<Paper Title>

Analysis of Future International Trade and Logistics in Africa: Considering Major Risks and Opportunities in the Post COVID-19 World

<List of authors>
ABE Masahiro – PACIFIC CONSULTANTS CO., LTD.
ONODERA Hitoshi – PACIFIC CONSULTANTS CO., LTD.
ALVES Lucas – PACIFIC CONSULTANTS CO., LTD.
TAKADA Yuki - PACIFIC CONSULTANTS CO., LTD.
FURUICHI Masahiko - International Association of Ports and Harbors
FUKUSHIMA Hiroyuki - Ministry of Land, Infrastructure, Transport and Tourism
SHIBASAKI Ryuichi – The University of Tokyo

<Abstract>

Africa, which is expected to develop rapidly as a sizeable world market, is attracting attention as an attractive investment destination in various fields such as infrastructure, agriculture, energy, ICT, and finance. In particular, the African Continental Free Trade Area (AfCFTA) is expected to stimulate African intra-region/international trade and further economic growth. On the other hand, there is concern that COVID-19 will impede the growth of African economies: real GDP growth in Sub-Saharan Africa was -2.4% in 2020, and even after 2021, it has been pointed out that the African economy may lag behind the rest of the world. Thus, it is important to comprehensively consider risks such as COVID-19 after 2020 and other opportunities such as AfCFTA and to eliminate bottlenecks in logistics infrastructure that could become obstacles to economic growth in Africa. With the aim of clarifying the future vision of the international trade in Africa, this study developed multiple future scenarios considering risks and opportunities in Africa after the expansion of COVID-19 infection and uses the GTAP-RD (Recursive Dynamic) model and the GLINS (Global intermodal Logistics Network Simulation) model. The analysis using the GTAP-RD model revealed the transition of Africa's international trade for each future scenario and revealed that the most desirable society in the world as a whole will improve Africa's trade balance the most. The GLINS model analysis showed the regional spread of logistics infrastructure development effects, indicating that the spread of logistics infrastructure development will accelerate the spread of effects throughout Africa. Finally, we estimated Africa's future exports and imports using the GTAP-RD model again, using the logistics cost reduction rate from the GLINS model as the "*ams*" variable in the GTAP-RD model and found that it would increase intra-African trade and also increase exports to the rest of the region.

1. Overview

Africa, which is expected to develop rapidly as a sizeable world market, is attracting attention as an investment destination in various fields such as infrastructure, agriculture, energy, ICT, finance, etc. (see EY (2021), etc.). The trend toward carbon neutrality in the context of climate change issues is also gaining importance in Africa, and there is a growing movement to promote more sustainable development. Japan International Cooperation Agency ("JICA") has been providing financial assistance and technical cooperation for the development of a wide range of logistics infrastructure, including ports, economic corridors, and trade facilitation facilities, which are important driving forces for the development of sustainable and resilient societies in Africa, based on the agreements reached at the Tokyo International Conference on African Development ("TICAD"), which has been led by the Japanese Government since 1993 on the theme of development of Africa, and on Country Assistance Policy for respective countries (see JICA (2018), etc.). In this context, we have been aware of the need to consider how to evaluate the comprehensive effectiveness of logistics infrastructure development in line with the fact that the entire world is constantly interconnected and exposed to various variables through logistics infrastructure, rather than to evaluate them individually. In particular, the AfCFTA (Africa Continental Free Trade Area), which entered into force in January 2021, is expected to boost intra-regional trade, while the novel coronavirus (COVID-19), which became a pandemic in 2020, is hampering the growth of African economies (see e.g., World Bank (2020), World Bank (2021a)). According to World Bank (2021a), in sub-Saharan Africa, the real GDP growth rate was -2.4% in 2020, and the forecast for 2021 and beyond also mentions that the recovery of African economies may be delayed compared to other regions. In light of these new developments surrounding Africa and risks such as COVID-19, it is important to understand the linkages within and outside the African region and consider infrastructure development to eliminate logistical bottlenecks that may become obstacles to economic growth.

Based on the awareness of these issues, this study attempted to create a vision of the future of intra-regional and extra-regional trade, particularly in African countries and regions. First, in Chapter 2, we summarize previous studies on the impact of COVID-19 on the African socioeconomy, and then we summarize the application of the recursive dynamic and multi-regional computable general equilibrium model, GTAP-RD model that is used in this study. In section 3, we described the future scenarios for estimation by the GTAP-RD model, the model's structure, and various parameter settings used in this paper, as well as an overview of the Global intermodal Logistics Network Simulation ("GLINS") model l, developed by Shibasaki et al. (2017). In particular, three future scenarios were developed based on socioeconomic trends, including the spread of COVID-19 in Africa and new economic development policies such as the AfCFTA. The GTAP-RD model was then used in section 4 to estimate the scale of international trade from 2014 to 2040 in Africa under each of the future scenarios through simulations. In addition to providing a clear picture of Africa's future import/export trends for each scenario and industry sector, the estimates show that the balance of imports and exports will improve the most for Africa when a desirable society is assumed in the future scenarios. In section 5, the logistics cost reduction rate by country/region when logistics infrastructures are developed according to current plans was estimated using the GLINS mode. The estimates indicate that the closer the economic corridor is to 100%, the more extensive the benefits of logistics cost reductions will be at an accelerated rate. Finally, in section 6, we examined the results of the GLINS model's estimation of logistics cost reduction rates, and fed the results into the GTAP-RD model's parameter "*ams*" to run the GTAP-RD model's future estimation calculations again; a comparative analysis of the estimation results before and after setting *ams* was conducted. While the effects of *ams* are demonstrated, particularly in Africa, some results are difficult to interpret economically, indicating the need for further analysis. The results of these analyses are comprehensively discussed, and section 7 summarizes the conclusions of this paper and future issues.

2. Review of Previous Studies

Some future estimates of the impact of COVID-19 were published within a year or so of the spread of COVID-19: the World Bank published Global Economic Prospects in June 2020 and the International Monetary Fund published World Economic Outlook in April 2020 (International Monetary Fund, 2020). Future estimates have been published continuously since then in response to changing circumstances and policy changes in various countries, including re-lockdowns due to the emergence of COVID-19 variants. Rakha et al (2020) used artificial intelligence (AI) technology and data from past economic crises to predict future economic impacts caused by COVID-19 in the United Kingdom (UK). However, all of these estimates are short-term forecasts. There are several possible reasons for this, as Boissay and Rungcharoenkitkul (2020) points out, for example, the UK was considered less affected than some other European countries in the early data, but as the pandemic progressed, the UK's performance has deteriorated in comparison to other countries, making it difficult to predict the spread of COVID-19 and the resulting impact on economic activities. In addition, Rakha et al (2020), citing BFPG (2020), argues that the duration and pattern of lockdown and social distancing measures taken by governments to limit the spread of the pandemic have asymmetric effects not only between countries but also between industrial sectors and on the supply-demand chain within countries, making it difficult to predict Gross Domestic Product (GDP). Also, as pointed out by Sakar et al (2004), published before the spread of COVID-19 infection, the lack of similar models that can be used to predict future performance in situations such as the disruption of demand and supply chains, transportation restrictions, national measures affecting almost all businesses, prolonged pandemic, huge job losses, and significant unemployment rates rise, the way education and other businesses are delivered, etc. add to the challenge. In this context, the approach adopted in this study is to develop multiple future scenarios under the assumption that there are uncertainties in COVID-19 and to conduct future estimates of imports and exports for each scenario. In other words, under the assumption of COVID-19 uncertainty, scenarios developed in the high case, low case, and middle case on multiple common axes in the socio-economy, and the differences among the scenarios in the estimation results, in addition to the results of each estimation, can be seen as the size of the uncertainty that COVID-19 will bring in the future. Shibasaki et al (2022) used the GTAP model to forecast the future mainly for African imports and exports based on future scenarios that take into account future uncertainties in the Indo-Pacific region including Africa, but their future estimates were based on the situation before the COVID-19 pandemic occurred. This paper conducted future estimates based on new future scenarios that take into account the COVID-19 situation, while referring to Shibasaki et al (2022) in their treatment of uncertainties. This paper sets estimated logistics cost reduction rates by the GLINS model as the values of *ams* as *ams*, introduced by Hertel et al (2001), can be set by origin, destination, and goods as a shock to exogenously provide reductions in international transaction costs due to advances in transportation technology, etc.,

Subsequently, *ams* was utilized in Fox et al (2003), which modeled transportation delay costs at Ameri-Mexico border crossings, and Francois et al (2005), which modeled WTO trade agreements. *ams* are also used in studies that analyze the mitigation or elimination of non-tariff barriers (NTBs) or non-tariff measures (NTMs), with Fugazza and Maur (2008) discussing the treatment of non-tariff barriers in CGE models and showing whether they are introduced with an import tariff shock or a technology We show that there can be significant differences in results depending on whether they are introduced by shocks to innovation (*ams*). Abe and Wilson (2008) examine the effects of reducing corruption and increasing transparency on trade costs in the Asia-Pacific Economic Cooperation region using *ams*. The results suggest that increased transparency to the regional average would increase trade in the region by 11% and expand global welfare by $406 billion and that promoting FTAs and trade facilitation simultaneously could work as a highly effective policy mix, complementing each other.

Yet other recent results related to *ams* include Elizabeth (2019) and Walmsley et al (2021). Zhu (2019), like the present study, focuses on Africa and examines the impact of the elimination of tariff and non-tariff barriers through the African Continental Free Trade Agreement (AfCFTA) on three African regional economic communities (COMESA, ECOWAS, and CEMAC) through the GTAP model. The results show that the elimination of non-tariff barriers (AMS) increases economic welfare, indicating the effectiveness of the elimination of non-tariff barriers as a policy. Walmsley and Struttl (2021) also note the importance of non-tariff measures in recent FTA negotiations and discuss the validity of the representation of NTMs in the CGE model in Fugazza and Maur (2008), which is based on tariffs, technological innovation (*ams*) with Walmsley and Minor (2020), and compares four methods, including two new methods developed by Minor (2020): the willingness-to-pay method and the export cost method, which directly adjusts the exporter's cost of production. The results lead Fugazza and Maur (2008) to the conclusion that technological innovation significantly changes real GDP, but they point out that careful consideration is needed when evaluating changes in NTM with the CGE model since all methods can lead to different results. Thus, the analysis by *ams* is often conducted in the context of NTB/NTM. This study considers a background of cross-border inefficiencies set in the GLINS model, which assumes long waits and congestion at the border customs clearance, including elements of NTM, and logistics infrastructure development, such as economic corridor development. There seems to be no other study that has set *ams* in such context. Although the validity of the GTAP model should be verified as a method to show the effects of logistics infrastructure development on imports and exports, it seems that *ams* is the only exogenous variable that can be set by OD combination and by goods among the exogenous variables that can be manipulated in the basic model of the GTAP model (including the GTAP-RD model). Therefore, in this paper, the future estimation will be conducted using only the settings in *ams*.

3. Methodology

The overall implementation flow of this study is shown in Figure 3-1 below. First, future scenarios were set based on socioeconomic trends in Africa, such as COVID-19, efforts towards carbon neutrality, and AfCFTA, based on the assumption of future estimation by the GTAP-RD model. The GTAP-RD model was then calculated for 26 periods from 2014 (the GTAP 10 base year) to 2040 using parameter shock settings based on these future scenarios, and the future import/export growth rate was estimated for the period from 2016, the base year of the MDS database published by MDS Transmodal used to estimate future cargo volumes, to 2040. The future cargo volume was estimated from this future import/export volume growth rate and the MDS database, and the GLINS model based on Shibasaki et al. (2017) was used to estimate the estimated future cargo volume and the expected logistics cost savings if economic corridor development is realized through 2040.

In this study, however, we will attempt to link the models through sequential recalculation by setting the logistics cost reduction effects estimated in the GLINS model to the parameters in the GTAP-RD model, recalculating them, and then utilizing the recalculated results in the GLINS model again. We believe that this will improve the accuracy of both the GTAP-RD model and GLINS model estimates and enable analysis that better captures the actual situation

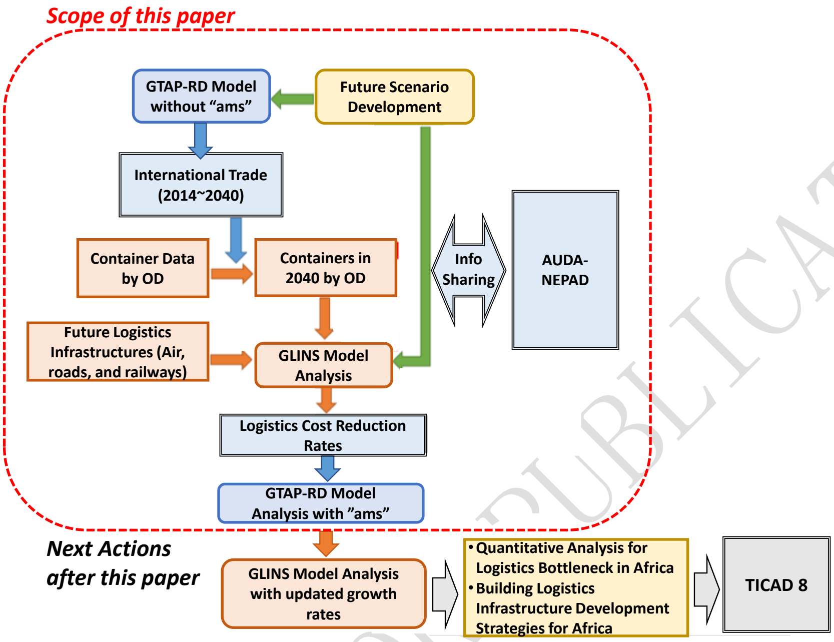


Figure 3-1 Study Flow

3-1 Overview of the GTAP-RD model

The GTAP-RD model is a dynamic version of the GTAP model (Hetel, 1997), which was developed as a static model. Its structure is presented in Aguiar et al (2019). Figure 3-2 below is a conceptual diagram of the GTAP model. The GTAP model is a basic applied general equilibrium model, representative of countries and regions. It is assumed that households consume both domestically produced goods and goods imported from other countries (substitutable) to maximize utility. Producers are formulated according to an Armington structure that assumes substitution of imported goods, the substitution of domestically produced and imported goods, and substitution of intermediate goods, based on cost-minimizing behavior. Each industry produces production goods using several substitutable intermediate goods, which are a composite of domestically produced goods and imported composites from different countries, and production factors, which are a composite of factor inputs of skilled labor, unskilled labor, capital, natural resources, and land. The basic GTAP model adopted in this study does not take into account the cross-border movement of production factors. In this study, future projections are conducted using the basic GTAP-RD model described in Aguiar et al (2019).

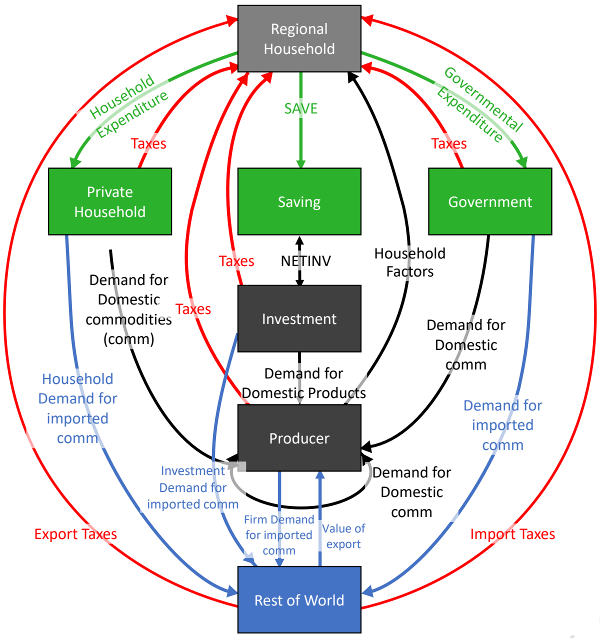


Figure 3-2 GTAP model Concept (prepared based on Aguiar et al (2019))

3-2 Future Scenario Configuration

First, in order to create future scenarios up to the year 2040, the JICA/AfGL project's expert committee (consisting mainly of logistics-related researchers and private sector practitioners) held a series of discussions to look at the world as a whole, with a focus on Africa, and to identify factors that could potentially affect the economies and societies of those countries in the future. The risks were categorized into opportunities (e.g., the latest technologies such as ICT) and risks (e.g., COVID-19). Then, since the expansion of COVID-19 infection after 2020 has already had various positive and negative impacts on the economy and society as described in World Bank (2021a), and the possibility of a prolonged impact has been pointed out, it was determined that the quality of responses to COVID-19 will have a significant impact on the uncertainty that will affect mid-to long-term economic growth. This uncertainty may imply both "opportunities (positive)" and "risks (negative)", and societies can diverge into three different futures: a "desirable future," and "undesirable but possible future," and a society somewhere in between. The above discussion can be summarized as shown in the logic tree in Figure 3-3 below.

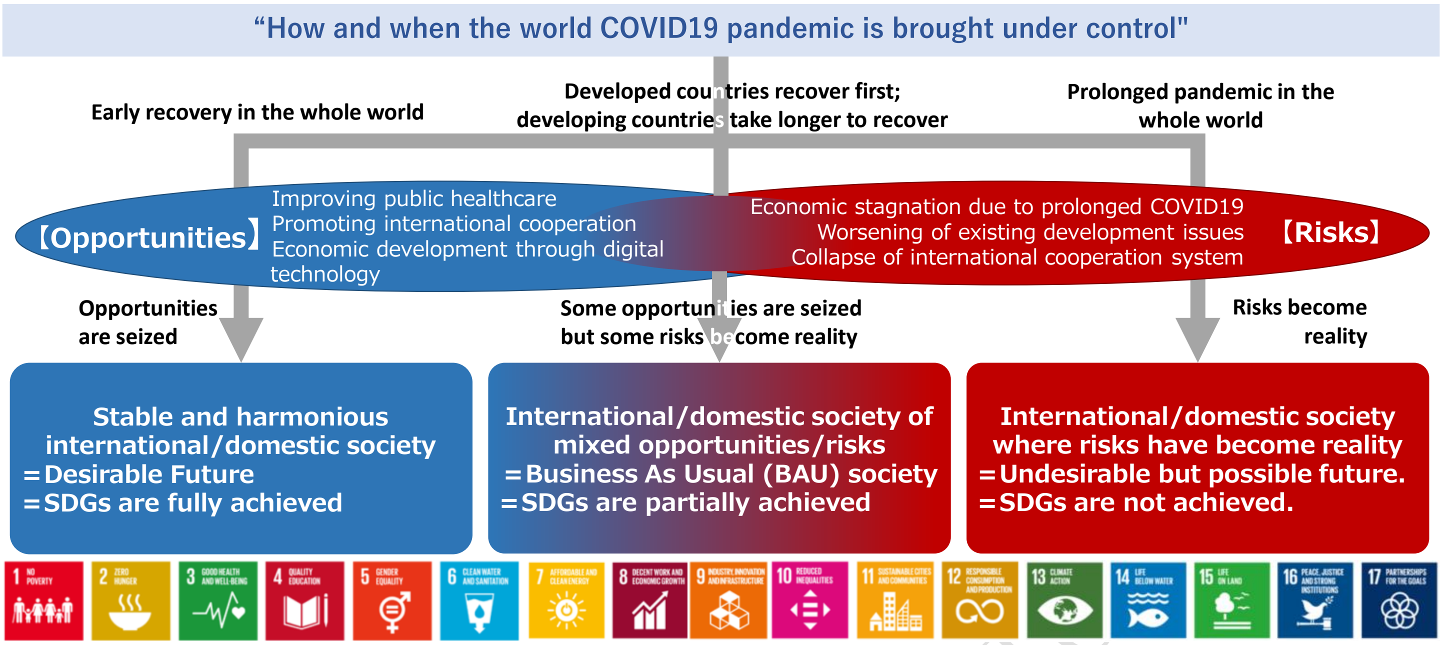


Figure 3-3 Scenario Logic Tree

Based on this premise, we summarized the results of the multiple discussions, including the situation of COVID-19, global opportunities that could be enjoyed or missed depending on the response to COVID-19, and global risks that could be mitigated or worsened (see Appendix 1), and summarized the following three possible visions of society and future expected to be realized depending on the speed of recovery from COVID-19: Stable and harmonious international/domestic society, International/domestic society of mixed opportunities/risks, International/domestic society where risks have become apparent (see Table 3-1)

Table 3-1 Convergence Assumptions for COVID-19 (Results of discussions at the Committee of Experts)

How the global pandemic of COVID-19 will unfold	Situation of opportunities and risks according to COVID-19	Visions of expected possible societies
Early recovery throughout the world	Fully embrace opportunities (healthcare, improved public health, promotion of international cooperation, economic development through digital technology)	Stable and harmonious international/domestic society
Sufficient recovery in middle- and high-income countries, but low-income countries recover late	Captures opportunities but also leaves certain risks	International/domestic society of mixed opportunities/risks
Prolonged global slowdown, especially in low- and middle-income countries	Opportunities are not fully captured, and risks become real problems (economic stagnation due to prolonged COVID-19, worsening and prolongation of existing development challenges, collapse of international cooperation system)	International/domestic society where risks have become apparent

Then, as a result of the discussions in the expert committee, we assumed that these three possible visions of future society have 12 common axes that are particularly relevant with respect to Africa, as shown in Table 3-2 below, each with a different specific situation (Appendix 2). Note that all 17 SDGs, which are common goals of the international community, are covered by the common axes.

Table 3-2 Common Axes

Common Axes	Corresponding SDGs
1. Technological Innovation	No.4, 7
2. Access to cutting-edge technology	No.4, 7, 8, 9, 13, 14, 15,16
3. Balanced industrial and free trade policies	No.1, 8, 9
4. Access to financial assistance	No.1, 2, 8, 11
5. Eliminating disparities in access to vaccines, medical care, and social welfare	No.1, 3, 6, 10
6. Education that encourages innovation, long-term perspective, and altruism	No.4, 5, 10, 12, 17
Energy (Green Energy, Blue Energy)	No.7, 13
8. Natural resource management	No.6, 12, 13, 14, 15
Climate change	No.13
10. Stable supply of labor	No.5, 8, 10, 11
11. Infrastructure Development	No.9, 16
12. start-up	No.8, 9

Three future scenarios are used as the policy for setting parameters and shocks in the GTAP-RD model: The "S1 Scenario" is a scenario in which a stable and harmonious international and domestic societies emerge, in which opportunities are seized worldwide, the "S2 Scenario" is a scenario of international and domestic society in which risks become apparent mainly in low- and middle-income countries, and the "BAU Scenario" is a scenario in which risks and opportunities become moderately apparent, and mainly low-income countries are negatively impacted. Note that the Shared Socio-economic Pathways (SSP), which are also used in the IPCC future simulations (Brian et al., 2011), are used in this model, especially considering that global income inequality varies depending on opportunities and risks and that Africa is particularly vulnerable to the manifestation of risks, 2017). SSP1 (Sustainability), SSP2 (Middle of the Road), and SSP3 (Regional Rivalry), respectively, will be used to determine the parameters for the S1, BAU, and S2 scenarios.

3-3 GTAP-RD model Configuration

In this study, the GTAP Database version 10 (GTAP 10) is used in constructing the GTAP-RD model. The world, which is divided into 141 countries/regions in the original GTAP 10, was consolidated into 43 countries/regions according to regional characteristics and economic scale. Of these, the African countries/regions were set as a regional setting (30 countries/regions), maintaining as much as possible of the original GTAP 10, in other words, maximum segmentation, so that the different impacts of each African country/region are clarified (see Figure 3-4).

Next, for the industrial sector setting, this study consolidated the 65 industrial sectors of GTAP 10 into 16 industrial sectors, as shown in Table 3-3. In this setting, we have taken into account that agriculture, one of Africa's major industries, and telecommunications and financial services, which utilize the latest technologies such as ICT and are recognized as highly prevalent in Africa, are independent industrial sectors, so that the differences among industrial sectors and industrial structures by country and region can be more clearly identified. In addition, "High GHG emitting industries" is based on the calculation for the year 2026, when the border carbon tax will be fully applied in the EU, by integrating the industrial sectors (steel, cement, fertilizer, aluminum, and electric power) that are subject to similar tariffs.

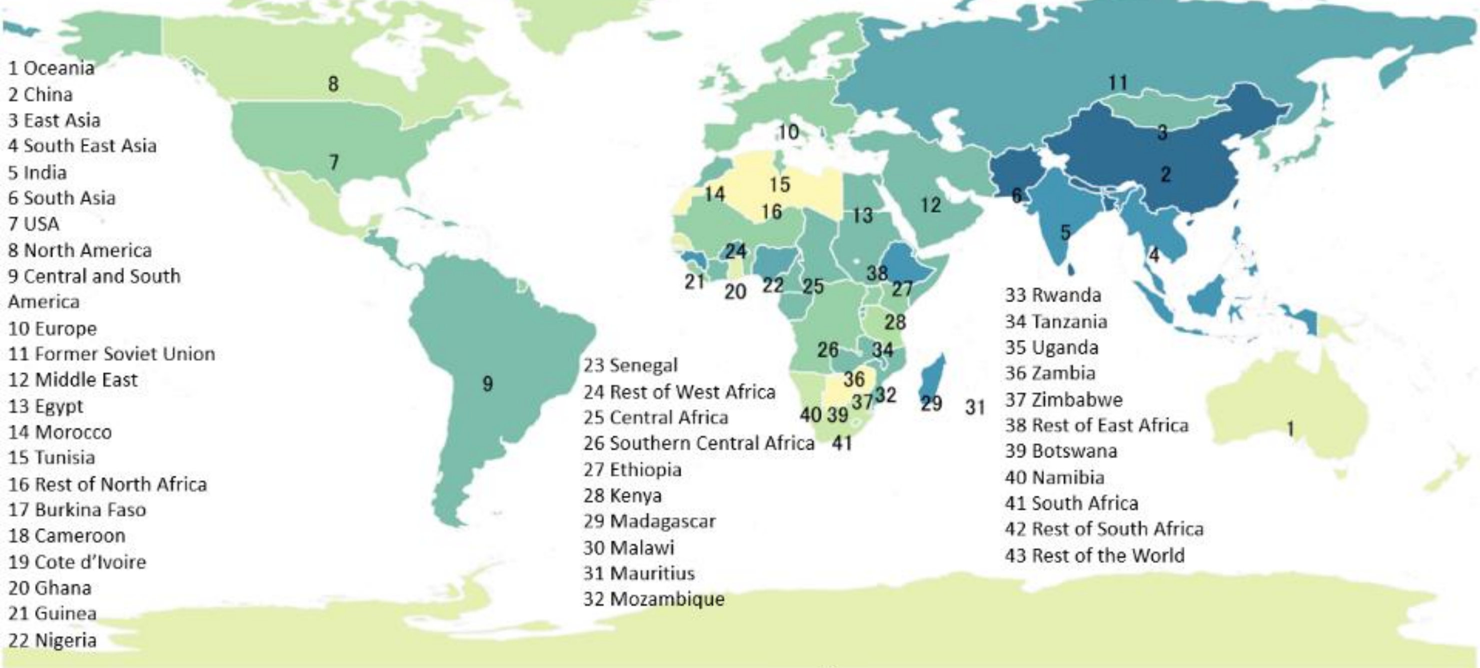


Figure 3-4 Country/Region Classification

Table 3-3 Industrial Sector Classification

1.	Cereals (Cer)	9.	Processing /Assembling (Pro)
2.	Other Edible Agriproducts (Oea)	10.	Motor Vehicles and Parts (Mvh)
3.	Fishing (Fis)	11.	Land Transport (Tla)
4.	Other Agriproducts and Forestry (Oaf)	12.	Water Transport (TWA)
5.	Natural Resources (Nat)	13.	Air Transport (Tai)
6.	Household Consumer Products (Hou)	14.	Communication (Com)
7.	Basic Industrial Materials (Bas)	15.	Financial Services (Fin)
8.	High GHG Emission Products (Ghg)	16.	Other Services (Oth)

3-4 GTAP-RD model Parameter Shock Settings

The basic parameters used in the analysis of the GTAP-RD model are set as shown in Table 3-4, and these parameter settings are set to cover the 12 axes described earlier (Appendix 3). Based on the assumption that the degree of economic growth slowdown by COVID-19 is affected by the per capita income group to which a country/region belongs, this study classifies countries/regions into three income groups: high-income countries (12,535USD -), middle-income countries (4,046 - 12,535USD), and low-income countries (- 4,046USD). The regions were categorized into different parameters and shock settings. For carbon neutrality and other responses to climate change, we qualitatively used Shared Socioeconomic Pathways (see Figure 3-5) settings that take into account both adaptation and mitigation of climate change. SSP3, which captures higher costs in both mitigation and adaptation, was applied.

Table 3-4 Parameters set *HIC: High-Income Countries, MIC: Middle-Income Countries, LIC: Low-Income Countries

Factors	BAU Scenario	S1 Scenario	S2 Scenario
Population	Growth in SSP2 updated with United Nations (2019)	Growth in SSP1 updated with United Nations (2019) and considering migrants.	Growth in SSP3 updated with United Nations (2019) and considering migrants.
Labor Force	Population group 15-64 growth in SSP2 updated with United Nations (2019) and middle/high education increase rate	Population group 15-64 growth in SSP1 updated with United Nations (2019) and educational improvement	Population group 15-64 growth in SSP3 updated with United Nations (2019) and educational improvement
Real GDP	**HIC:** Growth in SSP2. Growth in 2020-22 replaced with World Bank (2021a) for COVID-19. In 2023 V-shape recovery to the path. **MIC:** same as HIC **LIC:** Growth in SSP2. Growth in 2020-23 replaced with World Bank (2021a) for COVID-19.	**HIC:** Growth in SSP1. Growth in 2020-22 replaced with World Bank (2021a) for COVID-19. In 2023 V-shape recovery to the path. **MIC:** same as HIC **LIC:** same as MIC	**HIC:** Growth in SSP3. Growth in 2020-22 replaced with World Bank (2021a) for COVID-19. In 2023 V-shape recovery to the path. **MIC:** Growth in SSP3. Growth in 2020-23 replaced with World Bank (2021a) for COVID-19. **LIC:** same as MIC
Tech Change: Cereals	Average value for each of the 43 regions in the estimation by World Bank (2010), between 2000 and 2050.	**HIC:** +0.18%/year **MIC:** +0.18%/year **LIC:** +0.18%/year	**HIC:** -0.65%/year **MIC:** -0.65%/year **LIC:** -0.65%/year
Tech Change: Others (twice in Com, Fin)	**HIC:** +0.4%/year **MIC:** +0.72%/year **LIC:** +0.86%/year	**HIC:** +0.7%/year **MIC:** +0.95%/year **LIC:** +0.93%/year	**HIC:** +0.39%/year **MIC:** +0.6%/year **LIC:** +0.7%/year
FTA/EPA	FTA/EPA planned/designed as of 2021 will be realized as scheduled, and; **HIC:** the tariff rate will be eliminated/reduced in 5 years. **MIC:** same as HIC **LIC:** same as HIC	FTA/EPA planned/designed as of 2021 will be realized as scheduled, and the tariff will be eliminated/reduced in; **HIC:** 5 years. **MIC:** 10 years. **LIC:** same as MIC	FTA/EPA planned/designed as of 2021 will be realized as scheduled, and the tariff will be eliminated/reduced in; **HIC:** 5 years. **MIC:** 10 years. **LIC:** 15 years.

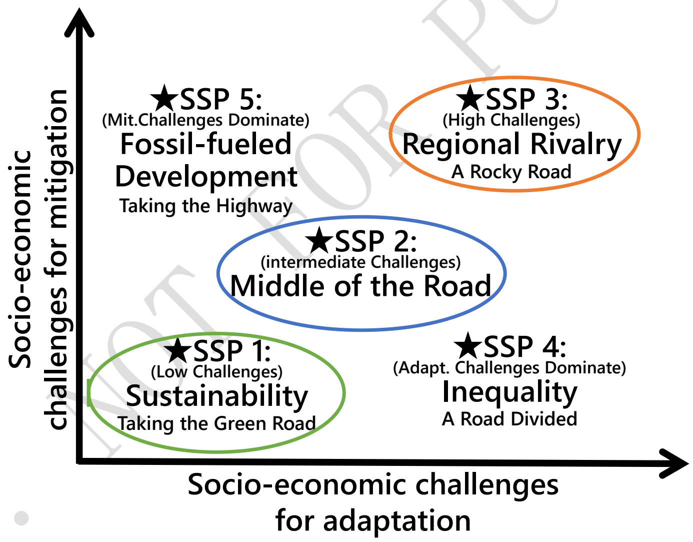


Figure 3-5 Concept of SSP (O'Neill et al, 2015)

The individual settings for each are described below.

3-4-1 Real GDP per capita growth rate (set in baseline calculation)

The real GDP per capita growth rate used in the baseline calculation was calculated from the real GDP and population estimated in SSP1-3. However, for the four years 2020, 2021, 2022, and 2023, when the impact of the COVID-19 expansion is estimated and projected, the real GDP growth rate is calculated based on the real GDP growth rate estimated in "Global Economic Prospects June 2021" (World Bank, 2021) published by the World Bank in June 2021 (see Table 3-5). World Bank (2021a) calculated real GDP using the growth rate (estimated and projected) and applied it to the calculation of real GDP per capita growth rate. Growth rates for 2021 and 2022 have been revised significantly upward, driven by high-income countries where vaccination is progressing. However, while high-income countries will see per capita income recover to 90% of the pre-pandemic level, low- and middle-income countries will see an overall recovery level of about one-third.

Table 3-5 Real GDP Growth Projections under COVID-19, World Band (2021)

	2020	2021	2022	2023
Advanced economies	-4.7%	5.4%	4.0%	2.2%
Emerging market and developing economies	-1.7%	6.0%	4.7%	4.4%
East Asia and Pacific	1.2%	7.7%	5.3%	5.2%
Europe and Central Asia	-2.1%	3.9%	3.9%	3.5%
Latin America and the Caribbean	-6.5%	5.2%	2.9%	2.5%
Middle East and North Africa	-3.9%	2.4%	3.5%	3.2%
South Asia	-5.4%	6.8%	6.8%	5.2%
Sub-Saharan Africa	-2.4%	2.8%	3.3%	3.8%
Nigeria	-1.8%	1.8%	2.1%	2.4%
South Africa	-7.0%	3.5%	2.1%	1.5%
Angola	-5.2%	0.5%	3.3%	3.5%

This study assumes that the degree of recovery of the real GDP growth rate will vary according to income class based on GDP per capita among countries and regions. In other words, high-income countries and regions are expected to recover early, as forecast by The World Bank (2021a), and even achieve a "V-shaped recovery" to return to the growth path before COVID-19, while low- and middle-income countries and regions, depending on international coordination and share of on vaccine supplies, the speed of recovery will vary. Therefore, under the S1 scenario, which assumes progress in international cooperation, a V-shaped recovery will be realized regardless of income level, while under the S2 scenario, which assumes no progress in international cooperation and regional disparities remain, low- and middle-income countries will not achieve a V-shaped recovery (under the intermediate BAU scenario, only middle- and high-income countries and regions will achieve a V-shaped recovery. see Figure 3-6).

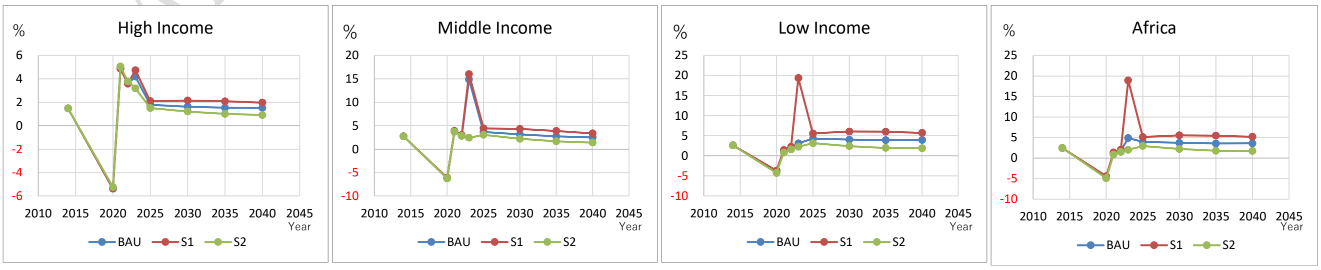


Figure 3-6 Real GDP per capita growth rate under COVID-19

3-4-2 Population Growth Rate

Comparing population data in GTAP 10 with United Nations' "World Population Prospects 2019" (United Nations, 2019), which is statistical data on demographic trends, GTAP 10 has 47 million fewer people in the 2014 population, and the middle-of-the-road scenario SSP2 in SSP. The projected population in 2040 based on growth rates is more than 300 million less than the United Nations (2019) Median Variant projection. The United Nations (2019) data and population growth rates projected, which are based on more recent information, therefore will be used for future projections in this study. The impact of the expansion of COVID-19 on global demographics is uncertain at this time and is not considered in this projection. We will consider the need to take this into account again in the future as soon as the latest reports by international organizations and other organizations are published.

The 2014 population used in the GTAP-RD model of this study is the value of the 2014 population in United Nations (2019), and the population growth rate for 2014-2040 applies to the growth rate in the Median Variant projection in United Nations (2019). However, in order to express the differences between scenarios, while the rate of increase in the Median Variant projection in United Nations (2019) is applied to the BAU scenario, the ratio of SSP1 to SSP2 (SSP1/SSP2) is applied in the S1 scenario and the ratio of SSP2 to SSP3 (SSP3/SSP2) is applied in the S2 scenario.

The differences in population growth rates between the scenarios in this study are also based on "migration status" and "climate change impacts (population growth rates in the base SSP scenario)" in addition to the SSP1-3. As for the current status of the migration, from the United Nations Population Division World Population Prospects: 2019 Revision and the International Migration database published by the OECD in 2018, the overall number of immigrants from non-OECD countries to OECD countries is 0.1% of the non-OECD population (= 0.1% of the population of each non-OECD country migrates to OECD countries each year) and0.47% of the population of OECD countries (= 0.47% of the population of each OECD country consists of immigrants from non-OECD countries) (see Table 3-6). In middle- and low-income countries, migration (outflow) impairs skilled labor and has a negative impact on industrial upgrading and human resource development. On the other hand, many high-income countries, which are the main recipients of immigrants, are facing a declining labor force and are increasingly accepting immigrants.

Table 3-6 Immigration Status (2018)

	Population (millions)	Immigration (millions)	Percentage of Immigrants in the population (%)
OECD	1,299	6.1 (inflow)	0.47 %
Non-OECD	6,249	6.1 (outflow)	0.10 %

3-4-3 Labor Force Growth Rate

The growth rate of the working population (15-64 years) from the UN World Population Prospects 2019 is used as the growth rate of the labor force for both skilled and unskilled labor. The rate of access to higher education is used as the growth rate for skilled labor and the rate of access to secondary education, for unskilled labor. In the BAU scenario, the growth rate of the working population (15-64 years) from United Nations (2019) itself is applied, while the ratio of SSP1 to SSP2 (SSP1/SSP2) is applied in the S1 scenario and the ratio of SSP2 to SSP3 (SSP3/SSP2) is applied in the S2 scenario in order to express the differences between scenarios.

3-4-4 Growth rate of skilled labor endowment (added to the growth rate common to skilled and unskilled labor)

As explained in Liu et al (1998), technicians, officials, managers, administrators, professionals, and para-professionals, who are classified as Skilled Labor in the GTAP-RD model, are assumed to have a level of education higher than secondary education (i.e. tertiary education). Therefore, it can be assumed that the rate of increase in skilled labor will increase only by the rate of increase in the share of people with higher education, and the rate of increase in the share of people with higher education was assumed to vary depending on the scenario. From World Bank (2021b), we calculated the average higher education attainment growth rate (CAGR) based on the growth rate of people with higher education in the most recent five years and add it to the labor intensity growth rate for the SSP scenario adopted in each scenario (see Table 3-7). In the GTAP-RD model, the labor participation growth rate is set according to the population growth rate for each SSP scenario, but there is no distinction between skilled and unskilled workers (skilled and unskilled workers increase at the same rate).

Table 3-7 Higher Education Enrollment Rate

	Year 2014	2015	2016	2017	2018	Average Growth Rate
High-income countries	74.5%	75.0%	76.0%	76.4%	77.0%	0.31%/year
Low and Middle-income countries	30.3%	31.4%	32.0%	32. 5%	33.0%	2.22%/year

3-4-5 Growth Rate of Unskilled Labor Allocation (Added to Growth Rate for Skilled and Unskilled Labor in Common)

As explained in Liu et al (1998), unskilled Labor in the GTAP-RD model consists of clerks, service/shop workers, agricultural, etc., without any account foreducational background. The increase or decrease of these unskilled labor categories is assumed to be determined by the extent to which people are new to the labor market. In other words, in addition to new entrants to the labor market who have reached working age, the labor force will increase due to the entry of women, ethnic and religious minorities, and other groups that had previously been prevented from entering the labor market. In order to encourage these new entrants to the labor market, they need to have access to secondary education as well as primary education (see Mastercard Foundation (2019), etc.). Therefore, it is possible to assume that unskilled labor will increase only at the rate of increase in the share of those with secondary education and that the rate of increase in the share of those with primary education will vary depending on the scenario (there is uncertainty there that depends on the social situation). From World Bank (2021c), the average rate of increase in secondary education enrollment (CAGR) is calculated from the increase in the number of people with secondary education in the last five years and added to the labor intensity increase rate employed in each scenario (see Table 3-8).

Table 3-8 Secondary Education Enrollment Rate

	Year 2014	2015	2016	2017	2018	Average Growth Rate
High-income countries	105.5%	106.0%	106.3%	106.4%	105.9%	0.08%/year
Low and Middle-income countries	71.4%	71.5%	71.8%	71.5%	72.5%	0.24%/year

The labor increment rate is set according to the SSP scenario employed in each scenario. In other words, the SSP1 scenario adopts the labor intensity growth rate of SSP1, the BAU scenario adopts the labor intensity growth rate of SSP2, and the S2 scenario adopts the labor intensity growth rate of SSP3. In this regard, it can be said that the effects of climate change are also taken into account in the rate of increase in labor intensity. In the S1 scenario, the base rate of increase plus α is achieved in all countries and regions for skilled and unskilled labor as a result of the expansion of opportunities for secondary and tertiary education in all countries. In the S2 scenario, the base growth rate +α is assumed to be achieved only in high-income countries.

3-4-6 Rate of technological progress in Cereals sector (*afeall*)

Climate change is projected to affect cereal monocultures (productivity) in the future (World Bank (2010), Iizumi et al (2017), etc.). In this regard, as the rate of technological progress in the Cereals sector in this study, we apply the rate of change in unit yield, which takes into account the effects of climate change. World Bank (2010) estimates the average yield of 11 agricultural products in 2050 by region (wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sunflower, and rapeseed), while Iizumi et al. (2017) estimated the global average unit yield by grain type (four species: wheat, rice, maize, and other crops). World Bank (2010) estimated that a 2°C temperature increase (equivalent to RCP 2.6) would result in a decrease in unit yield in all countries except Europe, Central Asia, and Canada, while Iizumi et al. (2017) states that even at RCP 8.5, global average unit yields will not fall below 2010 levels until 2050 (results by region not conducted or published).

In this study, the SSP scenarios and other policy parameters applied to each scenario are determined based on the assumption that the effects of climate change will be manifested to some degree. Based on this assumption, the rate of technological progress for each scenario is set with reference to World Bank (2010), which shows more pessimistic projection results (see Table 3-9).

Table 3-9 Average percent change in average unit yield of cereals (2000-2050 average)

No.	Country/Region	Average Annual percent change(%)	No.	Country/Region	Average Annual percent change (%)
1	Oceania (H)	-0.36%	22	Nigeria (L)	-0.21%
2	China (M)	0.16%	23	Senegal (L)	-0.43%
3	EAsia (H)	0.00%	24	ROWAfrica (L)	-0.30%
4	SEAsia (M)	-0.34%	25	CAfrica (L)	-0.18%
5	India (L)	-0.26%	26	SCAfrica (L)	-0.18%
6	SAsia (L)	-0.28%	27	Ethiopia (L)	0.01%
7	USA (H)	-0.03%	28	Kenya (L)	0.12%
8	NAmerica (H)	0.17%	29	Madagascar (L)	-0.01%
9	CSAmerica (M)	-0.06%	30	Malawi (L)	-0.06%
10	Europe (H)	0.07%	31	Mauritius (M)	-0.18%
11	FSU (M)	0.18%	32	Mozambique (L)	-0.22%
12	MEast (M)	-0.28%	33	Rwanda (L)	-0.18%
13	Egypt (L)	-0.65%	34	Tanzania (L)	-0.04%
14	Morocco (L)	-0.58%	35	Uganda (L)	-0.10%
15	Tunisia (L)	-0.18%	36	Zambia (L)	0.03%
16	RONAfrica (M)	-0.14%	37	Zimbabwe (L)	-0.22%
17	BurkinaFaso (L)	-0.09%	38	ROEAfrica (L)	-0.18%
18	Cameroon (L)	-0.14%	39	Botswana (M)	-0.18%
19	CotedIvoire (L)	-0.28%	40	Namibia (M)	-0.18%
20	Ghana (L)	-0.21%	41	SouthAfrica (M)	-0.11%
21	Guinea (L)	-0.18%	42	ROSAfrica (L)	-0.18%
			43	ROW (L)	-0.18%

3-4-7 Rate of technological progress in other industrial sectors (*afeall*)

The rate of technological progress parameter (*afeall*) for the other industrial sectors from the Cereals sector was established for each scenario.

First, it is assumed that the occurrence of technological innovation and the degree of diffusion of innovative technology are determined by the degree of international cooperation. In the S1 scenario, which assumes further development of international cooperation, it is assumed that technological innovation occurs, or innovative technologies become available in all countries (high productivity growth is also observed in low-income countries). In addition, the application of innovative technologies to production in low- and middle-income countries is assumed to be achieved through the sharing of know-how, etc., as technological cooperation projects are implemented in international coordination, and the highest productivity gains at each income level are achieved in other countries as well. The BAU scenario assumes that technological innovations are shared globally, but that productivity growth remains average for each income level due to the limited number of technologies that can be applied depending on the income level of each country. (i.e., there is no ready acceptance of innovative technologies and no technological cooperation projects are implemented).

The average rate of change in the UNCTAD Productive Capacities Index (PCI) since 2000 was used to set this *afeall*. The PCI is the geometric mean of 46 indicators for human capital, natural capital, energy, transportation, ICT, government agencies, private sector, and social structural change. The

Table 3-10 shows that the average rate of change in the PCI is gradually decreasing regardless of income group, with the highest average rate of change in 2000-2018, followed by 2009-2018, and the lowest in 2014-2018. The average rate of change for 2009-2018 is applied to the S1 scenario, the medium 2009-2018 for the BAU scenario, and the lowest 2014-2018 for the S2 scenario. However, for telecommunications and financial services, the values set are twice those of other industries, taking into account the fact that significant technological innovation is expanding globally.

Table 3-10 PCI Average Rate of Change

	2000	2009	2014	2018	Average rate of change (2014-18)	Average rate of change (2009-18)	Average rate of change (2000-18)
High-income country/region average	33.91	37.06	37.83	38.42	0.39%	0.40%	0.70%
Middle-income country/region average	27.14	30.15	31.46	32.17	0.60%	0.72%	0.95%
Low-income country/region average	20.99	22.96	24.07	24.80	0.70%	0.86%	0.93%

3-4-8 Rate of technological progress in international transportation

The GTAP-RD model allows for a rate of technological progress for international transportation between countries/regions. There are several parameters related to the rate of technological progress for international transportation in the GTAP-RD model, as shown in

Table 3-11 below

Table 3-11 International transportation technology progress rate parameters that can be set within the GTAP-RD model

Parameter	Description
ats(r)	International Transportation Technology Progress Parameters by Origin (r)
atd(s)	International Transportation Technology Progress Parameters by Destination (s)
atm(m)	International Transportation Technology Progress Parameters by Mode of Transportation (m)
ams(i,r,s)	Rate of Progress in Transportation Technology in International Trade

In Shibasaki et al (2022), to take into account the effects of the development of transportation infrastructure, OSBP, etc., which contribute to improving the efficiency of international transportation and reducing border resistance, simulations were conducted by giving the average productivity growth rate in the transportation sector in the past to the international transportation technical progress rate ats/atd by origin and destination for the entire calculation period from the first period. Although it was conducted, ats/atd is the rate of technological progress in international transportation that depends only on one origin/destination, and could not be limited by the combination of origin and destination. However, it is preferable to set the rate at the combination of origin/destination where the rate of technological progress in international transportation is enjoyed, such as shipping and air transportation routes, land transportation networks, and OSBP installed ports of entry, where infrastructure development is expected in the future, to capture actual development effects.

In this study, we employed *ams,* which can be set in three-dimensional combinations of origin-destination and goods, as a shock to exogenously reduce international transaction costs due to transportation technology progress, etc. The *ams* can be set by origin, destination, and goods, and are based on Hertel, Walmsley, and Itakura (2001). Subsequently, *ams* was utilized in Francois and Londono-Kent (2003), which modeled transportation delay costs at the US-Mexico border crossings, and Francois et al (2005), which modeled the WTO trade agreement.

As the setting value, this study uses the logistics cost reduction rate estimated by the GLINS model, which is based on the GTAP-RD model without *ams* setting, and uses a part of the output of the model. An overview of the GLINS model and how it is used in the *ams* settings is given below.

3-4-9 Tariff Rate

In this study, the reduction or elimination of tariff rates toward free trade in the context of international cooperation is a desirable future (S1 scenario), while maintaining protectionist-oriented tariff rates is an undesirable but possible future (S2 scenario), and the BAU scenario is an intermediate future between the two. The GTAP-RD model does not automatically reflect FTA/EPAs introduced in the real world after 2015, and it is necessary to reflect them as policy parameters in each year's calculation. For arrangements involving changes in tariff rates, tariff rates are phased out or reduced according to the status of the FTA/EPA as of 2021 ("in force", "signed", "under negotiation", or "in the concept stage") based on the WTO Regional Trade Agreements Database, as shown in Table 3-12. However, the speed of tariff rate reduction/elimination will be set to vary among the scenarios according to the progress of international cooperation and the degree of free trade orientation, which will differ among the scenarios (see Figure 3-7). It should be noted that within Africa, tariff rates will be reduced from 2021 on the assumption that the AfCFTA will be operational from 2021.

Table 3-12 FTA/EPA Configuration in the GTAP-RD model

Status as of 2021	Correspondence in GTAP-RD model
Entered into force	Gradual reduction or elimination of tariffs from the year of entry into force
Signed (not yet in effect)	Gradual reduction or elimination of tariffs beginning in 2022 (assuming entry into force in 2022)
Negotiations in progress	Gradual reduction of tariffs starting in 2025
Conceptual stage	Gradual reduction of tariffs starting in 2030

	Oceania (H)	China (M)	EAsia (H)	SEAsia (M)	India (L)	SAsia (L)	USA (H)	NAmerica (H)	CSAmerica (M)	Europe (H)	FSU (M)	MEast (M)	Egypt (L)	Morocco (L)	Tunisia (L)	RONAfrica (M)	BurkinaFaso (L)	Cameroon (L)	CotedIvoire (L)	Ghana (L)	Guinea (L)	Nigeria (L)	Senegal (L)	ROWAfrica (L)	CAfrica (L)	SCAfrica (L)	Ethiopia (L)	Kenya (L)	Madagascar (L)	Malawi (L)	Mauritius (M)	Mozambique (L)	Rwanda (L)	Tanzania (L)	Uganda (L)	Zambia (L)	Zimbabwe (L)	ROEAfrica (L)	Botswana (M)	Namibia (M)	SouthAfrica (M)	ROSAfrica (L)	ROW (L)
Oceania (H)	18	15	15	18	25		30	18	18	21	30	22					25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
China (M)	15	30	15	19	30	22	30	30	25	19	18	25																			20								25	25	25	25	
EAsia (H)	15	15	16	15			20	15	15	19	25	25																														18	
SEAsia (M)	18	19	15	18	25	18	30	18	18	16	22	15	22	22	22	22	22	22	22			22	22	22	22							22			22			22					
India (L)	25	30		25		25		25	25	25		25																										25					
SAsia (L)		22		18	25	22			22	22	22	22	22	22	22	22	22	22	22			22	22	22	22							22			22			22					
USA (H)	30	30	20	30				20	30	25	30	25																25															
NAmerica (H)	18	30	15	18	25		20	18	15	17	17	30		25																													
CSAmerica (M)	18	25	15	18	25	22	30	15	16	20	22	20	17	22	22	22	22	22	22	25	25	22	22	22	22	25	25	25	25	25	25	22	25	25	22	25	25	22	16	16	16	16	
Europe (H)	21	19	19	16	25	22	25	17	20	15	17	16	21	21	21	22	16	21	16	25	16	16	16	16	22	25	25	21	21	25	21	16	22	22	22	25	21	21	16	16	16	16	
FSU (M)	30	18	25	22		22	30	17	22	17	15	22	22	22	22	22	22	22	22			22	22	22	22							22			22			22					
MEast (M)	22	25	25	15	25	22	25	30	20	16	22	22	22	22	22	22	22	22	22	30	30	22	22	22	22	25	30	30	30	30	30	22	30	30	22	30	30	22	30	30	30	30	
Egypt (L)				22		22			17	21	22	22		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Morocco (L)				22		22		25	22	21	22	22	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Tunisia (L)				22		22			22	21	22	22	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
RONAfrica (M)				22		22			22	22	22	22	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
BurkinaFaso (L)	25			22		22			22	16	22	22	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Cameroon (L)	25			22		22			22	21	22	22	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
CotedIvoire (L)	25			22		22			22	16	22	22	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Ghana (L)	25								25	25		30	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Guinea (L)	25								25	16		30	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Nigeria (L)	25			22		22			22	16	22	22	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Senegal (L)	25			22		22			22	16	22	22	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
ROWAfrica (L)	25			22		22			22	16	22	22	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
CAfrica (L)	25			22		22			22	22	22	22	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
SCAfrica (L)	25								25	25		25	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Ethiopia (L)	25								25	25		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Kenya (L)	25						25		25	21		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Madagascar (L)	25								25	21		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	21	
Malawi (L)	25								25	25		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	21	
Mauritius (M)	25	20							25	21		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	21	
Mozambique (L)	25			22		22			22	16	22	22	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	21	
Rwanda (L)	25								25	22		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	21	
Tanzania (L)	25								25	22		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	21	
Uganda (L)	25			22		22			22	22	22	22	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	21	
Zambia (L)	25								25	25		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	21	
Zimbabwe (L)	25								25	21		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	21	21	
ROEAfrica (L)	25			22	25	22			22	21	22	22	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Botswana (M)	25	25							16	16		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	21	
Namibia (M)	25	25							16	16		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	21	
SouthAfrica (M)	25	25							16	16		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		21	
ROSAfrica (L)	25	25	18						16	16		30	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
ROW (L)																																											

Figure 3-7 Yar of elimination/reduction of tariffs (The number in each cell is the last two digits of the year of elimination/reduction of tariffs)

Note that as different from the other sectors, many countries have tariff rates over 100% in the cereals sector, and eliminating the tariff (0%) would be too burdensome (not calculable), so we decided to reduce the tariff rate to 50% of the 2014 rate. In addition, taking into account the movement of border carbon taxes in the EU, a flat 5% border carbon tax was added for imports of "high-GHG emission products" (steel, cement, fertilizer, aluminum, and electricity) by high-income countries from low- and middle-income countries in 2026, when the border carbon tax is fully applied in the EU. The new system was set up. Although the actual EU border carbon tax is based on the amount of GHGs emitted in the manufacturing and other processes, the setting in this study is simplified.

3-5 Overview of the GLINS model

It is clear that transportation technology is advancing day by day, as cargo ships become larger and road and rail infrastructures are improved, but it seems difficult to set a reasonable figure for the rate of technological progress from external information in a situation where various factors affect the rate of technological progress. Therefore, as a new attempt, we utilized the GLINS model developed by

Shibasaki et al. (2017), which allows for analysis based on parameters such as ocean transportation, land transportation, infrastructure information on border procedures, and transportation costs, and transportation time. Specifically, we first conducted future estimates using the GTAP-RD model with no *ams* settings and then converted the results into regional OD cargo volumes using trade statistics and regional economic indicators for each country in the world. Then, the GLINS model was used to estimate the rate of reduction in transportation costs due to infrastructure improvements such as ports, roads, railroads, and trade facilitation facilities. While a large part of the discussion in this paper is based on the future estimation results using the GTAP-RD model without *ams,* the differences in the GTAP-RD model estimation results caused by the presence of *ams* are also included in the discussion.

In the future estimation using the GLINS model, a logistics network consisting of ship, road, and rail transport networks was first constructed following the actual logistics infrastructure network, and a current model was built to ensure reproducibility using port statistics and trade statistics data in the current situation (as of 2016). Based on the current model, the future logistics infrastructure level and its capacity were set as exogenous variables in the international logistics model, and the future interregional freight demand obtained from the GTAP-RD model was input to construct a future model that can estimate future freight flows. The simulation of freight transport using this future model can quantitatively demonstrate the effects of economic corridor development and the construction of border customs clearance facilities (OSBPs), such as the reduction of freight transport costs.

The structure of the GLINS model is shown in Figure 3-8 below.

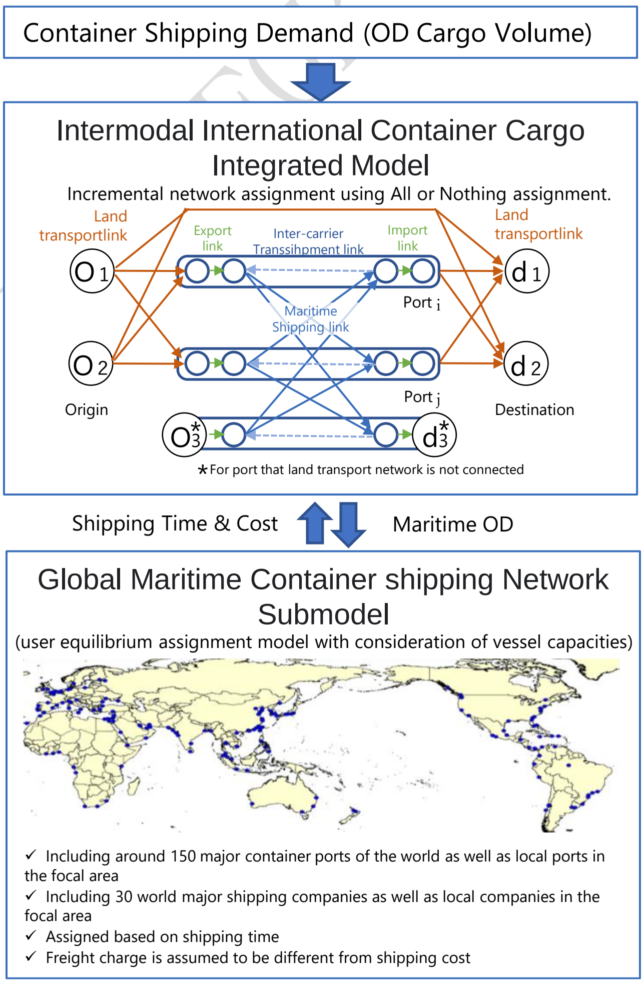


Figure 3-8 GLINS Model Concept (Prepared by the author)

The GLINS model is structured as two submodels: a user equilibrium allocation model based on the real networks of the maritime network and the hinterland network, respectively, and a stochastic allocation model on an intermodal virtual network integrating the two as the upper submodel. The inputs to the model are the demand for interregional containerized cargo transport, which is the input to the upper problem; the marine container transport network data in the submodel, which is the input to the lower submodel (container ship liner route data, capacity, distance, etc.), and the hinterland transport network consisting of road, rail, and inland water transport network data (geographic information, capacity, distance) should be constructed.

To verify the effect of the development of economic corridors, the case in which corridor infrastructure development (hard development) and customs clearance facilitation through OSBP development (soft development) are implemented simultaneously in the future model is defined as the "economic corridor development case", and calculations are performed with and without these measures. A comparative analysis of the results was conducted. These values are based on field interviews and PIDA (Programme for Infrastructure Development in Africa)'s plan (see Figure 3-9).

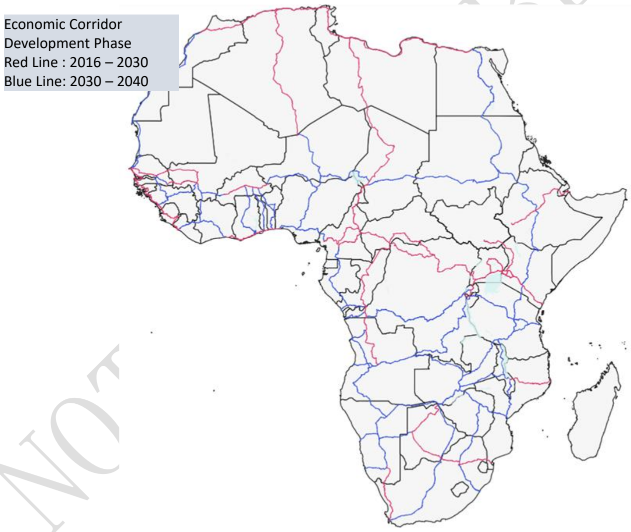


Figure 3-9 Economic Corridor Setting in the GLINS Model

4. GTAP-RD model future estimation results

The following are the future estimation results from the GTAP-RD model before setting the GLINS model estimates in the parameter *ams*. It should be noted that these are the values obtained by aggregating the variable *QXS* in the GTAP-RD model on a country/region basis, and do not include price changes from 2014 to 2040, but rather the "volume of imports and exports.

4-1 General exports and import

Below are the GTAP-RD model estimation results for normal import/export volumes and trade balance for the entire world.

4-1-1 General imports/exports and trade balance of total non-service sectors

Figure 4-1 below is the estimated results for the volume of normal imports and exports and the trade balance for the 10 non-service sectors as a whole. First, in terms of scenario setting, the S1 scenario (red line) shows the largest increase in overall imports and exports for all income groups. On the other hand, in terms of the balance of imports and exports, middle-income countries/regions total is the only category where the trade surplus increases under the S1 scenario, while the other low- and high-income countries/regions total and Africa total show the largest trade deficits under the S1 scenario (zero for the world as a whole).

Although exports from China and Southeast Asia, which are included in the middle-income countries/regions, are still large under the current situation, this trend is shown to remain unchanged and expand until 2040. On the other hand, low-income countries and regions include India and other South Asian countries whose manufacturing industries are expanding, but the scale of exports from these countries and regions is still nearly 10 times larger than that of China. The difference in the rate of change around 2020, although small, is due to baseline calculations that take into account the impact of COVID-19.

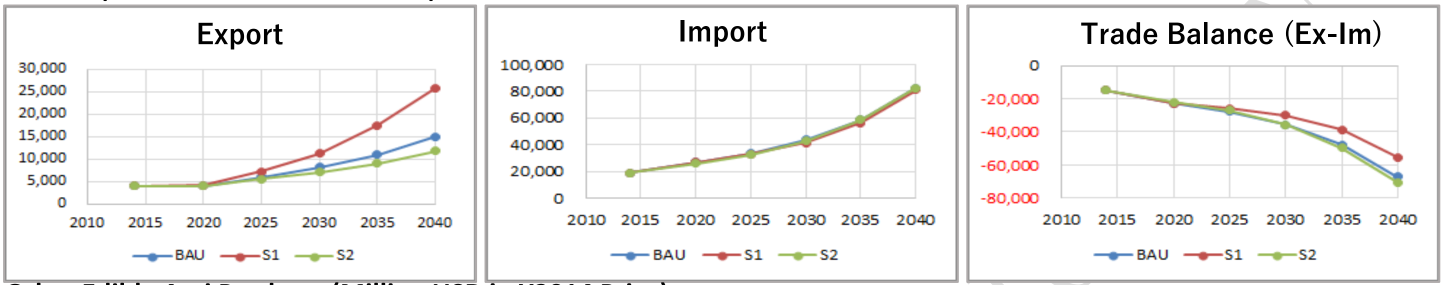
Figure 4-1 General imports/exports and trade balance of total non-service sectors
(vertical axis: Million USD in Y2014 Price, horizontal axis: Year)

4-1-2 General Import/export and trade balance by industrial sector

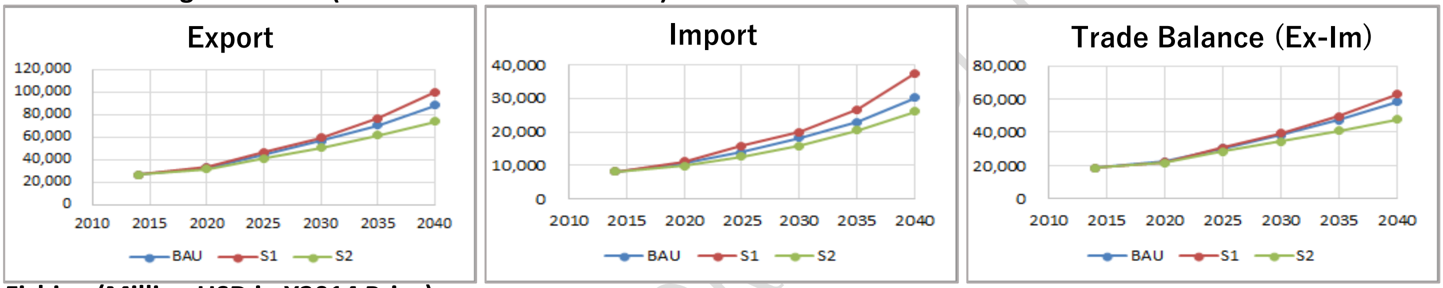
As shown in Figure 4-2 and Figure 4-3 below, with regard to normal imports and exports, exports have grown particularly in the cereals sector, consumer goods sector, and high GHG emitting industries sector, while imports have increased significantly in the other edible agricultural products sector, fisheries sector, and basic industrial materials sector. In terms of trade balance, Africa has trade surpluses in four sectors: other edible agricultural products, other non-food agricultural products and forestry, and natural resources. It is worth noting that this could be the second-largest source of foreign currency for Africa after natural resources. In other words, this suggests that the industrial sector should be targeted for preferential investment and the training of technicians as an industrial sector that should be promoted in the future. However, the trade deficit is shown to continue to grow in six other sectors.

By scenario, the S1 scenario (red line) shows the largest expansion in exports, imports, and balance of payments for most industries, but the cereals sector has the smallest deficit expansion in the S1 scenario. In the High GHG Emission Sector, exports increase significantly after 2035 under the S1 scenario, and only under this scenario trade surplus appear.

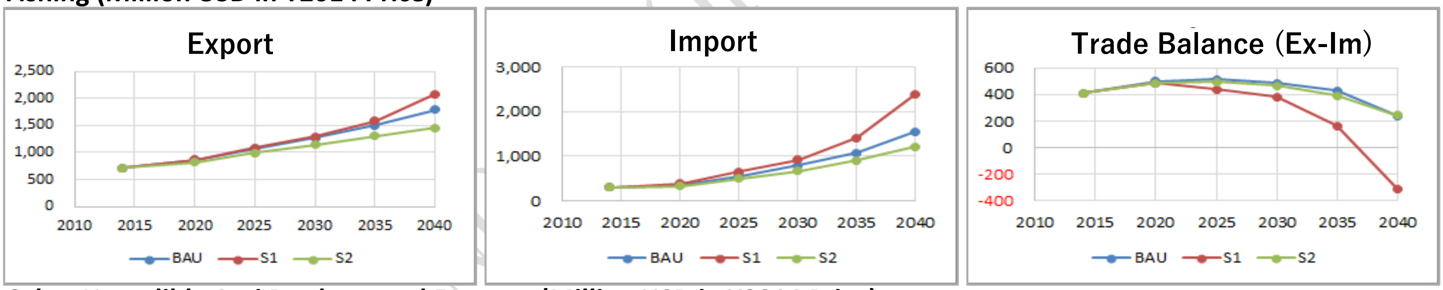
Cereals (Million USD in Y2014 Price)



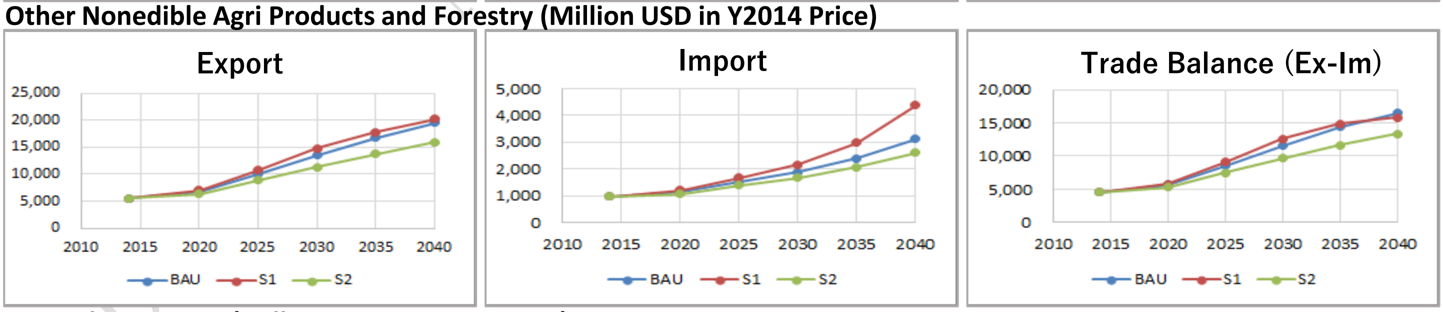
Other Edible Agri Products (Million USD in Y2014 Price)



Fishing (Million USD in Y2014 Price)



Other Nonedible Agri Products and Forestry (Million USD in Y2014 Price)



Natural Resources (Million USD in Y2014 Price)

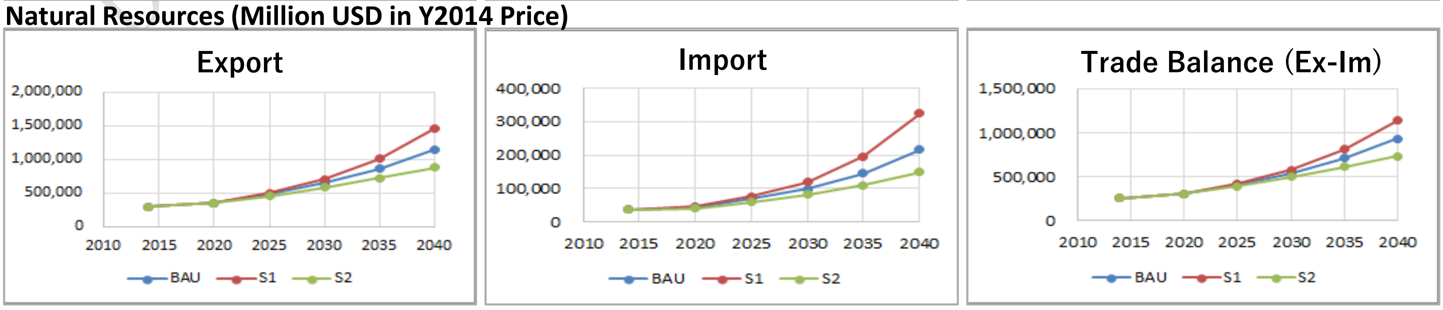
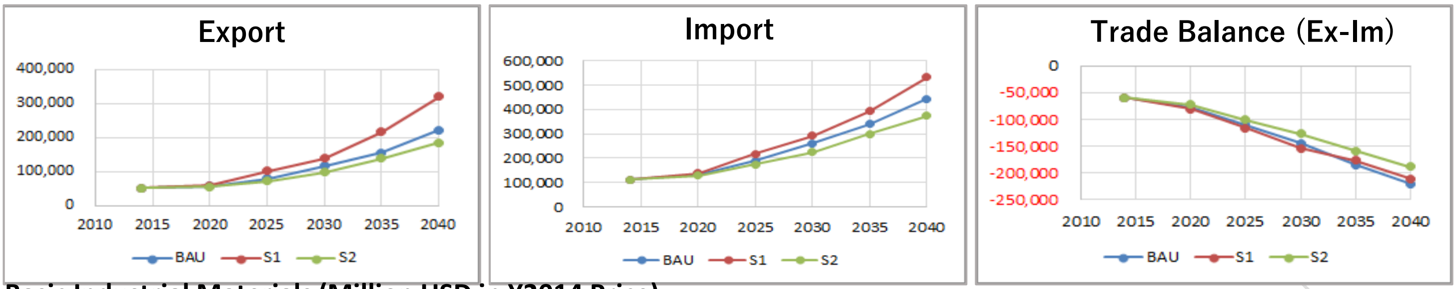
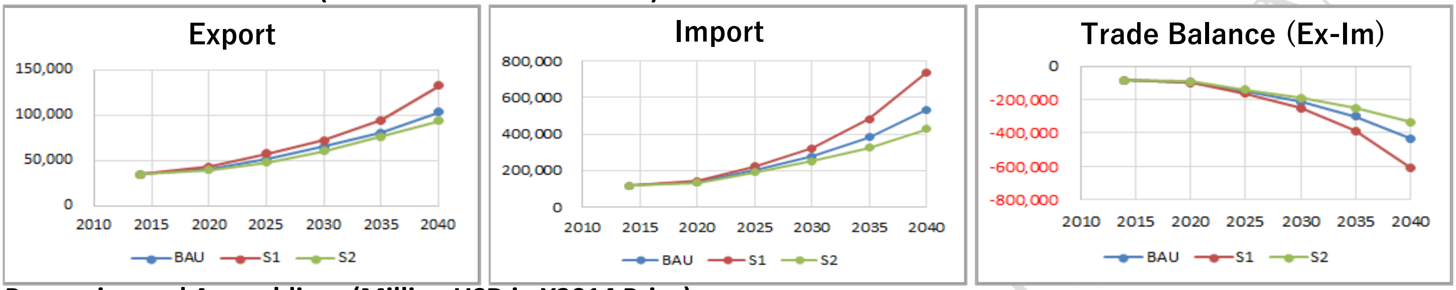


Figure 4-2 General Imports/exports and trade balance by industrial sector (Vertical axis: Million USD in Y2014 Price, Horizontal axis: Year)

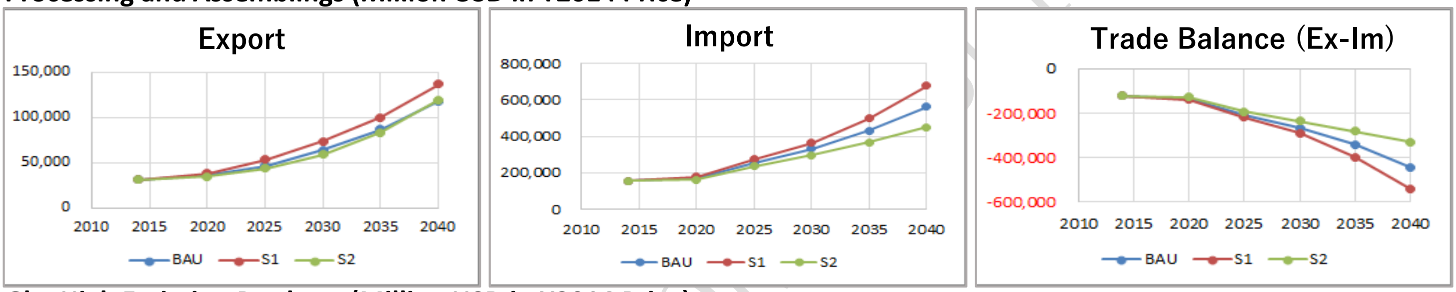
Household Consumer Products (Million USD in Y2014 Price)



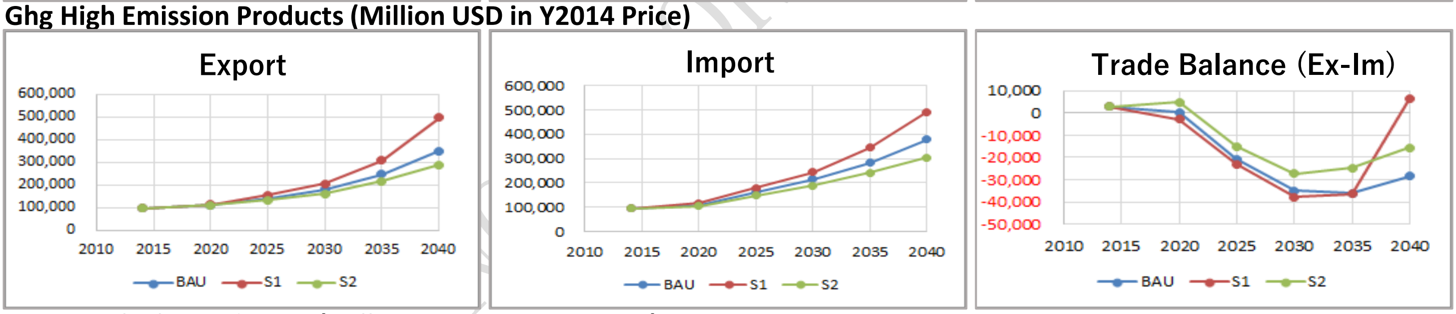
Basic Industrial Materials (Million USD in Y2014 Price)



Processing and Assemblings (Million USD in Y2014 Price)



Ghg High Emission Products (Million USD in Y2014 Price)



Motor Vehicles and Parts (Million USD in Y2014 Price)

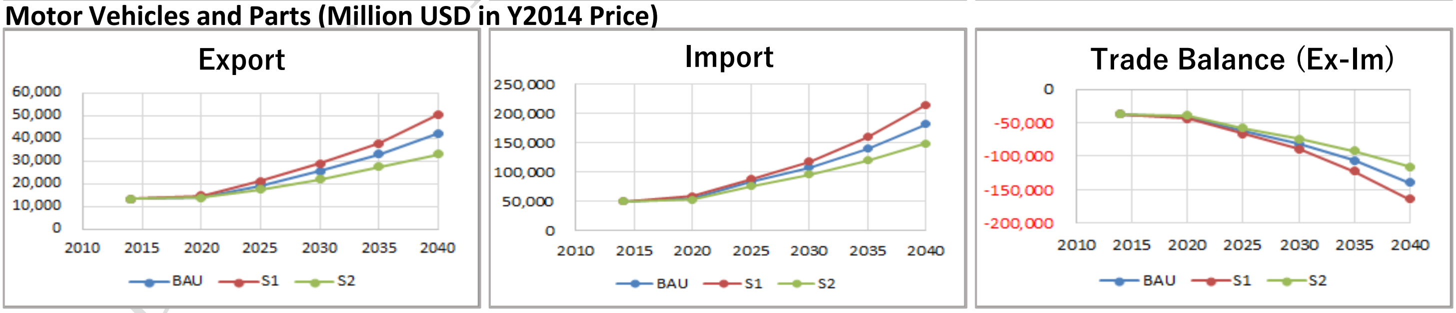


Figure 4-3 General import/exports and trade balance by industrial sector (Vertical axis: Million USD in Y2014 Price, Horizontal axis: Year)

4-2 Import/export and trade balance between Africa and non-Africa

Below are the results of future estimates of import/export volumes (*QXS*) and trade balance (exports-imports), limited to exports and imports between African countries and other non-African countries.

4-2-1 Import/export and trade balance of total non-service sectors between Africa and non-Africa

Figure 4-4 Below are the results of future estimates of exports and imports between African countries and other non-African countries for the 10 non-service sectors as a whole. It should be noted that, unlike regular imports and exports, African countries and regions are not included in the income grouping. In the case of exports and imports between Africa and non-Africa, the growth rates of both imports from Africa and exports to Africa are particularly high for middle-income countries and regions (not including Africa). In addition, although the value itself is not large, Africa's trade surplus in imports and exports between low-income countries/regions (not including Africa) and Africa as a whole indicates that Africa is an important trading partner region.

Figure 4-4 imports/exports and trade balance between Africa and non-Africa (vertical axis: Million USD in Y2014 Price, horizontal axis: Year)

4-2-2 Import/export and trade balance by industrial sector between Africa and non-Africa

If we restrict the analysis to imports and exports between Africa and non-Africa, as shown in Figure 4-5 and Figure 4-6, we find that exports, especially in the cereals sector, increased significantly, indicating that this increase in exports from Africa to non-Africa is the source of the improvement in the trade balance in the S1 scenario. The main factors behind this increase seem to be the expansion of production in African countries and regions, increased demand in non-African countries and regions, especially middle-income countries and regions, and reductions in tariff rates between Africa and non-Africa.

Other notable industry sectors include “other non-food agroforestry sectors”, where non-African imports into Africa increase after 2030, especially with the elimination of tariffs in the S1 scenario, while exports in the S1 scenario, on the contrary, show diminishing growth after 2030. While a gradual diminishing trend is desirable because the outflow of forest resources is a potential risk from the perspective of rural development and climate change, longer-term trend projections and analysis of individual policies, such as the introduction of export controls, are still awaited.

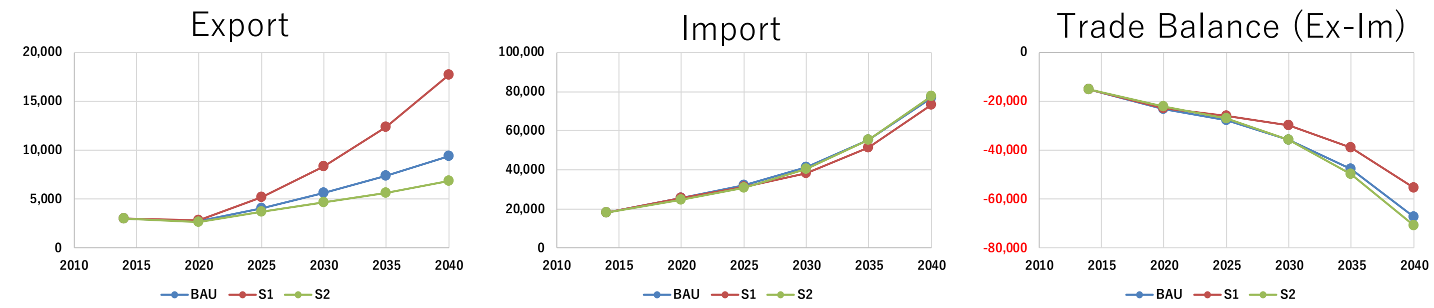
The difference between scenarios in both exports and imports tends to widen after 2030 in several sectors, mainly due to the different speeds at which tariff rates are reduced in each scenario (5 years for S1, 10 years for BAU, and 15 years for S2). In addition, it is suggested that the increase or decrease in imports and exports is affected by the degree to which the tariff elimination schedule is implemented after entry into force.

Other characteristic industrial sectors include the natural resources sector, which, depending on the progress of each country's climate change measures, may not be on such an increasing path, while the current border carbon tax by developed countries (taxing high GHG emitting sectors) has been shown not to reduce the demand for the natural resources sector. In addition, consumer goods are a relatively large sector of manufacturing production within the African region, and exports to non-Africa are increasing on a scale similar to imports. The balance of payments deficit could be further reduced after 2040, especially since the growth rate of exports is increasing gradually from 2030 onward.

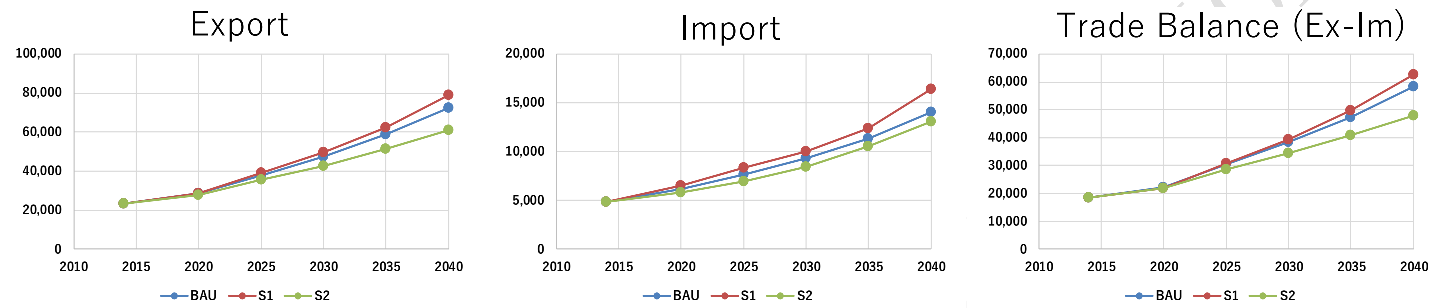
In the High GHG Emission sector, unlike other industrial sector goods, there is no significant difference between exports and imports in 2014, but under the S1 scenario, exports to non-African countries increase significantly after 2030, and the balance of payments turns into a surplus by 2040.

Non-African countries/regions include high-income countries/regions that impose a 5% border carbon tax on the High GHG Emission sector goods, to which exports have been declining, while exports to other non-African countries/regions that do not impose a border carbon tax have been increasing, and overall demand has exceeded demand from non-African countries/regions other than these high-income countries/regions.

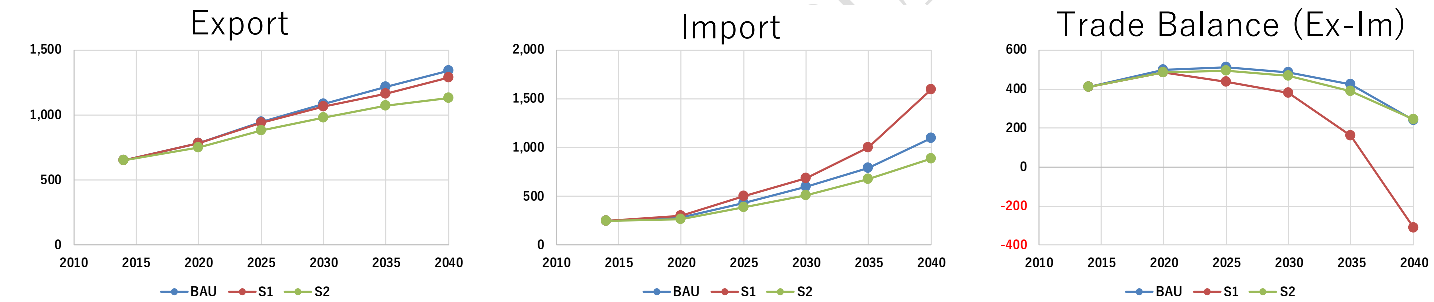
Cereals (Million USD in Y2014 Price)



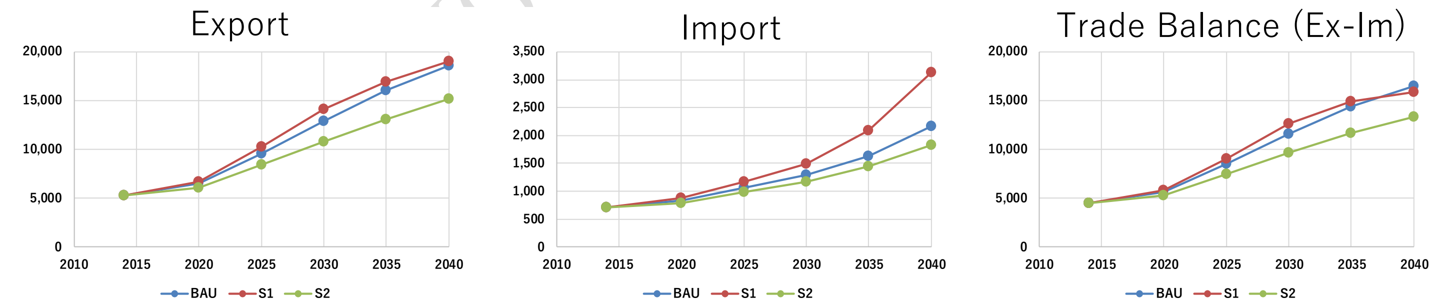
Other Edible Agri Products (Million USD in Y2014 Price)



Fishing (Million USD in Y2014 Price)



Other Nonedible Agri Products and Forestry (Million USD in Y2014 Price)



Natural Resources (Million USD in Y2014 Price)

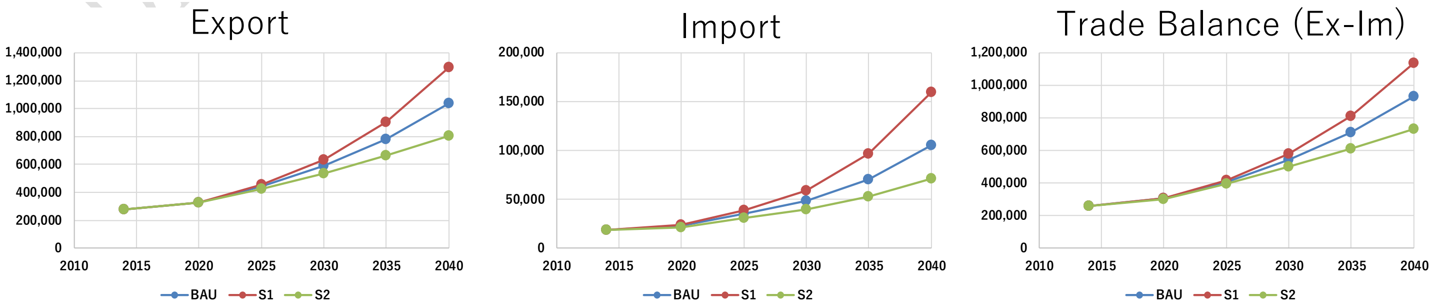
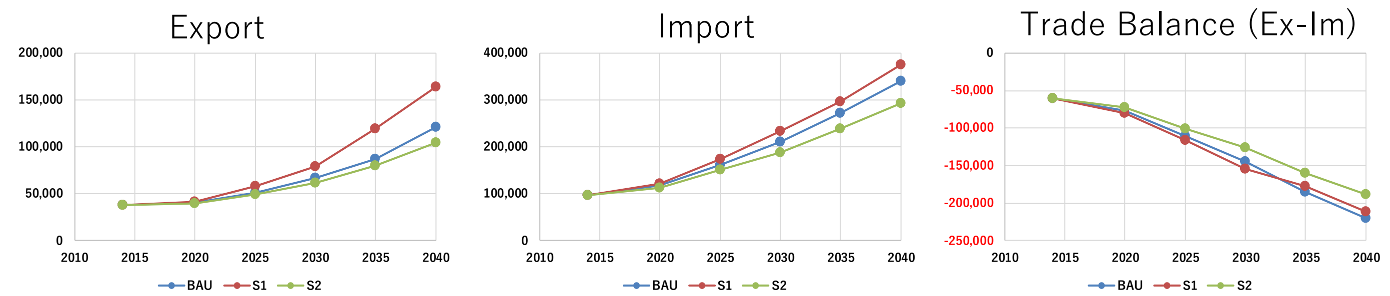
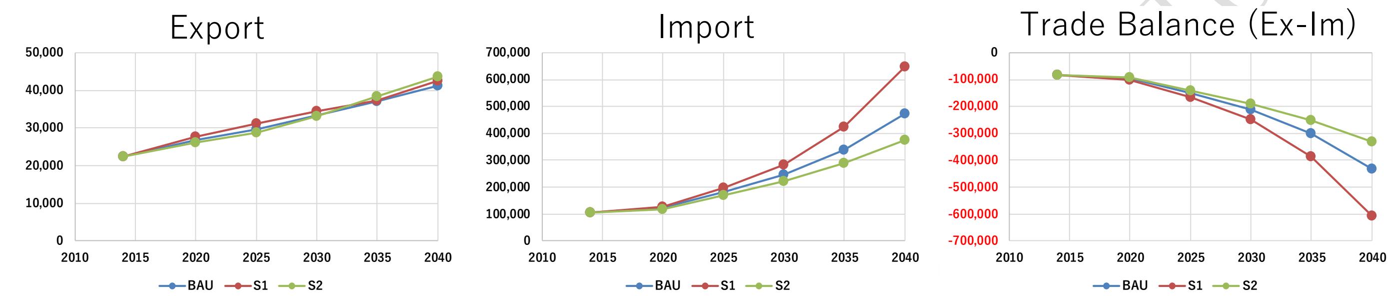


Figure 4-5 Import/export and trade balance between Africa and non-Africa by industrial sector
(Vertical axis: Million USD in Y2014 Price, Horizontal axis: Year)

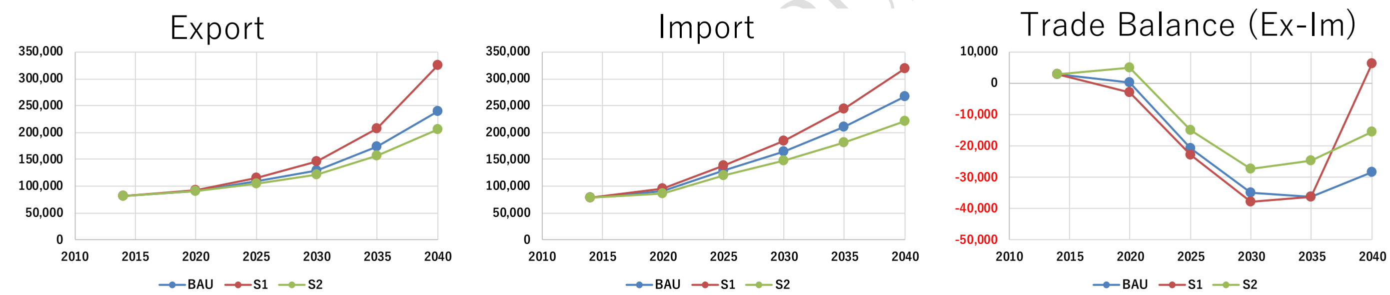
Household Consumer Products (Million USD in Y2014 Price)



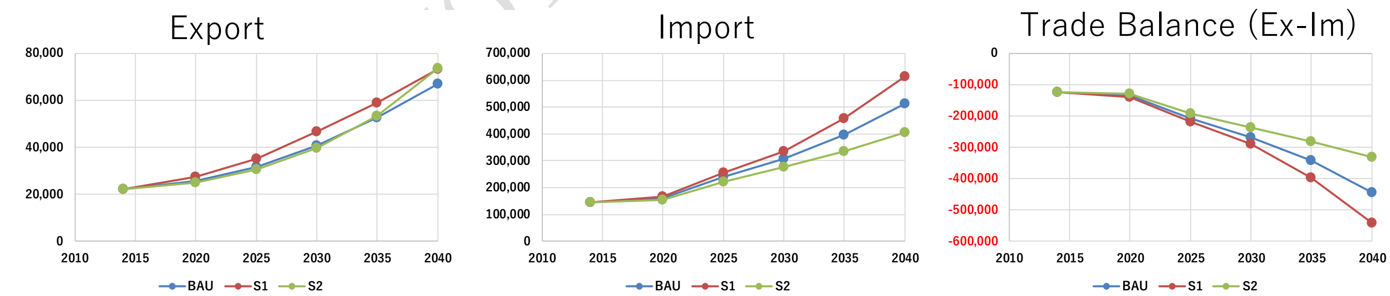
Basic Industrial Materials (Million USD in Y2014 Price)



Processing and Assemblings (Million USD in Y2014 Price)



Ghg High Emission Products (Million USD in Y2014 Price)



Motor Vehicles and Parts (Million USD in Y2014 Price)

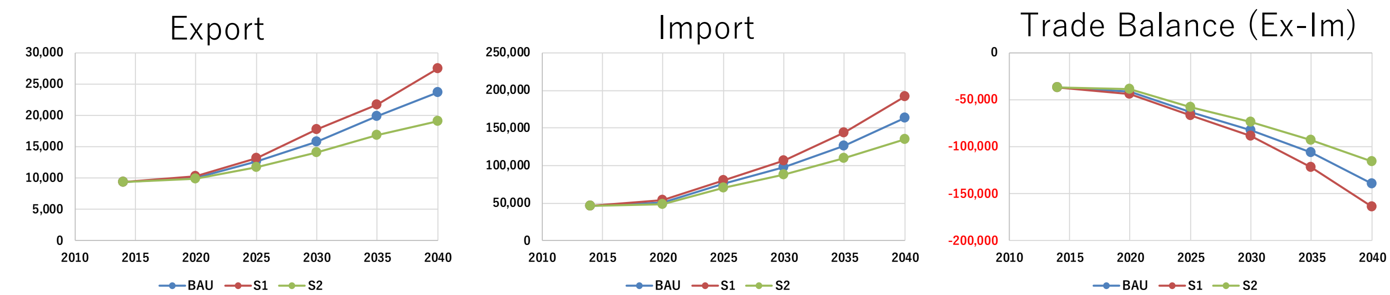


Figure 4-6 Imports/exports and trade balance between Africa and non-Africa by industrial sector (Vertical axis: Million USD in Y2014 Price, Horizontal axis: Year)

4-3 Summary of the GTAP-RD model analysis without *ams* setting

Global imports and exports are expected to grow substantially over the 26 years from 2014 to 2040 by 150%, 115%, and 85% (relative to 2014) under the S1, BAU, and S2 scenarios, respectively, while Africa alone is expected to grow by 365%, 275%, and 215% under the S1, BAU, and S2 scenarios, respectively. The scenario with the most growth, S1, showed a difference of more than 200 percentage points, which indicates the importance of various policies in Africa, such as the promotion of the AfCFTA, the promotion of industry for technological innovation, and the expansion of higher education to increase the supply of skilled labor.

However, although the expansion is greatest in the S1 scenario, which promotes trade liberalization, and smallest in the S2 scenario, there are some situations in which the gap between scenarios is reversed (expansion is greatest in the S2 and BAU scenarios than in the S1 scenario), depending on industrial sectors and regions. This result indicates that the impact of AfCFTA and COVID-19 is not necessarily uniform across regions and industries through international trade.

It is also important to note that Africa has the largest import surplus in the S1 scenario, where the size of trade expands the most. In other words, in the S1 scenario, which assumes a V-shaped recovery in Africa after COVID-19, high economic growth is achieved in Africa, but the current world industrial structure may be inherited, or the export and import industries may be more clearly divided.

These results can be interpreted as suggesting the need for policies to strengthen Africa's export competitiveness so that it can participate in the global supply chain on more favorable terms, and investment in logistics infrastructure is one such policy. Second, the trade surplus of the group of middle-income countries was estimated to increase with the rate of economic growth, but the large trade surplus of middle-income countries is largely due to the expansion of manufacturing exports from China and ASEAN, which belong to the middle-income countries. This result suggests that the promotion of free trade may fix the form and industrial structure of the international division of labor worldwide. This situation raises concerns that Africa's dependence on imports of industrial products will remain high unless policies are taken to promote higher value-added industries

.The implementation of a border carbon tax in this study resulted in a slowdown in exports of high-GHG emission products from middle-income countries, indicating that the border carbon tax has some effect. However, since this study did not assume the imposition of a border carbon tax by low- and middle-income countries, exports of high-GHG emission products from low-income countries increased after 2030 due to strong demand from middle-income countries. This result suggests that if a border carbon tax is not introduced globally, its curbing effect will be weakened.

In the cereal sector, Africa's main industry, imports expand significantly, as in the overall trend, but production and exports also increase significantly, with the trade deficit being the smallest in S1 of the three scenarios. Analyzing these results in terms of food self-sufficiency (domestic production/(domestic production + exports/imports)), COVID-19 causes the food self-sufficiency ratio to decline from 92% in 2014 to 90% in 2020 in all scenarios, but it recovers to 91.5% by 2040 in the S1 scenario. In contrast, the BAU and S2 scenarios fall below 89% by 2040. Since food self-sufficiency is a longstanding development issue in Africa and an important sustainability indicator, the S1 scenario is shown to be a highly sustainable scenario for Africa.

5. Results of the GLINS Model Analysis

Based on the calculation results of the GTAP model obtained in section 4, future cargo demand was projected for the S1 scenario, and the reduction in transportation costs (the sum of intra-African land transportation plus ocean transportation to import/export destinations) was estimated using the GLINS model, the results of which are shown on the map in Figure 5-1 below. The logistics cost reduction rate for the 14-year period 2030 is -24.7% - 22.9% (-2.00% - 1.49% per year), with an average value of -4.5% (-0.47% per year), and for the 10-year period 2030-2040, -25.2% - 33.6% (-0.47% per year). The average value was -4.5% (-0.34% per year) with -2.86 - 2.94% per year. The figure shows that corridor development in 2016-2030 lowers transportation costs mainly for countries along the corridor within Africa, while corridor development in 2030-2040 covers countries and regions where economic corridors were absent until 2030, lowering logistics costs across Africa. At this point, we are only estimating the ideal future (S1 scenario) in which the planned and envisioned economic corridors in Africa are developed as planned and envisioned, but we will also estimate the BAU and S2 scenarios in the future. In this case, the economic corridors to be realized in each scenario will be limited, but this information will be supplemented by interviews with AUDA-NEPAD and other organizations.

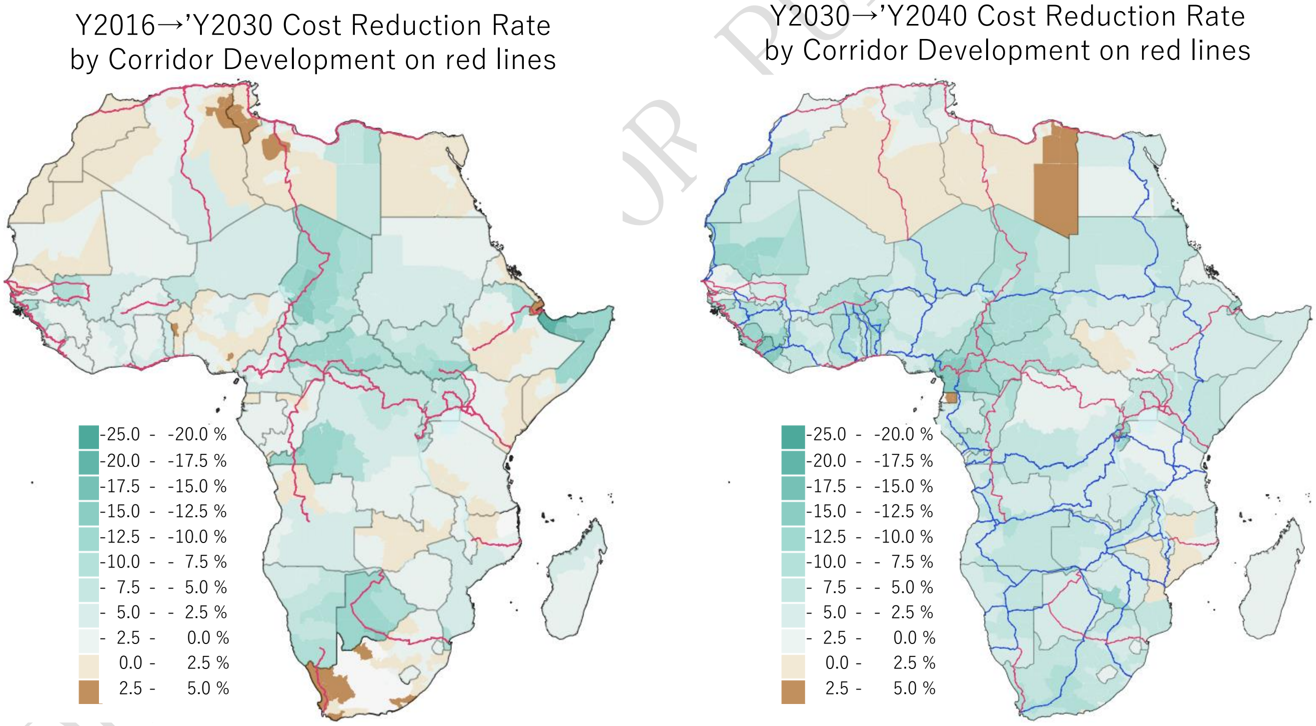


Figure 5-1 GLINS model estimation results

6. Results of the GTAP-RD model analysis with ams setting

The above GLINS model calculation results were set for *ams*, and the other parameters were calculated with the same settings as in the S1 scenario. As shown in Figure 6-1 below, Africa as whole exports (all within and outside Africa) USD12.2 billion more in 2040 (not including price changes) than it would have without the *ams* setting, while imports remain the same as before the *ams* setting, resulting in only an increase in exports and a decrease in Africa's trade deficit along the corridor. Development has shown an improving trend.

This result can be broken down into Africa-non-Africa imports and exports and intra-Africa imports and exports as shown in Figure 6-2 and Figure 6-3. First, Afrika-non-African exports are 91 Billion USD (not including price changes) higher than without *ams* set as of 2040, accounting for about 75% of the normal export growth. Imports, on the other hand, have declined by USD 4.5 Billion, although the setting of *ams* was expected to increase the size of African imports as much as exports, as the cost of procuring imported goods would fall. One possible cause is that there are several regions in the *ams* that are negative, i.e., Africa-non-Africa in particular, where transportation costs are expected to increase as a result of economic corridor development in the GLINS model, and thus may have received imports in particular. In addition, since the decrease in the cost of procuring imported goods is mainly within Africa, it could be said that the economic corridors have had little effect in boosting the size of imports since the economic corridors have only shifted what had previously relied on imports to procurement within Africa (imports and exports). These issues need to be examined more closely in the future.

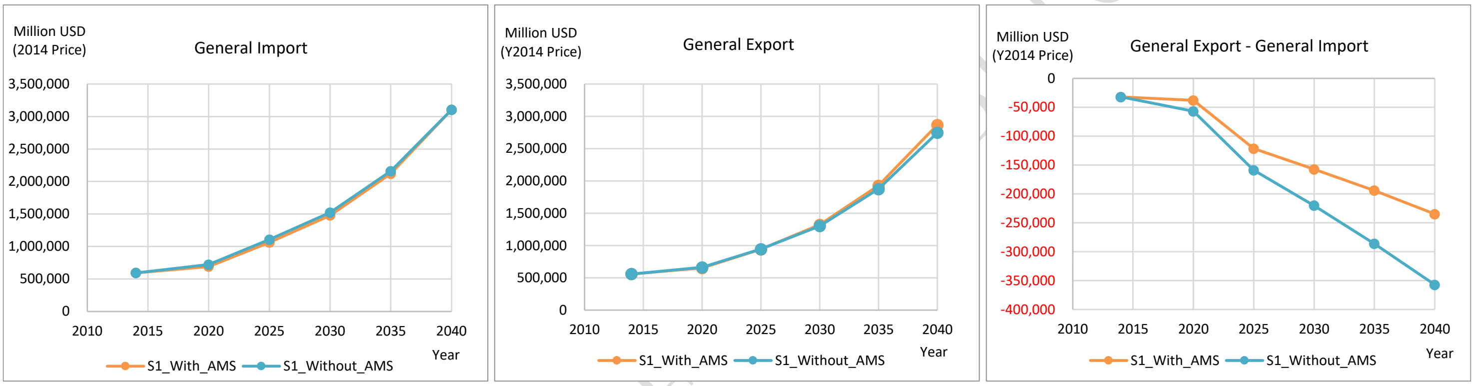


Figure 6-1 Comparison of general import/export volumes and trade balance (S1 Scenario)

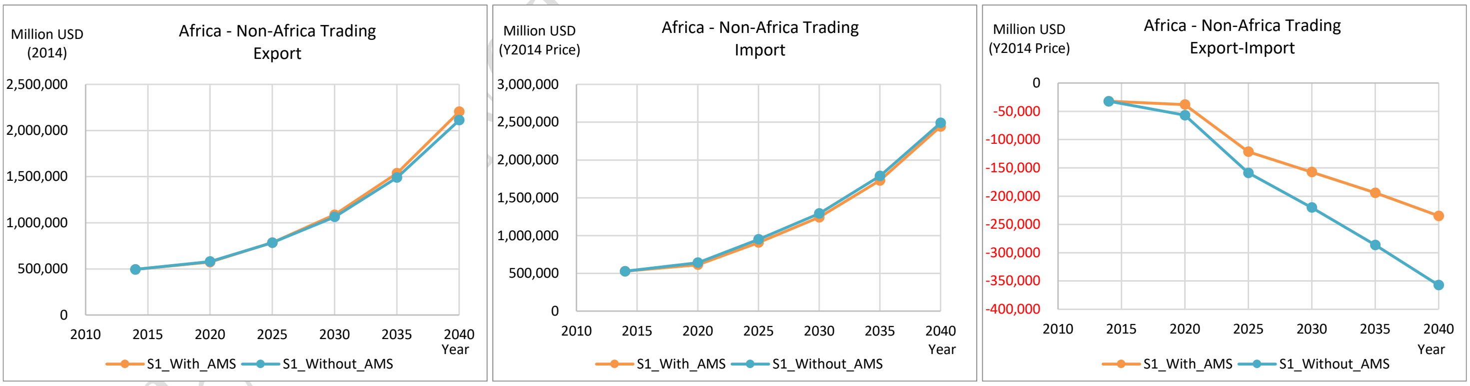


Figure 6-2 Comparison of Africa-Non-Africa import/export volumes (S1 scenario)

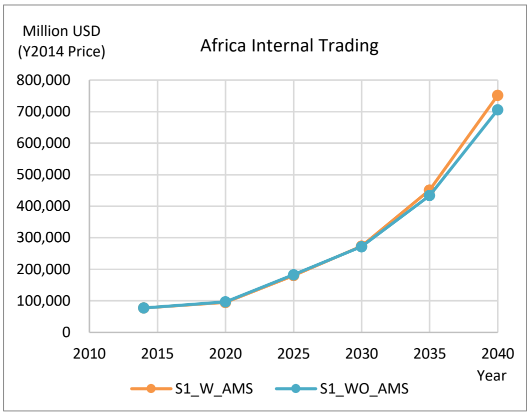


Figure 6-3 Comparison of intra-African imports and exports (S1 scenario)

7. Conclusion

With the aim of clarifying the future intra- and extra-regional trade picture of African countries and regions, this paper sets several future scenarios focusing on the impact of COVID-19, global trends toward carbon neutrality, technological innovation in agriculture, and other industries, AfCFTA and other trends. The GTAP-RD model was used to estimate international trade trends in Africa through 2040. In addition, the logistics cost reduction rate by country/region was estimated by the GLINS model if logistics infrastructure is developed according to the estimated future cargo volume based on the GTAP-RD model estimation results. Then, future estimation was conducted again by the GTAP-RD model using the results of GLINS to set the parameter *ams*.

The results of the following analyses conducted in this study are summarized and presented as conclusions: future estimates using the GTAP-RD model without ams, estimates of logistics cost reduction rates using the GLINS model, and a comparison of future estimates using the GTAP-RD model with and without the setting of ams.

First, the GTAP-RD model estimates of Africa's international trade (without setting the *ams*) showed that Africa's international trade expands the most under the S1 scenario, which assumes a V-shaped recovery from COVID-19 and other factors, and that it expands more significantly than that of the world as a whole. The importance of various policies in Africa, such as the promotion of AfCFTA, industrial promotion for technological innovation, and expansion of higher education to increase the supply of skilled labor.

However, there were situations in which some industrial sectors and countries/regions reversed between scenarios (expanding most in the S2 and BAU scenarios compared to the S1 scenario), indicating that the impact of AfCFTA and COVID-19 is not necessarily uniform across regions and industries through international trade.

It is also important to note that Africa has the largest import surplus in the S1 scenario, where the size of trade expands the most. In other words, in the S1 scenario, which assumes a V-shaped recovery in Africa after COVID-19, high economic growth is achieved in Africa, but the current world industrial structure may persist, or the export and import industries may be more clearly divided. These results can be interpreted as an indication of the need for policies to strengthen Africa's export competitiveness so that it can participate in the global supply chain on more favorable terms, and investment in logistics infrastructure is one such policy.

In the GLINS model estimation, future freight demand was projected for the S1 scenario, and logistics cost savings were estimated for two periods, 2016-2030 and 2030-2040, according to the economic corridor development projections based on PIDA and other information. For the period 2016-2030 (14 years), when the economic corridor covers part of the region, logistics costs were -24.7% - 22.9% (-2.00% - 1.49% per year), averaging -4.5% (-0.47% per year), mainly for countries along the economic corridor. On the other hand, in 2030-2040, when economic corridors are developed throughout Africa, the logistics cost reduction rate is -25.2% - 33.6% (-2.86% - 2.94% per year) with an average of -4.5% (-0.34% per year). While positive values indicate higher logistics costs, they are attributable to congestion caused by cargo volumes that exceed the capacity of economic corridors, and thus the level of maintenance may need to be confirmed for economic corridors where logistics costs are expected to increase.

The GTAP-RD model with the GLINS model estimates set to the *ams* parameter indicates that exports from Africa to the rest of Africa are USD 9.1 billion (not including price changes) higher in 2040 than they would have been without the *ams* parameter, while imports are 45% lower than before the *ams* parameter was set. billion USD (not including price changes), and intra-African imports and exports increased by 3.1 billion USD. This result can first be interpreted as an indication that Africa's trade deficit could be improved by economic corridor development.

However, setting *ams* was expected to increase the size of Africa's intra-regional imports as well as exports by lowering the cost of procuring imported goods, but this was not the case, which requires further scrutiny.

Finally, the findings are expected to be used to improve and prioritize plans for the development of logistics infrastructure such as economic corridors. However, the following issues remain. First, a detailed analysis is needed to interpret the fact that while exports increased as a result of the AMS, imports did not increase compared to the estimation done before AMS was set. In other words, while intuitively one would expect a decrease in the price of imported goods due to the setting of *ams*, leading to an increase in imports, this was not the case. *ams* values are also set between Africa and non-African countries, and while there are some combinations where logistics costs have increased due to the occurrence of some congestion, there are also some combinations where logistics costs are set to decrease even between non-African countries. These results will be analyzed in detail in the future. At this point, we estimated the future using the GLINS model and the GTAP-RD model using the results for the S1 scenario only, but the current global situation includes several risks, not only COVID-19 but also Myanmar's military coup, the Russian invasion of Ukraine, riots in Sri Lanka, etc. Since risks appear to be more apparent and destabilizing, we recognize the need to conduct similar estimations for other BAU scenarios and S2 scenarios in the future.

8. References

EY (2021) “Reset for growth: fast forward”, EY Attractiveness Report Africa, November 2021. Available at: https://www.ey.com/en_za/attractiveness

JICA (2018) Corridor Development Approach – Revitalize the Region Inclusively and Bring Strong Sustainable Economic Growth for the People –, March 2018. Available at: https://www.jica.go.jp/english/publications/brochures/index.html

World Bank (2020) “World Bank Confirms Economic Downturn in Sub-Saharan Africa, Outlines Key

Polices Needed for Recovery”, Press Release, Available at: https://www.worldbank.org/en/news/press-release/2020/10/08/world-bank-confirms-economic-downturn-in-sub-saharan-africa-outlines-key-polices-needed-for-recovery

World Bank (2021a). *Global Economic Prospects, June 2021*. Washington, DC. Available at: https://www.worldbank.org/en/publication/global-economic-prospects

Shibasaki, R., Iijima, T., Kawakami, T., Kadono, T., Shishido, T. (2017). Network assignment model of integrating maritime and hinterland container shipping: application to Central America, Maritime Economics & Logistics, 19(2), 234−273.

International Monetary Fund (2020), *World Economic Outlook, April 2020: The Great Lockdown*, April 2020. Available at: https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

Rakha, A., Hettiarachchi, H., Rady, D., Gaber, M.M., Rakha, E., Abdelsamea, M.M., (2021) “Predicting the Economic Impact of the COVID-19 Pandemic in the United Kingdom Using Time-Series Mining”. Economies, Vol. 9, No.137.

Boissay, F., and Rungcharoenkitkul, P,. (2020) “Macroeconomic Effects of COVID-19: An Early Review”, No. 7, Basel: Bank for International Settlements.

BFPG (2020) “COVID-19 Timeline” The British Foreign Policy Group. Available at: https://bfpg.co.uk/2020/04/COVID-19-timeline/.

Saker, L., Lee, K., Cannito, B., Gilmore, A., and Campbell-Lendrum, D. (2004) “Globalization and Infectious Diseases: A Review of the Linkages”, Geneva, UNDP/World Bank/WHO Special Programme on Tropical Diseases Research. Available at: https://apps.who.int/iris/handle/10665/68726

Shibasaki, R., Abe, M., Sato, W., Otani, N., Nakagawa, A. and Onodera, H. (2022), "Predicting African trade considering uncertainty by scenario planning", Maritime Business Review, Vol. ahead-of-print No. ahead-of-print.

Hertel, T., Walmsley, T. and Itakura, K. (2001) Dynamic Effects of the “New Age” Free Trade Agreement between Japan and Singapore. Journal of Economic Integration, 446-484.

Fox, A., Francois, J., and Londono-Kent, P. (2003), Measuring Border Crossing Costs and their Impact on Trade Flows: The United States-Mexican Trucking Case, GTAP resource No 1282. Available at: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=1282.

Francois, J., Meijl, H.V., Tongeren, F.V. (2005) “Trade liberalization in the Doha Development Round”, *Economic Policy*, Vol. 20, Iss. 42, 1 April 2005, Pages 350-391.

Fugazza, M.and Maur., J. (2008) “NON-TARIFF BARRIERS IN COMPUTABLE GENERAL EQUILIBRIUM MODELLING” Policy Issues in International Trade and Commodities Study Series, No. 38, United Nations Conference on Trade And Development.

Abe, K. and Wilson, J. S. (2008) “Governance, Corruption, and Trade in the Asia Pacific Region”, Policy Research Working Paper 4731, The World Bank Development Research Group Trade Team.

Zhu, E., (2019) "The Effects of the African Continental Free Trade Agreement on Africa's Regional Economic Communities: An Empirical Analysis," *Undergraduate Economic Review,* Vol.16, Iss.1, Article 24. Available at: https://digitalcommons.iwu.edu/uer/vol16/iss1/24

Walmsley, T., Strutt, A. (2021) “A Comparison of Approaches to Modelling Non-Tariff Measures”, Journal of Global Economic Analysis, Vol.6, No.1, pp.1-33.

Walmsley, T., and Minor, P. (2020). “Demand shifts and willingness to pay in applied trade models” World Economy, Vol.43, No.6, pp.1499-1520

Hertel, T. (1997) Global Trade Analysis: Modeling and Applications. Cambridge University Press.

Aguiar, A., Corong. E., and Mensbrugghe, D. (2019) “The GTAP Recursive Dynamic (GTAP-RD) Model: Version 1.0”, *Journal of Global Economic Analysis,* Vol.4, No.1, pp.1–27.

Brian C.O., Kriegler,E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., van Ruijven, B. J., van Vuuren, D. P., Birkmann, J., Kok, K., Levy, M,, Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change,* 42, January 2017, pp.169-180.

United Nations (2019) World Population Prospects 2019. Available at: https://population.un.org/wpp/

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Keywan, R., Rothman, D. S., Levy, M. a. (2015). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century.

World Bank. (2010). World Development Report 2010: Development and Climate Change.

Iizumi, T., Furuya, J., & Shen, Z. (2017). Responses of crop yield growth to global temperature and socioeconomic changes. Sci Rep 7, 7800. https://doi.org/10.1038/s41598-017-08214-4.

OECD. (2018) *International migration database*, OECD International Migration Statistics, OECD Library, OECD. Available at: https://www.oecd-ilibrary.org/social-issues-migration-health/data/oecd-international-migration-statistics/international-migration-database_data-00342-en?parentId=http%3A%2F%2Finstance.metastore.ingenta.com%2Fcontent%2Fcollection%2Fmig-data-en

Liu, J., Leeuwen, N. V., Vo, T. T., Tyers, R., and Hertel, T. W. (1998) "Disaggregating Labor Payments by Skill Level in GTAP", *GTAP Technical Paper*, No. 11. Available at: https://www.gtap.agecon.purdue.edu/resources/download/28.pdf

World Bank (2021b) School enrollment, tertiary (% gross) cited from UNESCO Institute for Statistics. Available at: https://data.worldbank.org/indicator/SE.TER.ENRR

Mastercard Foundation (2019) "SECONDARY EDUCATION IN AFRICA: PREPARING YOUTH FOR THE FUTURE OF WORK", Available at: https://mastercardfdn.org/research/secondary-education-in-africa/

World Bank (2021c) School enrollment, Secondary (% gross) cited from UNESCO Institute for Statistics. Available at: https://data.worldbank.org/indicator/SE.SEC.ENRR

UNCTAD (2018) "Productive capacities index, annual, 2000-2018", UNCTAD STAT, Available at: https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx

Appendix 1 Specific Opportunities and Risks Expected from COVID-19

Global opportunities that could be realized/missed depending on COVID-19	Global risks that could ease/worsen depending on COVID-19
• The acquisition of mass immunity to COVID-19 is expected to prevent the future spread of similar infectious diseases. • COVID-19 will be an opportunity to expand the healthcare and public health systems of each country. • COVID-19 will be an opportunity for countries to recognize the importance of international cooperation through WHO and other organizations, and to renew momentum for international cooperation (free trade agreements, international cooperation in addressing climate change, international resource management, etc.) • Digital technology is expected to spread at an accelerated pace not only in developed countries but also in developing countries due	• Economic stagnation due to intermittent restrictions on social activities caused by COVID-19 • Exacerbation and prolongation of development challenges that existed prior to COVID-19 (debt crisis, poverty, food self-sufficiency, gender, conflict, etc.) • Increased complexity of geopolitical tensions, conflicts, and confrontations, such as trade wars between major powers, BREXIT, coups d'état, etc. • Crisis of international coordination system centered on international organizations such as UN, OECD-DAC, IMF, WHO, etc. due to independent cooperation (funds, vaccines) outside the current international cooperation framework

to COVID-19, leading to leap-frog type development of highly efficient economic activities such as smart agriculture, smart logistics, and super applications. Such development in developing countries will contribute to the elimination of economic disparities between developed and developing countries.	• Depending on the response to COVID-19 and the resulting economic downturn, delays in the implementation of necessary policies due to accelerating instability within national political systems • In addition, it is assumed that the status of convergence of COVID-19 will depend on the accessibility of vaccines and medical services, etc., and that "early convergence will be achieved worldwide," "sufficient convergence will be achieved in middle- and high-income countries, but convergence will be delayed in low-income countries," and "prolonged convergence will be achieved worldwide, especially in low- and middle-income countries. The report also noted that there are three possible patterns based on the income level (degree of development) of the country/region.

Appendix 2 Assumptions for each possible society/future where the common axes are expected to be realized

Common axes	Stable and harmonious international/domestic society	International/domestic society of mixed opportunities and risks	International/domestic communities where risks have become prevalent
1.Technological innovation (SGD No.4, 7)	Technological innovation will progress in all industries in developed and developing countries.	Technological innovation progresses mainly in developed countries. In developing countries, technological innovation will progress in some industries such as service industry and agriculture.	Technological innovation progresses mainly in developed countries. Technological innovation in developing countries stagnates due to social unrest, etc.
2. Access to state-of-the-art technology (SDG No.4, 7, 8, 9, 13, 14, 15,16)	International rules on intellectual property will be thoroughly enforced, facilitating access to the latest technology regardless of whether a country is developed or developing.	The latest technology is accessible mainly in developed countries and coastal developing countries (in landlocked countries access is difficult).	Developing countries are unable to use the latest technology from developed countries due to the lack of international rules for intellectual property, risk of military diversion, inadequate infrastructure, etc.

3. Balanced industrial and free trade policies (SDG 1, 8, 9)	A policy that balances domestic industry development and free trade will be achieved in developed and developing countries.	Policies are weighted heavily toward free trade, and domestic industrial development is limited to a few industries.	Protectionist policies dominate and free trade recedes. In addition, protectionist policies for domestic industry inhibit production efficiency.
4. Access to Financial Assistance (SDG No.1, 2, 8, 11)	Appropriate support will be provided mainly by countries and the IMF, taking fiscal discipline into consideration. Regional development banks and ESG funds will provide support to the private sector in a way that promotes sustainability.	Although support from the countries and the IMF is available, risks remain, such as the occurrence of excessive debt in the recipient country and a slowdown in support due to economic conditions in the donor country.	Financial support is not available due to insolvency, support for terrorism, human rights abuses, and political corruption, especially in developing countries.
5. Eliminating disparities in access to vaccines, medical care, and social welfare (SDG No.1, 3, 6, 10)	In the event of a sudden outbreak of infectious diseases such as COVID-19, medical resources such as vaccines and masks will be available around the world, mainly through the WHO.	Medical resources, such as vaccines and masks, are flexible around the world, but they are also used as a diplomatic tool and are subject to certain restrictions in international politics.	Lack of coordination delays the sharing of information on infectious disease outbreaks, resulting in pandemics. Humanitarian aid provides medical resources, but it takes time due to political corruption and conflict.
6.Education that encourages innovation, long-term perspective and altruism (SDG No.4, 5, 10, 12, 17)	Expanding opportunities and narrowing gaps in higher education will promote the spread of education that encourages innovation, long-term vision, and altruistic activities.	Disparities in higher education still exist between developed and developing countries.	Social instability prevents the expansion of education, which in turn prevents progress in industrial development and poverty reduction, a negative cycle that cannot be broken.
7. Energy (Green Energy, Blue Energy) (SDG No.7, 13)	Not only will the use of renewable energy sources be promoted, but carbon neutrality of existing fossil fuel-derived energy sources will also spread, increasing energy availability worldwide, including in the old resource-rich countries.	The promotion of renewable energy and the use of existing fossil fuel-derived energy are not aligned, and some progress is not being made in the efficient use of energy resources.	While progress is being made in developed countries, inefficiencies in state-owned resource companies remain in developing countries, and the use of old fossil fuel-derived energy, charcoal, etc. also remains.
8. Natural	International joint	The international co-	Developing countries are

Resources Management (SDG No.6, 12, 13, 14, 15)	management of underground resources, forests, fisheries resources, etc. will progress for optimal and sustainable use.	management framework will be maintained but will be led by a few countries and remain unfair.	opposed to international co-management led by developed countries, and international rules are not adhered to.
9. Climate change (SDG No.13)	In international cooperation, a cost-efficient and equitable response that is close to marginal cost will be taken. Appropriate responses to climate change-related disasters will also be taken in international cooperation.	Partial inefficiencies remain in the response due to trends in the U.S., reduction mandates in China and India, and risks to the development of reduction and adaptation technologies.	No framework encompassing developed and developing countries has been established, and each country, especially developed countries, has responded inefficiently on an individual basis. The scale of the project is small, and the low cost of advanced technology is not achieved.
10. Stable supply of labor (SDG No.5, 8, 10, 11)	The social advancement and status of women and ethnic minorities will increase, and labor productivity will improve.	While women are advancing in society and improving their status in developed countries, in some developing countries they are inhibited by religious and other reasons, and an oversupply of labor in rural areas remains.	In addition to women and ethnic minorities, migration between urban and rural areas and low levels of education reduce both the size and quality of the labor supply.
11. Infrastructure Development (SDG No.9, 16)	Infrastructure investment will be promoted with financial support from the international community. However, inefficient infrastructure investment and investment that violates fiscal discipline will be eliminated.	Infrastructure investment will be promoted, but the risk remains that it will be scaled back due to the economic crisis on the investment side, etc.	Due to unstable social conditions and poor governance, infrastructure projects are not financed and new and maintenance projects are inadequate.
12. Startups (SDG No.8, 9)	Support for private companies and improved access to advanced technology will increase start-up company entrepreneurship and activity in many	Differences in accessibility to advanced technology will stimulate entrepreneurship in developed countries, and developed country startups will operate in	Startups emerge in developed countries, but the hurdles to expansion into other countries are high, and business development in developing countries is not progressing.

	countries. Become a source of absorption of excess labor in rural areas.	developing country markets.	

Appendix 3 Common Axes and Parameter Setting

Common Axes	Setup policy and key points in GTAP-RD model
1. Technological innovation	Setting of Innovation parameter *afeall* Set innovation parameter *afeall* in the telecommunications sector (innovation at a higher rate than in other sectors)
2. Access to state-of-the-art technology	
3. Balanced industrial and free trade policies	Tariff *tms* reduction/elimination Innovation parameter *afeall* setting
4. Access to Financial Assistance	Innovation parameter *afeall* setting in the financial sector (innovation at a higher rate than in other sectors)
5.Eliminating disparities in access to vaccines, medical care, and social welfare	Population growth rate *pop* setting (maintaining the population growth curve assumed in SSP1~3 for each scenario) SSP1: Sustainable = S1, SSP2: Middle way = BAU, SSP3: Regional fragmentation and disparity = S2
6.Education that encourages innovation, long-term perspective and altruism	Setting of labor endowment (skilled) *SkLab* (maintaining the labor endowment growth curve assumed for each of SSP1~3 in each scenario) SSP1: Sustainable = S1, SSP2: Middle way = BAU, SSP3: Regional fragmentation and disparity = S2
7. Energy (Green Energy, Blue Energy)	Setting of technological innovation parameters *afeall* in the grain production sector (utilizing the World Bank's unit yield forecasts) Real GDP per capita growth rate *GCP*, population growth rate *pop*, labor endowment *(SkLab, UskLab*) settings (each growth rate curve based on climate change responses assumed for each of SSP1~3 is maintained for each scenario) SSP1: Sustainable = S1, SSP2: Middle way = BAU, SSP3: Regional fragmentation and disparity = S2 Introduction of border carbon tax (5% added as border carbon tax to tariff *tms* in high-income countries)
8. Natural Resources Management	
9. Climate change	
10. Stable supply of labor	Setting of labor endowment (skilled) *UskLab* (maintaining the labor endowment growth curve assumed for each of SSP1~3 in each scenario) SSP1: Sustainable=S1, SSP2: Middle way=BAU, SSP3: Regional fragmentation and disparity=S2
11.Infrastructure Development	Set transportation innovation parameter *ams* (Not set in Phase I. Set GLINS model outputs as innovation parameters *ams* for international transactions and perform Phase II calculations)
12.Startups	Innovation parameters for the telecommunications and financial sector *afeall* Setting (innovation at a higher rate than other sectors)