Then, the manufacturing industries were divided into three types of imports: H (high), M (middle), and L (low), as shown in the 6th columns of Table 1. We linked the industries with low productivity and high-import-share, as group 1, which includes mining, chemical products, basic metal, and computer sectors, as shown in the 7th column of Table 1 (Experiment 3). However, the group with high productivity and low-import-share was not formed owing to a lack of target industries. The rest of the industries, except service, are also classified as "others".

Since the productivity improvement of industries with low productivity is a very important policy issue, a meaningful conclusion can be drawn by comparing the results of the last two experiments.

3.3. CGE Analysis Results

3.3.1. CGE Analysis for Three Main Sectors in 2015

The industries were broadly divided into three categories, agriculture, manufacturing, and services, and then input-output tables were converted into a social accounting matrix. The social accounting matrices were generated based on an input-output table, released by the Bank of Korea. Then, CGE analysis was conducted under the assumption that the tariff level converged to zero as an exogenous shock in the benchmark case.

The results in Table 2 show that tariff reduction increased productivity in manufacturing industries. After the tariff reduction, production factors such as labor and capital moved to the manufacturing industry, and production increased. In addition, imports increased significantly owing to lower import prices. Since the change in Armington consumption (Q_i), which is defined as the sum of imported (M_i) and domestic goods (D_i), is not as large as the change of imports, the demand for domestic goods seems to have decreased after tariff reduction. Meanwhile, despite such a decrease in demand for domestic goods, production (Z_i) has increased, apparently due to a significant increase in exports (E_i). Productivity (b_j) increased 0.01% as domestic production increased following tariff reductions.

Table 2. CGE Analysis Results for Three Main Sectors in 2015 (Unit: %)

	Agriculture	**Manufacture**	**Service**
Change rate in capital input	-0.65	1.07	-0.54
Change rate in labor input	-0.48	1.23	-0.37
Share of capital input after test by sector	0.84	0.59	0.45
Share of labor input after test by sector	0.16	0.41	0.55
Productivity level (b_j) after test	1.55	1.97	1.99
Productivity change rate	0.04	0.01	-0.01
Import (M_i) change rate	8.79	4.00	-0.92
Production(Z_i) change rate	-0.62	1.14	-0.45
Armington consumption(Q_i) change rate	0.91	1.15	-0.50
Change in Armington consumption price	-1.89	-3.15	-0.83
Private consumption (X_i^p)change rate	2.01	3.34	0.92
Gov't consumption (X_i^g) change rate	-5.39	-4.16	-6.40
Investment (X_i^v) change rate	1.88	3.20	0.79

In the agricultural sector, productivity also increased by 0.04% despite the decrease in production factors after tariff reductions. As can be seen from Table 3, this could be due to relatively higher share of imports in the agricultural sector, which contributed to improving productivity as import prices fell. On the other hand, government consumption (X_i^g) decreased in all sectors, apparently due to a drop in government revenue resulting from tariff cuts.

Table 3. Share of Production, Import, and Export by Sector

	Share of production	Share of import	Share of export
Agriculture, Mining, Food	0.049	0.241	0.012
Chemicals	0.093	0.146	0.178
Non-metallic & metal products	0.069	0.090	0.077
Computer, Electrical equipment	0.099	0.171	0.299
Machinery and vehicles	0.100	0.110	0.250
Other manufacturing	0.037	0.070	0.061
Service	0.554	0.173	0.124

3.3.2. CGE Analysis Between High and Low Productivity Groups

For this CGE analysis, five industries with relatively higher productivity were classified into group 1 and another ten industries into group 2. In 2015, wood, paper, printing; food products; machinery and equipment; metalworking products; textiles and leather goods were classified into the high productivity group (group 1) and the rest into the low productivity group (group 2).

For counterfactual testing, all industry tariffs were reduced to zero by policy at the same time. The noticeable change as shown in Table 4, is that production factors such as labor and capital moved to the low-productivity group (group 2) and production only increased in group 2. In addition, group 1 with higher productivity and group 2 with relatively lower productivity increased both imports (group 1: 9.44%, group 2: 2.97%) and Armington consumption (group 1: 0.90%, group 2: 1.34%). However, while Armington consumption increased to a similar level in both groups, imports in group 1 increased overwhelmingly. As a result, the demand for domestic goods in group 1 must have decreased significantly, resulting in a decrease in production by 0.91 % in group 1, but increased by 2 % in group 2. As a result, in group 1, there was no change in productivity, whereas in group 2, productivity improved by 0.03%.

This experiment is to check whether changes in productivity is greater in the group with relatively higher initial productivity. However, the results were different than expected. The change rate of productivity in industries with lower productivity was much larger after tariff reduction. The productivity change rate of group 1 was 0.00%, whereas that of group 2 was 0.03%. That is, the lower the productivity level of group2, the greater the productivity improvement effect due to the tariff reduction in Korean industries. Tariff reduction increases imports and exports in both groups, but in group 2, export increased more than import. Based only on the Armington CGE analysis results, it can be inferred that export increase contributed to productivity improvement in group 2.

It is likely that free trade contributed to the improvement of productivity in Korea. In addition, low productivity industries have not declined; rather, their productivity has been enhanced by an increase in exports after free trade. After tariff reduction, regardless of the initial level of productivity, production factors move toward industries with high export, and both production and exports increase, which contribute to productivity improvement.

Table 4. CGE Analysis Results of High and Low Productivity Groups (Experiment 1)

(Unit: %)

	Agri	Group 1	Group 2	Service
Change rate in capital input	-1.80	-1.02	1.91	-0.58
Change rate in labor input	-1.57	-0.80	2.14	-0.35
Share of capital input after test	0.84	0.49	0.63	0.45
Share of labor input after test	0.16	0.51	0.37	0.55
Productivity level (b_j) after test	1.55	2.00	1.94	1.99
Productivity change rate	0.05	0.00	0.03	-0.01
Import (M_i) change rate	7.68	9.44	2.97	-0.73
Production(Z_i) change rate	-1.76	-0.91	2.00	-0.45
Armington consumption(Q_i) change rate	-0.22	0.90	1.34	-0.48
Change in Armington consumption price	-1.91	-3.36	-3.06	-0.82
Private consumption (X_i^p)change rate	2.06	3.60	3.28	0.94
Gov't consumption (X_i^g) change rate	-5.31	-3.88	-4.17	-6.35
Investment (X_i^v) change rate	1.92	3.45	3.13	0.80

3.3.3. CGE Analysis for Low Productivity and High Export Group

The results in Table 5 showed that productivity changes in industries with low productivity and high-export-share (group 2: chemical and computer) were greater than those with high productivity and low-export-share (group 1: food and wood). Productivity increased by 0.06% in group2, by 0.00% in group 1, and by 0.02% in the rest of the manufacturing industries.

Table 5. CGE Analysis Results for Low Productivity and High Export Group (Unit: %)

	Group1	Group2	Others	Service
Change rate in capital input	-2.97	2.60	0.52	-0.70
Change rate in labor input	-2.64	2.96	0.87	-0.35
Share of capital input after test	0.49	0.71	0.56	0.45
Share of labor input after test	0.51	0.29	0.44	0.55
Productivity level (b_j) after test	2.00	**1.83**	1.98	1.99
Productivity change rate	0.00	0.06	0.02	-0.02
Import (M_i) change rate	15.28	2.49	4.01	-1.06
Production(Z_i) change rate	-2.80	2.71	0.67	-0.51
Armington consumption(Q_i) change rate.	0.16	1.59	0.94	-0.55
Change in Armington consumption price	-3.91	-2.52	-3.02	-0.77
Private consumption (X_i^p)change rate	4.25	2.76	3.29	0.95
Gov't consumption (X_i^g) change rate	-4.37	-5.74	-5.26	-7.40
Investment (X_i^v) change rate	4.26	2.77	3.30	0.96

As shown in the earlier experiments, it is also observed that labor and capital are reallocated from group1 to group 2. In addition, with the similar change rate of Armington consumption in both groups (group 1: 0.16%, group 2: 1.59%), imports increased overwhelmingly in group 1 (group 1: 15.28%, group 2: 2.49%). This caused the demand for domestic goods in group 1 to decrease significantly, resulting in a decrease in production by 2.8 % in group 1, compared to the increase of 2.17% in group 2. As a result, in group 1, there was no change in productivity, whereas in group 2, productivity improved by 0.06%.

This experiment was conducted with an additional export condition for the low-productivity group. As a result, productivity increased further by 0.06% after tariff reduction, compared to 0.03% for goup2 in Experiment 1. Our results are, in a limited sense, consistent with those of existing studies that emphasize the importance of exports on productivity improvement through learning by exporting (Fernandes and Isgut, 2005), economies of scale (Wanger, 2002), product innovation (Braun, 2008), and technology upgrading (Bustos, 2011).

3.3.4. CGE Analysis for Low Productivity and High Import Group

The purpose of this experiment is to test whether the low productivity and high- import-share increases productivity after tariff cuts. This experiment was inspired by import-driven factors such as learning effects through increasing quality and variety of imported intermediate materials (Blalock and Veloso, 2007; Keller, 2004), access to imported intermediate inputs (De Hoyos and Iacovone, 2013), and importing input varieties (Halpern, Koren, and Szeidl, 2015). We attempt to determine whether import-driven factors contribute to productivity improvement in a low productivity group.

As shown in Table 6, labor and capital are mostly reallocated into group 1. However, production increased in both group 1 and "others" (group 1: 2.22%, others: 0.31%). As a result, productivity improved by 0.05% in group 1, and by 0.01% in "others". The results of this experiment show that the production factors move to the low productivity and high import group (group 1) and, as a result, the amount of productivity fluctuations triggered larger than other sectors ("others") and service.

This experiment was conducted with additional import conditions for the low-productivity group. It was confirmed that productivity increased more in the high-import-share group. This result seems to be, in a limited sense, consistent with those of existing studies that emphasize the importance of imports on productivity improvement.

Table 6. CGE Analysis Results for Low Productivity and High Share of Import Group (Unit: %)

	Group1	**Others**	**Service**
Change rate in capital input	2.13	0.18	-0.65
Change rate in labor input	2.44	0.48	-0.35
Share of capital input after test	0.70	0.55	0.45
Share of labor input after test	0.30	0.45	0.55
Productivity level (b_j) after test	1.85	1.99	1.99
Productivity change rate	0.05	0.01	-0.01
Import (M_i) change rate	1.83	7.57	-1.19
Production(Z_i) change rate	2.22	0.31	-0.48
Armington consumption(Q_i) change rate	1.15	1.06	-0.54
Change in Armington consumption price	-2.66	-3.15	-0.76
Private consumption (X_i^p)change rate	2.89	3.41	0.92
Gov't consumption (X_i^g) change rate	-5.77	-5.30	-7.58
Investment (X_i^v) change rate	2.87	3.38	0.90

4. Conclusion

This study began with questions regarding the effect of tariff cuts on productivity in Korea's major industries and the effect of initial productivity levels before tariff cuts on productivity improvement after tariff cuts. To answer these questions, we proposed a new way to measure the change in productivity. Our method directly measures the value of the scale parameter by comparing the results of dynamic productivity shifts from the benchmark to the counterfactual equilibrium in the Armington CGE. This method allows us to find the new equilibrium values of endogenous variables at the counterfactual equilibrium point, which provide the basis for a new productivity calibration.

An Armington CGE analysis was conducted with a social accounting matrix, generated from the input-output table released by the Bank of Korea in 2015. This made it possible to explain the mechanism of productivity change after tariff reduction, based on estimated results of the movement of inter-industry production factors, changes in production and exports, and changes in import and domestic consumption.

Through the Armington CGE analysis, this study answered the two questions above. First, tariff reduction positively affected productivity improvement in Korea′s manufacturing industries. Second, productivity gains have been made by the low-productivity industries owing to export expansion. As production factors move to low productivity industries after tariff cuts, increases in production and export seem to contribute to productivity improvement. Low-productivity industries did not decline; rather, their productivity was enhanced through export expansion after free trade. The triggered productivity change in the low productivity group was 0.03% higher than that in the high-productivity group. The meaning of this value, 0.03% is different from that of the productivity change rate, which is estimated with dummy variables in micro-firm studies.

From those results, we attempted to determine whether import-driven or export-driven factors are more important productivity improvement in the low productivity sectors. This is because productivity improvement in low productivity industries could be a very important policy issue. Since it was found that Korean industries with a large export volume generally have a large amount of imports, the cross effect between high-export-share and low-import-share, or vice versa, could not be confirmed. The final two experiments, conducted with additional high-export-share or high-import-share conditions for the low-productivity groups, show higher productivity improvement (export: 0.06% and import: 0.05%) than all manufacturing industries (0.01%) and low productivity industries (0.03%). Even though these results seem to be influenced by which industries are linked in each experiment, greater productivity gains have been in the group with high-export-share or high–import-share for low productivity industries. These results are, in a limited sense, consistent with those of existing studies that emphasize the importance of exports and imports on productivity improvement, especially for low productivity industries.

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