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Global Productivity and Market Structure Implications of the US-China Trade War: A CGE Modeling Approach

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Abstract

Purpose – As the US-China trade war intensifies and lasts long time, there is growing concern about its potential effects on the global economy. In particular, for the countries like Korea that have a large economic dependence on the economy of the two countries, the US-China trade war may have a great repercussion in many ways. The aim of this paper is to investigate the global productivity and market structure implications of the US-China trade war for Korea, as well as for other surrounding countries and regions.

Design/methodology – In this paper, we develop a full multi-country/region multi-sector computable general equilibrium (CGE) model of global trade incorporating heterogeneous workers and firms in individual skill levels and used technologies. We then calibrate the model using a global Social Accounting Matrix (SAM) dataset extracted from the recently released GTAP 10 Database, and assess the potential effects of the US-China trade war on the aggregate real productivity and the market structure for Korea, as well as for other surrounding countries and regions.

Findings – We show that the US-China trade war may largely affect the aggregate productivity in each sector in each country/region, as well as the global market structure through entry and exit of firms, which results finally in considerable changes in the industrial comparative advantage of each country/region. Though the effects are diverse sector by sector, the results show that Korea may also be affected significantly: concerning the real productivity implications, it is shown that the machinery industry may be affected the most negatively; on the other hand, it is shown that the number of exporting firms may decrease the most in the other transports industry.

Originality/value – As the US-China trade war intensifies, many studies have tried to estimate the possible implications, and for this usually the CGE models have largely been used as the standard tool for evaluating the impacts of changes in trade policies. Standard CGE models, however, cannot be used to assess the global productivity and market structure implications due to the symmetric and simplified base assumptions. This paper is the first to analyze and quantify the possible impacts of the US-China trade war on the aggregate productivity and global market structure using a CGE model incorporating endogenous skill-technology assignment of heterogeneous workers and firms.

Keywords: Computable General Equilibrium (CGE) Modeling, Firm/Worker Heterogeneity and International Trade, Market Structure, Productivity, US-China Trade War
JEL Classifications: F15, F62

1. Introduction

The US-China trade war which started in 2018 is ongoing and even intensifying. Though there have been several attempts and deals to resolve the trade disputes between the US and China, the majority opinion seems to be that the US-China trade war will last since it is finally a combat to win the economic supremacy in the twenty-first century. As the US-China trade

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war continues and intensifies, there is growing concern about its potential effects on the global economy, considering the economic importance of the two countries in the world economy.

Since the beginning of the US-China trade war, many studies have been trying to estimate the possible implications. For example, recently using a standard CGE model, Li, Balistreri and Zhang (2020) find that the US-China trade war can significantly decrease the welfare of the two countries, while other countries' welfare may increase due to trade diversion effect. Itakura (2020) also evaluates the impact of the US-China trade war using a recursive dynamic CGE model of global trade, and argues that the US-China trade war can significantly decrease the real GDP of the two countries, though the trade diversion effect may contribute to a small positive impact on the real GDP for other countries.

On the other hand, focusing on the indirect impact on third countries through links in global supply chains, Mao and Gorg (2020) find that the US-China trade war may hit the most heavily other third countries, such as the EU, Canada, and Mexico, because of their close trading relationship with the US. This result implies that a country like Korea may also be heavily affected by the US-China trade war given its close trading relationship with China and the US. Table 1 shows Korea's main trading partners. China and the US have been the first and second country both in export and import. In particular, for an export-driven, small, and open economy such as Korea, the US-China trade war might cause fundamental changes in the industrial comparative advantage, and thus in the long-run growth path. Related to the topic, recent work by Jung Jae-Won and Kim Tae-Hwang (2019) suggest that mega-FTA formation and/or participation may be a good strategic trade policy option to mitigate any possible negative effects. However, given the large dependence of Korean economy on the two countries, if the US-china trade war would last long time, it might have a great repercussion on Korean economy in many ways.

China gradually opened up its economy to the rest of the world and has experienced rapid economic growth over the last decades. Among the China's market-oriented economic reforms to open its door to foreign trade and investment, two monumental events would be the normalization of diplomatic relations with the US in 1979 (after that, the US granted Most Favored Nations status (MFN) to China in early 1980) and the China's accession to WTO, which made China the world's largest manufacturing and exporting nation. At the time of these events, most foreign firms were eager to enter into trade relations with China due to its large market potential. A survey research by Tung (1982) reports that most US firms perceived trade relations with China to be more important to their image as a leader in the industry than to their overall profitability. Many researchers also highlighted the importance of institutional quality to enhance overall trade and FDI flows (see, e.g., Angkinand and Chiu, 2011; Wei, 2000). There is now a large consensus that institutional progress in many developing countries, such as in China, has been one of the key factors behind the rapidly globalizing world over the last decades.

Table 1. Korea's Main Trading Partners (2018, Rank Order of Export)

(Unit: US $ Million)

		Export	Import	Trade Balance
1.	China	162,125	106,489	55,636
2.	USA	72,720	58,868	13,852
3.	Vietnam	48,622	19,643	28,979
4.	Hong Kong	45,996	1,997	43,999
5.	Japan	30,529	54,604	-24,075

Table 1. (Continued)

		Export	Import	Trade Balance
6.	Taiwan	20,784	16,738	4,046
7.	India	15,606	5,885	9,721
8.	Philippines	12,037	3,569	8,468
9.	Singapore	11,782	7,974	3,808
10.	Mexico	11,458	5,090	6,368
11.	Australia	9,610	20,719	-11,109
12.	Germany	9,373	20,854	-11,481
13.	Malaysia	8,994	10,206	-1,212
14.	Indonesia	8,833	11,161	-2,328
15.	Thailand	8,505	5,582	2,923

Source: KITA (2019).

The US and China have been the two largest nations that lead the international trade and global economy. Given the market power and size of these two countries in the world economy today, it is inevitable that the US-China trade war will affect considerably the global value chains (GVCs) and trade, as well as the two countries. Concerning the current US-China trade war, economists claim to distinguish between the strategic competition and the economic competition since while the strategic competition might normally be a zero-sum game, a fair economic competition could generally create a win-win outcome in the long run (see, e.g., Liu and Woo, 2018). Economists have traditionally thought of market structure and competition as the fundamentals for economic efficiency and productivity (see, e.g., Syverson, 2004, and references therein). For this reason, one of the main concerns of trade economists has been how a trade reform or changes in trade environment would affect the overall market structure and productivity by entry and exit of firms and by restructuring of trade systems.

The aim of this paper is to investigate the global productivity and market structure implications of the US-China trade war for Korea, as well as for other surrounding countries and regions. We assess the potential effects of the US-China trade war on the aggregate real productivity of surrounding countries and regions, as well as on that of each sector in each country and region. We also study how the US-China trade war may affect the global market structure by investigating the potential impacts on the number of domestic and exporting firms in each sector in each country/region, which is closely related to the global industrial comparative advantage.

For this, a new CGE model is developed. Though market structure, competition and productivity have been the central issues for policy makers, conventional CGE models have mostly assumed a perfectly competitive world composed of homogeneous agents and technologies, which made it impossible to study the global productivity and market structure implications of any policy changes. As Jung Jae-Won (2020) shows, considering the close interplay between heterogeneous agents and technologies, as well as the competition among heterogeneous firms, should be important for policy assessment not only quantitatively but also even qualitatively. In this paper, we first develop a new CGE model incorporating heterogeneous workers and firms. The firm heterogeneity literature in international trade highlights that firms are different (heterogeneous) in many aspects. Many systematic links between the characteristics of firms and their degree of internationalization have been uncovered. In particular, in terms of the productivity, there is now ample evidence that exporting firms are more productive and use higher technologies than domestic firms (see, e.g., Aw, Chung and Roberts, 2000; Bernard and Jensen, 1999; Clerides, Lach and Tybout, 1998; Girma, Gorg and Strobl, 2004; Helpman, Melitz and Yeaple, 2004). Based on evidence, and differently from most previous CGE models, we model two types of firms (domestic vs. exporting) using different technologies (low-tech vs. high-tech). Domestic firms use a low-fixed-cost high-marginal-cost technology, while exporting firms use a high-fixed-cost low-marginal-cost technology. Workers are differentiated in their skill levels and endogenously sorted between technologies according to their respective comparative advantage, so that the aggregate productivity (sectoral and country/region-wide) is endogenously determined by skill-technology assignment in equilibrium. This modeling approach is also closely related to the recent theoretical development in international trade highlighting the globalization-induced real productivity gains (see, e.g., Antras, Garicano and Rossi-Hansberg, 2006; Blanchard and Willmann, 2016; Costinot and Vogel, 2010; Helpman, Itskhoki and Redding, 2010; Grossman and Maggi, 2000; Grossman, 2004; Jung Jae-Won, 2017/2019/2020; Melitz, 2003; Yeaple, 2005). Among others, Jung Jae-Won (2019) highlights that if technology would exhibit any increasing returns to skill, the equilibrium skill-technology matching itself could have considerable implications for economy-wide aggregate productivity.

The developed multi-country/region multi-sector CGE model with heterogeneous workers and firms was calibrated using a global Social Accounting Matrix (SAM) dataset extracted from the recently released GTAP 10 Database. As will be shown, the simulated results show that the US-China trade war may generate pervasive negative productivity effects for all countries and regions. It is also shown that the US-China trade war may largely affect the global market structure through entry and exit of firms, and considerably change the industrial comparative advantage of each country/region. Though relatively less pronounced than other countries and regions, it is shown that Korea also experiences a negative aggregate productivity effect of a fall of 0.007%. In terms of the effects on Korean exporting firms, it is shown that exporting firms decrease in the petroleum and chemicals, machinery, and other transports industries, while there is a more entry of exporting firms in the steel and metal, electronics and electrics, motor vehicles and parts, and other manufacturing industries, with a largest decrease of 11.547% in the other transports industry and a highest increase of 8.100% in the other manufacturing industry.

The rest of the paper is organized as follows. In Section 2, we describe the basic model and its CGE application. In Section 3, we study the effects of US-China trade war on the country and sector-wide productivity and market structure. Section 4 concludes with some remarks.

2. The Model and Application

2.1. Model Description

2.1.1. Technologies and Production

We model two types of firms using different technologies in each sector. When entering the market, firms choose whether to serve only domestic market or export. Exporting to foreign markets requires higher set-up fixed costs. Also, there is now ample evidence that exporting firms are more productive than domestic firms. Based on evidence, we assume two different technologies in each sector: low-tech (L) and high-tech (H); we associate domestic firms with low-tech-low-fixed-cost technology, and exporting firms with high-tech-high-fixed-cost technology. In what follows, if no confusion arises, country/region and sector indexes are omitted.

Production of final goods requires primary factors and intermediate goods. Following the standard CGE models, we assume that capital is homogeneous and the Armington assumption applies to the intermediate demands. On the other hand, existence of different technologies implies worker allocation to different technologies. We assume that workers are differentiated by their individual skill level z. The skill distribution in the population in each country/region is given by $G(z)$ with density $g(z)$ on support $[z_{min}, z_{max}]$.

We denote by $\varphi_j(z), j \in \{L, H\}$, the technology-augmented productivity of a worker with skill level z. $\varphi_j(z)$ is increasing in z and continuous. Also, at a given skill level z, using high technology is more productive than using low technology: $\varphi_H(z) > \varphi_L(z)$. Furthermore, we assume a comparative advantage aspect of skill in technologies. Specifically, we assume that:

$$0 < \frac{\partial \varphi_L(z)}{\partial z} \frac{1}{\varphi_L(z)} < \frac{\partial \varphi_H(z)}{\partial z} \frac{1}{\varphi_H(z)}, \tag{1}$$

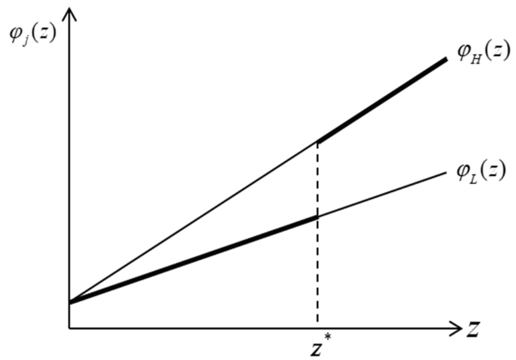
with $\varphi_L(z_{min}) = \varphi_H(z_{min})$. Our technology specification implies that workers with higher skill level are relatively more productive when they are matched with higher technologies. Consequently, in our framework, workers with relatively low skill levels have relative comparative advantage in low technology (working in domestic firms using low-tech), while workers with relatively high skill levels have relative comparative advantage in high technology (working in exporting firms using high-tech). There should, then, be a skill threshold in each sector. Let z^* denote the equilibrium skill thresholds between z_{min} and z_{max}: $z_{min} < z^* < z_{max}$. Finally, in equilibrium, workers with $z \in (z_{min}, z^*)$ are matched with low-tech domestic firms and worker with $z \in (z^*, z_{max})$ are matched with high-tech exporting firms. The equilibrium skill threshold z^* is, of course, different sector by sector and endogenously determined. Fig. 1 illustrates the equilibrium technology/skill assignment.

In a perfectly competitive labor market, the threshold worker's wage should be the same whether he is assigned to domestic firms or exporting firms, which leads to the following no-arbitrage condition:

$$w_L \varphi_L(z^*) = w_H \varphi_H(z^*), \tag{2}$$

where w_L and w_H are technology-specific efficiency wage rates.

Fig. 1. Equilibrium Skill Allocation to Different Technologies



2.1.2. Competition and Equilibrium

We assume Dixit-Stiglitz preferences over a continuum of varieties, and monopolistic competition to prevail in each sector. Firms charge a constant mark-up over marginal production costs:

$$p_L = \frac{\sigma}{\sigma-1}w_L \text{ and } p_H = \frac{\sigma}{\sigma-1}w_H. \tag{3}$$

Zero-profit conditions from free entry satisfy that mark-up revenues exactly cover the fixed costs of each firm type:

$$\frac{1}{\sigma}p_L x_L = w_L f_L \text{ and } \frac{1}{\sigma}p_H x_H = w_H f_H, \tag{4}$$

where x_L and x_H are demands for individual varieties, and f_L and f_H are technology-specific fixed costs for each firm type. These free entry conditions determine the equilibrium number of each firm type: N_L and N_H.

For the derivation of demands for individual varieties, usual constant elasticity of substitution (CES) formulation is used. Also, for the supply decision of exporting firms between domestic and foreign market, usual constant elasticity of transformation (CET) formulation is used. Note that in each country/region there are three groups of goods: varieties of domestic low-tech firms, varieties of high-tech exporting firms supplied for domestic market, and varieties of foreign high-tech exporting firms imported for domestic market.

One important feature of this model is that the technology-augmented total efficiency units of labor are endogenously determined by the skill-technology assignment in equilibrium, though the labor supply itself is fixed in each country/region as in conventional CGE models. In each sector-*s* in each country/region-*i*, the technology-augmented total efficiency units of labor are given by:

$$LE_{is}^{Tot} = L_{isL}^{sup} + L_{isH}^{sup}, \tag{5}$$

$$L_{isL}^{sup} = \gamma_{is}\left(\int_{z_{min}}^{z_{is}^*} \varphi_{isL}(z)dz\right) L_{is}^{sh}, \tag{6}$$

$$L_{isH}^{sup} = \gamma_{is}\left(\int_{z_{is}^*}^{z_{max}} \varphi_{isH}(z)dz\right) L_{is}^{sh}, \tag{7}$$

where γ_{is} is a scale parameter and L_{is}^{sh} is a sectoral labor employment share variable with $\sum_s L_{is}^{sh}$=1 in each country/region.

In a perfectly competitive labor market, the sectoral employment share variable L_{is}^{sh} is determined by the no-arbitrage condition of the average worker in each sector:

$$\frac{w_L L_{isL}^{sup} + w_H L_{isH}^{sup}}{L_{is}^{sh}} = \lambda_{ist}^0 \frac{w_L L_{itL}^{sup} + w_H L_{itH}^{sup}}{L_{it}^{sh}}, \quad s \neq t \tag{8}$$

where λ_{ist}^0 is a parameter of the initial average wage difference between sector *s* and *t*.

Equilibrium wages are determined by labor supply and demand in efficiency units:

$$L_{isL}^{sup} = (L_{isL}^{dem} + f_{isL})N_{isL}, \quad (9)$$

$$L_{isH}^{sup} = (L_{isH}^{dem} + f_{isH})N_{isH}. \quad (10)$$

All the other basic settings and equations follow the conventional full multi-country/region multi-sector global CGE models with monopolistic competition.

2.2. CGE Application

The developed model is calibrated using a global Social Accounting Matrix (SAM) dataset extracted from the recently released GTAP 10 Database. The database was aggregated to 11 countries/regions and 10 sectors.

The 11 countries and regions are Korea, China, Japan, USA, EU, India, ASEAN 4, ASEAN 6, Oceania 2, America 4, and Rest of World (RoW). Country groups are divided depending on their mega-FTA participation. ASEAN 4 countries include Vietnam, Malaysia, Singapore, and Brunei which participate in both the Regional Comprehensive Economic Partnership (RCEP) and the Comprehensive & Progressive Agreement for Trans-Pacific Partnership (CPTPP), while ASEAN 6 countries include Thailand, Indonesia, Philippines, Myanmar, Cambodia, and Laos which participate only in RCEP. Oceania 2 countries include Australia and New Zealand which participate in both RCEP and CPTPP. America 4 countries include Canada, Mexico, Peru, and Chile which participate only in CPTPP.

The 10 sectors include primary, petroleum & chemicals, steel & metal, electronics & electrics, machinery, motor vehicles & parts, other transports, other manufactures, utility & construction, and services. We apply our developed model to the manufacturing sectors. On the other hand, for the primary, utility & construction, and services sectors, conventional perfect competition settings with homogeneous goods are used. Following Table 2 summarizes the classification of countries/regions and industries.

Table 2. Classification of Countries/Regions and Industries

Country / Region	Industry
Korea	Primary
China	Petroleum & Chemicals
Japan	Steel & Metal
USA	Electronics & Electrics
EU	Machinery
India	Motor Vehicles & Parts
ASEAN 4	Other Transports
ASEAN 6	Other Manufactures
Oceania 2	Utility & Construction
America 4	Services
Rest of World	

Notes: 1. ASEAN 4: Vietnam, Malaysia, Singapore, Brunei (RCEP & CPTPP participation).
2. ASEAN 6: Thailand, Indonesia, Philippines, Myanmar, Cambodia, Laos (RCEP participation).
3. Oceania 2: Australia, New Zealand (RCEP & CPTPP participation).
4. America 4: Canada, Mexico, Peru, Chile (CPTPP participation).

For the model calibration, we need to specify the functional form of $\varphi_j(z), j \in \{L, H\}$. We assume linear technologies as shown in Fig. 1:

$$\varphi_j(z) = 1 + a_j z, \qquad j \in \{L, H\}, \tag{11}$$

and following Bernard and Jensen (2004), we set a_H/a_L=1.085.

For the skill distribution, we assume uniform distribution and normalize the skill levels so that $z_{min} = 0$ and $z_{max} = 1$.

Fixed costs $f_j, j \in \{L, H\}$ are calibrated so that Equation (4) is satisfied for all monopolistic competition sectors in all countries and regions. All the other parameter values are also calibrated so that we exactly reproduce the initial Social Accounting Matrix (SAM) extracted from the recently released GTAP 10 Database.

Finally, in this paper we also fully model the Rest of World (RoW) and choose the aggregate consumption price index of the Rest of World (RoW) as our numeraire. In Jung Jae-Won (2020), the Rest of World was treated rather exogenously.

3. Effects of the US-China Trade War

Given our model construction and calibration, in this section we investigate the effects of the US-China trade war. Specifically, we will consider a case where the US and China increase reciprocally the tariff rates by 1.5 times for all imported goods from each other, and analyze how such bilateral tariff increases between the G2 affect the global productivity and market structure.

For the global productivity implications, we will investigate how the bilateral tariff increases between the G2 affect the skill/technology thresholds and the technology-augmented efficiency units of labor in each industry and in each country/region. For the global market structure implications, we will investigate the induced effects on the number of each firm type (low-tech domestic vs. high-tech exporting) in each sector and in each country/region.

In the Appendix, the results of the unilateral tariff increases are also reported.

3.1. Implications on the Productivity

Table 3 first shows the effects on the skill/technology thresholds z^* in manufacturing industries. As described before, a decrease (leftward shift) of z^* implies that now more firms and workers are matched with high technology in that sector. Note that Table 3 shows the induced percentage changes of the skill/technology thresholds z^*, and that a negative number in the cell indicates a leftward shift of z^* (skill/technology-upgrading), while a positive number indicates a rightward shift of z^* (skill/technology-downgrading).

We can see that the sectoral effects as well as the effects for each country/region are largely diverse. For the US and China, it is shown that overall negative effects prevail. For the US, the motor vehicle and parts industry may be affected the most negatively with an increase of the threshold by 32.924%, while, for the China, the other manufacturing industry was affected the most negatively with an increase of the threshold by 96.698%. On the other hand, some industries may experience some positive effects resulted from the indirect general equilibrium effects. For example, it is shown that the machinery industry in China may have a skill/technology upgrading effect with a leftward shift of the threshold by 5.156%. In the US, it is shown that the steel and metal industry may experience a slightly positive effect with a leftward shift of the threshold by 0.091%.

Not surprisingly, the US-China trade war influences not only the countries directly concerned, but also the other countries. Looking at the effects on Korea, it is shown that the petroleum and chemicals, electronics and electrics, machinery, and other transports industries are negatively affected with an increase of the skill/technology thresholds, while the steel and metal, motor vehicles and parts, and other manufacturing industries are positively affected with a decrease of the thresholds. In terms of the effects on the skill/technology thresholds, Korea may have the most negative effect in the machinery industry with a rightward shift of the threshold by 12.753%.

The effects for the other countries and regions are also largely diverse. Japan is affected the most negatively in the steel and metal industry with a rightward shift of the threshold by 24.866%, while the EU is affected the most negatively in the petroleum and chemicals industry with a rightward shift of the threshold by 32.413%. Otherwise, it is shown that the other transports industry in the America 4 countries is affected the most negatively with a rightward shift of the threshold by 50.988%.

Table 3. Effects of US-China Trade War on Thresholds

(Unit: % Changes)

	Petrol. Chem.	**Steel Metal**	**Electr.**	**Mach.**	**Motor Parts**	**Other Transp.**	**Other Manuf.**
Korea	3.933	-6.670	4.120	12.753	-4.562	8.396	-7.594
China	20.906	2.281	17.617	-5.156	-2.587	2.512	96.698
Japan	-48.306	24.866	5.219	24.747	-1.889	14.795	-8.083
USA	2.006	-0.091	2.388	3.245	32.924	11.748	1.255
EU	32.413	-1.242	-6.172	4.676	0.298	9.017	7.450
India	18.001	-8.664	-6.985	-4.011	-11.904	-8.683	1.768
ASE4	13.650	23.356	13.522	3.367	7.119	11.126	29.522
ASE6	31.567	6.584	24.237	33.708	0.062	10.353	33.523
Ocea2	3.745	7.957	2.487	4.694	1.900	1.960	-0.810
Amer4	11.628	-13.505	3.572	0.466	19.066	50.988	4.208
RoW	-19.514	11.834	17.323	4.033	5.107	-3.494	-5.325

Table 4 shows the induced effects on the sectoral real productivity for each country/region. We measure the sectoral real productivity level as the average efficiency units of labor in each sector, i.e., $\int_{z_{min}}^{z^*} \varphi_L(z)\, g(z) dz + \int_{z^*}^{z_{max}} \varphi_H(z)\, g(z) dz$. Following the shifts of the skill/technology thresholds, Table 4 shows the induced percentage changes of the average real productivity level in each sector and for each country/region.

We can see again that the sectoral effects as well as the effects for each country/region are largely diverse. We see that for the sectors where the skill/technology threshold moved rightwards there is a fall in the average real productivity, while for the sectors where the threshold moved leftwards there is a rise in the average real productivity.

For the US and China, it is shown that there is an overall negative real productivity effect. For the China, we can see that the other manufacturing industry experiences the most negative real productivity effect with a decrease of the average real productivity by 0.567%.

For the US, it is shown that the motor vehicles and parts industry may have the most negative real productivity effect with a fall of the average real productivity by 0.152%. In total, the aggregate real productivity decreases by 0.103% and 0.034% in China and the US, respectively. Thus, the results show that in terms of the real productivity China may be affected more negatively than the US following the reciprocal tariff increases between them.

Concerning Korea, it is shown that the average real productivity decreases in the petroleum and chemicals, electronics and electrics, machinery, and other transports industries by 0.016%, 0.017%, 0.054% and 0.035%, respectively, which leads to an overall decrease of 0.007%. On the other hand, it is shown that Korea's real productivity loss may be relatively small compared to other countries and regions, except for the India. India has a positive aggregate productivity effect with an increase of 0.010%, while all the other countries and regions experience negative aggregate productivity effects. In our classification of regions, the ASEAN countries are shown to be affected the most negatively after China. The aggregate real productivity decreases by 0.090% and 0.063% in ASEAN 6 and ASEAN 4 countries, respectively, which are larger than even for the US.

Table 4. Effects of US-China Trade War on Real Productivity

(Unit: % Changes)

	Petrol. Chem.	**Steel Metal**	**Electr.**	**Mach.**	**Motor Parts**	**Other Transp.**	**Other Manuf.**	**Total**
Korea	-0.016	0.026	-0.017	-0.054	0.018	-0.035	0.029	-0.007
China	-0.091	-0.009	-0.076	0.020	0.010	-0.010	-0.567	-0.103
Japan	0.145	-0.111	-0.021	-0.110	0.007	-0.063	0.031	-0.017
USA	-0.008	0.000	-0.010	-0.013	-0.152	-0.049	-0.005	-0.034
EU	-0.149	0.005	0.024	-0.019	-0.001	-0.037	-0.031	-0.030
India	-0.078	0.033	0.027	0.016	0.044	0.033	-0.007	0.010
ASE4	-0.058	-0.103	-0.057	-0.014	-0.029	-0.046	-0.134	-0.063
ASE6	-0.145	-0.027	-0.107	-0.156	0.000	-0.043	-0.155	-0.090
Ocea2	-0.015	-0.033	-0.010	-0.019	-0.008	-0.008	0.003	-0.013
Amer4	-0.049	0.050	-0.014	-0.002	-0.083	-0.253	-0.017	-0.053
RoW	0.070	-0.050	-0.074	-0.016	-0.021	0.014	0.021	-0.008

3.2. Implications on the Market Structure

Now we investigate the effects on the sectoral number of firms in each country/region. Note that the changes in the number of each firm type (domestic or exporting) do not necessarily coincide with the changes in the skill/technology thresholds. A leftward shift of the threshold z^* implies that a worker who was previously matched with low-tech domestic firms is now matched with high-tech exporting firms. However, the total variation of number of firms is not only induced by the allocation of workers within each sector, but also by the allocation of workers between sectors in equilibrium.

Table 5 first shows the percentage changes of domestic firms in each sector and for each country/region. It is shown that following the reciprocal tariff increases between the US and China, more domestic firms prevail in both countries. Such effects are more pronounced in China. In the other manufacturing industry in China, it is shown that the domestic firms increase by 93.991%, which is followed by the petroleum and chemicals industry with an increase of 22.738%. In the US, we see also an overall increase of domestic firms though less pronounced compared to China. It is shown that in the US the motor vehicles and parts industry is more dominated by domestic firms.

Concerning Korea, the effects on the sectoral domestic firms are quite diverse. It is shown that the number of domestic firms decreases in the steel and metal, motor vehicles and parts, other transports, and other manufacturing industries by 5.665%, 3.706%, 0.852% and 3.027%, respectively, while increases in the petroleum and chemicals, electronics and electrics, and machinery industries by 0.564%, 7.805% and 9.219%, respectively.

Otherwise, it is shown that following the reciprocal tariff increases between the US and China, the ASEAN countries are highly dominated by low-tech domestic firms. Among others, it is shown that the low-tech domestic firms increase the most in the other manufacturing industry of the ASEAN countries, with an increase of 38.952% and 33.042% in ASEAN 4 and ASEAN 6 countries, respectively.

Table 5. Effects of US-China Trade War on Domestic Firms

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	0.564	-5.665	7.805	9.219	-3.706	-0.852	-3.027
China	22.738	6.943	21.017	1.405	5.259	12.698	93.991
Japan	-46.877	19.425	1.970	15.916	-2.505	11.791	-2.625
USA	4.952	-0.573	3.070	0.553	29.511	12.460	7.266
EU	26.621	1.461	-0.303	5.429	1.913	9.732	8.886
India	18.102	-4.299	-5.657	-4.821	-12.979	-7.450	2.768
ASE4	5.853	20.684	18.578	14.967	4.935	12.784	38.952
ASE6	28.440	16.784	32.402	41.488	4.588	15.119	33.042
Ocea2	5.033	5.586	0.481	0.299	-1.538	0.862	3.611
Amer4	9.918	-6.229	17.666	-1.246	18.896	1.944	6.232
RoW	-16.282	4.410	2.939	-0.128	1.131	-2.494	-1.623

Finally, we investigate the effects on the high-tech exporting firms. As mentioned before, note that an increase(a decrease) of domestic firms does not necessarily lead to a decrease(an increase) of exporting firms. The total variation of number of firms is not only induced by the allocation of workers within each sector, but also by the allocation of workers between sectors in equilibrium. If more workers move to a sector due to an expansion of that sector in equilibrium, both domestic and exporting firms may increase. Likewise, if less workers are allocated to a sector due to a contraction of that sector, both domestic and exporting firms may decrease in that sector. The final outcomes would depend not only on the competition within a country (competition between firms and sectors within a country), but also on the competition between countries and regions (competition with foreign firms and sectors).

Table 6 shows the percentage changes of exporting firms in each sector and for each country/region. As before, it is shown that the sectoral effects are largely diverse. In China, it is shown that exporting firms decrease in the petroleum and chemicals, electronics and electrics, and other manufacturing industries, while increase in the steel and metal, machinery, motor vehicles and parts, and other transports industries; exporting firms decrease the most in the other manufacturing industry with a fall of 37.880%, while increase the most in the motor vehicles and parts industry with a rise of 9.162%.

In the US, it is shown that exporting firms decrease in the steel and metal, electronics and electrics, machinery, motor vehicles and parts, and other transports industries, while increase in the petroleum and chemicals, and other manufacturing industries; exporting firms decrease the most in the motor vehicles and parts industry with a fall of 15.012%, while increase the most in the other manufacturing industry with a rise of 5.415%.

In Korea, it is shown that exporting firms decrease in the petroleum and chemicals, machinery, and other transports industries, while increase in the steel and metal, electronics and electrics, motor vehicles and parts, and other manufacturing industries; exporting firms decrease the most in the other transports industry with a fall of 11.547%, while increase the most in the other manufacturing industry with a rise of 8.100%.

It would also be of our great interest to look at the effects on the Japanese exporting firms given their high competition with the Korean exporting firms in the international market. In Japan, it is shown that exporting firms decrease in the steel and metal, electronics and electrics, machinery, and other transports industries, while increase in the petroleum and chemicals, motor vehicles and parts, and other manufacturing industries; exporting firms decrease the most in the machinery industry with a fall of 16.119%, while increase the most in the petroleum and chemicals industry with a rise of 22.921%.

Table 6. Effects of US-China Trade War on Exporting Firms

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	-4.754	3.759	1.846	-7.996	2.724	-11.547	8.100
China	-6.837	3.612	-4.228	9.098	9.162	8.850	-37.880
Japan	22.921	-13.732	-5.087	-16.119	0.116	-8.294	9.343
USA	2.074	-0.447	-0.275	-3.849	-15.012	-3.981	5.415
EU	-16.549	3.242	8.860	-1.141	1.490	-2.928	-1.647
India	-7.035	8.397	4.244	0.732	3.452	4.840	0.279
ASE4	-11.896	-11.154	-1.131	9.737	-4.792	-2.959	-5.132
ASE6	-14.462	6.713	-3.614	-8.179	4.497	0.049	-13.433
Ocea2	-0.255	-5.262	-2.918	-5.970	-4.097	-1.840	4.792
Amer4	-6.059	14.247	12.001	-1.885	-7.658	-45.853	0.245
RoW	12.152	-11.005	-18.238	-5.530	-5.726	2.430	6.104

Finally, the results of Table 6 also indicate that the US-China trade war may induce considerable changes in the industrial comparative advantage of each country/region. Other things being equal, an increase of exporting firms in a certain industry of a country implies that that country has more comparative advantage for that industry, and exports more those goods to the global market.

In Table 6, we can see that the effects are more pronounced in certain industries. For example, for the petroleum and chemical goods, Japan's comparative advantage may increase significantly, while that of the EU and the ASEAN decreases significantly. On the other hand, Japan may lose considerably its comparative advantage in the steel and metal goods and in the machinery goods. Concerning Korea, it is shown that Korea may lose considerably its comparative advantage in the other transports industry, while gain comparative advantage in the other manufacturing industry. It is also worthy of notice that the US may lose largely its comparative advantage in the motor vehicles and parts industry.

4. Conclusion

Though there have been several attempts and deals to resolve the trade disputes between the US and China, the ongoing US-China trade war is even intensifying and it is widely believed that the US-China trade war will last long time since it is finally a combat to win the economic supremacy in the twenty-first century. If it would be the case, not only countries like Korea that have a large economic dependence on the economy of the two countries but also other outside countries might have great repercussions through links in global supply chains.

In this paper, we developed a full multi-country/region multi-sector computable general equilibrium (CGE) model of global trade incorporating endogenous skill-technology assignment of heterogeneous workers and firms, and investigated possible impacts of the US-China trade war on the aggregate productivity and global market structure.

The simulated results show that the US-China trade war may largely affect the aggregate productivity in each sector in each country/region, as well as the global market structure through entry and exit of firms using different technologies, which may finally result in considerable changes in the industrial comparative advantage of each country/region. Though the effects may be diverse sector by sector and country by county, the results show that all countries may be affected significantly given the importance of the two economies in the world economy as well as the close economic interdependence in today's globalized world. Above all, it was shown that the US-China trade war might decrease the aggregate productivity of all countries and regions. One exception of an aggregate productivity gain was found in the case of the India. In a dynamic setting, however, it may be very likely that the pervasive aggregate productivity losses all over the world would finally affect negatively the India too, and such dynamic negative effects might be much larger for export-driven, small, and open economies such as Korea. The results of this paper may therefore suggest that the US-China trade war is not just about the US and China, and thus that other third countries have also high incentives to resolve the trade disputes together.

Finally, the results of the paper also imply that if the US and China would increase bilateral tariffs for some targeted industries, all the productivity and market structure implications could change again not only quantitively but also qualitatively. Also, extending the basic model to dynamic settings and analyzing dynamic implications may provide other interesting dynamic insights. Though market structure, competition and productivity have been the central issues for policy makers, conventional CGE models have mostly assumed a perfectly competitive world composed of homogeneous agents and technologies. The heterogeneous-agent/technology framework of this paper may widely be used to evaluate or re-evaluate the impacts of any policy changes when the competition and productivity issues are important (or at least not negligible). I leave them for future research.

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Appendix

Table A. Effects on Thresholds (Unilateral Tariff Increases by the US)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	1.839	3.854	15.010	28.869	-3.998	5.293	-6.310
China	10.726	-5.541	39.001	-17.289	-7.026	-3.166	77.673
Japan	-25.046	55.612	24.145	63.578	-3.658	33.744	-4.819
USA	-11.302	-11.090	-19.363	-12.312	-6.790	-13.830	-3.315
EU	10.641	-1.065	-7.198	5.197	55.632	-24.429	1.231
India	25.075	-3.371	-3.658	-0.791	-4.139	-30.002	7.067
ASE4	30.692	12.950	23.983	28.270	8.981	-1.352	20.249
ASE6	33.566	-1.790	43.231	19.431	9.042	13.085	38.971
Ocea2	2.083	-5.566	-0.318	0.575	0.753	2.786	-1.482
Amer4	-14.176	48.687	17.715	33.839	7.004	-2.031	-10.173
RoW	7.711	18.852	20.070	9.950	2.816	21.390	1.693

Table B. Effects on Real Productivity (Unilateral Tariff Increases by the US)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.	Total
Korea	-0.007	-0.016	-0.064	-0.131	0.016	-0.022	0.024	-0.028
China	-0.045	0.021	-0.184	0.062	0.027	0.012	-0.427	-0.076
Japan	0.087	-0.281	-0.107	-0.332	0.014	-0.156	0.019	-0.108
USA	0.042	0.041	0.069	0.046	0.026	0.051	0.013	0.041
EU	-0.044	0.004	0.027	-0.021	-0.281	0.085	-0.005	-0.034
India	-0.112	0.013	0.014	0.003	0.016	0.101	-0.029	0.001
ASE4	-0.140	-0.055	-0.106	-0.128	-0.037	0.005	-0.088	-0.078
ASE6	-0.155	0.007	-0.208	-0.084	-0.037	-0.055	-0.184	-0.102
Ocea2	-0.008	0.021	0.001	-0.002	-0.003	-0.011	0.006	0.001
Amer4	0.052	-0.240	-0.076	-0.157	-0.029	0.008	0.038	-0.058
RoW	-0.032	-0.082	-0.087	-0.041	-0.011	-0.094	-0.007	-0.051

Table C. Effects on Domestic Firms (Unilateral Tariff Increases by the US)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	1.107	4.054	17.304	23.374	2.268	-9.472	-2.781
China	11.939	-1.973	30.559	-10.279	0.925	1.634	75.027
Japan	-23.400	46.862	26.736	47.002	0.915	32.204	-0.261
USA	-8.418	-4.820	-14.866	-14.873	-12.743	-16.235	1.528
EU	9.649	-0.200	-1.182	4.860	41.522	-13.415	2.713
India	25.765	1.404	4.941	-1.471	-4.191	-27.753	7.756
ASE4	18.580	13.985	29.519	22.016	11.300	0.828	31.904
ASE6	34.243	9.388	53.611	46.661	9.615	7.200	36.942
Ocea2	3.717	-4.252	13.951	-5.160	2.046	-6.941	1.855
Amer4	-14.012	11.162	51.825	-5.533	15.822	-4.374	-6.870
RoW	8.287	15.880	20.094	7.566	14.070	-0.238	4.174

Table D. Effects on Exporting Firms (Unilateral Tariff Increases by the US)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	-1.444	-1.338	-4.060	-15.080	8.216	-15.812	6.360
China	-3.187	6.065	-20.357	15.924	11.578	6.267	-30.948
Japan	12.487	-26.081	-7.584	-32.296	6.267	-14.207	6.795
USA	7.872	11.724	13.635	1.796	-3.891	2.502	6.379
EU	-5.073	1.300	9.527	-2.366	-28.748	25.763	0.969
India	-9.387	6.348	10.507	-0.374	1.585	15.589	-2.155
ASE4	-20.226	-4.243	-5.402	-15.446	-1.490	2.758	0.958
ASE6	-12.715	12.174	-10.906	13.387	-3.075	-10.103	-16.462
Ocea2	0.766	3.626	14.459	-5.916	0.983	-10.455	3.993
Amer4	5.863	-39.422	19.973	-38.746	5.234	-1.608	7.873
RoW	-2.539	-9.746	-7.868	-6.006	9.710	-24.701	1.754

Table E. Effects on Thresholds (Unilateral Tariff Increases by China)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	-5.998	-4.438	-2.534	0.267	-8.324	-11.474	0.091
China	2.327	1.761	-1.631	3.158	-0.068	-0.998	3.686
Japan	-4.317	-1.415	2.550	-5.428	0.874	-8.957	-0.632
USA	8.272	5.264	11.802	9.042	37.479	18.404	3.107
EU	18.046	1.990	4.402	3.520	-21.486	40.309	4.920
India	1.501	-2.876	-2.436	-2.067	-7.255	8.390	-0.806
ASE4	-7.937	9.263	-1.709	-21.628	-0.217	11.712	2.449
ASE6	1.977	-1.491	0.556	2.773	-15.168	-5.425	1.774
Ocea2	1.820	10.557	2.606	3.841	1.345	0.019	3.004
Amer4	15.771	-20.969	1.291	-7.762	16.359	43.012	9.179
RoW	-13.349	-2.336	-5.118	-2.472	1.832	-15.260	-2.994

Table F. Effects on Real Productivity (Unilateral Tariff Increases by China)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.	Total
Korea	0.023	0.017	0.010	-0.001	0.032	0.043	0.000	0.018
China	-0.009	-0.007	0.006	-0.013	0.000	0.004	-0.015	-0.005
Japan	0.017	0.006	-0.010	0.021	-0.003	0.034	0.002	0.009
USA	-0.034	-0.021	-0.049	-0.037	-0.176	-0.080	-0.012	-0.059
EU	-0.078	-0.008	-0.018	-0.014	0.076	-0.192	-0.020	-0.036
India	-0.006	0.011	0.010	0.008	0.028	-0.035	0.003	0.003
ASE4	0.030	-0.038	0.007	0.076	0.001	-0.049	-0.010	0.002
ASE6	-0.008	0.006	-0.002	-0.011	0.055	0.021	-0.007	0.008
Ocea2	-0.007	-0.044	-0.010	-0.015	-0.005	0.000	-0.012	-0.014
Amer4	-0.067	0.074	-0.005	0.030	-0.070	-0.207	-0.038	-0.040
RoW	0.049	0.009	0.020	0.010	-0.007	0.056	0.012	0.021

Table G. Effects on Domestic Firms (Unilateral Tariff Increases by China)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	-5.282	-3.509	-0.190	-2.226	-9.098	-0.198	0.837
China	2.685	1.997	0.041	2.996	1.195	4.343	4.024
Japan	-4.342	-1.484	-0.158	-4.146	-0.868	-7.338	-0.100
USA	8.681	1.552	10.495	9.369	39.597	22.281	3.852
EU	15.256	2.875	5.621	4.295	-16.835	22.132	4.774
India	1.124	-2.081	-2.827	-2.119	-7.978	8.561	-0.712
ASE4	-6.755	6.387	-1.868	-7.737	-4.888	7.417	1.618
ASE6	0.318	0.297	-0.364	-4.331	-11.836	2.974	1.759
Ocea2	1.429	8.059	0.302	3.378	-3.373	6.491	3.047
Amer4	14.782	-8.517	5.049	1.794	11.228	5.903	7.889
RoW	-11.376	-4.163	-6.950	-4.070	-7.080	-5.683	-2.408

Table H. Effects on Exporting Firms (Unilateral Tariff Increases by China)

(Unit: % Changes)

	Petrol. Chem.	Steel Metal	Electr.	Mach.	Motor Parts	Other Transp.	Other Manuf.
Korea	3.172	2.753	3.439	-2.589	2.436	17.851	0.710
China	-0.575	-0.467	2.356	-1.401	1.290	5.809	-1.134
Japan	1.695	0.492	-3.622	3.543	-2.068	5.402	0.787
USA	-2.889	-5.515	-5.723	-3.254	-13.204	-4.136	-0.506
EU	-9.321	0.075	-0.593	-0.653	15.032	-26.655	-2.083
India	-0.967	1.971	0.562	0.765	2.076	-3.154	0.414
ASE4	4.496	-6.198	0.516	27.925	-4.599	-8.284	-1.772
ASE6	-2.397	2.417	-1.134	-7.937	10.231	11.231	-0.717
Ocea2	-1.100	-6.320	-3.249	-1.953	-5.162	6.463	-1.144
Amer4	-7.027	25.458	3.178	13.754	-10.589	-38.352	-4.764
RoW	7.737	-0.960	0.060	-0.676	-9.414	18.037	1.798