

# Country-Specific Framework for Environmental Policy Analysis: Assessing International Financing for Climate Change Adaptation in Bangladesh

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## Abstract

We present a single-region computable general equilibrium (CGE) model with trade elasticities calibrated based on a two-region setup. Our goal is to offer a concise, reusable framework for domestic policy analysis while explicitly representing the nominal exchange rate, a key variable often absent from global models. In addition, we incorporate an established theoretical framework to improve the modeling of domestic production, exports, imports and exchange rate dynamics. We then apply our model on Bangladesh to simulate foreign climate-finance transfers and temperature-driven productivity losses. The main finding is that foreign transfers raise aggregate consumption while re-allocating activity toward non-tradables in a Dutch disease (i.e., income windfall) pattern, and that an annual transfer of 2.8 billion USD through 2050 can offset specified warming-induced welfare losses.

## Keywords

Computable General Equilibrium Model, Country-Level Analysis, Climate Finance

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## 1. Introduction

As global warming continues to intensify, climate change-induced impacts are threatening human life and causing socio-economic damage worldwide (IPCC, 2023). Developing and financially challenged countries are especially vulnerable to this trend due to their limited resources and low adaptive capacity. Therefore,

it is critical to develop analytical approaches to evaluate the climate impacts on the economy and options for mitigation and adaptation, in order to inform effective strategies for protecting the economies.

Global integrated assessment models (IAMs) and computable general equilibrium (CGE) models—either embedded within IAMs or used as standalone frameworks—are widely employed for climate and environmental policy analysis (IPCC, 2023). These models are indispensable in analyzing policies and impacts with worldwide coverage and transboundary nature. However, applying these models to detailed analyses of individual countries is often challenging. To avoid the curse of dimensionality, multi-region models typically adopt limited sectoral resolution. Even so, solving them can still be computationally burdensome and may encounter numerical difficulties and data limitations. These challenges become even more pronounced when the models include numerous economic sectors, technologies, or production factors.

In this study, we develop a country-specific modeling tool, which is derived based on GTAPinGAMS (Rutherford, 1998). It also benefits from applying the Global Trade Analysis Project (GTAP) database (Aguilar et al., 2023; Chepeliev, 2023) and an approach for the dynamic structure from a large energy-economic model (Chen et al., 2022). Our framework, called the country-specific framework for environmental policy analysis (CSAVE), provides the flexibility of focusing on a particular country of interest in the GTAP database. It also offers the option of pursuing a higher sectoral resolution without substantially increasing the levels of efficiency penalty or numerical challenge.

The goal of our effort is to offer a succinct scheme for analyzing energy, climate, and environmental policy impacts on domestic economy by applying a country-level CGE model. Our country-level framework allows a detailed representation of the evolution of an economy under different scenarios of economic development and policy. With a single-country setting, the representation of international trade between the domestic economy and the rest of the world is particularly important. For trade-related elasticities, we use an approach developed by Schreiber et al. (2024) to derive them from the simulated trade response to changes in prices of imports and exports. Besides, one important aspect of our country-level framework is an explicit representation of exchange rate dynamics under different trade closure settings. Global multi-region models, on the contrary, are typically formulated in the same currency for all regions (e.g., US dollars) and therefore the price of foreign exchange is usually not represented. This brings up another contribution of CSAVE, which incorporates the theoretical framework developed by Dervis et al. (1982) and Devaragan et al. (1990) to improve the modeling of price of foreign exchange, domestic production, imports and exports.

To test our model, we apply it to the issue of international climate financing. We focus on Bangladesh as one of most vulnerable countries to climate change (Government of Bangladesh, 2022). We represent the impacts of climate change on cropland and labor productivities based on Reilly et al. (2007) and Hsiang

(2010), and draw the temperature projection from Choi et al. (2021) for deriving the productivity impacts. We then calculate the level of foreign climate financing needed to compensate Bangladesh's welfare loss, and find that the aggregate consumption in Bangladesh increases with the amount of transfer, but over time non-tradable sectors expand while tradable sectors shrink, i.e., the economy shows the symptoms of Dutch disease (see, for example, Ebrahimzadeh (2025) for a description of the term Dutch disease that refers to harmful consequences of large increases of a country's income). We also consider scenarios when transfers are received by either a representative agent, or affected agricultural sectors, or when transfers are dedicated to subsidizing carbon-free power generation. Similar modeling exercises may also be conducted for other developing countries that are exploring the opportunity of international climate financing.

The rest of the paper is organized as follows: Section 2 provides the settings and structure of CSAVE, Section 3 offers background information of Bangladesh's economy and how cropland and labor productivity impacts are quantified, Section 4 presents simulation results for the welfare loss of Bangladesh due to climate change, and foreign transfers needed to compensate the loss. Section 5 provides conclusions and future research directions.

## 2. Model

### 2.1. Framework

CSAVE is a single-region multi-sector recursive dynamic computable general equilibrium (CGE) model interacting with the rest of the world through international trade. The model utilizes the subroutine of GTAPinGAMS to produce the desired sectoral aggregation using the GTAP-power database (Chepeliev, 2023). The input-output table of the focused region is extracted from the aggregated dataset. In CSAVE, activities of various agents and their interactions are summarized by: 1) zero-profit conditions; 2) market-clearing conditions; and 3) income-balance conditions. For a producer, the economic activity is output, and for a household, the activity is utility. A zero-profit condition formulated as a Mixed Complementarity Problem (MCP) is:

$$MC - MR \geq 0; Q \geq 0; [MC - MR] \cdot Q = 0 \quad (1)$$

For a production activity, if the equilibrium output  $Q > 0$ , the first-order condition requires that the marginal cost equals the marginal revenue ( $MC = MR$ ). Alternatively, if  $MC > MR$  in equilibrium,  $Q = 0$  as there is no incentive to produce. Finally,  $MC < MR$  does not constitute an equilibrium since in that state it is profitable to increase the output  $Q$  until  $MC = MR$ . Other activities such as imports, exports, investment, and commodity aggregation have their own zero-profit conditions.

For each market-clearing condition, the price level is determined based on demand and supply. The market-clearing condition in MCP format can be written as:

$$S \geq D; P \geq 0; [S - D] \cdot P = 0 \quad (2)$$

The condition states that for each market, if there is a positive equilibrium price  $P$ , the price will make supply and demand equal ( $S = D$ ). If  $S > D$  in equilibrium,  $P = 0$  due to the excess supply. Similarly,  $S < D$  is not an equilibrium because in that case, suppliers are able to increase the price until the market is cleared.

The income-balance condition specifies the income supporting the household expenditure and savings. For consistency, the condition is expressed in MCP format as:

$$E \geq I; E \geq 0; [E - I] \cdot E = 0 \quad (3)$$

In Condition (3),  $E$  represents expenditure plus savings, and so the condition states that any positive expenditure plus savings equals the income  $I$ . In the model, the price of utility is chosen as the numeraire of the model, and all other prices are measured relative to it.

## 2.2. Social Accounting Matrix

The core of CSAVE is formulated in MPSGE (Rutherford, 1999) and the rest is written in GAMS (Bussieck and Meeraus, 2004). The model structure is best described by the social accounting matrix (SAM) in a “micro-consistent matrix” format (Figure 1), where each row of SAM is associated with a market-clearing condition of a commodity or service (Condition 2), and each column corresponds to a zero-profit condition of an activity (Condition 1), except for the last column, which represents the income-balance condition of the economy (Condition 3). Cells in blue denote output of each activity, supply of each market, or endowment of the representative agent (those in the rightmost column); Cells in light orange are input of each activity, demand for the commodity of each market, or aggregate consumption of the representative agent (those in the rightmost column). Notations for elements in SAM are explained in Tables 1-5, and Table 6 presents tax revenue components of the income-balance condition, which is handled automatically in the background by MPSGE.

For instance, for a non-electricity sector  $j$  (see the column “ $Y_j | not elec$ ” in Figure 1) without using fixed factors (land and natural resources), when a positive output  $vom0_j$  is produced in the base year, it would require the use of primary factor  $vfm0_{f,j}$  and the intermediate input  $vafm0_{i,j}$ . The output and input values of the production activity are shown in (4) and (5), respectively:

$$P_j \cdot (1 - rto0_j) \cdot vom0_j \quad (4)$$

$$\sum_{f \in mf} PP_f \cdot (1 + rtf0_{f,j}) \cdot vfm0_{f,j} + \sum_i PAC_i \cdot (1 + rtf0_{i,j}) \cdot vafm0_{i,j} \quad (5)$$

The accounting identity (4) = (5) corresponds to a zero-profit condition with a positive output. Also taking the non-electricity sector  $j$  as an example, the market for the domestic output (the row labeled by  $P_j$ ) is formed by: 1) the supply of the domestic output  $vom0_j$ , 2) the domestic demand of that output  $vdffms_j$ , which

is the domestic component of the Armington good  $j$ , and 3) the foreign demand of that output  $e0_j$ , which is just the exports of  $j$ . The positive output of  $j$  implies a positive price of  $j$  (i.e.,  $P_j > 0$ ) in this market, which has the following equilibrium condition:

$$vom0_j = vdfms_j + e0_j \quad (6)$$

Finally, the column denoted by “RA” corresponds to an income balance condition of the representative agent (consumer), with the value of total expenditure (savings included) being:

$$PU \cdot vum0 \quad (7)$$

The value of the endowment is the sum of the following terms

$$\sum_{mf} PP_{mf} \cdot evfm0_{mf} \quad (\text{Labor and capital endowments}) \quad (8)$$

$$\sum_{sf} \sum_i PF_{sf,j} \cdot vfm0_{sf,i} \quad (\text{Non-power sector land \& natural resources}) \quad (9)$$

$$\sum_{sf} \sum_i PF_{-sf,j} \cdot vfm0_{-sf,i} \quad (\text{Similar to (9) but for power subsectors}) \quad (10)$$

$$-\sum_i PAC_i \cdot vafm0_{i,"g"} \quad (\text{Government expenditure}) \quad (11)$$

$$-\sum_i PESTAR_i \cdot e0_i \quad (\text{Exports}) \quad (12)$$

$$\sum_i PMSTAR_i \cdot m0_i \quad (\text{Imports}) \quad (13)$$

$$sum\_tax \quad (\text{Sum of tax revenue. See Table 6 for details}) \quad (14)$$

The income-balance condition is the following identity, which states that the consumer’s savings included total expenditure equals the value of the endowments he owns:

$$(7) = \sum_{n=8}^{14} (n) \quad (15)$$

### 2.3. International Trade

Following Dervis et al. (1982), CSAVE assumes that for a given commodity  $i$ , the domestic economy may face a negatively sloped export demand (i.e., demand for exports from abroad), due to product differentiation<sup>1</sup>. Here, the price on the vertical axis is the foreign commodity price for exports from the country we model (See Equation (17)). The foreign commodity price here is the price the (hypothetical) foreign consumers face.

In addition, CSAVE also allows the domestic economy to face a positively sloped import supply (i.e., supply of imports from abroad) curves. Similarly, the price on the vertical axis is the foreign price of commodity imported by the country we model (See Equation (19)). The foreign commodity price here is the price the (hypothetical) foreign suppliers face. To elaborate the setting, let us denote  $PWE_i$  as the foreign price index of commodity  $i$  exported from the domestic economy. Following notations defined in Table 1 and Table 5,  $PWE_i$  can be expressed as:

<sup>1</sup>See pp. 224-226 in Dervis et al. (1982).

	Y not elec	Y elec	M	A	AC	U	Z	E	Y_	Y_  nfs	Y__	INV	RA
P	vom0 -e0 rto0	vom0		vdfms									
PE	e0 rto0	e0						e0 -rtxse					
PM			vim0	vifms									
PP mf	vfm0 rtf0								vfm0_ rtf0_				evfm0
PF sf	vfm0 rtf0												vfm0
PF_ sf									vfm0_ rtf0_				vfm0_
PA				vafms	vafm0 ctaxr								
PAC	vafm0 rtfa0				vafm0		vafm0 rtfa0		vafm0_ rtfa0_			vafm0 rtfa0	-vafm0
PU						vum0							vum0
PZ						vom0	vom0						
PESTAR								e0					-e0
PMSTAR			m0 rtms0										m0
P_		vom0_							vom0_ rto0_	vom0_	vom0_		
P__		vom0_dn								vom0_	vom0_f		
PINV						vafmi						vafmi	
tax_Y													Sum of tax
tax_AC					tax_Z			tax_E	tax_Y_		tax_INV		

Figure 1. SAM structure of CSAVE.

Table 1. Price indices.

Price notation	Definition
$P(i)$	Domestic output price index
$PM(i)$	Import price index
$PP(f)$	Labor or capital rent index
$PE(i)$	Price index for tax & subsidy excluded exports in domestic currency
$PW(i)$	Foreign price index for tariff excluded imports of domestic economy
$PF(f, i)$	Land or natural resource rent index
$PF_(f, i_)$	Power sector natural resource rent index
$PA(i)$	Armington good price index
$PAC(i)$	Carbon-penalty-included PA
$PU$	Price index for utility (savings included)

**Continued**

$PZ$	Price index for aggregate consumption
$PESTAR(i)$	Price index for tax & subsidy included exports in domestic currency
$PMSTAR(i)$	Price index for tariff excluded imports
$P_{\underline{i}}$	Power subsector domestic output price index
$P_{\underline{\quad}}$	Domestic output price index for dispatchable generation
$PINV$	Price index for investment
$ER$	Nominal exchange rate (Price index of foreign currency)
$PWE(i)$	Foreign price index of commodity $i$ exported from the domestic economy

**Table 2.** Activities.

Activity	Definition
$Y(i)$	Supply (domestic production) index
$M(i)$	Imports index
$A(i)$	Armington good/service index
$AC(i, g)$	Index for Armington good/service with carbon penalty
$U$	Utility index
$Z$	Aggregate consumption index
$E(i)$	Exports index
$Y_{\underline{i}}$	Index for supply (domestic production) of a power subsector
$Y_{\underline{\quad}}(i)$	Index for power subsectors' homogeneous transformation: nuclear, hydro and others
$Y_{\underline{\quad}}$	Index for fossil generation aggregation
$INV$	Index for investment

**Table 3.** Sets.

Set notation	Definition
$g$	Goods + private consumption ("c"), government expenditure ("g"), & investment ("I")
$i$	Goods/sectors: subset of $g$
$j$	Alias of $i$ : subset of $g$
$f$	Primary factors
$mf$	Mobile primary factors (labor & capital)
$sf$	Sector-specific primary factors (land & natural resources)
$\underline{i}$	Power subsectors
$\underline{j}$	Alias of $\underline{i}$

**Table 4.** Parameters with base year values.

Parameter	Definition
$vom0(g)$	Total supply (domestic output) at market prices
$vom0(j_)$	Power subsectors' total supply (domestic output) at market prices
$vfm0(f, j)$	Endowments (factors) – firms' purchases at market prices
$vfm0(f, j_)$	Endowments (factors) – power subsectors' purchases at market prices
$vdfm0(i, g)$	$g$ 's domestic purchase of $i$ (tax excluded)
$vdfms(i)$	Sum of $vdfm0(i, g)$ over $g$
$vifm0(i, g)$	$g$ 's purchase of imported $i$ (tax excluded)
$vifms(i)$	Sum of $vifm0(i, g)$ over $g$
$vafm0(i, g)$	Armington good $i$ used by $g$ (tax excluded); = $vdfm0(i, g) + vifm0(i, g)$
$vafm0(i, j_)$	Armington good $i$ used by power subsectors $j_$ (tax excluded)
$vom0(i_)$	Power subsector total supply (domestic output) at market prices
$vom0_d$	Aggregate dispatchable generations
$vim0(i)$	Tariff-included imports
$m0(i)$	Tariff-excluded & importing-transport-service-included imports
$vum0$	Utility level
$vafmi$	Aggregate investment
$e0(i)$	Subsidy-excluded & exporting-transport-service-included exports
$evfm0(mf)$	Non-fixed factor endowment (labor; capital) at market prices
$vfm0(sf, i)$	Fixed factor endowment (land; natural resources) at market prices
$vfm0(sf, i_)$	Power subsectors' fixed factor endowment (land; natural resources) at market prices

**Table 5.** Base year tax or subsidy rates.

Tax/subsidy rate	Definition
$rto0(j)$	Tax/subsidy rate on output
$rto0(j_)$	Tax/subsidy rate on output (of power subsector $j_$ )
$rtf0(f, j)$	Tax/subsidy rate on primary factor
$rtf0(f, j_)$	Tax/subsidy rate on primary factor (of power subsector $j_$ )
$rtfa0(i, g)$	Base year effective tax/subsidy rate on Armington good $i$ use by $g$
$rtfa0(i, j_)$	Base year effective tax/subsidy rate on Armington good $i$ use by power subsector $j_$
$rtms0(i)$	Tax/subsidy rate on imports
$rtxse0(i)$	Export incentive rate in the base year imposed by home country
$rtxse(i)$	Export incentive rate imposed by home country
$ctaxr(i)^*$	Carbon tax rate

\*The base year carbon tax rate  $ctaxr(i) = 0$ .

**Table 6.** Base year tax revenues.

Revenue	Definition
$tax\_Y(j)$	$rto0(j) \cdot vom0(j) + \sum_f rtf0(f, j) \cdot vfm0(f, j) + \sum_i vafm0(i, j) \cdot rtfa0(i, j)$
$tax\_AC(i, g)^*$	$vafm0(i, g) \cdot ctaxr(i)$
$tax\_Z$	$\sum_i vafm0(i, "c") \cdot rtfa0(i, "c")$
$tax\_E(i)$	$e0(i) \cdot rtaxe(i)$
$tax\_Y(j_-)$	$rto0_-(j_-) \cdot vom0_-(j_-) + \sum_f rtf0_-(f, j_-) \cdot vfm0_-(f, j_-) + \sum_i vafm0_-(i, j_-) \cdot rtfa0_-(i, j_-)$
$tax\_INV$	$\sum_i vafm0(i, "i") \cdot rtfa0(i, "i")$
$sum\_tax$	$\sum_j tax\_Y(j) + \sum_i \sum_g tax\_AC(i, g) + tax_z + \sum_i tax\_E(i) + \sum_{j_-} tax\_Y(j_-) + tax\_INV$

\*The base year carbon tax rate  $ctaxr(i) = 0$ , and so in base year  $tax\_AC(i, g) = 0$ .

$$PWE_i = PE_i \cdot (1 + rtaxe_i) / ER \quad (16)$$

Equation (16) reveals that imposing export subsidy (setting  $rtaxe_i < 0$ ) and devaluation of domestic currency ( $ER$  increases) will make the export of  $i$  more competitive. Let us denote the elasticity of export demand by  $\alpha_i$ :

$$\alpha_i = d \ln E_i / d \ln PWE_i; \alpha_i \leq 0 \quad (17)$$

$PWE_i$  in Equation (17) is the price faced by foreign consumers (not represented explicitly in the single country framework). The export demand for commodity  $i$ , denoted by  $E_i$ , can be derived accordingly as:

$$E_i = E_i^0 \cdot \left[ \frac{(1 + rtaxe_i^0) \cdot ER}{(1 + rtaxe_i) \cdot PE_i} \right]^{-\alpha_i} \quad (18)$$

Therefore,  $E_i$  increases if there is: 1) a devaluation in domestic currency, 2) an increase in export subsidy ( $rtaxe_i < 0$  but  $|rtaxe_i|$  increases), and 3) a decrease in  $PE_i$  (domestic price index of  $E_i$  excluding the export subsidy). Equation (18) also shows that when  $\alpha_i \rightarrow -\infty$ , the home country is “small” for the export of  $i$  since other things being equal, even a tiny increase in  $PE_i$  beyond the base year level will lose all of the exports. On the other hand, when  $\alpha_i \rightarrow 0$ , the home country is “large” for exporting  $i$  since exports are insensitive to  $PE_i$ .

The import supply  $M_i$  can be derived from the elasticity of import supply  $\beta_i$ :

$$\beta_i = d \ln M_i / d \ln PW_i; \beta_i \geq 0 \quad (19)$$

$PW_i$  in Equation (19) is the pre-tariff foreign price index of commodity  $i$  imported by the domestic economy (Table 1), and it is the price perceived by foreign suppliers (not represented explicitly in the single country framework). The import supply  $M_i$  is therefore:

$$M_i = M_i^0 \cdot PW_i^{\beta_i} = M_i^0 \cdot \left( \frac{PMSTAR_i}{ER} \right)^{\beta_i} \quad (20)$$

In Equation (20), import supply  $M_i$  will go up when  $PW_i$  increases, and for

a given  $PMSTAR_i$ , the pre-tariff domestic price index of imported commodity  $i$ , an appreciation in domestic currency (i.e.,  $ER$  decreases) will increase  $PW_i$  and consequently raises  $M_i$  for any  $\beta_i > 0$ . In addition, when  $\beta_i \rightarrow \infty$ , the domestic economy is “small” as an importer of  $i$  since if it is willing to pay a slightly higher price than the world price, there will be a huge increase in import supply relative to the original import level  $M_0$ . Alternatively, when  $\beta_i$  is small, the domestic economy is “large” because even it is willing to pay a significant premium over the world price, the import supply will not increase much relative to the original import level  $M_0$ . In the extreme case  $\beta_i \rightarrow 0$ , the import supply remains at  $M_0$  regardless of any premium paid.

To parameterize  $\alpha_i$  and  $\beta_i$ , we follow Schreiber et al. (2024) and build a 2-region CGE that has the domestic economy and the rest of the world, with structure and parameterization mirroring those in CSAVE, except for settings of region and international trade. The goal is to derive  $\alpha_i$  and  $\beta_i$  by shocking the relevant price variables, as illustrated in Equations (21) and (22):

$$\alpha_i = \frac{\% \text{ change in foreign demand for } i \text{ exported by the domestic economy}}{\% \text{ change in } PE_i} \quad (21)$$

$$\beta_i = \frac{\% \text{ change in foreign supply of } i \text{ imported by the domestic economy}}{\% \text{ change in } PW_i} \quad (22)$$

We aggregate GTAP dataset into 30 sectors, and find that in general, Bangladesh is a price taker of various commodities in international trade, especially in terms of imports (Table 7). Note that when deriving elasticities, for some sectors there are no exports or imports in the base year data, and in that case the export demand or import supply elasticities cannot be simulated. In the modeling exercise, each missing elasticity will be assigned the value of zero. Indeed, the Armington (1969) aggregation commonly used in CGE modeling implies that sectors without exports or imports in the base year will continue to exhibit zero trade flows in subsequent simulations. Therefore, assigning values to missing elasticities does not affect the results. For numerical reasons, import supply elasticities that are higher than 100 will be represented by 100.

For the export market of commodity  $i$ , besides the export demand (Equation (18)), the export supply of each commodity  $i$  is determined by the zero-profit condition (Condition (1)) for a joint production technology that differentiates and distributes the producer’s output between export and domestic sales for profit maximization.

Likewise, for the import market of commodity  $i$ , in addition to the import supply (Equation (20)), the import demand is the derived demand of the representative consumer’s utility maximization problem—the level of import demand is dependent on the zero-profit condition for the “production” of Armington good, which aggregates imported and domestic products, and the Armington good demand is in turn determined by the zero-profit condition for the “production” of utility. The import and export markets as well as trade balance closure setting will determine  $ER$ , the price of foreign exchange (i.e., nominal exchange

rate), which will be discussed in Section 2.5.

**Table 7.** Simulated export demand and import supply elasticities.

Sector	export demand	import supply
paddy rice	-9.6	>100
Wheat	-	30.3
cereal grains nec	-	98.3
vegetables-fruit-nuts	-3.5	53.3
oil seeds	-5.1	89.3
sugar cane-sugar beet	-	-
plant-based fibers	-4.1	9.4
crops nec	-6.1	>100
bo horses	-	-
animal products nec	-2.6	>100
raw milk	-8.3	>100
wool-silk-worm cocoons	-	-
forestry	-4.6	>100
fishing	-2.4	>100
coal	-	>100
oil	-	>100
gas	-	-
bo meat products	-	>100
meat products	-10.8	>100
vegetable oils and fats	-7.4	32.2
dairy products	-	>100
processed rice	-5.8	31.9
sugar	-6.7	33.9
food products nec	-4.5	>100
beverages and tobacco products	-2.4	>100
petroleum-coal products	-5.5	38.3
other industrial sectors	-0.4	2.1
electricity	-	77.9
service sectors-tradable	-3.3	>100
service sectors-non-tradable	-	-

## 2.4. Technology and Preference

In CSAVE, constant elasticity of substitution (CES) functions (Arrow et al., 1961) is used to model the production technologies and consumer utility. While the output of utility function is the welfare level (a.k.a. utility), the output for each production technology is a composite that includes domestic sales and exports—the distribution of them is modeled by a constant elasticity of transformation (CET) function (Powell and Gruen, 1968). To provide an example for a production tech-

nology with a CES input and CET output, let us consider a technology that uses two inputs—labor  $F_L$  and capital  $F_k$ —to produce domestic sales  $Q_D$  and exports  $Q_E$ . Using the calibrated share form (Rutherford, 1998) and normalizing prices and quantities at the calibration point to unity, the CES production function for the composite good  $Q$  is:

$$Q = \left( \sum_m \gamma_m F_m^\rho \right)^{\frac{1}{\rho}}; m = L, K \quad (23)$$

where  $\gamma_m$  is the base year (i.e., the calibration point) cost share of the primary factor  $F_m$  ( $m = L; K$ ), and  $\rho$  is the parameter that relates to the elasticity of substitution between the two primary factors, denoted by  $\sigma$ , in the following equation:

$$\sigma \equiv \frac{d\left(\frac{F_L}{F_k}\right)}{\left(\frac{F_L}{F_k}\right)} \bigg/ \frac{d\left(\frac{P_k}{P_l}\right)}{\left(\frac{P_k}{P_l}\right)} = \frac{1}{1-\rho} \quad (24)$$

In Equation (24),  $P_l$  and  $P_k$  are the rental prices for labor and capital, respectively. Let us denote the dual of the production function as  $C(P_l, P_k, Q)$ , which is the cost function for producing  $Q$ :

$$C = \left( \sum_m \gamma_m P_m^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \cdot Q \quad (25)$$

A positive substitution elasticity holds if and only if  $\rho < 1$ . When  $\rho \rightarrow 0$  the CES function becomes Cobb-Douglas. Other special cases include: 1) perfect substitution between inputs ( $\rho \rightarrow 1$ ); and 2) Leontief, i.e., no substitution possibility between inputs ( $\rho \rightarrow -\infty$ ).

On the output side, the composite good  $Q$  is transformed into  $Q_D$  and  $Q_E$  according to the CET function:

$$Q = \left( \sum_n \theta_n Q_n^v \right)^{\frac{1}{v}}; n = D, E \quad (26)$$

where  $\theta_n$  is the base year value share of commodity  $n$  ( $n = D; E$ ) and  $v$  is the parameter that is associated with the elasticity of transformation  $\tau$  between domestic sales and exports:

$$\tau \equiv \frac{d\left(\frac{Q_E}{Q_D}\right)}{\left(\frac{Q_E}{Q_D}\right)} \bigg/ \frac{d\left(\frac{P_E}{P_D}\right)}{\left(\frac{P_E}{P_D}\right)} = \frac{1}{v-1} \quad (27)$$

In Equation (27),  $P_E$  and  $P_D$  are prices for exports and domestic sales, respectively. Let us denote the dual of the transformation function as  $R(P_E, P_D, Q)$ , which is the revenue function for a given level of composite  $Q$ :

$$R = \left( \sum_n \theta_n P_n^{\tau-1} \right)^{\frac{1}{\tau-1}} \cdot Q \quad (28)$$

Likewise, a positive transformation elasticity holds if and only if  $v > 1$ . When

$\nu \rightarrow 1$ , there is a perfect transformation possibility between outputs, and when  $\nu \rightarrow \infty$ , there is no transformation possibility between outputs.

The optimal levels of exports and domestic sales are determined by their respective zero-profit conditions. Taking the level of exports as an example, the marginal cost for the production of exported good is:

$$MC_E \equiv \frac{\partial C}{\partial Q_E} = \frac{\partial C}{\partial Q} \cdot \frac{\partial Q}{\partial Q_E} \tag{29}$$

Based on Equations (25) and (26), we have:

$$\frac{\partial C}{\partial Q} = \left( \sum_m \gamma_m P_m^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{30}$$

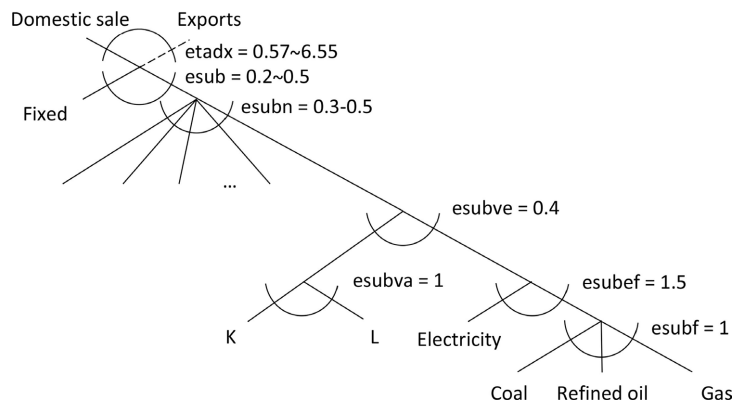
$$\frac{\partial Q}{\partial Q_E} = Q^{1-\nu} Q_E^{\nu-1} \tag{31}$$

Since  $\nu = 1/\tau + 1$  (Equation (28)),  $MC_E$  can be written as:

$$MC_E = \left( \sum_m \gamma_m P_m^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \cdot Q^{-1/\tau} Q_E^{1/\tau} \tag{32}$$

Therefore, the marginal cost for producing the exported good is an increasing function of its level  $Q_E$ , a decreasing function of composite  $Q$ , and an increasing function of the price for each input  $m$ . To determine  $Q_E$ , one can use the corresponding zero-profit condition (Condition (1)) based on Equation (32). **Figures 2-4** illustrate the structures of production technologies and the representative consumer’s preferences.

Besides, the power sector in CSAVE includes 9 subsectors (**Figure 5**). Following **Gurgel et al. (2023)**, we make renewables (wind and solar) perfect substitutes to other forms of generation, while considering the value factor adjustment proposed by **Mowers et al. (2023)**. The adjustment considers the observation that higher market shares of renewables in total electricity generation increase the “profit-adjusted levelized costs of electricity (PLCOE)” for renewables (**Figure 5**), i.e., the generation costs of renewables are higher as their market shares get larger. The cost function structure for power sector aggregation is also presented in **Figure 5**.



**Figure 2.** Cost function for a non-power sector.

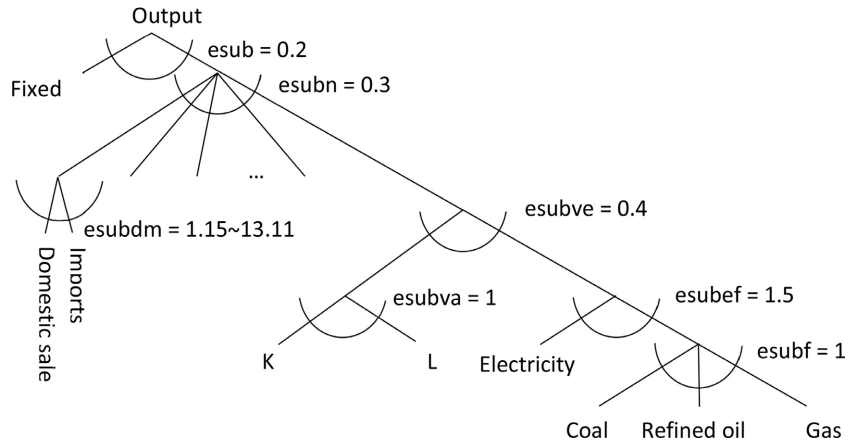
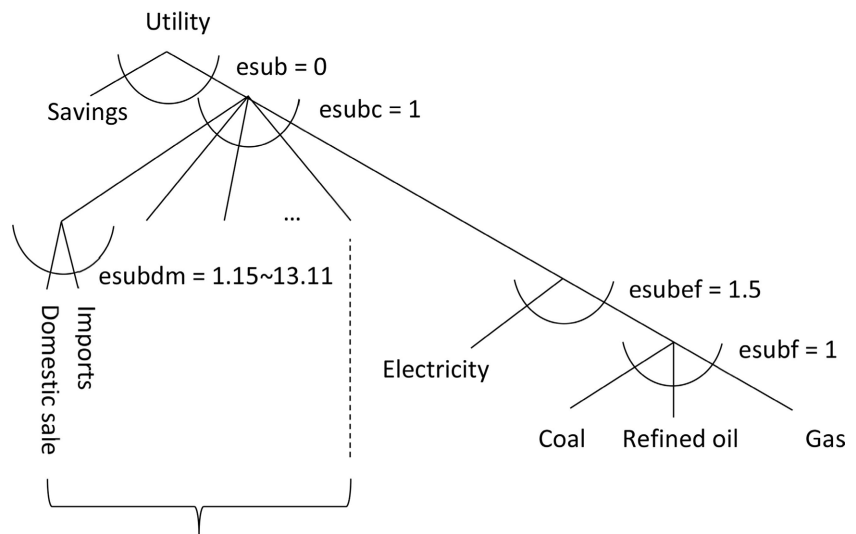


Figure 3. Cost function for a power subsector.



Final consumption (exclude energy)

Figure 4. Expenditure function.

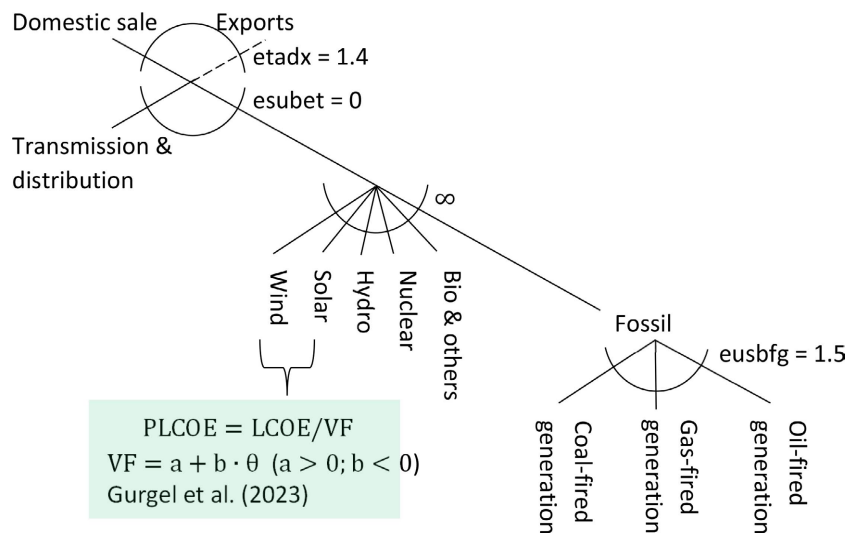


Figure 5. Cost function for aggregating power subsectors.

## 2.5. Model Closures

Closures of a CGE model specify the rules for how markets are cleared or macro balances (receipts equal payments) are achieved (UNESCWA, 2020). Each closure involves a decision about what variable can be adjusted to reestablish an equilibrium after the model receives a shock (Cornerstone CGE, 2024). Key closures of CSAVE include those for: 1) labor market; 2) trade balance; 3) macroeconomics; and 4) government expenditure.

The labor market closure of our model considers the circumstance where the economy is in full employment—wage rate is flexible and can be adjusted upward or downward to equalize labor supply and demand<sup>2</sup>. In our model, labor supply level is fixed within a given period. Therefore, the wage rate is fully determined by labor demand, which can be derived from producers' cost minimization problems using the Shephard's Lemma (Shephard, 1970).

CSAVE allows modelers to choose different settings for trade balance closure for comparison purposes or to better represent the country-specific characteristic. To illustrate this, let us denote the net capital outflow of the domestic economy by  $F$ , which is just the difference between the values of exports and imports, and denote the received foreign transfer by  $FTD$ :

$$F = FTD + \frac{1}{ER} \cdot \sum_i \frac{PE_i}{1 + rtxse_i} \cdot E_i - \sum_i PW_i \cdot M_i \quad (33)$$

To model the flexible exchange rate setting, the net capital outflow is fixed within a given period, and can be either fixed or updated across periods. The price of foreign exchange (i.e., nominal exchange rate)  $ER$  in Equation (33) is therefore endogenous, and as all other prices, it is measured relative to the price of utility, the numeraire of the model (See Section 2.1). Alternatively, when the price of foreign exchange is fixed,  $ER$  is constant and other prices are adjusted to meet the relevant market clearing conditions. In this case, the net capital outflow  $F$  in Equation (33) becomes endogenous. Throughout the study, we consider the flexible exchange rate setting where within a period, the net capital outflow remains constant, but over time it will be updated proportional to previous period's gross domestic product (GDP) level.

In CSAVE, the representative consumer allocates the income between consumption and savings to maximize his utility, and savings provide fund for investment, i.e., investment is driven by savings, i.e., the more the economy saves, the higher investment it achieves. The investment beyond the depreciation level eventually expands the production capacity of the following period. The setting constitutes the model's macroeconomics closure.

For the government expenditure closure, we assume the "quantities" of government purchases from various sectoral outputs are fixed within a given time period,

<sup>2</sup>The full employment setting is common in CGE models (e.g., Dervis et al. (1982); Devaragan et al. (1990); Rutherford (1998); Lanz and Rutherford (2016)). For our Bangladesh application, it is also relatively close to reality, as currently Bangladesh's unemployment rate is about 4.7% (World Bank, 2025).

i.e.,  $vafm0_{i,g}$  in Equation (11) remains a constant vector in that period. However, over time those quantities are updated proportional to the GDP of the economy. Besides, the standard setting of CSAVE assumes that tax revenues are recycled in a lump-sum fashion back to the representative consumer. Nevertheless, with some revisions, other settings can be incorporated into modeling exercises. We will provide some examples with different tax revenue recycling assumptions later.

## 2.6. Parameterization and Calibration

The SAM of CSAVE comes from the input-output dataset presented in GTAP-power version 11 (Chepeliev, 2023). In the database, the input-output table for Bangladesh was contributed by the Bangladesh Planning Commission (Aguilar et al., 2023), and the Bangladesh data and those for other countries were adjusted and recompiled to ensure global consistencies in trade flows for the base year of 2017. The data are key inputs in parameterizing preference and various technologies in general (see Section 2.2 for details).

Another data required in calibrating technologies and preference are elasticities of substitution between inputs and elasticities of transformation between outputs (see Section 2.4 for details). These elasticities are mostly sourced from existing studies (Table 8), except for the elasticities of transformation between outputs for domestic sale and those for exports, which are often unavailable for existing research.

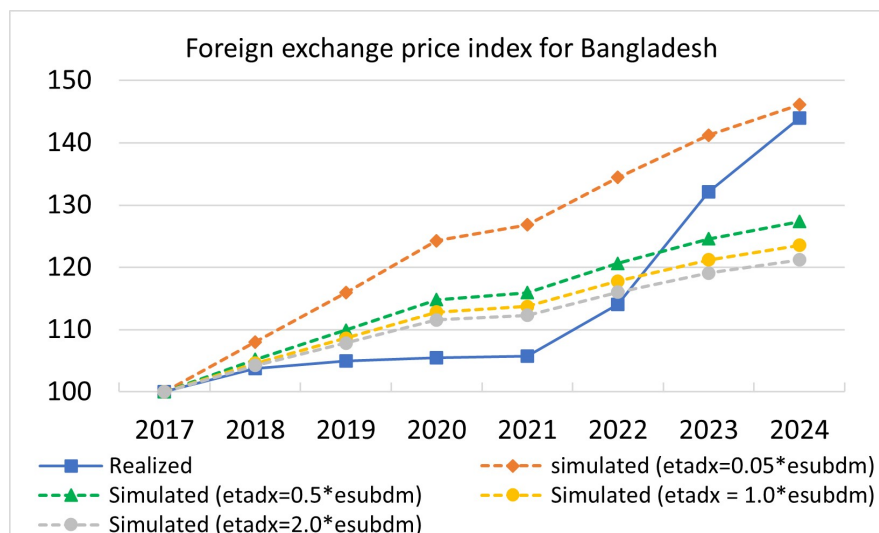
To overcome this, Lanz and Rutherford (2016) assume that for each commodity type, the transformation elasticity is proportional to the substitution elasticity between imported good and the indigenous product sold domestically. We adopt the strategy and calibrate transformation elasticities  $etadx$  such that they are half the levels for the corresponding substitution elasticities  $esubdm$ . The calibration ensures that CSAVE captures the average trend of Bangladesh's historical foreign exchange rate evolution (Figure 6). Besides, with lower transformation elasticities, it is harder for the domestic economy in diverting production resources to increase exports, which provide foreign exchange in supporting for the purchase of imports. In this case, there will be a higher extent of devaluation in domestic currency (Figure 6).

Another critical task for building CSAVE is calibrating the growth path for GDP under the reference scenario. In this study, the simulated reference GDP growth for Bangladesh up to 2030 is calibrated to IMF World Economic Outlook (IMF, 2025). For years beyond 2030, the growth is assumed to decrease exponentially to 3% in 2050. To match the given GDP growth path, following Chen et al. (2022), for each period, the total factor productivity (TFP) of the economy is endogenously solved first. The solution for TFP is saved and used to parameterize the model for subsequent simulations, and it remains exogenous across scenarios. While the solved TFP path allows the model to reproduce the targeted GDP growth path under the reference scenario, in general, the GDP growth as well as

other economic variables will deviate from the reference levels under a policy run<sup>3</sup>.

**Table 8.** Substitution and transformation elasticities of CSAVE.

	Notation	Value	Source
<b>Substitution elasticity between</b>			
fixed factor and other inputs (top nest)	esub	0.3 - 0.5	Cossa (2004)
aggregate consumption and savings (top nest)	esub	0	Chen et al. (2022)
intermediate inputs	esubn	0.3 - 0.5	Hertel (1997)
primary factors (labor & capital)	esubva	1	Balistreri et al. (2003)
value-added and energy	esubve	0.4	Paltsev et al. (2005)
electricity and fossil fuels	esubef	1.5	Chen et al. (2022)
fossil fuels	esubf	1	Chen et al. (2022)
investment goods	esubi	1	Paltsev et al. (2005)
consumption goods	esubc	1	Rutherford (1998)
T&D and generation	esubet	0	Chen et al. (2022)
fossil fuel generation	esubfg	1.5	Chen et al. (2022)
imports and indigenous product sold domestically	esubdm	1.2 - 13.1	Chepeliev (2023)
<b>Transformation elasticity between</b>			
output for domestic sale and that for exports	etadx	0.6 - 6.6	See Section 2.6



**Figure 6.** Foreign exchange price index under different transformation elasticity levels.

### 3. Implications of Receiving Foreign Transfers from Climate Finance

To alleviate the impact of climate change, during the 29th Conference of the Parties (COP29), the New Collective Quantified Goal on Climate Finance (NCQG)

<sup>3</sup>The file structure and workflow for running CSAVE are presented in **Appendices 1** and **2**, respectively.

was agreed by almost 200 countries after yearslong preparations and negotiations. Under the climate finance agreement, by 2035, annual finance to developing countries is planned to scale up to 300 billion US dollars, and to 1.3 trillion US dollars when efforts from private sectors are counted (UNFCCC, 2024). Under the context, we use CSAVE to explore implications on Bangladesh's economy when it receives foreign transfers via the climate finance.

Foreign transfers supply the domestic economy extra resources at its disposal. As a result, the domestic welfare (i.e., aggregate consumption) is non-decreasing when foreign transfers increase. On the other hand, the capital influx may also change prices, outputs and resource allocations, which means while some sectors benefit, others may suffer.

The 1-2-3 model developed by Devaragan et al. sheds light upon potential impacts of receiving foreign transfers. The one-country model has two sectors producing an export good  $E$  and a domestic good  $D$ , respectively, and it also has an import  $M$ . World prices for exports and imports are fixed following the small-country assumption. The representative consumer has a CES preference over  $D$  and  $M$  with a substitution elasticity  $\sigma$ , and the representative producer has a CET production technology in producing  $D$  and  $E$  with a transformation elasticity  $\Omega$ .

Devaragan et al. normalize import and export prices to unity, and assumes initially there is no capital inflow. The production is determined by the relative price  $P_D/P_E$  tangent to the production possibility frontier (PPF) in the 4<sup>th</sup> quadrant (Figure 7(a)). The output  $D$  is supplied to the domestic market, and the export  $E$  determines how much import  $M$  the country can buy based on the balance of trade constraint. The combinations of these  $M$  and  $D$  form the consumption possibility frontier (CPF). The consumer chooses products on the CPF to maximize his utility under the relative price  $P_D/P_M$  (see the 2<sup>nd</sup> quadrant of Figure 7(a)). In equilibrium, the economy produces at point  $P$  and consumes at point  $C$ .

When the country receives a foreign transfer  $\bar{B}$ , the balance of trade line will shift upward by  $\bar{B}$ , and this in turn moves the CPF up also by  $\bar{B}$ . In the new equilibrium, the economy consumes at point  $C'$  and produces at point  $P'$  (Figure 7(b)). Consumption levels of  $M$  and  $D$  rise, and the price of domestic good  $P_D$  goes up, which leads to a real appreciation that favors the domestic good against exports, i.e., the economy would have a "Dutch disease".

While CSAVE parameterizations for  $\alpha_i$  (elasticity of export demand) and  $\beta_i$  (elasticity of import supply) may not precisely agree with the small-country assumption used in the 1-2-3 model, as long as both imported and domestic goods are normal, receiving foreign transfers would increase the consumption of both commodities, and incentivizes the shift of production from exports to domestic sales, as Devaragan et al. predict.

To verify this, we first consider a scenario where the foreign climate finance given to Bangladesh goes to domestic consumers in a lump-sum fashion. The simulation shows that when the transfer increases (Figure 8), the aggregate consump-

tion goes up since the sales of both domestic and imported goods rise (Figure 9; Figure 10).

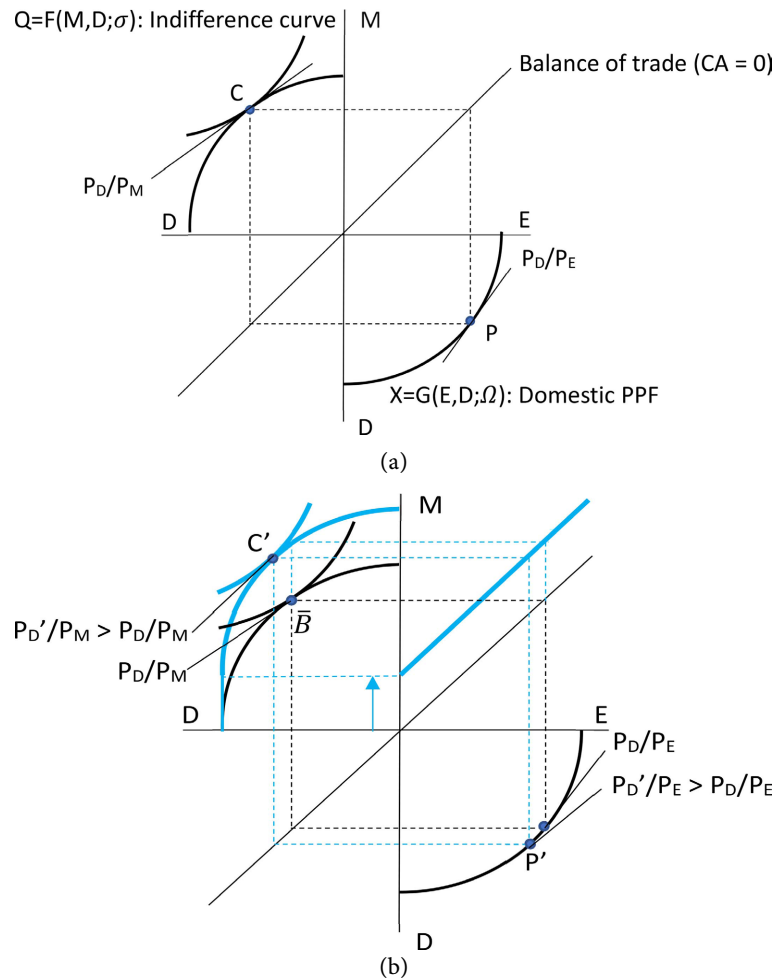
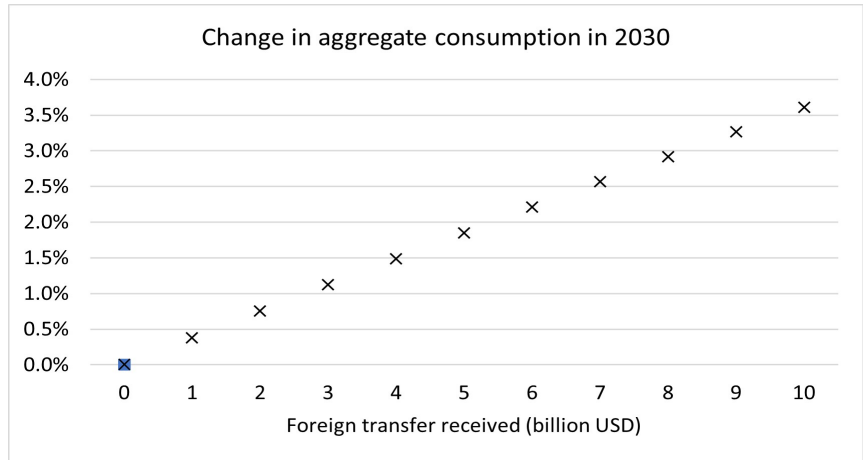


Figure 7. (a) The 1-2-3 model: Baseline; (b) The 1-2-3 model: Receiving a foreign transfer.

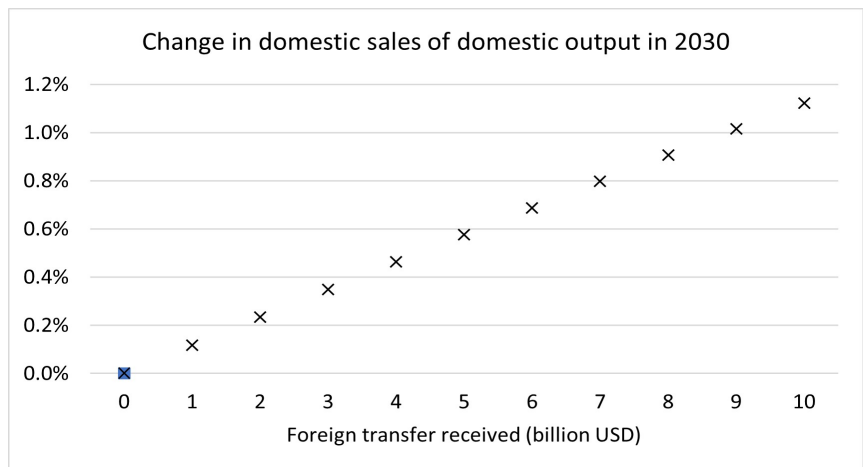
At the same time, the average price for sales of domestic output goes up, and prices for imports and exports drop (Figure 11), consistent with the projection of increased  $P_D/P_M$  and  $P_D/P_E$  by the 1-2-3 model. The shift of the relative price is in favor of domestic goods and against exports, which is supported by the simulation for exports (Figure 12). In addition, our simulation also shows that the inflow of foreign transfer raises the overall supply of foreign exchange and therefore lowers the nominal exchange rate (Figure 13).

Instead of a lump-sum transfer to consumers, climate finance funds are usually connected to particular goals, such as subsidizing low-carbon energy supply technologies, or mitigating or compensating the loss due to impacts of global warming. For example, the Loss and Damage Fund supports farmers in poorer countries that are suffering most from the climate crisis (World Economic Forum, 2024). As a result, we present another two scenarios, where climate transfers to

Bangladesh are used in 1) subsidizing carbon-free power generation; and 2) subsidizing agricultural sectors, which are vulnerable to global warming.



**Figure 8.** Change in aggregate consumption.



**Figure 9.** Change in domestic sales of domestic output.



**Figure 10.** Change in imports.

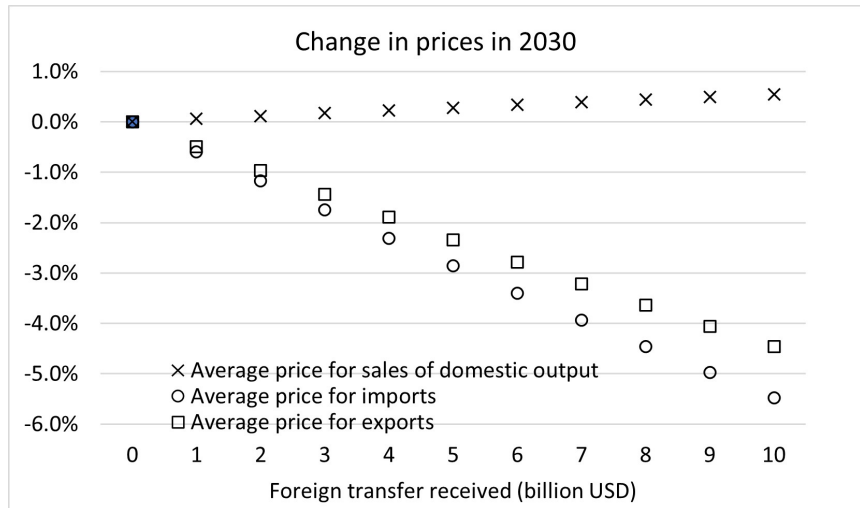


Figure 11. Change in prices.

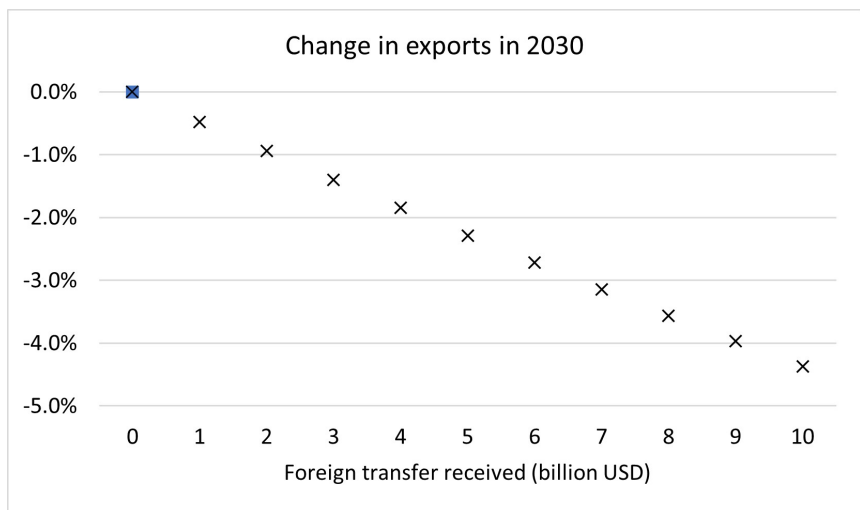


Figure 12. Change in exports.

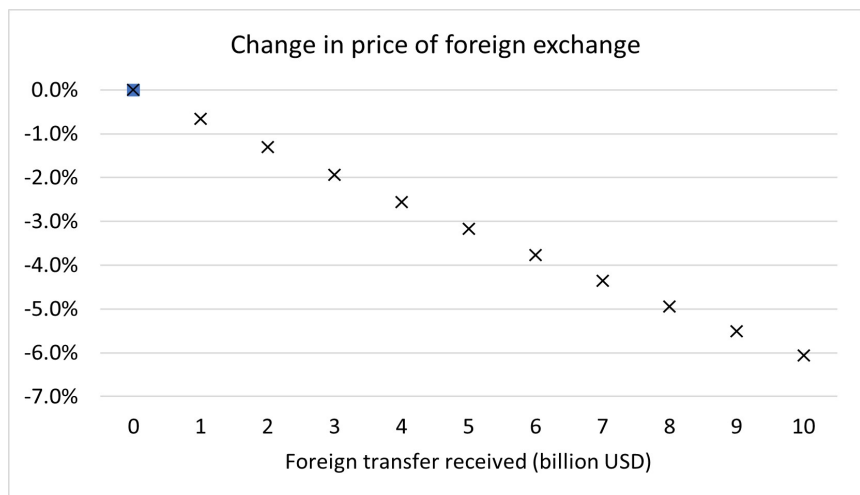
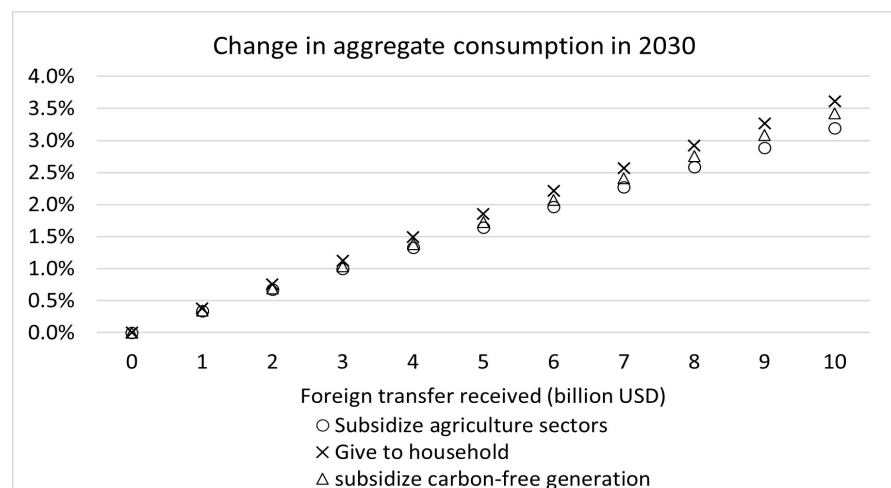


Figure 13. Change in price of foreign exchange.

For each of the two additional scenarios, the aggregate consumption goes up as foreign transfers rise, too, since the representative consumer is also the owner of primary factors (labor, capital, and natural resources) that are used in various production sectors. Subsidies to industrial sectors increase the representative consumer's income for consumption and decrease the relative prices of the subsidized commodities. With that, the increase in aggregate consumption is highest with the lump-sum transfer to household (**Figure 14**), since without restrictions on the usage of transfers, the allocation of primary factors among sectors is most efficient—it is determined purely by profit maximization without being affected by policies favoring some sectors and discriminating against others beforehand.

For these subsidy scenarios, the lower increase in aggregate consumption reflects the new equilibrium prices yield suboptimal resource allocations in welfare maximization, and changes in domestic sales of domestic outputs, imports, and exports are qualitatively similar to those under the lump-sum transfer case. Production resources shift from exports to outputs dedicated for domestic sales, and imports goes up, i.e., the Dutch disease story still holds in these simulations (**Appendix 3**).



**Figure 14.** Change in aggregate consumption under different subsidy usages.

#### 4. Economic Impacts of Climate Change

Choi et al. (2021) find that under the RCP 8.5 scenario, the annual mean web-bulb temperature of Bangladesh may increase from 26.7°C in 2020 to 27.8°C in 2050. Based on this projection, we consider changes in cropland and labor productivities due to a higher temperature. Our cropland productivity impact is from Reilly et al. (2007), which shows that without efforts on emissions mitigation, compared with the 2020 level, cropland productivity may drop by about 18% in 2050 (**Figure 15**).

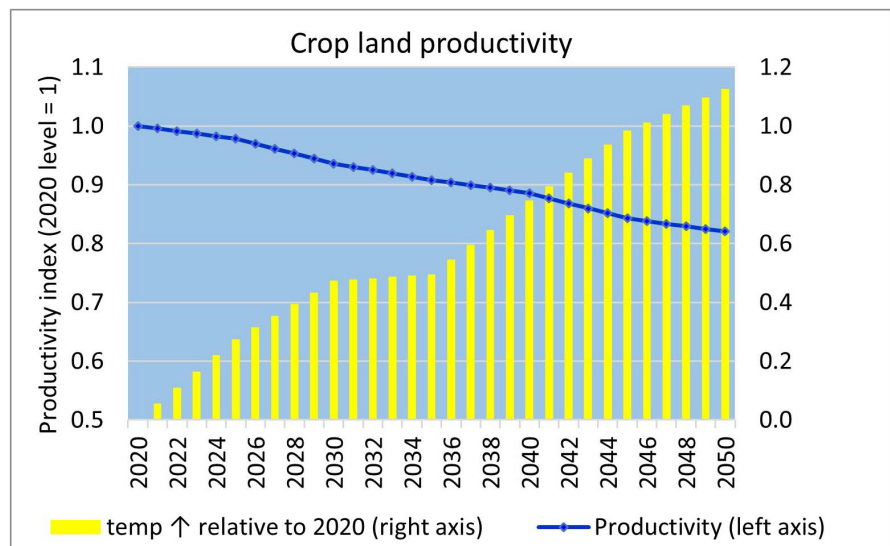
On the other hand, the labor productivity impact is from the literature review of Hsiang (2010) for laboratory evidence obtained from a controlled environment. The review finds that task efficiency reduces by around 1% - 2% per degree Cel-

sius, once the web-bulb temperatures rise above 25°C (Pilcher et al., 2002; Seppänen et al., 2003). According to the review, we assume that the labor productivity will fall by 1.5% per degree Celsius under the same climatic environment (i.e., the condition where the web-bulb temperature is above 25°C). With this consideration, the labor productivity of Bangladesh in 2050 is projected to fall by around 1.7% relative to the 2020 level (Figure 16).

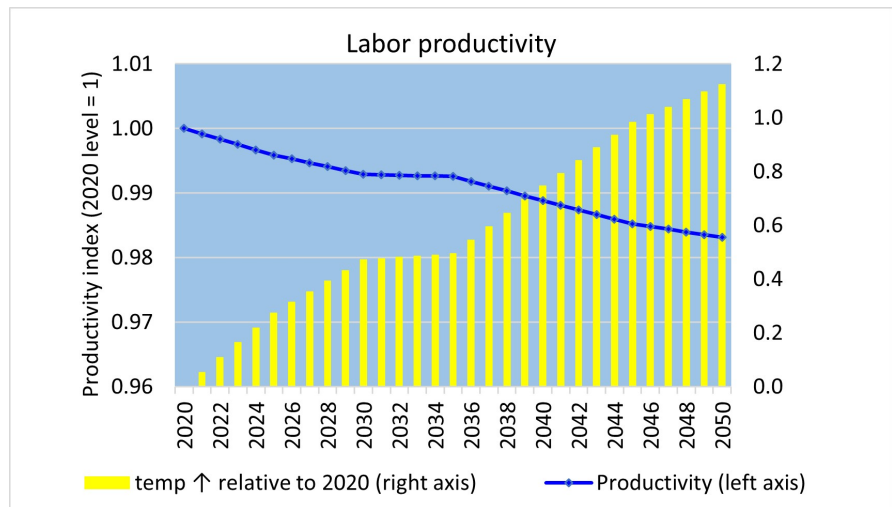
Our simulation shows that the impacts of global warming via the two productivity channels could potentially lower Bangladesh's aggregate consumption by around 0.6% in 2035 and 1.6% in 2050 (Figure 17). To compensate the projected welfare loss during 2020 and 2050, we calculate the sum for the present values of aggregate consumption with a 4% discount rate from 2020 to 2050 under the reference scenario without the productivity impacts, use the sum as the target, and run CSAVE to find a fixed amount of annual foreign transfer in nominal term starting from 2026 up to 2050 to achieve the aggregate consumption target without productivity impacts. Our findings suggest that for Bangladesh, between 2020 and 2050, the present value of welfare loss due to global warming is around 89.8 billion USD (averaged to 2.9 billion USD per year), and begins from 2026 up to 2050, an annual foreign transfer of 2.8 billion USD is needed in compensating the loss. The modeling exercise reveals that in 2050, the price of foreign exchange may increase by around two thirds of the 2017 level, which explains a foreign transfer arrangement with a shorter payment period (25 years instead of 30 years for the economic loss considered) and a somewhat smaller amount is enough for welfare compensation.

## 5. Conclusion

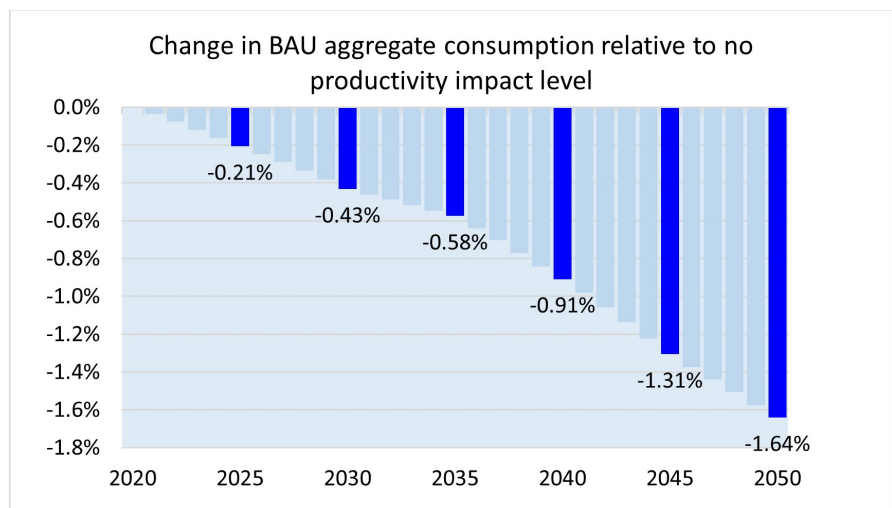
In this paper we present CSAVE, a single-country multi-sector general equilibrium framework with the trade response parameterized based on the behavior of



**Figure 15.** Cropland productivity index with the temperature increase of reference scenario.



**Figure 16.** Labor productivity index with the temperature increase of the reference scenario.



**Figure 17.** Change in aggregate consumption under the reference scenario relative to no productivity impact level.

a multi-regional global CGE. An advantage of our approach is the ability to explicitly model the exchange rate dynamics and explore the impacts of climate financing on a country that receives transfers from international organizations or other foreign sources. Based on the model, we offer an illustrative example of Bangladesh—a country notably vulnerable to climate change, assess the potential impact of receiving a foreign climate transfer on domestic economy, and simulate the welfare loss due to a rising temperature. Our research reveals the potential side effects of contracting the Dutch disease from receiving a large transfer, and calculates the required level of annual transfer for compensating the welfare loss.

Our study demonstrates that when research questions are country-specific, using a single-country model can also provide valuable insights. While the modeling exercises for Bangladesh presented in this paper focus on macroeconomic impli-

cations of climate transfers, the concise framework of CSAVE allows modelers to conduct more detailed or targeted analyses by adopting sectoral resolutions higher than those typically used in many multi-regional global models, without substantially increasing computational costs or the likelihood of numerical challenges.

Future development of a country-level CGE model such as CSAVE can proceed in several directions. For instance, to analyze the distributional impacts of climate transfers, it would be useful to incorporate multiple representative agents and to consider alternative labor market closures that allow for nonemployment<sup>4</sup>. Besides, sector-specific capital structures could be incorporated, such as vintage capital and the dynamics governing its evolution. This would help capture the observed hysteresis in resource allocation following policy changes. Alternatively, low-carbon energy supply options not presented in the base year could be calibrated using engineering data and incorporated into the model. These technologies may become economically viable under certain conditions, thereby providing deeper insights into potential decarbonization pathways.

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## Model and Data Availability Statement

The model developed in this paper is available from the corresponding author upon request. The aggregated GTAP dataset used in the analysis may also be shared, subject to the requester providing proof of a valid license for the GTAP 11 Power database.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

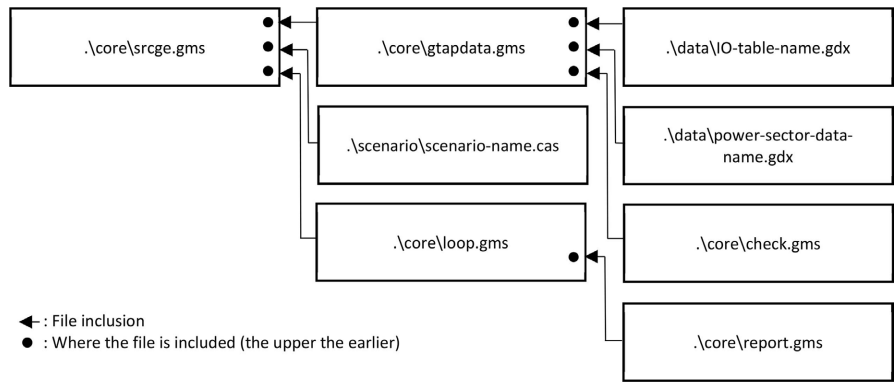
- Aguiar, A., Chepeliev, M., Corong, E., & van der Mensbrugge, D. (2023). The Global Trade Analysis Project (GTAP) Data Base: Version 11. *Journal of Global Economic Analysis*, 7, 1-37. <https://doi.org/10.21642/jgea.070201af>
- Armington, P. S. (1969). A Theory of Demand for Products Distinguished by Place of Production. *Staff Papers-International Monetary Fund*, 16, 159-176. <https://doi.org/10.2307/3866403>
- Arrow, K. J., Chenery, H. B., Minhas, B. S., & Solow, R. M. (1961). Capital-Labor Substitu-

<sup>4</sup>The authors are grateful to an anonymous referee for this valuable insight.

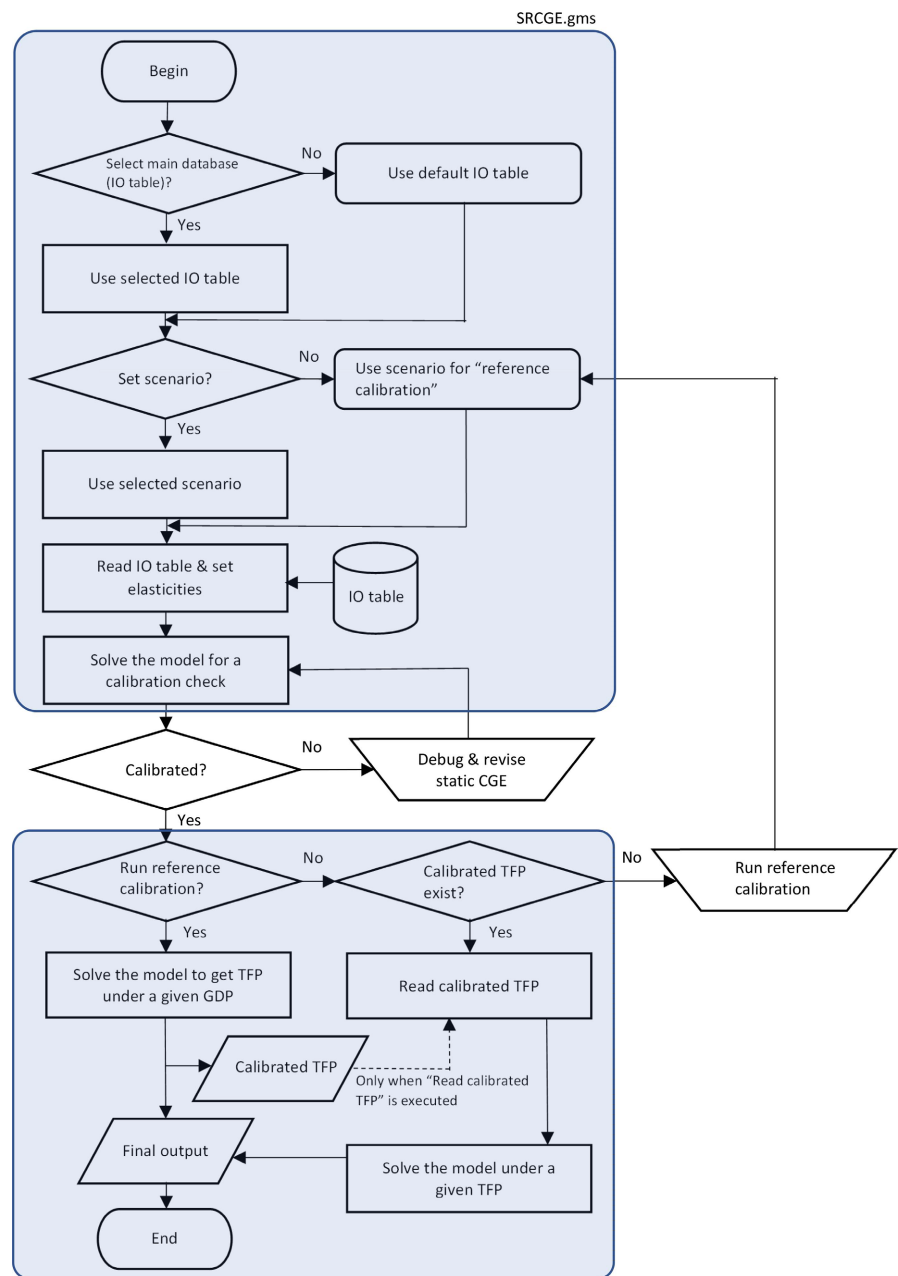
- tion and Economic Efficiency. *The Review of Economics and Statistics*, 43, 225-250. <https://doi.org/10.2307/1927286>
- Balistreri, E. J., McDaniel, C. A., & Wong, E. V. (2003). An Estimation of US Industry-Level Capital-Labor Substitution Elasticities: Support for Cobb-Douglas. *The North American Journal of Economics and Finance*, 14, 343-356. [https://doi.org/10.1016/s1062-9408\(03\)00024-x](https://doi.org/10.1016/s1062-9408(03)00024-x)
- Bussieck, M. R., & Meeraus, A. (2004). General Algebraic Modeling System (GAMS). In J. Kallrath (Eds.), *Applied Optimization* (pp.137-157). Springer. [https://doi.org/10.1007/978-1-4613-0215-5\\_8](https://doi.org/10.1007/978-1-4613-0215-5_8)
- Chen, Y. H., Paltsev, S., Gurgel, A., Reilly, J. M., & Morris, J. (2022). A Multisectoral Dynamic Model for Energy, Economic, and Climate Scenario Analysis. *Low Carbon Economy*, 13, 70-111. <https://doi.org/10.4236/lce.2022.132005>
- Chepeliev, M. (2023). GTAP-Power Data Base: Version 11. *Journal of Global Economic Analysis*, 8, 101-135. <https://doi.org/10.21642/jgea.080203af>
- Choi, Y., Campbell, D. J., Aldridge, J. C., & Eltahir, E. A. B. (2021). Near-Term Regional Climate Change over Bangladesh. *Climate Dynamics*, 57, 3055-3073. <https://doi.org/10.1007/s00382-021-05856-z>
- Cornerstone CGE (2024). *Fundamentals of Computable General Equilibrium (CGE) Modeling. An Online Course Developed by Cornerstone CGE*. The Open University. <https://www.open.edu/openlearncreate/mod/page/view.php?id=214558#:~:text=Learning%20Outcome,total%20investment%20is%20also%20fixed>
- Cossa, P. (2004). *Uncertainty Analysis of the Cost of Climate Policies*. Master of Science Thesis, Massachusetts Institute of Technology.
- Dervis, K., De Melo, J., & Robinson, S. (1982). *General Equilibrium Models for Development Policy*. Cambridge University Press.
- Devaragan, S., Lewis, J. D., & Robinson, S. (1990). Policy Lessons from Trade-Focused, Two-Sector Models. *Journal of Policy Modeling*, 12, 625-657. [https://doi.org/10.1016/0161-8938\(90\)90002-v](https://doi.org/10.1016/0161-8938(90)90002-v)
- Ebrahimzadeh, C. (2025). *Dutch Disease: Wealth Managed Unwisely*. International Monetary Fund. <https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/Dutch-Disease>
- Government of Bangladesh (2022). *National Adaptation Plan of Bangladesh (2023-2050)*. Ministry of Environment, Forest and Climate Change.
- Gurgel, A., Mignone, B. K., Morris, J., Khesghi, H., Mowers, M., Steinberg, D. et al. (2023). Variable Renewable Energy Deployment in Low-Emission Scenarios: The Role of Technology Cost and Value. *Applied Energy*, 344, Article 121119. <https://doi.org/10.1016/j.apenergy.2023.121119>
- Hertel, T. W. (1997). *Global Trade Analysis: Modeling and Applications*. Cambridge University Press. <https://econpapers.repec.org/bookchap/gtagtapbk/7685.htm>
- Hsiang, S. M. (2010). Temperatures and Cyclones Strongly Associated with Economic Production in the Caribbean and Central America. *Proceedings of the National Academy of Sciences*, 107, 15367-15372. <https://doi.org/10.1073/pnas.1009510107>
- IMF (2025). *World Economic Outlook (April 2025)*. [https://www.imf.org/external/datamapper/NGDP\\_RPCH@WEO/BGD?zoom=BGD&highlight=BGD](https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/BGD?zoom=BGD&highlight=BGD)
- IPCC (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate*

- Change* [Core Writing Team, H. Lee and J. Romero (eds.)] (pp. 35-115). IPCC.
- Lanz, B., & Rutherford, T. F. (2016). GTAPinGAMS: Multiregional and Small Open Economy Models. *Journal of Global Economic Analysis*, 1, 1-77.  
<https://doi.org/10.21642/jgea.010201af>
- Mowers, M., Mignone, B. K., & Steinberg, D. C. (2023). Quantifying Value and Representing Competitiveness of Electricity System Technologies in Economic Models. *Applied Energy*, 329, Article 120132. <https://doi.org/10.1016/j.apenergy.2022.120132>
- Paltsev, S., Reilly, J., Jacoby, H., Eckaus, R., McFarland, J., & Babiker, M. (2005). *The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4*. MIT JPSPGC Report 125.
- Pilcher, J. J., Nadler, E., & Busch, C. (2002). Effects of Hot and Cold Temperature Exposure on Performance: A Meta-Analytic Review. *Ergonomics*, 45, 682-698.  
<https://doi.org/10.1080/00140130210158419>
- Powell, A. A., & Gruen, F. H. G. (1968). The Constant Elasticity of Transformation Production Frontier and Linear Supply System. *International Economic Review*, 9, 315-328.  
<https://doi.org/10.2307/2556228>
- Reilly, J., Paltsev, S., Felzer, B., Wang, X., Kicklighter, D., Melillo, J. et al. (2007). Global Economic Effects of Changes in Crops, Pasture, and Forests Due to Changing Climate, Carbon Dioxide, and Ozone. *Energy Policy*, 35, 5370-5383.  
<https://doi.org/10.1016/j.enpol.2006.01.040>
- Rutherford, T. (1998). *GTAPinGAMS: The Dataset and Static Model*. Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP).  
[https://www.gtap.agecon.purdue.edu/resources/res\\_display.asp?RecordID=409](https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=409)
- Rutherford, T. F. (1999). Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax. *Computational Economics*, 14, 1-46. <https://doi.org/10.1023/a:1008655831209>
- Schreiber, A., Marten, A., & Wolverson, A. (2024). Approximating Terms of Trade Effects in Single Country CGE Models. *Journal of Global Economic Analysis*, 9, 70-111.  
<https://doi.org/10.21642/jgea.090202af>
- Seppänen, O., Fisk, W. J., & Faulkner, D. (2003). Cost Benefit Analysis of the Night-Time Ventilative Cooling in Office Building. Lawrence Berkeley National Laboratory. Technical Report LBNL-53191. <https://escholarship.org/uc/item/3j82f642>
- Shephard, R. W. (1970). *Theory of Cost and Production Functions*. Princeton University Press. <http://www.jstor.org/stable/j.ctt13x11vf>
- UNESCWA (2020). Theoretical Development of a Basic CGE Model. Slides Presented for the Workshop *Capacity Building for the Ministry of Finance (MOF) in Tunisia on "Computable General Equilibrium Modelling*.  
<https://www.unescwa.org/events/capacity-building-ministry-finance-mof-tunisia-%E2%80%9Ccomputable-general-equilibrium-modelling%E2%80%9D>
- UNFCCC (2024). *COP29 UN Climate Conference Agrees to Triple Finance to Developing Countries, Protecting Lives and Livelihoods*. UN Climate Change News, UNFCCC.  
<https://unfccc.int/news/cop29-un-climate-conference-agrees-to-triple-finance-to-developing-countries-protecting-lives-and>
- World Bank (2025). *Unemployment, Total (% of Total Labor Force) (Modeled ILO Estimate)—Bangladesh*. World Bank Open Data, The World Bank Group.
- World Economic Forum (2024). *Farmers Must Be Front of the Line for Climate Compensation after COP29. Here's Why*.  
<https://www.weforum.org/stories/2024/11/cop29-agriculture-loss-damage-fund/>

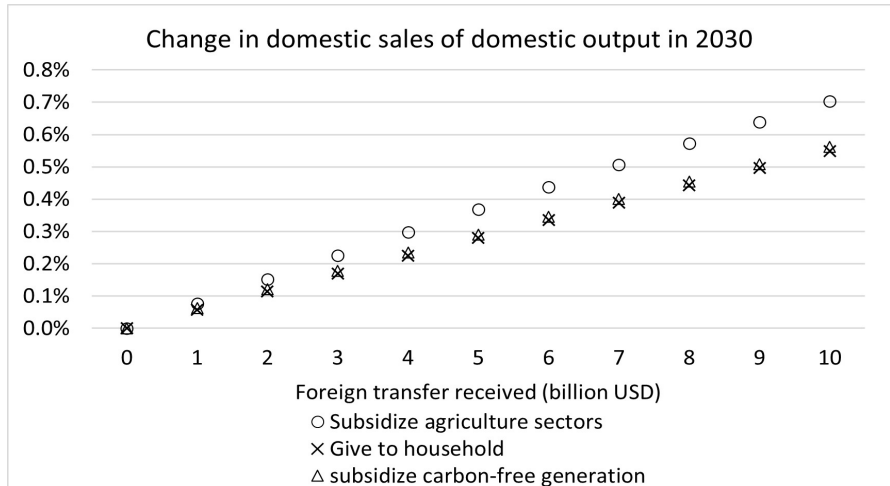
### Appendix 1. File Structure of CSAVE



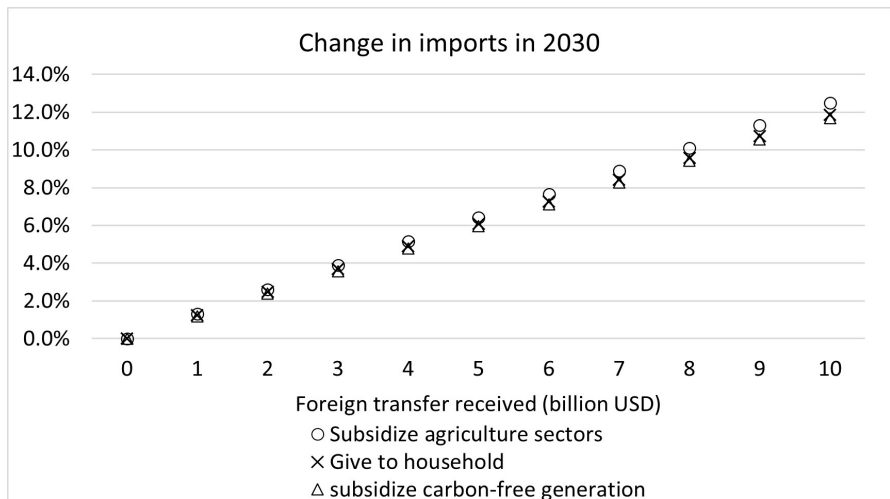
## Appendix 2. Workflow for Running CSAVE



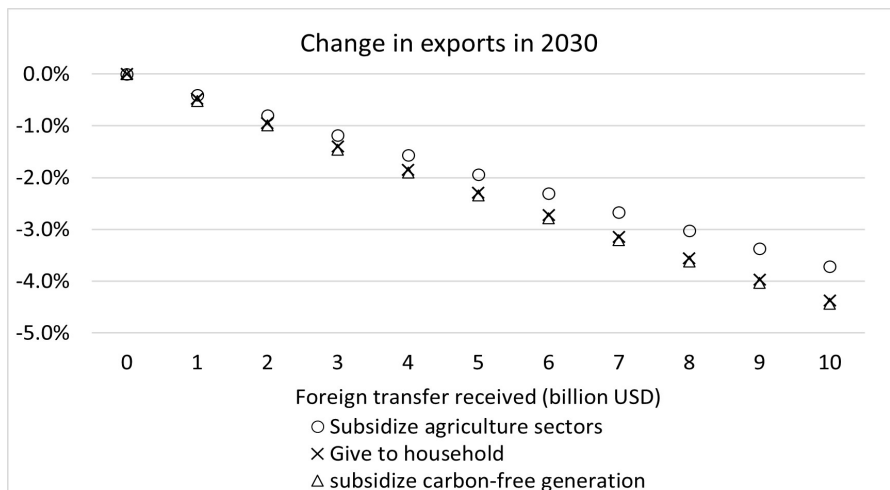
### Appendix 3. Changes in Key Economic Variables under Subsidy Scenarios



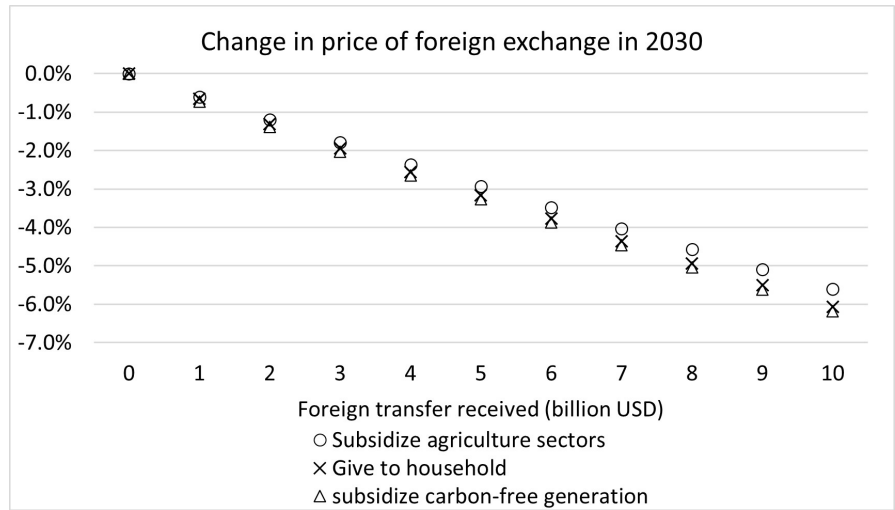
(a) Change in domestic sales of domestic output under different subsidy usages



(b) Change in imports under different subsidy usages



(c) Change in exports under different subsidy usages



(d) Change in price of foreign exchange