Research Article

The Economic Effects of Matarbari Port in Bangladesh under Different Without Case Settings

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Abstract: Indicators such as CBR, NPV and/or EIRR, which are based on accrual-based benefits, are generally used to conduct an economic analysis of infrastructure projects. In this paper, the economic effects of the development of Matarbari Port in Bangladesh are estimated by the computable general equilibrium (CGE) analysis or the input-output (IO) analysis according to the nature of input data, after setting two Without cases. As a result, it is clarified that the development of the port will contribute to a wide range of domestic industrial sectors including RMG industry. In order for Bangladesh to achieve healthy economic growth, the development of Matarbari Port which will promote foreign trade and generate significant economic effect (2% increase in GDP at maximum) is necessary. It is clarified that the port development in a country where capacity limits have been reached is indispensable for national economic growth.

Keywords: Port, Economic Effect, CGE, IO, Matarbari Port, Bangladesh.

1. INTRODUCTION

In Bangladesh, the cargo demand of international trade has been strong and the annual GDP growth rate has exceeded 6% in the 2010s. The container cargo handled at Chattogram Port, which handles 98% of the container cargo in Bangladesh, increased from 1.34 million TEU (Twenty-feet Equivalent Unit) in 2010 to 2.89 million TEU in 2019. The recent container cargo levels are exceeding the handling capacity of the container terminals in the port resulting in ships constantly waiting to berth. The maximum draft of vessels entering the port is limited to 9.5m. For this reason, the loading capacity of vessels entering the port is 1,800 TEU on average. In order to meet the future cargo demand and taking into account the global trend toward deploying larger vessels, it is urgently necessary to develop a new port with a sufficient water depth that can accommodate larger vessels. Based on this situation, the Japanese ODA loan project "Matarbari Port Development Project" consisting of terminals with a depth of 16 m from the lowest water level CDL and an access road was planned to meet the increasing cargo demand, accommodate larger vessels and thereby contribute to the promotion of international trade of Bangladesh (Sato, 2021; Sato, 2019; JICA, 2018).

On the other hand, when conducting an economic analysis of infrastructure projects in order to determine the efficiency of economic resource inputs for society, the indicators Cost Benefit Ratio (CBR), Net Present Value (NPV) and/or Economic Internal Rate of Return (EIRR), which are based on accrual-based benefits, are generally used (MLIT Japan, 2018; JICA, 2017; MLIT Japan, 2016). The EIRR was used in the economic analysis of Matarbari Port as well (JICA, 2018).

In this paper, the economic effects to national industries and economy derived from the

development of Matarbari Port are estimated. When conducting an economic analysis of port development, it is common to set a With case and Without case and compare the costs and benefits of each. However, when setting a Without case in the development of a new port, plural Without cases can be assumed, and the analysis results based on them may differ significantly. In this paper, two Without cases are assumed first, namely, 1) containers which will overflow the existing total port capacity will be transshipped from ocean-going container ships to/from barges by the offshore ship-to-ship (STS) operation in the Bay of Bengal, and 2) containers which will overflow the existing total port capacity will not be handled. Next, the annual economic effects of both cases at the time when the handling capacity of Matarbari Port reaches its capacity is estimated by computable general equilibrium (CGE) analysis or input-output (IO) analysis according to the nature of input data. For example, productivity improvement is suitable as input data for CGE analysis, while changes in the final demand is suitable as input data for IO analysis. Lastly, the difference in economic effects due to the difference in Without case settings will be interpreted from the perspective of the development of domestic industries and economy.

2. SETTING CASES FOR MEASURING ECONOMIC EFFECTS

2.1 With case

It is assumed that the container handling capacity of the existing ports in Bangladesh is fixed at the current 3 million TEU/year, and 0.8 million TEU/year will be additionally handled in Matarbari Port. It is also assumed that the size of the container ship entering Matarbari Port will be increased to 4,700 TEU on average by taking advantage of a deep-sea port.

2.2 Without case 1

It is assumed that the container handling capacity of the existing ports (except river ports) in Bangladesh is fixed at the current level of 3 million TEU/year, and 0.8 million TEU/year which was planned to be handled at Matarbari Port will be transshipped from ocean-going container ships to/from barges by the offshore STS operation at the Outer Anchorage in the port limit of Chattogram Port and then transported to/from river ports around Dhaka. In this case, the ocean-going container ship will be smaller than that entering Matarbari Port due to the limitation of the vessel draft. In addition, the offshore STS container operation would be suspended in stormy weather.

The benefit (B) of Matarbari Port at a time when its container throughput reaches its capacity is estimated to be about 300 million USD/year. The benefit consists of savings in transport cost by deploying larger ships and shortening ship turnaround time. The EIRR based on this benefit and the project economic costs is confirmed to be at an acceptable level as an infrastructure project in Bangladesh.

Here, the suspension of the offshore STS operation during stormy weather is discussed. The offshore STS operation of non-container cargo is routinely performed at the Outer Anchorage. However, since it is located in the Bay of Bengal, offshore STS operation is susceptible to meteocean conditions. According to local sources, the annual number of suspension days is about 75, mainly during the rainy season from May to October. When this is compared with the local wave data, it corresponds to the number of days with a wave height of 1.5m to 2.0m or more.

However, when actually handling a container, the slingers of stevedore need to accurately engage or disengage the hooks attached to the four sling ropes suspended by the ship crane to

the top four corner casts of the container as shown in **Fig. 1**. Working on the top of a container on a swaying ship or a barge is difficult and dangerous. Therefore, in reality, the offshore STS container operation at wave heights of 1.5m to 2.0m is likely to be difficult. Assuming that the criteria for suspending the offshore STS container operation are wave heights of 1.0 m or 0.5 m, the annual suspension days becomes 228 days or 352 days respectively.

The offshore STS container operation, or Mid-Stream Operation (MSO), is carried out only at the anchorage in the Port of Hong Kong among the major ports in the world. This anchorage is located in a relatively calm water area shielded by Hong Kong Island and does not face the ocean directly. In Hong Kong, potentially hazardous or unfavorable working conditions including inclement weather that will likely affect the safety of container handling operation are to be eliminated or minimized. In addition, the person in charge of works and the employer must develop guidelines stating when work is to be stopped due to adverse weather such as heavy swell or wave and so on (Marine Department of Hong Kong, 2013).

In calculating the benefit above, it is assumed that the annual suspension days would be 75 days for container cargo handling taking into account the "principle of conservative estimation" in estimating the economic effect (JICA, 2017), even though that the offshore STS operation may not be a feasible transport option without sacrificing safety.

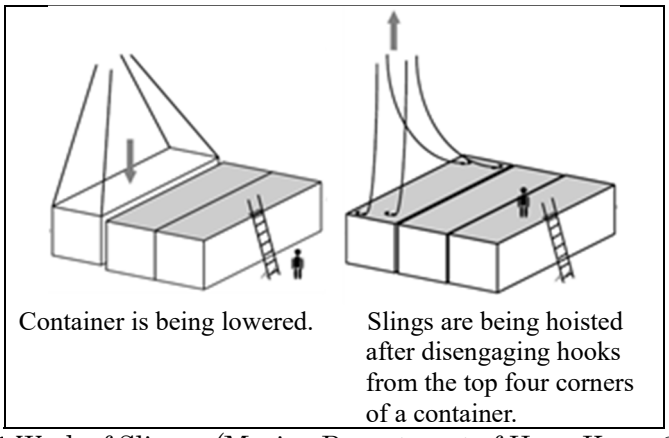


Fig. 1 Work of Slinger (Marine Department of Hong Kong, 2013)

2.3 Without case 2

While the container throughput of Bangladesh is not capped in Without case 1, it is capped in Without case 2. Particularly, it is assumed that containers which were planned to be handled at Matarbari Port, cannot be handled, and the container throughput in Bangladesh will be capped at the current level of about 3 million TEU/year. Imported containers are almost all loaded and are affected by the cap, but export containers are not affected by the cap for the time being because the empty container ratio is about half within export containers. Without case 2 would give the maximum economic effect to the development of Matarbari Port.

2.4 Other Without case

Scenarios in which existing ports are used in the Without case are not envisaged by the authors. The first reason is that there is currently no port in Bangladesh with sufficient container handling capacity without port expansion. The second reason is that the nearest port where large vessels can enter is Visakhapatnam Port on the east coast of India, but the road distance from Dhaka is about 1,200 km and the land transport cost would be very high. In addition, it is not possible for Bangladesh at its own discretion to expand the facilities located in a foreign country

that will be needed in the near future.

3. METHODOLOGY DEPLOYED TO ESTIMATE THE ECONOMIC EFFECTS

3.1 Estimation of the economic effect compared to Without case 1

Estimation of the economic effect of With case compared to Without case 1 is conducted by using the CGE analysis (Hosoe et al., 2010) based on microeconomics (Takekuma, 2016), assuming that the estimated benefits will lead to productivity improvement in the domestic industries. The procedure of calculation is as follows:

3.1.1 Preparing Social Accounting Matrix (SAM)

The Social Accounting Matrix (SAM) is an input data to the CGE analysis, and was prepared based on the 2017 Input-Output Table of Bangladesh (ADB, 2019). The SAM Bangladesh 2017 and its abbreviation list are shown in APPENDIX A and APPENDIX B respectively.

3.1.2 Constructing CGE model

The CGE model was devised as a model that can obtain numerical solutions in order to use the general equilibrium theory of the competitive market economy, which was originated by Léon Walras, for the formulation and evaluation of concrete economic policies such as efficient resource allocation in the market economy.

In the market economy, efficient resource allocation is achieved through a price mechanism. **Fig. 2** shows the circular flow of goods and money. Households demand goods and spend for consumption in the goods market, and supply factor (labor and capital) and receive income and interest in the factor market in order to maximize utility subject to budget constraints. On the other hand, firms demand factor (labor and capital) and spend production costs in the factor market, and supply goods and generate revenue in the goods market in order to maximize profits subject to production technology. The price changes so that the amount of demand and the amount of supply are in equilibrium.

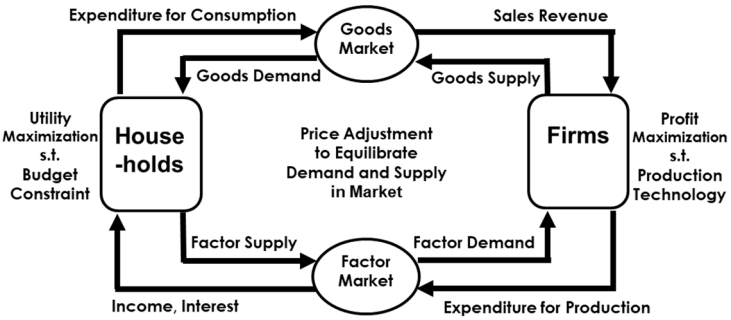


Fig. 2 Circular Flow of Goods and Money

The CGE model constructed in this paper can solve the problem on a computer using numerical calculation software GAMS (GAMS). The GAMS can selectively use solvers for solving the Non Linear Programming Problems (NLP), the Mixed Complementarity Problems (MCP) and so on. In this paper, solver PATH for solving MCP is used in the GAMS. The CGE model and its GAMS program code are shown in APPENDIX C and APPENDIX D respectively.

3.1.3 Confirming appropriateness in the CGE analysis with GAMS

It was confirmed by the following method (Ueda et al., 2010; Takeda) that the computer calculation of the CGE analysis with GAMS was performed appropriately.

1) The number of endogenous variables and the number of equations in the model match.
2) There is no error message, "SOLVER STATUS" shows "Normal Completion" and "MODEL Status" shows "Optimal" in simulating an equilibria with GAMS.
3) Reproduction of the benchmark SAM by simulating an equilibria with GAMS is established.
4) The system is homogeneous of degree zero in price. Therefore, variables related to quantity don't change even if the Numéraire is changed.
5) Walras's law is established.

3.1.4 Simulating general equilibria

Doi et al. (2001) investigated the impact of increased efficiency of ports in Japan using the CGE model. Haddad et al. (2010) introduced the Spatial Computable General Equilibrium (SCGE) model to simulate the impacts of increases in port efficiency in Brazil. Ishikura (2014) constructed the SCGE model with a transnational interregional IO table considering iceberg-type transport cost explicitly. There are several methodologies for expressing changes in transportation in the CGE analysis, such as a method of expressing changes with productivity improvement and a method similar to the iceberg-type transportation cost (Ishikura, 2020).

Methodology adopted in this paper can be classified as a method of expressing changes with productivity improvement. Specifically, the benefits consisting of savings in transport costs, which are deemed to lead to higher productivity in the domestic sectors through lower international shipping freight rates, are first allocated to each sector with the share of the import and export of each good. Then scaling coefficient in the composite factor production function (b_j, see APPENDIX C) is increased by the ratio of the allocated benefits to the value added of each sector.

Sensitivity analysis to verify the robustness of the result against the changes in selected parameters (sigma: elasticity of transformation in the Armington composite good production function, psi: elasticity of transformation of the good transformation function, see APPENDIX C) are also conducted.

3.2 Estimation of the economic benefit compared to Without case 2

The IO table, developed by American economist and Novel laureate Wassily Leontief in 1936, has come to be widely used due to its high accuracy and usefulness for economic forecasting. The IO analysis is a method of forecasting changes in sector-wise output by inputting changes in final demand (MIC Japan, 2020; Doi et al., 2019: Konagaya et al., 2012; Ishimura et al., 2009).

The IO analysis is an analysis method in which changes in final demand are exogenously input based on the current transaction relationships organized in an IO table, and the induced production is calculated. Multiplying the induced production by the value-added ratio yields the value added. However, it is necessary to keep in mind the limitations of the IO analysis; namely, that it is a linear model with fixed input requirement coefficients, that it cannot take into account the constraint of production factors (capital and labour), that it cannot take into account price changes accompanying changes in final demand, and that it takes a certain amount

of time for spillover effects to emerge.

In Japan, the IO table has been prepared by the Japanese government every 5 years since 1950s. The IO analysis has been conducted by central and local governments, financial institutions, research institutes, etc.; for example, more than fifty IO analyses have been conducted using the 2000 IO Table (MIC Japan, 2009). The IO analysis of the case of decreasing final demand has also been conducted (Hosoe, N., 2011).

In Bangladesh, the latest available IO table is the above-mentioned 2017 Input-Output Table of Bangladesh (ADB, 2019). Yunus et al. (2019) are preparing an updated IO table and SAM of Bangladesh as well as CGE modeling. Hossain et al. (2020) conducted CGE analysis on the FDI in the RMG sector using Bangladesh SAM for 2012 constructed by the Bangladesh Planning Commission.

In this paper, according to the assumption of Without case 2 in Chapter 2.3, a Leontief inverse matrix (import endogenous type) was prepared based on the 2017 Input-Output Table of Bangladesh first. Next, the production inducement was calculated by inputting changes in the final demand by sector to which changes in imports by sector are converted.

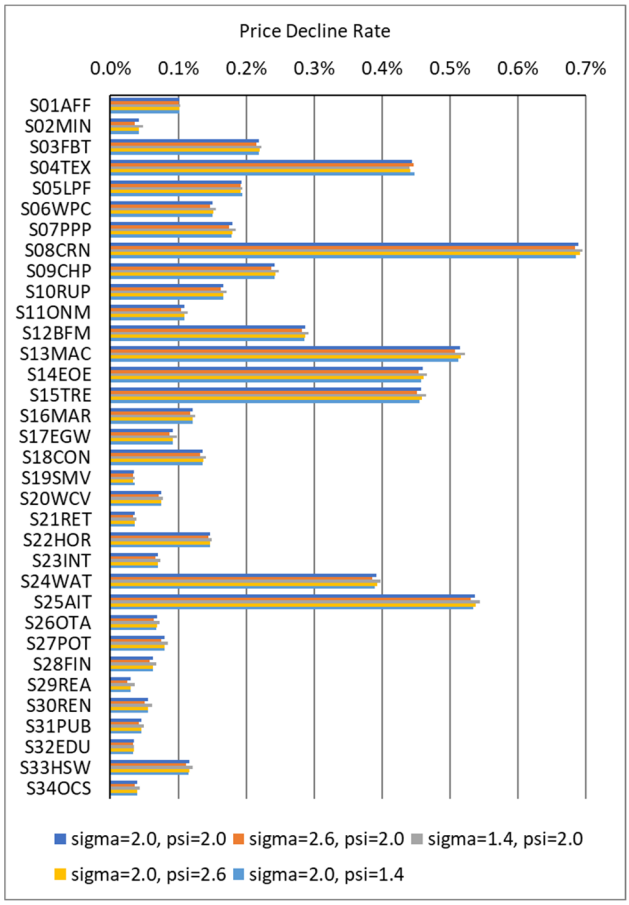
Here, when the container throughput at Matarbari Port reaches its capacity, the container throughput in Bangladesh would reach 3.8 million TEU/year. While, the container throughput in Bangladesh in Without case 2 would remain at 3 million TEU/year which is equivalent to 0.79 (=3/3.8) of With case. Therefore, 0.21 (= 1-0.79) is used as changes in imports by sector. In addition, the share of containerized transportation in imports is roughly estimated to be 70% on a price basis.

Indirect secondary economic effects associated with income changes are sometimes included in the economic effects, but they are omitted here.

4. ESTIMATION RESULTS AND THEIR INTERPRETATIONS

4.1 Economic Effect compared with the Without case 1

Calculated Equivalent Variation (EV) is about 300 million USD/year which is almost the same as the accrual-based benefit mentioned in Chapter 2.2. The ratio of EV to GDP (EV/GDP) becomes 0.13%. Price decline rates of intermediate inputs are shown in **Fig. 3**. Sensitivity analysis shows that the result of calculation is considered to be robust enough since the direction of price change of each good does not change, nor does the ranking of sectors with significant changes. It is confirmed that lowering the price of goods means that real income will increase while price of labor is fixed as the Numéraire, and that this extends to a wide range of sectors. In particular, the price decline rate in the S04TEX sector (textiles and textile products) shows large price decline. Its export accounts for about 80% of total exports of Bangladesh.



Note: Sigma is elasticity of transformation in the Armington composite good production function, and psi is elasticity of transformation of the good transformation function.

Fig. 3 Price Decline Rate with Sensitivity Analysis

4.2 Economic Effect compared with the Without case 2

The production inducement and the GDP change rate are calculated to be 7,853 million USD/year and 2% respectively as shown in **Table 1**, when the changes in imports by sector are conventionally converted to changes in the final demand. Indirect secondary economic effects associated with income changes are not included in this result as explained in Chapter 3.2. Even without capturing indirect secondary effects, a benefit as much as 16 times compared with that mentioned in Chapter 2.2 is calculated, hence the economic efficiency of the project is clear.

Table 1 Production Inducement by Changes in Final Demand

Total Production in 2017 =	390,054 million USD
GDP =	237,881 million USD
GDP / Total Production in 2017 =	61.0%
Total Imports in 2017 =	43,684 million USD
Changes in Final Demand (CFD) = (21% * 70% of Total Import)	6,422 million USD
Production Inducement / CFD =	122%
Production Inducement by CFD =	7,853 million USD
Changes in GDP	4,790 million USD
Changes in GDP (%) =	2.0%

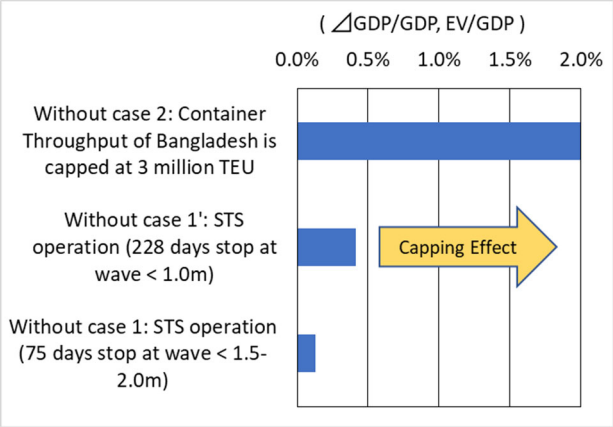
4.3 Interpretation of the Results

The estimated economic effects compared to Without case 2 indicate that the impact on the national economy would be enormous with GDP change rate of 2% if the container handling capacity is capped and the international trade volume is constrained. The future economic growth of Bangladesh would be constrained as well. Without case 2 would give the maximum economic effect to the development of Matarbari Port.

In Without case 1, the offshore STS container operation was assumed. In calculating the benefit, it is assumed that the annual number of suspension days for container operation is the same as that for non-container operation taking into account the "principle of conservative estimation" in estimating the economic effect.

However, when actually handling a container, the slingers on a swaying ship or a barge need to accurately engage or disengage the hooks attached to the four sling ropes suspended by the ship crane to the top four corner casts of the container. Therefore, in reality, the offshore STS container operation at wave heights of 1.5m to 2.0m is likely to be difficult and dangerous.

Assuming that the criteria for suspending the offshore STS container operation are wave heights of 1.0 m or 0.5 m, the annual number of suspension days becomes 228 days or 352 days, respectively. Further, the annual suspension days of 228 days or more would be a fatal shortcoming especially for time conscious commodities. Out-of-season deliveries of such commodities are worthless. Therefore, in the real world of business, the annual suspension days of 228 days or more would approach the situation of Without case 2 in which container throughout of Bangladesh is capped. In this paper, the authors would like to call this "the Capping Effect" as shown in **Fig. 4**.



Note: The indirect secondary effect is not included in the economic effect of Without case 2

Fig. 4 Image of Capping Effect

5. CONCLUSIONS

In this paper, the economic effects of the development of Matarbari Port in Bangladesh are estimated after setting two Without cases which are relatively likely to be realized. In Without case 1, it is assumed that containers which will overflow the existing total port capacity will be transshipped from ocean-going container ships to/from barges by the offshore STS operation at the Outer Anchorage and then transported to/from river ports around Dhaka. In Without case 2, it is assumed that containers which will overflow the existing total port capacity will not be handled, and the container throughput in Bangladesh will be capped at the current level. The CGE analysis for Without case 1 and the IO analysis for Without case 2 were adopted taking into account the nature of input data.

As a result of the CGE analysis for Without case 1, it is clarified that the development of the port will contribute to a wide range of domestic industrial sectors including the country's main exporter RMG industry. As a result of the IO analysis for Without case 2, it is clarified that constraints in international trade volume may lead to constraints in national economic development.

The main reason for the big difference in the estimated economic effects of both cases is that the annual suspension days for container operation is set in consideration of the "principle of conservative estimation" in Without case 1, even though the authors suspect that the offshore STS operation may not be feasible transport option unless sacrificing safety. Assuming that the criteria for suspending the offshore STS operation for container are set more strictly, the annual suspension days would increase significantly and it would be a fatal shortcoming especially for time conscious commodities such as textiles and textile products. Therefore, in the real world of business, Without case 1 would approach the situation of Without case 2 in which container throughout of Bangladesh is capped.

In order for Bangladesh to achieve healthy economic growth, Without case 1 which relies on unsafe operations would be unfavorable. Therefore, the development of Matarbari Port which will promote foreign trade (0.8 million TEU increase) and generate significant economic effect (2% increase in GDP at maximum) is necessary. It is, however, necessary to keep in mind the limitations of the IO analysis; namely, that it is a linear model with fixed input requirement coefficients, that it cannot take into account the constraint of production factors (capital and labour), that it cannot take into account price changes accompanying changes in final demand, and that it takes a certain amount of time for spillover effects to emerge.

Lastly, It is clarified that the port development in a country where capacity limits have been reached is indispensable for national economic growth.

ACKNOWLEDGEMENT

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APPENDIX A SAM Bangladesh 2017 (unit: million USD)

	S01AFF	S02MIN	S03FBT	S04TEX	S05LPF	S06WPC	S07PPP	S08CRN	S09CHP	S10RUP	S11ONM	S12BFM	S13MAC	S14EOE	S15TRE	S16MAR	S17EGW	S18CON	S19SMV	S20WCV	S21RET
S01AFF	4312	0	5191	3158	775	541	99	0	1	76	0	0	0	0	0	446	0	1296	0	0	0
S02MIN	43	57	270	307	47	0	20	0	85	64	399	388	19	7	9	57	587	1232	0	0	0
S03FBT	1060	3	1182	272	22	13	18	0	172	4	8	12	0	0	3	15	3	84	0	0	2
S04TEX	366	1	576	22218	474	24	16	0	7	70	113	22	0	0	75	417	36	435	2	108	117
S05LPF	1	0	3	18	756	68	1	0	0	197	119	0	0	0	86	538	0	109	0	79	0
S06WPC	79	7	12	10	0	50	54	0	12	15	14	39	5	5	25	275	46	312	0	2	3
S07PPP	12	2	261	244	4	1	131	0	34	17	28	24	1	0	1	23	36	23	0	233	0
S08CRN	4	0	1	11	0	0	1	0	1	0	1	2	0	0	1	0	1	1	0	0	0
S09CHP	688	9	68	265	5	10	88	1	164	38	50	38	7	4	30	40	34	390	0	41	0
S10RUP	6	10	27	50	6	1	0	0	19	6	16	21	0	0	1	70	20	1209	0	17	0
S11ONM	16	35	72	164	0	0	2	0	71	17	55	83	1	0	2	231	70	4208	0	58	0
S12BFM	196	18	47	270	11	9	18	1	50	2	2	2037	63	17	238	334	143	2697	1	35	43
S13MAC	4	1	2	14	1	1	2	0	1	1	1	3	1	1	4	1	1	16	0	1	3
S14EOE	4	1	3	9	1	1	2	0	1	1	1	3	1	1	4	1	1	15	0	3	0
S15TRE	62	15	59	105	12	17	25	1	10	13	14	38	11	6	41	16	21	206	0	2	26
S16MAR	1	0	144	5	1	0	0	0	0	0	0	149	0	0	1	740	1	647	4	76	143
S17EGW	193	89	69	846	1	17	63	4	82	72	274	327	9	13	83	85	70	657	0	3	13
S18CON	512	49	72	749	5	15	81	3	30	29	131	178	4	8	53	131	38	5590	8	117	283
S19SMV	35	0	30	151	0	3	0	0	0	0	0	10	0	0	2	12	3	69	0	3	3
S20WCV	1489	35	1686	3228	423	164	133	1	182	118	169	617	25	12	116	571	204	1969	6	3	148
S21RET	152	3	30	281	0	3	0	0	0	0	0	12	1	0	6	85	9	1132	1	15	32
S22HOR	30	0	224	447	0	4	0	0	0	0	201	373	0	0	8	182	62	412	9	210	299
S23INT	531	18	712	1150	153	66	49	0	77	52	89	323	24	26	128	227	182	1095	2	62	66
S24WAT	51	1	55	84	13	16	7	0	8	15	12	43	2	0	30	36	22	102	0	32	0
S25AIT	3	0	13	51	13	11	0	0	0	0	0	1	0	2	0	1	0	12	0	32	0
S26OTA	58	33	108	80	14	52	23	4	45	17	50	54	13	19	58	28	57	47	0	41	0
S27POT	28	2	44	372	26	33	42	9	31	69	37	170	3	21	58	44	27	86	3	63	83
S28FIN	288	20	295	2850	35	109	107	5	119	44	489	594	9	15	99	260	68	2113	13	260	321
S29REA	10	3	166	270	2	8	10	1	13	11	30	51	8	4	87	93	41	3	3	170	44
S30REN	90	36	117	227	13	61	94	2	168	32	52	135	22	24	65	152	297	516	0	296	0
S31PUB	179	10	79	624	5	16	30	3	33	17	40	97	5	7	49	42	31	467	5	46	189
S32EDU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33HSW	23	0	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34OCS	369	45	244	1414	45	21	42	1	96	27	224	614	6	10	93	190	281	1388	457	648	690
CAP	385	4070	2349	9099	1220	722	459	5	1401	462	2638	698	110	158	4012	3220	2863	13104	1300	6323	6237
LAB	32632	181	2238	7636	605	319	268	7	468	234	786	1230	61	62	833	1286	407	5098	1515	7688	7329
IDT	242	30	182	609	9	30	61	4	67	39	86	296	14	21	110	85	74	853	20	101	98
TRF	53	7	40	134	2	7	13	1	15	9	19	65	3	5	24	19	16	187	4	22	22
HOH																					
GOV																					
INV																					
EXT	4423	123	3749	5716	264	312	310	386	1145	209	509	2868	639	500	7944	538	377	4022	18	1158	263
Total	48630	4917	20499	63137	4963	2728	2272	439	4608	1976	6657	11614	1070	951	14379	10492	6131	51803	3373	17949	16457

	S22HOR	S23INT	S24WAT	S25AIT	S26OTA	S27POT	S28FIN	S29REA	S30REN	S31PUB	S32EDU	S33HSW	S34OCS	CAP	LAB	IDT	TRF	HOH	GOV	INV	EXT	Total
S01AFF	1972	0	0	0	0	0	0	49	0	0	0	43	40					30091	0	83	458	48630
S02MIN	122	920	0	0	0	0	0	20	0	0	0	1	0					255	0	0	6	4917
S03FBT	680	63	1	1	0	1	36	2	5	6	7	3	162					16500	0	85	72	20499
S04TEX	166	179	4	11	3	7	14	44	15	39	24	25	357					12302	0	353	24516	63137
S05LPF	34	385	0	23	0	0	1	0	26	2	31	3	39					1471	0	21	950	4963
S06WPC	3	2	0	0	0	1	5	14	2	2	2	3	4					1656	0	63	4	2728
S07PPP	27	49	5	4	18	63	194	0	79	64	91	6	163					420	0	8	6	2272
S08CRN	0	10	1	2	0	0	1	0	0	3	0	1	0					364	0	22	8	439
S09CHP	29	76	10	22	4	22	35	0	8	8	12	600	18					1727	0	16	51	4608
S10RUP	29	17	2	0	0	2	24	0	2	3	34	1	53					296	0	1	29	1976
S11ONM	92	54	9	1	0	8	86	0	5	10	117	17	185					883	0	35	71	6657
S12BFM	9	119	12	12	10	7	3	13	1	18	2	5	39					234	0	4752	142	11614
S13MAC	1	7	2	1	2	1	3	0	1	2	1	2	4					156	0	804	22	1070
S14EOE	1	6	1	1	1	1	2	0	1	1	1	1	2					95	0	756	30	951
S15TRE	22	65	7	4	9	5	20	1	4	15	3	12	11					950	0	12276	276	14379
S16MAR	146	132	17	14	22	42	185	10	28	74	79	79	206					1618	0	5910	17	10492
S17EGW	19	365	17	17	9	32	131	0	13	22	17	15	23					2351	0	118	9	6131
S18CON	145	920	297	120	25	77	132	482	13	63	38	0	171					0	0	41221	12	51803
S19SMV	15	10	0	0	0	1	3	0	0	1	1	0	3					2114	0	111	794	3373
S20WCV	554	303	22	36	17	36	113	24	43	69	84	291	247					1204	0	3185	419	17949
S21RET	187	182	0	0	0	5	37	4	0	3	12	0	11					12604	0	1149	500	16457
S22HOR	2	164	15	16	0	175	326	0	138	72	49	4	278					4681	0	0	56	8436
S23INT	375	182	18	19	18	49	181	36	44	71	107	100	159					17204	0	1572	72	25240
S24WAT	13	22	9	1	0	6	3	4	5	12	13	9	18					3631	1	144	31	4451
S25AIT	1	5	0	19	0	9	28	0	0	26	7	13	28					2006	0	29	24	2338
S26OTA	0	55	16	22	0	0	0	0	0	37	0	0	0					301	0	1	4	1238
S27POT	37	44	12	58	4	43	252	25	6	32	37	25	59					2334	0	39	66	4321
S28FIN	93	535	28	46	14	196	399	70	177	228	48	3	466					2575	0	67	27	13086
S29REA	67	112	0	30	38	18	161	1	64	47	49	36	112					12800	0	0	1	14565
S30REN	54	242	27	26	40	66	230	48	53	44	57	20	213					2009	0	7	18	5554
S31PUB	15	216	17	21	13	11	121	22	37	113	37	4	91					0	10526	1	16	13236
S32EDU	0	0	0	0	0	0	0	0	0	984	0	0	134					4588	2719	0	3	8428
S33HSW	0	0	0	0	0	0	0	0	0	835	0	0	0					4536	1403	0	1	6876
S34OCS	228	421	65	59	28	226	531	201	258	145	105	13	319					19312	83	0	2025	30922
CAP	248	9719	858	1	467	2221	7035	12767	4134	6211	1	3129	18125					0	0	0	0	125751
LAB	2159	7972	798	210	390	659	2085	508	122	3561	7082	1728	8562					0	0	0	0	106718
IDT	109	413	71	98	41	75	170	24	65	92	60	2	187									4438
TRF	24	91	16	22	9	16	37	5	14	20	13	0	41									974
HOH														125751	106718							232469
GOV																4438	974	8700				14112
INV																		60501	(621)		12950	72829
EXT	759	1184	2093	1423	55	239	500	186	193	300	207	684	389									43684
Total	8436	25240	4451	2338	1238	4321	13086	14565	5554	13236	8428	6876	30922	125751	106718	4438	974	232469	14112	72829	43684	

APPENDIX B Abbreviation of SAM Entry

Abreviation	Description
S01AFF	Agriculture, hunting, forestry, and fishing
S02MIN	Mining and quarrying
S03FBT	Food, beverages, and tobacco
S04TEX	Textiles and textile products
S05LPF	Leather, leather products, and footwear
S06WPC	Wood and products of wood and cork
S07PPP	Pulp, paper, paper products, printing, and publishing
S08CRN	Coke, refined petroleum, and nuclear fuel
S09CHP	Chemicals and chemical products
S10RUP	Rubber and plastics
S11ONM	Other nonmetallic minerals
S12BFM	Basic metals and fabricated metal
S13MAC	Machinery, nec
S14EOE	Electrical and optical equipment
S15TRE	Transport equipment
S16MAR	Manufacturing, nec; recycling
S17EGW	Electricity, gas, and water supply
S18CON	Construction
S19SMV	Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel
S20WCV	Wholesale trade and commission trade, except of motor vehicles and motorcycles
S21RET	Retail trade, except of motor vehicles and motorcycles; repair of household goods
S22HOR	Hotels and restaurants
S23INT	Inland transport
S24WAT	Water transport
S25AIT	Air transport
S26OTA	Other supporting and auxiliary transport activities; activities of travel agencies
S27POT	Post and telecommunications
S28FIN	Financial intermediation
S29REA	Real estate activities
S30REN	Renting of M&Eq and other business activities
S31PUB	Public administration and defense; compulsory social security
S32EDU	Education
S33HSW	Health and social work
S34OCS	Other community, social, and personal services
CAP	Capital
LAB	Labour
IDT	Indirect Tax
TRF	Tariff
HOH	Households
GOV	Government
INV	Investment
EXT	Import / Export

Note 1: The "value added at basic prices" in the 2017 Input-Output Table of Bangladesh processed by ADB is disaggregated by the authors into CAP and LAB. Values of LAB row are estimated by using employment and wage data from Labor Force Survey 2016-17 (BBS). Values of CAP row are calculated residually by deducting values of LAB row from the above "value added at basic prices".

Note 2: The "taxes less subsidies on products" in the 2017 Input-Output Table of Bangladesh processed by ADB is disaggregated by the authors into IDT and TRF. IDT and TRF for each sector are conveniently set with the certain share values of the above "taxes less subsidies on products". The share values are extracted from Bangladesh Economic Review 2021 (MOF Bangladesh).

APPENDIX C CGE Model

The CGE model deployed in this paper is based on the "Standard CGE Model (stdcge)" (Hosoe et al., 2010; Hosoe et al., 2004) with the minimum modification (Sato et al., 2012).

C.1 Framework and formulation of the CGE model

C.1.1 Framework of the CGE model

The framework of the CGE model is set under the following assumptions:

1) The economy of Bangladesh is regarded as a single economy.
2) Thirty four (34) goods and two (2) factors (capital and labour) exist in the economy.
3) The economy has agents consisting of a household, thirty four (34) firms (one for each good/sector) and a government.
4) The market is perfectly competitive and all agents are price takers.
5) A household provides firms with all the factors of production they own, receives income in return, and purchases goods to maximize its utility.
6) Firms input intermediate inputs and production factors provided by the household to produce goods in order to maximize their profits.
7) The economy is in a long-term equilibrium state, and the demand and supply of goods and production factors match, and the supplier price and consumer price match.
8) The government collects direct taxes, production taxes, and import duties at a fixed tax rate, and allocates all tax revenues to government consumption except for government savings.
9) Savings and investments are made. The relation between private savings and investment is set as an investment-driven type, namely, investment is fixed at an initial level first and private savings are calculated to ensure that investments and total savings are in balance. Government savings follow an average propensity to savings.
10) It is an open economy where international trade takes place. At that time, the assumption of a small country (the prices of export goods and imported goods denominated in foreign currencies are constant) and the assumption of Armington (imported goods and domestic goods are incomplete substitutions) are made.

The overview of the CGE Model is depicted in **Fig. C1**. The utility function is described by a Cobb-Douglas type, the composite goods production function by a CES (Constant Elasticity of Substitution) type, the domestic production transformation function by a CET (Constant Elasticity of Transformation) type, the domestic production function by a Leontief type, and the composite production element production function by a Cobb-Douglas type.

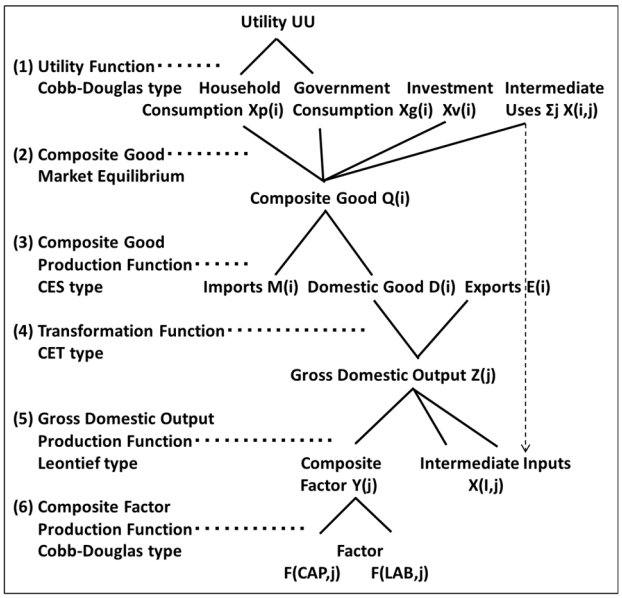

Fig. C1 Overview of the CGE Model

C.1.2 Formulation of the CGE model

The whole model is a system of simultaneous equations consisting of 24 sets / 1,808 equations (= 2 * 34 + 34 * 34 + 17 * 34 + 4 + 2) and the same number of endogenous variables. However, since this system is homogeneous of degree zero in price and Walras's law always holds, one of the equations is redundant. Therefore, if one of the goods or production factors is selected as the Numéraire (a standard good/factor) and the price is fixed, the others are expressed as relative prices. In this paper, one unit of labor of 1 million USD is set as the Numéraire.

a) Domestic Production:

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \quad \forall j \qquad (1)$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \quad \forall h, j \qquad (2)$$

$$X_{i,j} = ax_{i,j} Z_j \quad \forall i, j \qquad (3)$$

$$Y_j = ay_j Z_j \quad \forall j \qquad (4)$$

$$p_j^z = ay_j p_j^y + \sum_i ax_{i,j} p_i^q \quad \forall j \qquad (5)$$

b) Government:

$$T^d = \tau^d \sum_h p_h^f FF_h \qquad (6)$$

$$T_j^z = \tau_j^z p_j^z Z_j \quad \forall j \qquad (7)$$

$$T_i^m = \tau_i^m p_i^m M_i \quad \forall i \qquad (8)$$

$$X_i^g = \frac{\mu_i}{p_i^q}\left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g\right) \quad \forall i \qquad (9)$$

c) Investment and savings:

(Investment-driven type macro closure between X^v and S^p)

$$X_i^v = X_i^{v0} \quad \forall i \qquad (10)$$

$$S^p = \sum_i p_i^q X_i^v - S^g - \varepsilon S^f \qquad (11)$$

$$S^g = ss^g \left(T^d + \sum_j T_j^z + \sum_j T_j^m \right) \qquad (12)$$

d) Household:

$$X_i^p = \frac{\alpha_i}{p_i^q} \left(\sum_h p_h^f FF_h - S^p - T^d \right) \quad \forall i \qquad (13)$$

e) Export and import prices, and the balance of payment constraint:

$$p_i^e = \varepsilon p_i^{We} \quad \forall i \qquad (14)$$

$$p_i^m = \varepsilon p_i^{Wm} \quad \forall i \qquad (15)$$

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i \qquad (16)$$

f) Substitution between imports and domestic goods (Armington composite)

$$Q_i = \gamma_i (\delta m_i {M_i}^{\eta_i} + \delta d_i {D_i}^{\eta_i})^{\frac{1}{\eta_i}} \quad \forall i \qquad (17)$$

$$M_i = \left(\frac{{\gamma_i}^{\eta_i} \delta m_i p_i^q}{(1+\tau_i^m) p_i^m} \right)^{\frac{1}{1-\eta_i}} Q_i \quad \forall i \qquad (18)$$

$$D_i = \left(\frac{{\gamma_i}^{\eta_i} \delta d_i p_i^q}{p_i^d} \right)^{\frac{1}{1-\eta_i}} Q_i \quad \forall i \qquad (19)$$

g) Transformation between exports and domestic goods

$$Z_i = \theta_i \left(\xi e_i {E_i}^{\phi_i} + \xi d_i {D_i}^{\phi_i} \right)^{\frac{1}{\phi_i}} \quad \forall i \qquad (20)$$

$$E_i = \left(\frac{{\theta_i}^{\phi_i} \xi e_i (1+\tau_i^z) p_i^z}{p_i^e} \right)^{\frac{1}{1-\phi_i}} Z_i \quad \forall i \qquad (21)$$

$$D_i = \left(\frac{{\theta_i}^{\phi_i} \xi d_i (1+\tau_i^z) p_i^z}{p_i^d} \right)^{\frac{1}{1-\phi_i}} Z_i \quad \forall i \qquad (22)$$

h) Market clearing condition:

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j} \quad \forall i \qquad (23)$$

$$\sum_j F_{h,j} = FF_h \quad \forall h \qquad (24)$$

i) Endogenous variables: 24 sets/1,808 single equations

Y_j : composite factor, produced in the first stage and used in the second stage by the j-th firm,

$F_{h,j}$: the h-th factor used by the j-th firm in the first stage,
$X_{i,j}$: intermediate input of the i-th good used by the j-th firm,
Z_j : gross domestic output of the j-th firm,
X_i^p : household consumption of the i-th good,
X_i^g : government consumption of the i-th good,
X_i^v : demand for the i-th investment good,
E_i : exports of the i-th good,
M_i : imports of the i-th good,
Q_i : the i-th Armington composite good,
D_i : the i-th domestic good,
p_h^f : price of the h-th factor,
p_j^y : price of the j-th composite factor,
p_j^z : price of the j-th gross domestic output,
p_i^q : price of the i-th composite good,
p_i^e : export price of the i-th good in terms of domestic currency,
p_i^m : import price of the i-th good in terms of domestic currency,
p_i^d : price of the i-th domestic good,
ε : foreign exchange rate (domestic currency / foreign currency),
S^p : household savings,
S^g : government savings,
T^d : direct tax,
T_j^z : production tax on the j-th good,
T_i^m : import tariff on the i-th good.

j) Exogenous variables:

FF_h : endowments of the h-th factor for the household,
S^f : current accounts deficit in terms of foreign currency (or equivalently foreign savings),
p_i^{We} : export price of the i-th good in terms of foreign currency,
p_i^{Wm} : import price of the i-th good in terms of foreign currency,
τ^d : direct tax rate,
τ_j^z : production tax rate on the j-th good,
τ_i^m : import tariff rate on the i-th good.

k) Parameters:

α_i : share parameter in the utility function $(0 \le \alpha_i \le 1, \sum_i \alpha_i = 1)$,
μ_i : share of the i-th good in government expenditure $(0 \le \mu_i \le 1, \sum_i \mu_i = 1)$,
$ax_{i,j}$: input requirement coefficient of the i-th intermediate input for a unit output of the j-th good,
ay_j : input requirement coefficient of the j-th composite good for a unit output of the j-th good,
$\beta_{h,j}$: share coefficient in the composite factor production function $(0 \le \beta_{h,j} \le 1, \sum_h \beta_{h,j} = 1)$,
b_j : scaling coefficient in the composite factor production function,
λ_i : expenditure share of the i-th good in total investment $(0 \le \lambda_i \le 1, \sum_i \lambda_i = 1)$,
ss^p : average propensity for savings by the household,
ss^g : average propensity for savings by the government,
γ_i : scaling coefficient in the Armington composite good production function,
$\delta m_i, \delta d_i$: input share coefficients in the Armington composite good production function :

$$0 \le \delta m_i \le 1,\ 0 \le \delta d_i \le 1,\ \delta m_i + \delta d_i = 1,$$

η_i : parameter defined by the elasticity of substitution :

$$\eta_i = \frac{(\sigma_i - 1)}{\sigma_i}, \quad \eta_i \le 1 ,$$

σ_i : elasticity of substitution in the Armington composite good production function :

$$\sigma_i \equiv -\frac{\frac{d(M_i/D_i)}{M_i/D_i}}{\frac{d\left(p_i^m/p_i^d\right)}{p_i^m/p_i^d}} \quad (=\ 2\ \textit{is assumed in this paper}),$$

θ_i : scaling coefficient of the i-th transformation function,

$\xi e_i, \xi d_i$: share coefficients for the i-th good transformation function :

$$\xi e_i + \xi d_i = 1, \quad \xi e_i, \xi d_i \ge 0 ,$$

ϕ_i : parameter defined by the elasticity of transformation :

$$\phi_i = \frac{\left(\psi_i + 1\right)}{\psi_i}, \quad 1 \le \psi_i ,$$

ψ_i : elasticity of transformation of the i-th good transformation function :

$$\psi_i \equiv \frac{\frac{d(E_i/D_i)}{E_i/D_i}}{\frac{d\left(p_i^e/p_i^d\right)}{p_i^e/p_i^d}} \quad (=\ 2\ \textit{is assumed in this paper}).$$

C.2 Estimating unknown parameters by calibration

A method called calibration is used to estimate the parameters of the CGE model. This method is carried out by reproducing the SAM which is the benchmark equilibrium data set of the model. Normally, solving the simultaneous equation system of the CGE model means inputting known exogenous variables and parameters to obtain the unknown endogenous variables. In calibration, however, the endogenous variables at the time of benchmark equilibrium are known. Therefore, necessary tasks are to input these known endogenous variables and exogenous variables, and obtain the unknown parameters. This method has the disadvantage of abandoning statistical verification of the validity of the parameters. On the other hand, this method has the advantage of estimating the parameters with only one benchmark equilibrium solution shown in the SAM.

In order to specify the values of endogenous variables (quantity and price) at the time of benchmark equilibrium, it is necessary to divide the value of the SAM of monetary amount display into quantity and price. Therefore, in this paper, the quantity (price without tax) that can be bought for one million USD at the time of benchmark equilibrium is set as one quantity unit for all goods and factors. As a result, the value in the SAM, which is the amount display, can be treated as the value in the quantity display. Also, to be consistent with this, export price in terms of foreign currency (p_i^{We}) and import price in terms of foreign currency (p_i^{Wm}) are also set to one.

The coefficient estimation formulas are as follows:

$$\alpha_i = \frac{p_i^{q0} X_i^{p0}}{\sum_j p_j^{q0} X_j^{p0}} \quad \forall i \qquad (25)$$

$$\beta_{h,j} = \frac{p_h^{f0} F^0{}_{h,j}}{p_j^{y0} Y_j^0} = \frac{p_h^{f0} F^0{}_{h,j}}{\sum_k p_k^{f0} F^0{}_{k,j}} \quad \forall h, j \qquad (26)$$

$$b_j = \frac{Y_j^0}{\prod_h F^0{}_{h,j}{}^{\beta_{h,j}}} \quad \forall j \qquad (27)$$

$$ax_{i,j} = \frac{X_{i,j}^0}{Z_j^0} \quad \forall i, j \qquad (28)$$

$$ay_j = \frac{Y_j^0}{Z_j^0} \quad \forall j \qquad (29)$$

$$\mu_i = \frac{p_i^{q0} X_i^{g0}}{\sum_j p_j^{q0} X_j^{g0}} \quad \forall i \qquad (30)$$

$$\lambda_i = \frac{p_i^{q0} X_i^{v0}}{(S^{p0} + S^{g0} + \varepsilon^0 S^{f0})} \quad \forall i \qquad (31)$$

$$\delta m_i = \frac{(1+\tau_i^m) p_i^{m0} M_i^{0(1-\eta_i)}}{(1+\tau_i^m) p_i^{m0} M_i^{0(1-\eta_i)} + p_i^{d0} D_i^{0(1-\eta_i)}} \quad \forall i \qquad (32)$$

$$\delta d_i = \frac{p_i^{d0} D_i^{0(1-\eta_i)}}{(1+\tau_i^m) p_i^{m0} M_i^{0(1-\eta_i)} + p_i^{d0} D_i^{0(1-\eta_i)}} \quad \forall i \qquad (33)$$

$$\gamma_i = \frac{Q_i^0}{\left(\delta m_i {M_i}^{0\eta_i} + \delta d_i {D_i}^{0\eta_i}\right)^{\frac{1}{\eta_i}}} \quad \forall i \qquad (34)$$

$$\xi e_i = \frac{p_i^{e0} E_i^{0(1-\phi_i)}}{p_i^{e0} E_i^{0(1-\phi_i)} + p_i^{d0} D_i^{0(1-\phi_i)}} \quad \forall i \qquad (35)$$

$$\xi d_i = \frac{p_i^{d0} D_i^{0(1-\phi_i)}}{p_i^{e0} E_i^{0(1-\phi_i)} + p_i^{d0} D_i^{0(1-\phi_i)}} \quad \forall i \qquad (36)$$

$$\theta_i = \frac{Z_i^0}{\left(\xi e_i {E_i}^{0\phi_i} + \xi d_i {D_i}^{0\phi_i}\right)^{\frac{1}{\phi_i}}} \quad \forall i \qquad (37)$$

$$ss^p = \frac{S^{p0}}{\sum_h p_h^{f0} FF_h} \qquad (38)$$

$$ss^g = \frac{S^{g0}}{T^{d0} + \sum_j T_j^{z0} + \sum_j T_j^{m0}} \qquad (39)$$

$$\tau^d = \frac{T^{d0}}{\sum_h p_h^{f0} FF_h} \qquad (40)$$

In simulating general equilibria for Without case 1, the parameter b_j is exogenously given by the authors. Specifically, the benefits consisting of savings in transport costs, which are deemed to lead to higher productivity in the domestic sectors through lower international shipping freight rates, are first allocated to each sector with the share of the import and export of each good. Then the parameter b_j is increased by the ratio of the allocated benefits to the value added of each sector.

C.3 Measurement of economic welfare

The changes in economic welfare of the society by a fictitious scenario is measured with Hicksian Equivalent Variation (EV).

$$EV \equiv ep(\mathbf{p^{q0}}, UU^1) - ep(\mathbf{p^{q0}}, UU^0) \qquad (41)$$

$$ep(\mathbf{p^q}, UU) \equiv \min_{\mathbf{X^p}} \left\{ \mathbf{p^q \cdot X^p} \middle| UU(\mathbf{X^p}) = UU \right\} \qquad (42)$$

where:

$ep(\cdot)$: expenditure function,

$\mathbf{X^p}$: consumption vector,

$\mathbf{p^q}$: price vector,

UU : utility level (given),
UU(・) : utility function.

Although the utility level of households is basically used as an evaluation scale for economic welfare, since the utility has only an ordinal nature, this paper introduces an expenditure function to convert the utility level into a monetary terms. The expenditure function indicates the minimum expenditure level to satisfy the given utility level. This allows the change in economic welfare between the fictitious equilibrium and the benchmark equilibrium to be defined as the change in the monetary-converted utility level. Since the equilibrium price is different between the fictitious equilibrium and the benchmark equilibrium, and the expenditure amount cannot be simply compared, the price at the benchmark equilibrium is used for evaluation, and the influence of the price change on the utility level is removed. The change in utility level can be decomposed into the substitution effect and the income effect, and the equivalent variation measures the income effect. In this paper, since the utility function is specified in the Cobb-Douglas type in Section B.1, the expenditure function can be obtained as the optimal solution to the expenditure minimization problem for a given utility level UU.

$$\mathrm{ep} = \frac{\mathrm{UU}}{\prod_i \left(\frac{\alpha_i}{p_i^q}\right)^{\alpha_i}} \qquad (43)$$

APPENDIX D GAMS Program Code (core part)

The following GAMS program code is based on the "Standard CGE model (stdcge)" (Hosoe et al., 2004) with the minimum modifications for the purpose of this paper. The outline of the program flow is as follows:

1) Define sets for suffix for industrial sectors, etc.;
2) Read the SAM from EXCEL;
3) Read initial values of variables, etc. from the SAM;
4) Estimate the parameters by calibration;
5) Define the model system consisting of endogenous variables and equations;
6) Set the Numeraire;
7) Solve the model using MCP and check the benchmark equilibrium;
8) Conduct simulation run with hypothetical scenarios;
9) Measure economic welfare (EV);
10) Output the calculation results to EXCEL (omitted);

Note: Rows with * in the first column are memo rows.

```
$ Title Matarbari CGE Model (matarcge, seq=002)
* Definition of sets for suffix ---------------------------------------
Set         u         SAM entry         /
S01AFF, S02MIN, S03FBT, S04TEX, S05LPF, S06WPC, S07PPP, S08CRN, S09CHP,
S10RUP, S11ONM, S12BFM, S13MAC, S14EOE, S15TRE, S16MAR, S17EGW, S18CON,
S19SMV, S20WCV, S21RET, S22HOR, S23INT, S24WAT, S25AIT, S26OTA, S27POT,
S28FIN, S29REA, S30REN, S31PUB, S32EDU, S33HSW, S34OCS,
CAP, LAB, IDT, TRF, HOH, GOV, INV, EXT/
            i(u)      goods             /
S01AFF, S02MIN, S03FBT, S04TEX, S05LPF, S06WPC, S07PPP, S08CRN, S09CHP,
S10RUP, S11ONM, S12BFM, S13MAC, S14EOE, S15TRE, S16MAR, S17EGW, S18CON,
S19SMV, S20WCV, S21RET, S22HOR, S23INT, S24WAT, S25AIT, S26OTA, S27POT,
S28FIN, S29REA, S30REN, S31PUB, S32EDU, S33HSW, S34OCS/
            h(u)      factor            /CAP, LAB/;
Alias (u,v), (i,j), (h,k);
* Loading SAM etc.-----------------------------------------------------
$onEcho > howToRead.txt
par = SAM     rng = input!E6:AU48        Cdim=1 Rdim=1
*par = axnew rng = input!E100:AU134   Cdim=1 Rdim=1
par = db        rng = input!F62:AM63       Cdim=1
$offEcho
$CALL GDXXRW.EXE 220503_SAM_Bangladesh_2017.xlsx @howToRead.txt
$GDXIN 220503_SAM_Bangladesh_2017.gdx
Parameter           SAM(u,v)            social accounting matrix;
$LOAD SAM
*Parameter          axnew(i,j)          new intermediate input;
*$LOAD axnew
Parameter           db(j)               change in scale parame. in prod. func.;
$LOAD db
$GDXIN
```

```
* Loading the initial values ----------------------------------------
Parameter       Y0(j)           composite factor
                F0(h,j)         the h-th factor input by the j-th firm
                X0(i,j)         intermediate input
                Z0(j)           output of the j-th good
                Xp0(i)          household consumption of the i-th good
                Xg0(i)          government consumption
                Xv0(i)          investment demand
                E0(i)           exports
                M0(i)           imports
                Q0(i)           Armington's composite good
                D0(i)           domestic good
                Sp0             private saving
                Sg0             government saving
                Td0             direct tax
                Tz0(j)          production tax
                Tm0(j)          import tariff
                FF(h)           factor endowment of the h-th factor
                Sf              foreign saving in a foreign currency
                pWe(i)          export price in a foreign currency
                pWm(i)          import price in a foreign currency
                tauz(i)         production tax rate
                taum(i)         import tariff rate;
Td0     = SAM("GOV", "HOH");
Tz0(j)  = SAM("IDT", j);
Tm0(j)  = SAM("TRF", j);
F0(h,j) = SAM(h, j);
Y0(j)   = sum(h, F0(h, j));
X0(i,j) = SAM(i, j);
Z0(j)   = Y0(j) + sum(i, X0(i, j));
M0(i)   = SAM("EXT", i);
tauz(j) = Tz0(j) / Z0(j);
taum(j) = Tm0(j) / M0(j);
FF(h)   = SAM("HOH", h);
Xp0(i)  = SAM(i, "HOH");
Xg0(i)  = SAM(i, "GOV");
Xv0(i)  = SAM(i, "INV");
E0(i)   = SAM(i, "EXT");
Q0(i)   = Xp0(i) + Xg0(i) + Xv0(i) + sum(j, X0(i, j));
D0(i)   = (1 + tauz(i)) * Z0(i) - E0(i);
Sp0     = SAM("INV", "HOH");
Sg0     = SAM("INV", "GOV");
Sf      = SAM("INV", "EXT");
pWe(i)  = 1;
pWm(i)  = 1;
* Calibration -------------------------------------------------------
Parameter       sigma(i)        elasticity of substitution
                psi(i)          elasticity of transformation
                eta(i)          substitution elasticity parameter
```

```
                phi(i)          transformation elasticity parameter;
sigma(i)  = 2;
psi(i)    = 2;
eta(i)    = (sigma(i)-1)/sigma(i);
phi(i)    = (psi(i)+1)/psi(i);
Parameter       alpha(i)        share parameter in utility func.
                beta(h,j)       share parameter in production func.
                b(j)            scale parameter in production func.
                ax(i,j)         intermediate input requirement coeff.
                ay(j)           composite fact. input req. coeff.
                mu(i)           government consumption share
                lambda(i)       investment demand share
                deltam(i)       share par. in Armington func.
                deltad(i)       share par. in Armington func.
                gamma(i)        scale par. in Armington func.
                xid(i)          share par. in transformation func.
                xie(i)          share par. in transformation func.
                theta(i)        scale par. in transformation func.
                ssp             average propensity for private saving
                ssg             average propensity for gov. saving
                taud            direct tax rate;
alpha(i)  = Xp0(i)/sum(j, Xp0(j));
beta(h,j) = F0(h,j)/sum(k, F0(k,j));
b(j)      = Y0(j)/prod(h, F0(h,j)**beta(h,j));
ax(i,j)   = X0(i,j)/Z0(j);
ay(j)     = Y0(j)/Z0(j);
mu(i)     = Xg0(i)/sum(j, Xg0(j));
lambda(i) = Xv0(i)/(Sp0+Sg0+Sf);
deltam(i) =(1+taum(i))*M0(i)**(1-eta(i))/((1+taum(i))*M0(i)**(1-eta(i))+D0(i)**(1-eta(i)));
deltad(i) = D0(i)**(1-eta(i))/((1+taum(i))*M0(i)**(1-eta(i)) +D0(i)**(1-eta(i)));
gamma(i)  = Q0(i)/(deltam(i)*M0(i)**eta(i)+deltad(i)*D0(i)**eta(i))**(1/eta(i));
xie(i)    = E0(i)**(1-phi(i))/(E0(i)**(1-phi(i))+D0(i)**(1-phi(i)));
xid(i)    = D0(i)**(1-phi(i))/(E0(i)**(1-phi(i))+D0(i)**(1-phi(i)));
theta(i)  = Z0(i)/(xie(i)*E0(i)**phi(i)+xid(i)*D0(i)**phi(i))**(1/phi(i));
ssp       = Sp0/sum(h, FF(h));
ssg       = Sg0/(Td0+sum(j, Tz0(j))+sum(j, Tm0(j)));
taud      = Td0/sum(h, FF(h));
* Defining model system ----------------------------------------------
Variable        Y(j)            composite factor
                F(h,j)          the h-th factor input by the j-th firm
                X(i,j)          intermediate input
                Z(j)            output of the j-th good
                Xp(i)           household consumption of the i-th good
                Xg(i)           government consumption
                Xv(i)           investment demand
                E(i)            exports
                M(i)            imports
                Q(i)            Armington's composite good
                D(i)            domestic good
```

```
                pf(h)           the h-th factor price
                py(j)           composite factor price
                pz(j)           supply price of the i-th good
                pq(i)           Armington's composite good price
                pe(i)           export price in local currency
                pm(i)           import price in local currency
                pd(i)           the i-th domestic good price
                epsilon         exchange rate
                Sp              private saving
                Sg              government saving
                Td              direct tax
                Tz(j)           production tax
                Tm(i)           import tariff
                UU              utility [fictitious];
Equation        eqpy(j)         composite factor agg. func.
                eqF(h,j)        factor demand function
                eqX(i,j)        intermediate demand function
                eqY(j)          composite factor demand function
                eqpzs(j)        unit cost function
                eqTd            direct tax revenue function
                eqTz(j)         production tax revenue function
                eqTm(i)         import tariff revenue function
                eqXg(i)         government demand function
                eqXv(i)         investment demand function
                eqSp            private saving function
                eqSg            government saving function
                eqXp(i)         household demand function
                eqpe(i)         world export price equation
                eqpm(i)         world import price equation
                eqepsilon       balance of payments
                eqpqs(i)        Armington function
                eqM(i)          import demand function
                eqD(i)          domestic good demand function
                eqpzd(i)        transformation function
                eqDs(i)         domestic good supply function
                eqE(i)          export supply function
                eqpqd(i)        market clearing cond. for comp. good
                eqpf(h)         factor market clearing condition
                obj             utility function [fictitious];
*[domestic production] ----------
eqpy(j)..       Y(j)    =e= b(j)*prod(h, F(h,j)**beta(h,j));
eqF(h,j)..      F(h,j)  =e= beta(h,j)*py(j)*Y(j)/pf(h);
eqX(i,j)..      X(i,j)  =e= ax(i,j)*Z(j);
eqY(j)..        Y(j)    =e= ay(j)*Z(j);
eqpzs(j)..      pz(j)   =e= ay(j)*py(j) +sum(i, ax(i,j)*pq(i));
*[government behavior] ----------
eqTd..          Td      =e= taud*sum(h, pf(h)*FF(h));
eqTz(j)..       Tz(j)   =e= tauz(j)*pz(j)*Z(j);
eqTm(i)..       Tm(i)   =e= taum(i)*pm(i)*M(i);
```

```
eqXg(i)..          Xg(i)  =e= mu(i)*(Td +sum(j, Tz(j)) +sum(j, Tm(j)) -Sg)/pq(i);
*[investment behavior] ---------------
*savings-driven type or invest-driven type macro closure between Xv and Sp
* eqXv(i)..        Xv(i)  =e= lambda(i)*(Sp +Sg +epsilon*Sf)/pq(i);
eqXv(i)..          Xv(i)  =e= Xv0(i);
*[savings] --------------------------
* savings-driven type or investment-driven type macro closure between Xv and Sp
* eqSp..           Sp     =e= ssp*sum(h, pf(h)*FF(h));
eqSp..             Sp     =e= sum(i,pq(i)*Xv(i)) -Sg -epsilon*Sf;
eqSg..             Sg     =e= ssg*(Td +sum(j, Tz(j))+sum(j, Tm(j)));
*[household consumption] -------------
eqXp(i)..          Xp(i)  =e= alpha(i)*(sum(h, pf(h)*FF(h)) -Sp -Td)/pq(i);
*[international trade] ---------------
eqpe(i)..          pe(i)  =e= epsilon*pWe(i);
eqpm(i)..          pm(i)  =e= epsilon*pWm(i);
eqepsilon..        sum(i, pWe(i)*E(i)) +Sf =e= sum(i, pWm(i)*M(i));
*[Armington function] ----------------
eqpqs(i).. Q(i) =e= gamma(i)*(deltam(i)*M(i)**eta(i)+deltad(i) *D(i)**eta(i))**(1/eta(i));
eqM(i)..   M(i)=e=(gamma(i)**eta(i)*deltam(i)*pq(i)/((1+taum(i))*pm(i)))**(1/(1-eta(i)))*Q(i);
eqD(i)..   D(i) =e= (gamma(i)**eta(i)*deltad(i)*pq(i)/pd(i))**(1/(1-eta(i)))*Q(i);
*[transformation function] -----------
eqpzd(i).. Z(i) =e= theta(i)*(xie(i)*E(i)**phi(i)+xid(i)*D(i)**phi(i))**(1/phi(i));
eqE(i)..   E(i) =e= (theta(i)**phi(i)*xie(i)*(1+tauz(i))*pz(i)/pe(i))**(1/(1-phi(i)))*Z(i);
eqDs(i)..  D(i) =e= (theta(i)**phi(i)*xid(i)*(1+tauz(i))*pz(i)/pd(i))**(1/(1-phi(i)))*Z(i);
*[market clearing condition] ---------
eqpqd(i)..         Q(i)   =e= Xp(i) +Xg(i) +Xv(i) +sum(j, X(i,j));
eqpf(h)..          sum(j, F(h,j)) =e= FF(h);
*[fictitious objective function] -----
obj..              UU          =e= prod(i, Xp(i)**alpha(i));
* Initializing variables -----------------------------------------------
Y.l(j)      = Y0(j);
F.l(h,j)    = F0(h,j);
X.l(i,j)    = X0(i,j);
Z.l(j)      = Z0(j);
Xp.l(i)     = Xp0(i);
Xg.l(i)     = Xg0(i);
Xv.l(i)     = Xv0(i);
E.l(i)      = E0(i);
M.l(i)      = M0(i);
Q.l(i)      = Q0(i);
D.l(i)      = D0(i);
pf.l(h)     = 1;
py.l(j)     = 1;
pz.l(j)     = 1;
pq.l(i)     = 1;
pe.l(i)     = 1;
pm.l(i)     = 1;
pd.l(i)     = 1;
epsilon.l   = 1;
```

```
Sp.l        = Sp0;
Sg.l        = Sg0;
Td.l        = Td0;
Tz.l(j)     = Tz0(j);
Tm.l(i)     = Tm0(i);
* Numeraire ----------------------------------------------------------
pf.fx("LAB") = 1;
* Defining and solving the model --------------------------------------
Model matarcge /   eqpy.py, eqF.F, eqX.X, eqY.Y, eqpzs.pz, eqTd.Td, eqTz.Tz,
                   eqTm.Tm, eqXg.Xg, eqXv.Xv, eqSp.Sp, eqSg.Sg, eqXp.Xp,
                   eqpe.pe, eqpm.pm, eqepsilon.epsilon, eqpqs.pq, eqM.M,
                   eqD.D, eqpzd.Z, eqE.E, eqDs.pd, eqpqd.Q, eqpf.pf, obj.UU /;
matarcge.reslim=60;
Option mcp = PATH;
Solve matarcge using mcp;
* Simulation Runs-----------------------------------------------------
*ax(i,j)  = axnew(i,j);
b(j)       = b(j)*(1+db(j));
Solve matarcge using mcp;
* Making a new SAM ----------------------------------------------------
Parameter           SAM2(u,v);
SAM2(i,j)                 = pq.l(i) * X.l(i,j);
SAM2(h,j)                 = py.l(j) * Y.l(j) * beta(h,j);
SAM2("IDT",j)             = Tz.l(j);
SAM2("TRF",j)             = Tm.l(j);
SAM2("EXT",i)             = pm.l(i) * M.l(i);
SAM2(i,"HOH")             = pq.l(i) * Xp.l(i);
SAM2(i,"GOV")             = pq.l(i) * Xg.l(i);
SAM2(i,"INV")             = pq.l(i) * Xv.l(i);
SAM2(i,"EXT")             = pe.l(i) * E.l(i);
SAM2("GOV","HOH")   = Td.l;
SAM2("INV","HOH")   = Sp.l;
SAM2("INV","GOV")   = Sg.l;
SAM2("HOH","CAP")   = sum(j,SAM2("CAP",j));
SAM2("HOH","LAB")   = sum(j,SAM2("LAB",j));
SAM2("GOV","IDT")   = sum(j,SAM2("IDT",j));
SAM2("GOV","TRF")   = sum(j,SAM2("TRF",j));
SAM2("INV","EXT")   = sum(j,SAM2("EXT",j)) - sum(i,SAM2(i,"EXT"));
* Welfare measure: Hicksian equivalent variations ---------------------
Parameter           UU0               utility level in the Base Run Eq.
                    ep0               expenditure func. in the Base Run Eq.
                    ep1               expenditure func. in the C-f Eq.
                    EV                Hicksian equivalent variations;
UU0       = prod(i, Xp0(i)**alpha(i));
ep0       = UU0 /prod(i, (alpha(i)/1)**alpha(i));
ep1       = UU.l/prod(i, (alpha(i)/1)**alpha(i));
EV        = ep1-ep0;
* end of model -------------------------------------------------------
```

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