Simulating the decoupling world under Russia's invasion of Ukraine: an application of IDE-GSM

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Abstract

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Keywords: Decoupling of the world, Simulation analysis, IDE-GSM

JEL classification: E27, F17, R12

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The Institute of Developing Economies (IDE) is a semigovernmental, nonpartisan, nonprofit research institute, founded in 1958. The Institute merged with the Japan External Trade Organization (JETRO) on July 1, 1998. The Institute conducts basic and comprehensive studies on economic and related affairs in all developing countries and regions, including Asia, the Middle East, Africa, Latin America, Oceania, and Eastern Europe.

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1. Introduction

The Russian military invasion of Ukraine began on February 24, 2022. It is ongoing after nearly ten months and has resulted in numerous military and civilian casualties. The North Atlantic Treaty Organization camp has not intervened militarily in response to the Russian invasion; however, major countries, such as the United States, Japan, and Europe, have imposed various economic sanctions, including the exclusion of Russian banks from the Society for Worldwide Interbank Financial Telecommunication (SWIFT) payment system, the freezing of the Russian officials' assets, and the prohibition of the export/import of certain items from/to Russia.

Prior to the Russian invasion of Ukraine, the United States–China trade war began in July 2018 when US President Donald Trump imposed 25% tariffs on 818 Chinese goods valued at 34 billion USD. President Trump and President Xi Jinping of China negotiated to resolve various trade issues, including exchange rates and intellectual property rights, as the trade war escalated. However, the agreement has not yet been reached under the Biden administration, which succeeded Trump's.

Since the end of the Cold War between the United States and the Soviet Union in the early 1990s, the global economy has rapidly moved toward globalization. The development of containerized logistics systems utilizing information and communication technology has allowed corporations to extend their supply chains beyond the global East–West and North–South barriers. The globally optimized procurement has taken root, in which parts and components manufactured in countries with the lowest production costs are traded and assembled into final products via international logistics networks.

However, the trade war between the United States and China, the economic disruption caused by COVID-19, and Russia's invasion of Ukraine have raised concerns that globalization may be reversing. The world may once again be divided by numerous "walls." On the economic security front, as evidenced by the United States' exclusion of Huawei, a Chinese high-tech company, companies must clarify whether they are technologically aligned with the United States or China. Russia's recent invasion of Ukraine was unexpected in that it revealed the risk of a new East–West divide. Aside from these walls, we must investigate whether business partners are striving for zero CO2 emissions and whether they are polluting the environment, and whether they overwork foreign workers and employ child labor, in terms of human rights. It is becoming increasingly difficult to add a trading partner to the supply chain without overcoming numerous obstacles, especially when targeting developed countries as final markets.

Meanwhile, many countries, particularly developing countries, are neutral towards this new situation. Many developing countries that rely on Russia for their diplomacy and security wish to remain neutral in the face of the Russian invasion of Ukraine, as evidenced by the 82 countries that have opposed or abstained from voting to suspend Russia's membership in the UN Human Rights Commission. In addition, they disregard or cannot afford to consider the environmental and ethical standards established by developed countries.

The world appears to be divided into three blocs: the Chinese–Russian bloc, the Western alliance, and the rest of the world, which is neutral in the conflict between the former camps. What impact will this "decoupling" of the world economy have? How will the reorganization of the coalition affect the economic impacts in each country? In this paper, we estimate the economic impacts of "decoupling" scenarios on each country and region using a computable general equilibrium (CGE)-type simulation model called the geographical simulation model developed by the Institute of Developing Economies (IDE-GSM).

The remainder of this paper is structured as follows. Section 2 describes the IDE-GSM model, data, and parameters in brief detail. Section 3 constructs two "decoupling" world scenarios. Section 4 simulates the scenarios and analyzes the economic impacts on each economy using simulations. Finally, Section 5 concludes the paper with a summary of the results and policy implications.

2. Background of the IDE-GSM

Since 2007, IDE-JETRO has been developing the spatial economics-based computable general equilibrium (CGE) model IDE-GSM (Kumagai et al., 2013). The model is utilized by international organizations such as the Economic Research Institute for ASEAN and East Asia (ERIA), the World Bank, and the Asian Development Bank to evaluate the economic impact of international infrastructure development projects. Due to the fact that tariff data and non-tariff barriers (NTBs) are factored into our trade cost calculations, we can estimate the global economic impact of a "decoupling" of the global economy from each economy by adjusting their rates.

2.1. The model

The economic model in IDE-GSM is a CGE model based on spatial economics, and its structure closely resembles that of chapter 16 of Fujita, Krugman, and Venables (1999). Thus, our model is based on the work of Dixit and Stiglitz (1977). However, our model has been modified to be consistent with our data set. Our model focuses on the agricultural and mining industries in greater detail. Furthermore, the inter-industry mobility of workers among eight industries and inter-regional labor migration between regions within a country are permitted based on differences in real wages.

The model divides the economy into several sectors, including agriculture, mining, and services, and the manufacturing sector into five subsectors. Agriculture and mining use labor and land as inputs under constant returns to scale. We assume that households in the same region receive land rents. Furthermore, we apply the Armington assumption to the agricultural and mining sectors.

Manufacturing and service firms produce their goods using technology with increasing returns to scale, necessitating input from their own and other sectors and labor. We assume worker mobility within a country and between economic sectors, but not across international countries. All goods and services can be traded. We opt for transportation costs that resemble an iceberg. In particular, the quantity of a product melts *en route*. Thus, only a portion of the quantity shipped reaches its destination. That is, the quantity sent from a location includes the quantity to be melted. Therefore, the delivered price is the melted portion multiplied by the mill price to maintain the same total payment to the shipped amount between the place of origin and the destination, implying that the delivered price includes transportation costs. Further detail of the economic model is described in Appendix.

2.2. Data set

We constructed a geo-economic dataset for subnational simulation analysis. The dataset contains information on 170 countries/economies and 3,288 subnational regions. We have constructed the regional-level GDP (Regional GDP) data for the agriculture sector, the mining sector, five manufacturing sub-sectors, and the service sector for 2015, primarily using official statistics from respective countries. Food processing, garments and textiles, electronics and electric (E&E), automotive, and other manufacturing are the five manufacturing sub-sectors. Typically, we utilize national and regional GDP data with industrial surveys/census to divide the GRDP into finer sub-sectors if the country lacks the GDP data by sub-national region and industry.

The number of routes included in our transport network data set is 20,091 (land, 12,880; sea and inland waterway, 1,348; air, 2,669; railway, 3,119; and high-speed railway, 75). The route data consists of the start city, the end city, the distance between the cities, and the quality of the route, which is represented by the vehicle's speed along the route.

2.3. Parameters

Transport costs in IDE-GSM (Figure 1) account for numerous variables.

=== Figure 1 ===

The sum of tariffs and NTBs (TNTBs) is computed utilizing the log odds ratio method developed by Head and Mayer (2000). We estimate TNTBs at the industry level for 69 countries. The TNTBs for the remaining sampled countries are obtained by dividing their TNTBs by their GDP per capita. We require the substitution elasticity to evaluate these estimates for TNTBs, whose sources are described in the following.

Next, we subtract tariff rates from TNTBs to obtain NTBs. Our data source for tariff rates is the World Integrated Trade Solution, in particular TRAINS (Trade Analysis and Information System) raw data. Using a simple average, we aggregate the lowest tariff rates among all available tariff schemes at the tariff-line level into a single tariff rate for each industry. In addition to multilateral and bilateral free trade agreements (FTAs), other tariff schemes are available, such as the Generalized System of Preferences. In addition to AFTA, we also consider the tariff elimination schedule in six ASEAN + 1 FTAs (ASEAN free trade area). We determine whether each product achieves a zero rate in the ASEAN+1 FTA from the FTA database developed by ERIA. In the case of AFTA, the final rates for all products are set to zero. Thus, we obtain different (bilateral) tariff rates and (importer-specific) NTBs by industry on a tariff-equivalent basis. Finally, our total transport costs are the product of the sum of physical transport and time costs and the sum of TNTBs.

Industry-specific parameters are provided in Table 1. We mainly adopt Hummels' (1999) elasticity of substitution for manufacturing sectors and estimate it for services. Estimates for the elasticity of services are derived from estimating the standard gravity equations for trade services, which include independent variables such as the importer's GDP, the exporter's GDP, the importer's corporate tax, the geographical distance between countries, a dummy for FTAs, a linguistic commonality dummy, and a colonial dummy. We rely heavily on the "Organization for Economic Co-operation and Development Statistics on International Trade in Services" for this estimation.

=== Table 1 ===

In the model, the consumption share of consumers by industry is determined uniformly for the entire region. Changing the proportion by country or region would be more realistic; however, we lack reliable consumption data for this to be possible. In the model, the single labor input share for each industry is applied uniformly across the entire region and period. Although it may vary between countries/regions and over time, we use an "average" value; in this case, we use the value for Thailand, a country in the middle stage of economic development, as determined by the 2005 Asian International Input–Output Table by IDE-JETRO. JETRO's (2013) survey information is used as the manufacturing sector data source.

3. Scenarios

Following the trade between the United States and China and Russia's invasion of Ukraine, it is difficult to predict the nature of the "decoupling" among countries. Here, we have developed two scenarios and conducted simulations to estimate the economic impacts of "decoupling" on each country and region.

Simulations of the "decoupling" were conducted according to the following scenarios:

Baseline: No "decoupling" scenario; assumes the international situation in 2019 persists through 2030. This scenario includes tariff rates through 2019[1] (including FTA preferential rates). The tariff reduction schedules established by the Regional Comprehensive Economic Partnership (RCEP) and ASEAN+1 FTAs are incorporated beyond 2019. Aside from this, the baseline scenario assumes that TNTBs will remain the same in subsequent years. This indicates that the tariff reduction schedule determined by existing FTAs is not considered after the most recent year. In the IDE-GSM, the

[1] However, tariff rates as of 2018 are included for South Korea and Thailand and as of 2014 for Malaysia due to data constraints.

country-by-country economic growth rates at the national level within the simulation in the baseline scenario are modified to reflect the national-level economic growth rate forecasts published by the IMF in the World Economic Outlook for many years into the future. The impact of COVID-19 is reflected in a slowdown in each country's economic growth rate, as reported and estimated in the IMF's April 2022 World Economic Outlook.

Scenario 1: Assume that there is "decoupling" between the Russia–Belarus camp and the 43 IDE-GSM countries out of the 49 "unfriendly" countries nominated by Russia.[2] An increase in NTB rates equivalent to the additional tariff rates on the U.S. side in the U.S.–China trade war is assumed to be imposed on trade between countries in different camps beginning in 2023, which is nearly equivalent to the additional tariff rate imposed during the trade war between the United States and China. All economic sectors are subject to additional NTBs, including the services sector. The additional NTB rates imposed are 14.3% for the agricultural sector, 21.3% for the automotive sector, 18.3% for the E&E sector, 14.5% for the textile and garment sector, 11.7% for the food processing sector, 16.7% for other manufacturing sectors, and 16.3% for the mining sector. For the services sector, the average of all the sectors, 16.2%, is applied. Trade between a country in each camp and a neutral country within each camp and between neutral countries will continue as normal.

Scenario 2: The assumption is similar to Scenario 1, but with China (including Hong Kong and Macao) joining the Russia–Belarus camp. Starting in 2022, trade between the two camps will be subject to additional NTB rates equivalent to the additional tariff rates on the U.S. side in the U.S.–China trade war. All economic sectors are subject to additional NTBs, including the services sector. It is assumed that trade between a country in each camp and a neutral country within each camp and between neutral countries will continue as usual.

In Scenarios 1 and 2, the conflict is assumed to continue from 2022 to 2030. To calculate economic impacts to each country/region, we compared the 2030 GDP of each country and region under Scenarios 1 and 2 to the baseline scenario, taking the differences in GDPs as the economic impact of "decoupling."

The simulations do not account for the temporary increase in commodity prices during the global supply–demand adjustment due to fears of difficulties in importing crude oil and natural gas imports from Russia and the impact of exchange rate fluctuations and global economic uncertainty. Multiple

[2] The 49 countries are Albania, Andorra, Australia, Bahamas, Canada, Iceland, Japan, South Korea, Liechtenstein, Micronesia, Monaco, Montenegro, New Zealand, North Macedonia, Norway, San Marino, Singapore, Switzerland, Taiwan, Ukraine, United Kingdom, United States, and the EU member countries. Among them, the countries not included in IDE-GSM are Andorra, Liechtenstein, Micronesia, Monaco, North Macedonia, and San Marino.

financial and trade sanctions, such as the financial impact of the exclusion from SWIFT, are assumed to be reflected in the increase in NTBs for goods trade and the services sector.

4. Results and analysis

4.1. Economic Impacts

Table 2 and Figure 2 illustrate the economic impacts of "decoupling," according to Scenario 1, the confrontation between Russia–Belarus and their "unfriendly" countries. Compared to the baseline, the impact on the global economy is negligible at 0.0%. This is because Russia's economy is relatively small in terms of GDP, comparable to that of South Korea or Brazil, despite its substantial military presence.

=== Table 2 ===

=== Figure 2 ===

Compared to the baseline, the impact on the Russian economy is −0.6% of GDP and on the Belarusian economy it is −2.2%. The impact on the Russian economy is insignificant, but the impact on certain industries is not insignificant. The impact on other manufacturing (−6.1%) and the food processing sector (−5.1%) are relatively significant, whereas the impact on the automotive industry (2.1%) is positive. Belarus substantially negatively impacts the other manufacturing (−8.7%) and food processing industries (−3.9%).

The impact on Russia's electronics and electrical industries is only small at −0.2%. It is believed that this is because IDE-GSM adopts the broad category of electronics and electrical machinery industries rather than specific categories such as "semiconductors" and that the elasticity of substitution is the same regardless of trading partner countries. If we consider more specific products, such as Taiwanese semiconductors, the substitutability is lower and the impact of making imports more difficult will be greater.

The positive impact on the Russian automotive industry may appear peculiar. The IDE-GSM does not differentiate between foreign and domestic technological levels. Therefore, the IDE-GSM is structured so that the withdrawal of foreign capital will not result in a decline in productivity in the automotive industry. This may be suitable for a short-term setting. However, given that the share of Chinese companies in automobile sales has already increased significantly (Reuters, December 8, 2022), companies from neutral countries, such as China, and local companies may fill the void left by the withdrawal of foreign capital in the medium term, such as 2030. In such a scenario, the automobile industry would be relatively less impacted by trade restrictions than an affected number of other industries, and production could expand relatively more.

In this scenario, the impacts on "unfriendly" countries are minimal. Compared to the baseline, the impact on the U.S. economy is -0.1%, whereas the impact on the European Union (EU) economy is −0.2%. The economic impact on Russia's neighbors, such as Ukraine and the Baltic States, ranges between −0.6% and −0.2%. The impacts on the remaining countries in the "unfriendly" countries are minimal. Nonetheless, the mining sector has a relatively large negative impact sector-by-sector because these countries import energy resources from Russia, primarily natural gas. In Albania and Estonia, the mining industry has a negative impact of 8.9% and 8.0%, respectively, which is greater than around −5% in several Eastern European countries. Moreover, Eastern Europe has a negative impact of −3.3% on the mining industry, whereas Western Europe has a negative impact of −2.2%.

Nonetheless, the impacts on the mining sector in the EU appear to be less severe than expected. In the simulation, pipelines are not configured as a mode of transport, which contributes to the smaller impact. Pipelines are an extremely inexpensive mode of transport. If they were shut down, the consequences would be greater than if natural gas (LNG) was transported by land or sea. In the model, the EU's imports of natural gas from Russia are viewed as being more easily replaced by imports from other countries than they are in reality, with no significant additional costs. Nevertheless, given that the projections are for the longer term, as of 2030, it may be reasonable to assume a higher degree of substitutability.

The impact on neutral countries that do not belong to either camp is also negligible. The economic impact on the Chinese economy is 0.0% compared with the baseline. For the majority of neutral countries, the impact on GDP is positive, but only about 0.1% or less. In this scenario, these countries cannot profit, whereas others wage war.

The economic impacts of "decoupling" under Scenario 2 are depicted in Table 3 and Figure 3. In stark contrast to Scenario 1, the economic impact on the global economy is significantly greater in Scenario 2 at −1.8% compared with the baseline. The impact on the Chinese economy, which has joined the Russian camp, is enormous at −3.0%. However, the impact on the Russian economy is −0.5%. Compared to Scenario 1, the economic impact on Belarus is smaller at −1.9%. A smaller impact on the Russian economy can be attributed to the "trade diversion effect," in which trade between China and "unfriendly" countries is replaced by trade with Russia as China joins its camp. The manufacturing sectors in the Chinese economy recorded relatively large declines. As for the Russian economy, food processing, and other manufacturing industries decreased by around 5%, whereas the automotive, and services increased, thereby positively impacting its GDP.

=== Table 3 ===

=== Figure 3 ===

Among "unfriendly" countries, Asian nations, including Japan, South Korea, Taiwan, Singapore, Australia, and New Zealand, have a negative economic impact of approximately −2% to −3% relative to the baseline. In contrast, the negative impact on the U.S. economy is −2.1%, whereas the negative impact on the EU is −2.3%, smaller than in Asia. The industries with the most significant negative impacts vary by country. In Japan, agriculture has the greatest negative impact at −3.6%, whereas, in Korea, the automotive sector has the greatest negative impact at −5.2%, respectively. In Taiwan, the automotive industry has the greatest negative impact at −3.9%. In contrast, the mining industry has the most significant negative impact on the EU, at −3.7%.

Among the neutral countries that do not join either camp, the GDP of ASEAN countries, other than Singapore alone in the "unfriendly" camp, is affected positively by 0.5 to 1%. India is also positively affected by 0.2%, whereas African countries are positively affected by 0.1% relative to the baseline. If China joins the Russian camp, neutral countries that do not belong to either camp will gain a substantial amount of money, whereas others fight.

4.2. Changes in trade

Figure 4 depicts the changes in Russia's export value by country and region for Scenarios 1 and 2. In both scenarios, the changes in trade values are not significantly different. The exports to "unfriendly" countries decreased significantly, whereas exports to neutral countries increased moderately. Due to China's entry into the Russian camp, scenario 1 shows a 2.8% increase in Russia's exports to China, whereas scenario 2 exhibits a much larger increase of 4.3% compared with the baseline.

=== Figure 4 ==

Figure 5 illustrates the changes in the value of China's exports by country and region under Scenarios 1 and 2. In scenario 1, China's exports by country/region are not significantly different from the baseline, except for exports to Russia, which decrease by -2.8% compared to the baseline. In the second scenario, Chain's exports by country/region decline significantly. The decline is more pronounced for exports to "unfriendly" countries and less pronounced for exports to the Russian camp and neutral countries.

=== Figure 5 ===

Figure 6 illustrates the changes in the value of Japan's exports by country and region under Scenarios 1 and 2. In scenario 1, Japan's exports by country/region are not significantly different from the baseline, except for exports to Russia, which decline by 44.8% relative to the baseline. In scenario 2, Japan's exports to China decline significantly by 37.1%, whereas total exports fall by 12.6%. Scenario 2 depicts a moderate increase in exports to North America and neutral countries.

=== Figure 6 ===

5. Conclusions

In this analysis, we utilized the IDE-GSM to estimate the impact of "decoupling" on the global economy in terms of a difference in GDP by 2030. Specifically, we calculated the economic impact of the division between Russia/Belarus and Russia's "unfriendly" countries, as well as the economic impact of China's entry into the Russian camp.

The simulation results indicated that an increase in NTB rates equivalent to the additional tariff rates on the U.S. side in the U.S.–China trade war between the Russian camp and its "unfriendly" countries would have little impact on the global economy as a whole. This is because, contrary to its military presence, the Russian economy is comparable in GDP size with South Korea or Brazil. Compared with the baseline, the impact on the Russian economy was found to be −0.6% of GDP and −2.2% in Belarus, which is not negligible but also not exceptionally large. Russia's exports to neutral countries, such as China, South Asia, the Middle East, Central Asia, and Latin America, are increasing and partially supporting Russia's economy, so economic sanctions imposed by "unfriendly" countries on Russia and Belarus are not as effective as they could be.

Meanwhile, if China were to join the Russian camp, the impact of "decoupling" on the global economy would be significantly greater, that is, −1.8% compared with the baseline. Moreover, the impact on the Chinese economy would be enormous, −3.0%. On the "unfriendly" countries, economic impacts on Asian countries such as Japan, South Korea, Taiwan, Singapore, New Zealand, and Australia are all in the negative −2% to −3%. In contrast, the impact on the U.S. economy is −2.1%, whereas the impact on the EU is −2.3%, which is slightly less than the impact on Asian countries. If China joins the Russian camp, East Asia's dense production networks will become the front line of economic conflict.

Comparing this scenario to the baseline scenario, we determine that the impact on the Russian economy is negative at 0.5%, whereas the impact on the Belarusian economy is negative at −1.9%. The adverse effect of "decoupling" appears to be mitigated. This is because the participation of China, an economic superpower, in its camp has created a "trade diversion effect," in which Russia and Belarus substitute trade between China and "unfriendly" countries. In other words, the dilemma of "unfriendly nations" is that the sanctions against Russia and Belarus will be less effective if China does not join them. However, if China is sanctioned alongside Russia and Belarus, the trade diversion effect will compensate for the negative impact of sanctions on Russia's economy.

In addition, it is foreseeable that China would incur substantial economic losses if it joined the Russian camp. Insinuating secondary sanctions against China for cooperating with Russia is therefore regarded as an effective deterrent.

The results of this analysis have particular implications for the policies of East Asian countries. As long as a significant number of neutral countries remain outside of both camps, the sanctions against Russia and Belarus will remain ineffective. When China and Russia are sanctioned by its "unfriendly" countries, the situation changes dramatically. The negative impact on East Asian countries with close trade ties to China will be greater than that on Western countries. Due to geopolitical conflicts between Europe and Russia and the United States and China, East Asia will be at the forefront of the economic conflict. In determining their foreign policies, particularly regarding economic sanctions against China, East Asian countries must realistically evaluate the political ramifications and economic costs that they will incur.

With this analysis, we believe we have shown that the impact of Russian sanctions on the global economy is, contrary to our intuition, not very large, while the impact of China joining the Russian camp on the global economy would be significant. It should be noted, however, that this analysis does not take into account the possibility that uncertainty brought by the 'decoupling' could affect the global economy via exchange rate and stock market fluctuations or that rising prices could slow the global economy through higher interest rates by national central banks.

Future research will need to address the productivity gaps between foreign and domestic capital that are not captured in the current model, as well as the impact of trade in certain semiconductors, rare earths and rare metals, and other less substitutable goods on the sustainability in production networks.

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Table 1: Industry-specific parameters

	Elasticity of substitution: σ	Share of labor input: β	Share in consumption: μ
Agriculture	3.8	0.41	0.035
Automotive	4.0	0.40	0.014
Electronics	6.0	0.40	0.022
Textile	8.4	0.37	0.015
Food	5.1	0.34	0.026
Others	5.3	0.44	0.129
Service	3.0	0.57	0.700
Mining	5.6	0.17	0.058

Source: Authors.

Table 2: Economic Impacts under Scenario 1 (2030, against the baseline, % of GDP)

	Agriculture	Automotive	E&E	Textile	Food Proc.	Oth. Mfg.	Services	Mining	GDP
Russia	-0.1%	2.1%	-0.2%	-2.1%	-5.1%	-6.1%	0.4%	-0.1%	-0.6%
Belarus	-1.6%	-1.3%	-1.4%	-2.7%	-3.9%	-8.7%	-0.8%	-0.1%	-2.2%
EU	-0.1%	-0.3%	-0.2%	0.0%	0.0%	0.0%	-0.2%	-2.8%	-0.2%
United States	-0.1%	-0.1%	-0.1%	0.0%	0.1%	0.0%	-0.1%	-0.1%	-0.1%
Japan	0.0%	-0.3%	-0.2%	0.0%	0.0%	0.0%	0.0%	-0.5%	-0.1%
Korea	0.0%	-0.4%	-0.2%	0.0%	0.0%	-0.1%	0.0%	-0.9%	-0.1%
Taiwan	0.0%	-0.2%	-0.3%	-0.1%	0.0%	-0.1%	-0.1%	0.2%	-0.1%
China	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
India	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
East Asia	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Southeast Asia	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
South Asia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Central Asia	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Oceania	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.4%	-0.1%
Middle East	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eastern Europe	-0.2%	-0.4%	-0.3%	-0.1%	0.0%	-0.3%	-0.2%	-3.3%	-0.2%
Western Europe	-0.1%	-0.3%	-0.2%	0.0%	0.0%	0.0%	-0.2%	-2.2%	-0.1%
North Europe	-0.2%	-0.3%	-0.2%	0.0%	0.0%	-0.1%	-0.2%	-0.6%	-0.2%
Africa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
North America	-0.1%	-0.1%	-0.1%	0.0%	0.1%	0.0%	-0.1%	-0.1%	-0.1%
Latin America	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Russian Camp	-0.4%	1.9%	-0.3%	-2.1%	-5.0%	-6.2%	0.4%	-0.1%	-0.7%
'Unfriendly' Camp	-0.1%	-0.3%	-0.2%	0.0%	0.0%	0.0%	-0.1%	-0.7%	-0.1%
World	0.0%	-0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%

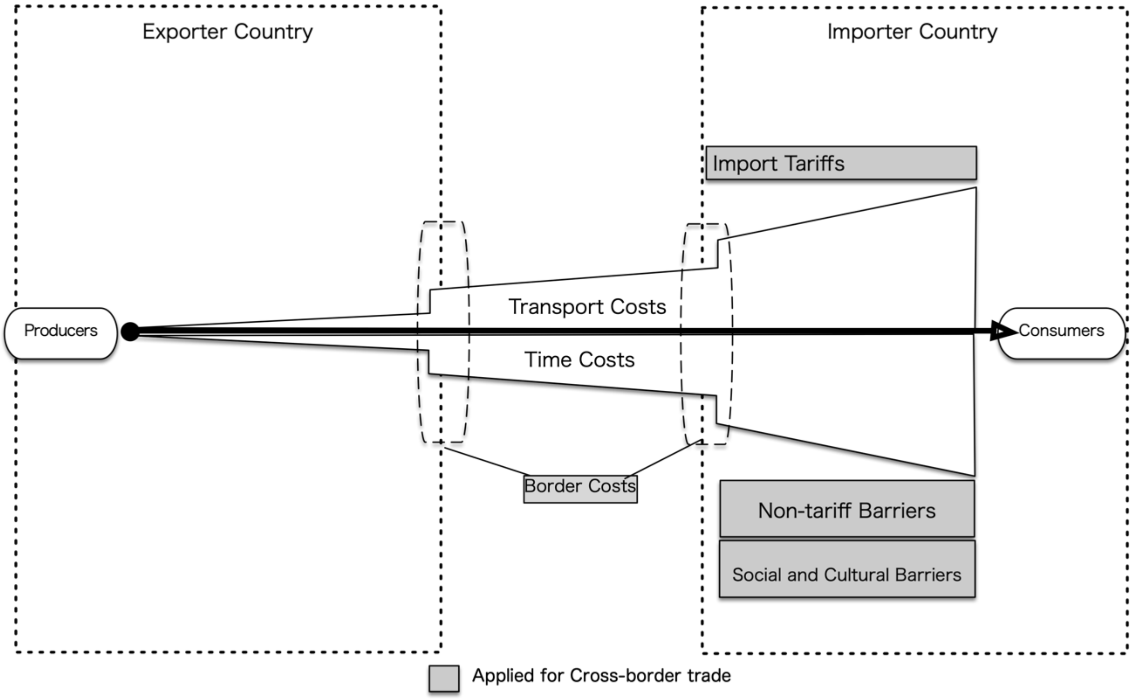
Source: Calculated by IDE-GSM.

Table 3: Economic Impacts under Scenario 2 (2030, against the baseline, % of GDP)

	Agriculture	Automotive	E&E	Textile	Food Proc.	Oth. Mfg.	Services	Mining	GDP
Russia	-0.1%	2.3%	-0.3%	-2.0%	-5.2%	-5.4%	0.4%	-0.1%	-0.5%
Belarus	-1.7%	-0.9%	-1.2%	-2.0%	-4.1%	-7.7%	-0.6%	-0.1%	-1.9%
China	-0.1%	-7.0%	-8.5%	-5.0%	-6.8%	-8.1%	0.8%	-0.8%	-3.0%
EU	-2.8%	-3.5%	0.9%	3.1%	-0.5%	0.5%	-2.8%	-3.7%	-2.3%
United States	-1.5%	-1.1%	1.6%	4.7%	-0.8%	1.4%	-2.5%	-1.0%	-2.1%
Japan	-3.6%	-3.2%	0.8%	4.6%	-0.3%	1.3%	-3.3%	-3.0%	-2.6%
Korea	-3.9%	-5.2%	-1.1%	3.1%	0.8%	-1.5%	-2.4%	-4.7%	-2.2%
Taiwan	-2.6%	-3.9%	-2.9%	4.3%	-2.9%	-2.1%	-2.9%	0.0%	-2.7%
India	0.0%	0.1%	0.6%	3.7%	-0.2%	1.0%	-0.1%	-0.1%	0.2%
East Asia	-0.7%	-5.9%	-6.6%	-4.7%	-5.5%	-6.9%	-0.7%	-1.0%	-2.8%
Southeast Asia	-0.1%	-0.1%	1.3%	3.6%	0.0%	0.8%	-0.2%	0.0%	0.1%
South Asia	0.0%	0.1%	0.6%	3.7%	-0.2%	1.0%	-0.1%	-0.1%	0.2%
Central Asia	0.0%	0.5%	0.2%	1.0%	0.0%	1.2%	0.0%	0.0%	0.2%
Oceania	-2.6%	-2.8%	1.7%	3.5%	0.0%	0.7%	-3.5%	-1.8%	-3.0%
Middle East	0.0%	0.2%	0.8%	3.8%	-0.1%	1.3%	0.2%	0.1%	0.4%
Eastern Europe	-2.6%	-4.6%	-0.1%	2.3%	-0.7%	-0.1%	-2.4%	-4.0%	-2.1%
Western Europe	-2.6%	-3.3%	1.2%	3.5%	-0.4%	0.7%	-2.9%	-3.1%	-2.4%
North Europe	-3.3%	-3.5%	0.3%	3.5%	-0.8%	-0.2%	-2.6%	-1.0%	-2.1%
Africa	-0.2%	0.3%	0.7%	1.7%	-0.2%	0.6%	0.1%	0.1%	0.1%
North America	-1.6%	-1.5%	1.6%	4.5%	-0.8%	1.2%	-2.5%	-1.0%	-2.1%
Latin America	-0.1%	0.2%	0.4%	1.3%	-0.7%	0.7%	0.1%	0.0%	0.2%
Russian Camp	-0.1%	-6.7%	-8.4%	-5.0%	-6.6%	-8.0%	0.7%	-0.5%	-2.7%
'Unfriendly' Camp	-2.6%	-3.1%	0.5%	3.6%	-0.5%	0.6%	-2.7%	-1.7%	-2.3%
World	-0.6%	-3.1%	-3.4%	-2.3%	-2.2%	-2.9%	-1.6%	-0.5%	-1.8%

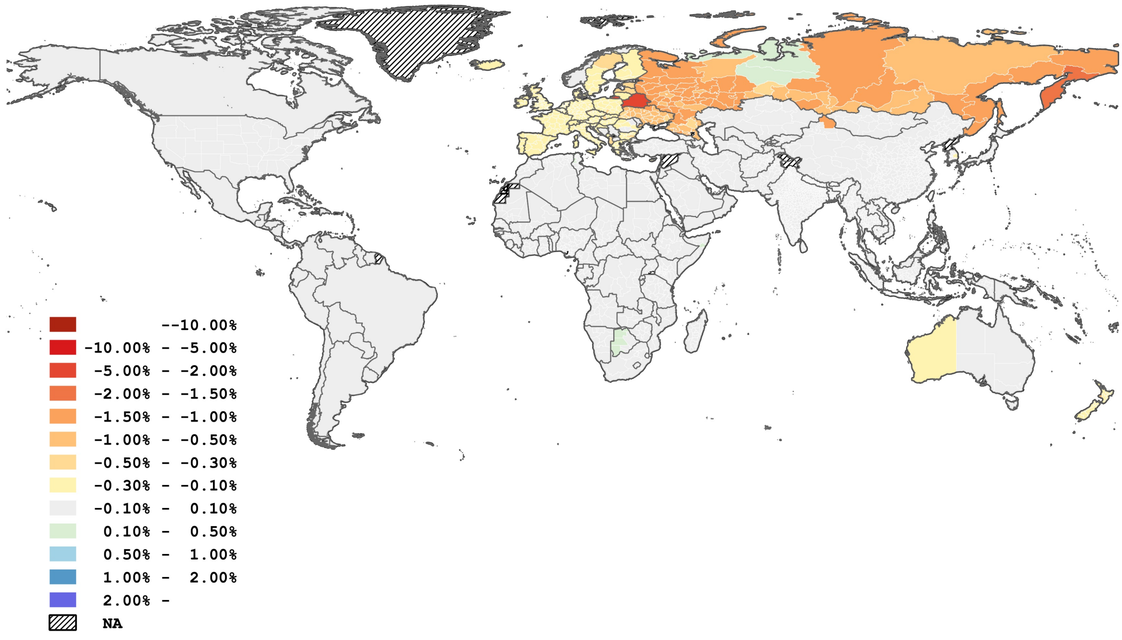
Source: Calculated by IDE-GSM.

Figure 1: Trade costs taken into account in IDE-GSM



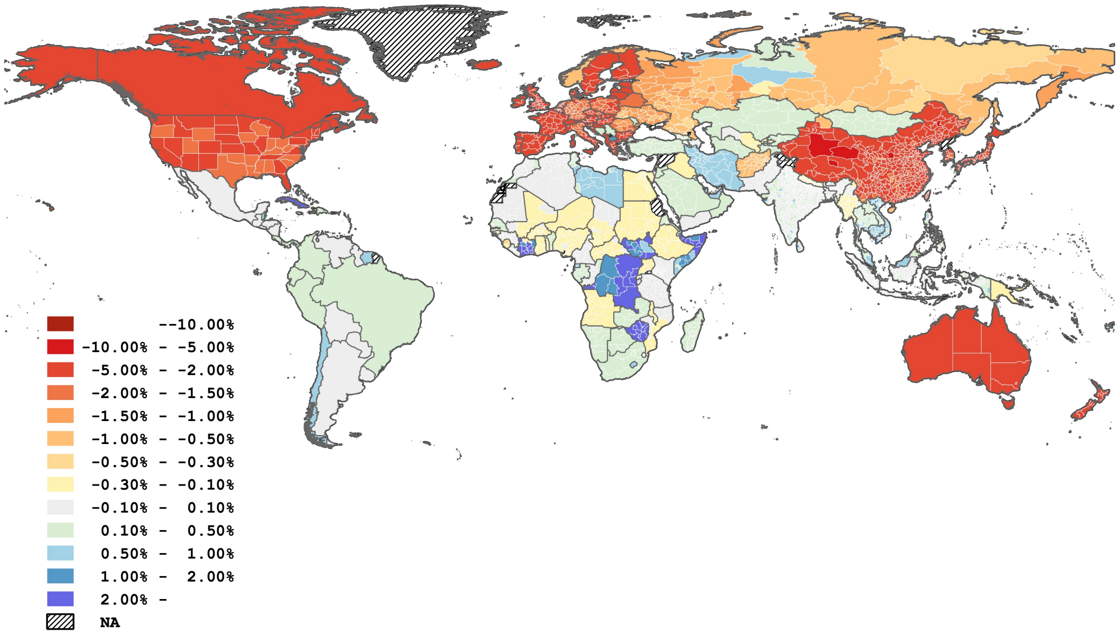
Source: Authors.

Figure 2: Economic Impacts under Scenario 1 (2030, against the baseline, % of GDP)



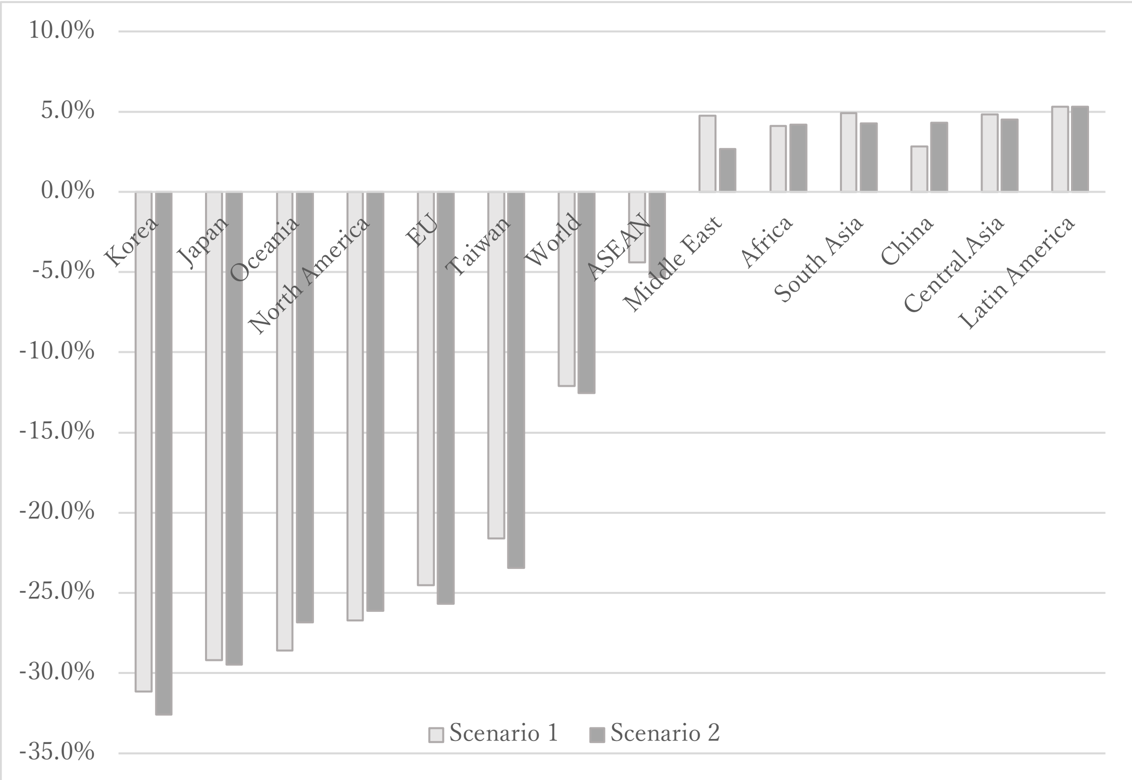
Source: Calculated by IDE-GSM.

Figure 3: Economic Impacts under Scenario 2 (2030, against the baseline, % of GDP)



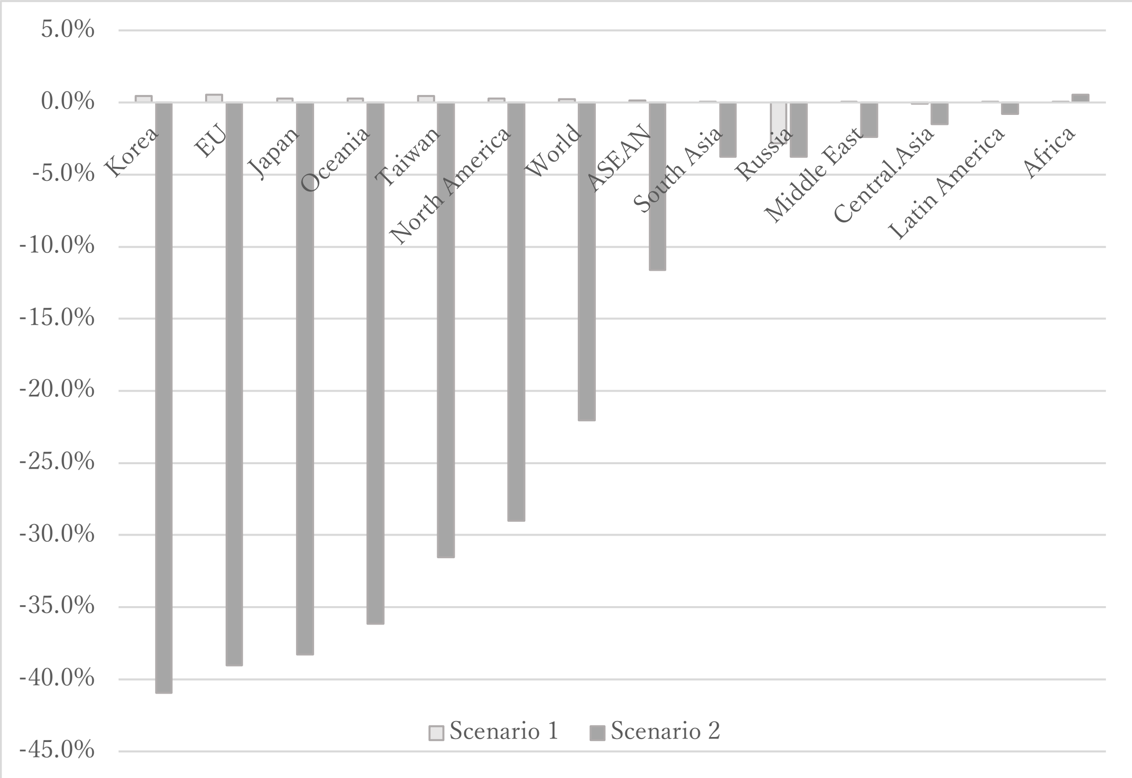
Source: Calculated by IDE-GSM.

Figure 4: Changes in Russia's export value by country and region (2030)



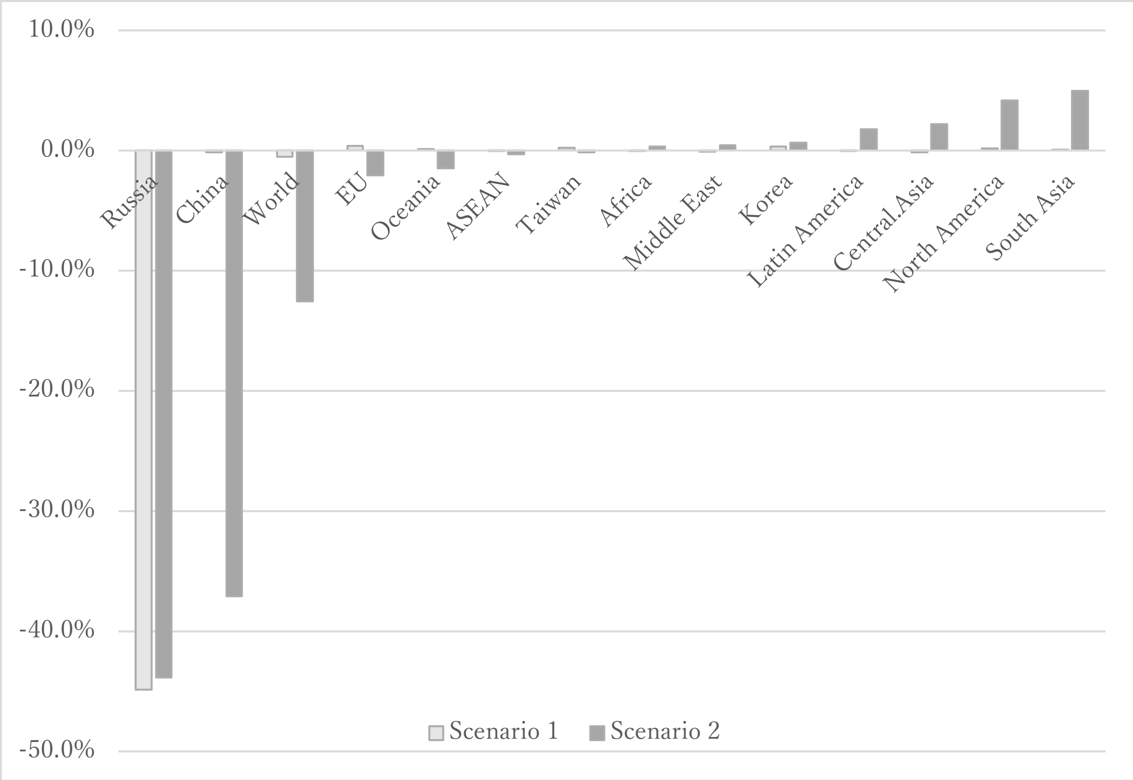
Source: Calculated by IDE-GSM.

Figure 5: Changes in China's export value by country and region (2030)



Source: Calculated by IDE-GSM.

Figure 6: Changes in Japan's export value by country and region (2030)



Source: Calculated by IDE-GSM.

Appendix

The number of regions and countries is given by the data. To specify industry k, we, respectively, express agriculture, mining, automotive, electrical and electronic (E&E), garments and textile, food processing, other manufacturing, and service as k=1, 2, 3, 4, 5, 6, 7 and 8 in the following equations. Each consumer is endowed with a unit of labor and other units of land. The amount of land in a region is given and distributed equally among the region's population. The exogenous share of land in production is set for agriculture, and the remaining share is allocated to mining.

Consumer behavior

Every consumer shares the same Cobb–Douglas preferences for the eight types of composite indices for consumption, namely agriculture, mining, automotive, electronics, textile, food, other manufacturing, and services. Each type of composite index is a sub-utility function defined over the varieties of each good in the type and defined by a function of constant elasticity of substitution (CES). Minimizing the expenditure to the variety subject to the CES function determines the consumption of each variety in an index. The price index of the composite index is defined such that expenditure of the varieties is equivalent to the product of the price index and the amount of the composite index. The amount of the composite index is obtained by maximizing the utility subject to the budget constraints. Income is the sum of wage income and land rent and is only used to purchase eight types of goods. Substituting the derived amounts of the composite index for a type into the derived consumption of each variety for the type yields the demand for a variety of the type.

We assume iceberg transport technology. That is, the produced amount at the gate of a factory is the transport costs times the demand of consumers or firms. The amount produced more than the demand of consumers or firms is melted away during transportation. The delivered price becomes the mill price multiplied by the transportation costs.

Production

We assume that all products are used for final consumption and intermediate inputs. Labor is used in every industry. Despite this, the land is utilized for agriculture and mining. Eight industries are divided into primary industries, which are both of agriculture and mining, and the remaining industries. We assume that the primary industries use constant returns to scale technology under perfect competition, whereas firms in the remaining industries use increasing returns to scale technology under monopolistic competition. Applying the Armington assumption, the product in a region of a primary industry and the products in the industry from the different regions are imperfect substitutes. The product of each firm in manufacturing and services industries is differentiated in a type of the industry.

The production function of the agricultural or mining sector is a Cobb-Douglass function given as

$$f(i,k) = A(i,k)L(i,k)^{\alpha_k}F(i,k)^{1-\alpha_k-\sum_{l=1}^{8}\alpha_{kl}}\prod_{l=1}^{8}N(i,l,k)^{\alpha_{kl}}, \quad k = 1 \text{ or } 2$$

where $f(i,k)$ expresses the amount of production of industry k at location i, $A(i,k)$ the total factor productivity (TFP) of industry k at location i, $L(i,k)$ labor inputs for industry k at location i, $F(i,k)$ land input for industry k at location i, $N(i,l)$ intermediate inputs for location i provided by industry l. Note that industry l may not be the same as industry k. Furthermore, $\alpha_k \in (0,1)$ and $\alpha_{kl} \in (0,1)$ are, respectively, the input share of labor and intermediate inputs produced by industry l for industry k. We assume the positive share of land input, $1-\alpha_k-\sum_{l=1}^{8}\alpha_{kl} > 0$.

Maximizing the profit of industry k, k=1 or 2, located at i with respect to labor input yields nominal wage rate for industry k at location i, $w(i,k)$, as follows:

$$w(i,k) = \alpha_k \frac{f(i,k)}{L(i,k)} p(i,k), \quad k = 1 \text{ or } 2$$

where $p(i,k)$ expresses the price of a good produced in industry k at location i. Maximizing the profit of industry k, k=1 or 2, at location i with respect to an intermediate input yields the amount of intermediate inputs provided by industry l for the usage in industry k at location i, $N(i,l,k)$, as follows:

$$N(i,l,k) = \alpha_{kl}\frac{f(i,k)}{G(i,l)}p(i,k), \qquad k = 1 \text{ or } 2.$$

Using the zero-profit condition for agriculture and mining at location i, we obtain the budget constraint of a representative consumer at the location as follows:

$$\mathrm{Y}(i) = \sum_{k=1}^{2}\left(p(i,k)f(i,k) - \sum_{l=1}^{8}G(i,l)N(i,l,k)\right) + \sum_{k=3}^{8}\mathrm{w}(i,k)L(i,k)$$

which can be regarded as nominal GDP in location i. The price index of goods in industry 1 or 2 in location i, $G(i,k)$, is defined as follows:

$$G(i,k) = \left(\sum_{j=1}^{R}p(i,k)^{-(\sigma_k-1)}T_{ji}^{k\,-(\sigma_k-1)}\right)^{-\frac{1}{\sigma_k-1}}, \quad k = 1 \text{ or } 2$$

where σ_k>1 shows the elasticity of substitution between any varieties of goods in industry k, and T_{ji}^{k} transport costs for shipping goods in industry k from location j to location i. We assume $T_{ji}^{k} > 1$ if $j \neq i$ and $T_{ji}^{k} = 1$ if $j = i$. In other words, transportation in the same region is costless.

Firms in the manufacturing and service sectors use an input composite expressed by a Cobb-Douglass function of labor and intermediate goods. The input composite is used in the fixed cost and the marginal cost of a firm. We choose units such that the marginal input requirement equals the price-cost markup. Profit maximization yields the price of a variety produced by a firm in industry k and location i, $p(i,k)$, as follows:

$$p(i,k) = \frac{w(i,k)^{1-\sum_{l=1}^{8}\beta_{kl}} \prod_{l=1}^{8} G(i,k)^{\beta_{kl}}}{A(i,k)}, \quad k = 3, 4, 5, 6, 7 \text{ or } 8$$

where $A(i,k)$ is the total factor productivity of industry k at location i, and $\beta_{kl} \in (0,1)$ intermediate share provided by industry l for industry k. We assume the positive share of labor input, $1 - \sum_{l=1}^{8}\beta_{kl} > 0$.

Let the number of firms in industry k at location i be $n(i,k)$, the output of each firm in industry k at location i $q(i,k)$, and the number of workers in industry k at location i $L(i,k)$. The total value of output in industry k at location i is $n(i,k)p(i,k)q(i,k)$. Thus, the wage bill in industry k at location i, $w(i,k)L(i,k)$, is a share $1 - \sum_{l=1}^{8}\beta_{kl}$ of $n(i,k)p(i,k)q(i,k)$. We choose units such that $q(i,k) = 1 - \sum_{l=1}^{8}\beta_{kl}$, so that we obtain $n(i,k) = w(i,k)L(i,k)/p(i,k)$. Since the price index of industry i=3 to 8 is defined as $G(i,k)^{-\sigma_k - 1} = \sum_{j=1}^{R} n(i,k)p(i,k)^{-(\sigma_k-1)}T_{ji}^{k^{-(\sigma_k-1)}}$, we obtain:

$$G(i,k) = \left\{\sum_{j=1}^{R} L(j,k)A(j,k)^{\sigma_k} w(j,k)^{1-\sigma_k\left(1-\sum_{l=1}^{8}\beta_{kl}\right)} T_{ji}^{k^{-(\sigma_k-1)}} \prod_{l=1}^{8} G(j,l)^{-\sigma_k\beta_{kl}}\right\}^{-\frac{1}{\sigma_k-1}},$$

$i = 3, \ldots, 7$ or 8.

Output of industry k is consumed as final products and used as intermediate inputs. The amount consumed as final products is $\mu_k \mathrm{Y}(i)$. The quantity used as intermediate inputs by industry l=1 or 2 is $\alpha_{lk}p(i,k)f(i,k)$, and that by industry l=3, 4, 5, 6, 7 or8 is $\beta_{lk}n(i,l)p(i,l)q(i,l)$. Using the constant share of wage payment in sales, we obtain expenditure on industry k at location i, $E(i,k)$, as follows:

$$E(i,k) = \mu_k \mathrm{Y}(i) + \sum_{l=3}^{8} \frac{\beta_{lk}}{1-\sum_{k=1}^{8}\beta_{lk}} \mathrm{w}(i,l)L(i,l) + \sum_{l=1}^{2} \frac{\alpha_{lk}}{\alpha_l} \mathrm{w}(i,l)L(i,l).$$

Rewriting the market clearing condition for a good produced by agricultural or mining sector at location i yields

$$p(i,k) = \left[\sum_{j=1}^{R} E(j,k)T_{ij}^{k^{-(\sigma_k-1)}} G_A(j,k)^{\sigma_k-1} / f(i,k)\right]^{\frac{1}{\sigma_k}}, \quad k = 1 \; or \; 2.$$

Rewriting the market clearing condition for a good produced by one of manufacturing and service sectors at location i yields the nominal wage rate of industry k in location i as follows:

$$w(i,k) = \left\{ \frac{A(i,k)\left(1-\sum_{l=1}^{8}\beta_{kl}\right)^{\frac{1}{\sigma_k}} \left[\sum_{j=1}^{R} E(j,k) T_{ij}^{k^{-(\sigma_k-1)}} G(j,k)^{\sigma_k-1}\right]^{\frac{1}{\sigma_k}}}{\prod_{l=1}^{8} G(i,l)^{\beta_{kl}}} \right\}^{\frac{1}{1-\sum_{l=1}^{8}\beta_{kl}}}, \quad k = 3, \dots, 7 \; or \; 8.$$

Given the number of workers in each industry and location, the following equations are used to determine all endogenous variables: nominal wage rate for each industry and location, the price of goods for each industry and location, the price index for each industry and location, expenditure to an industry in each location, income in each location, and the amount of intermediate inputs for agriculture or mining sector in each location, and the final production of agriculture or mining sector in each location. These endogenous variables are expressed on the left-hand side of the equations in this subsection. It is worth to note that the level of TFP is not determined as an endogenous variable of this economic model, but rather as a result of assuming that the economy is in equilibrium at the initial stage of the values in the data set, we collected.

Using two replicator equations, we also determine the number of workers in each industry and location. First, the rate of change of the share of workers for industry k in location i with respect to time, $\dot{\lambda}_k(i)$, is given by the following equation:

$$\dot{\lambda}_k(i) = \gamma_k \left(\frac{\omega_k(i)}{\bar{\omega}(i)} - 1 \right) \lambda_k(i)$$

where $\lambda_k(i)$ shows the share of workers for industry k in location i, $\omega_k(i)$ the real wage rate in industry k and location i, $\bar{\omega}(i)$ the average real wage rate in location i and γ_k a positive parameter for industry k. Note that the revenue from land in location i is expressed as $\sum_{k=1}^{2} \frac{1-\alpha_k-\sum_{l=1}^{8}\alpha_{kl}}{\alpha_k} w(i,k)\, L(i,k)$. Thus, the real wage rate in industry k and location i is obtained as

$$\omega_k(i) = \frac{w(i,k) + \left(\sum_{k=1}^{2} \frac{1-\alpha_k-\sum_{l=1}^{8}\alpha_{kl}}{\alpha_k} w(i,k)\, L(i,k) \right) / \sum_{k=1}^{8} L(i,k)}{\prod_{l=1}^{8} G(i,l)^{\mu_k}}.$$

This dynamics determine the selection of job by workers from one industry to another industry in a location.

The rate of change of the share of workers for location i with respect to time, $\dot{\lambda}_L(\mathrm{i})$, is given by

$$\dot{\lambda}_L(\mathrm{i}) = \gamma_L \left(\frac{\omega(i)}{\bar{\omega}_C(i)} - 1 \right) \lambda_L(i)$$

where $\lambda_L(i)$ shows the share of workers in location i, $\omega(i)$ the average real wage rate in location

i, $\overline{\omega}_C(i)$ the average real wage rate of a country where location i belongs, and γ_L a positive constant. The average real wage rate in location i, $\omega(i)$, is given by

$$\omega(i) = \frac{Y(i)/\sum_{k=1}^{8} L_k(i)}{\prod_{k=1}^{8} G(i,k)^{\mu_k}} = \overline{\omega}(i).$$

This dynamics determines the relocation of workers from one location to another location in a country.