An Environmental-Economic Modeling for Climate Change Policy

Keiji Ujikawa[1]

[1] Professor, igsss, YOKOHAMA National University, Yokohama, Kanagawa, Japan.
Email: ujikawa-keiji-wf@ynu.ac.jp Tel: +81-45-339-3538

ABSTRACT

In recent years, countries have set emission reduction targets to address climate change. This study is the first attempt to verify the long-term feasibility of achieving emission reduction targets for multiple greenhouse gases in Japan by sector. This study applies System of Environmental-Economic Accounting (SEEA) data and statistical frameworks and constructs a dynamic computable general equilibrium model. Greenhouse gas and sector-specific emission reduction rates are set based on annual SEEA data. The results indicate that carbon dioxide (CO_2) emissions from manufacturing, business services, and energy transition sectors, as well as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride emissions, are projected to remain below the 2030 emission targets under a balanced growth scenario. If the capital accumulation rate increases, it is possible that emissions from the manufacturing and other service sectors will exceed the emission targets. However, CO_2 emissions from the transportation and household sectors, and methane (CH_4) and dinitrogen monoxide (N_2O) emissions primarily from the agriculture, forestry, and fisheries sectors, are projected to exceed the emission targets if current trends continue. In conclusion, policies need to focus on measures to reduce CO_2 emissions from the transportation and household sectors, which exceed emission targets, and CH_4 and N_2O emissions from the agriculture, forestry, and fisheries sectors. Furthermore, depending on changes in the capital accumulation rate and economic growth, CO_2 emissions from the manufacturing and other sectors may exceed emission targets, indicating that continuous policy measures will be necessary.

KEYWORDS

Environmental-economic modeling, Dynamic model, Computable general equilibrium model, Greenhouse gases, SEEA, SDGs targets

1. INTRODUCTION

Climate change is a significant and complex global problem. A major challenge in addressing climate change is the concrete implementation of the United Nation’s sustainable development goals (SDGs). Recently, there has been increasing interest in the System of Environmental-Economic Accounting (SEEA), a satellite system of the System of National Accounts (SNA) by United Nations et al. (2014). The SEEA has become an international statistical standard for analyzing integrated policies related to climate change, the circular economy, and SDG issues, as well as their interactions with the economy by European Commission et al. (2017). In 2017, the United Nations Statistical Commission approved the SEEA as a supporting framework for applying SDGs to policies.

In May 2016, the Government of Japan established the SDGs Promotion Headquarters, a Cabinet body led by the Prime Minister and composed of all ministers, to ensure a comprehensive and effective implementation of the 2030 Agenda. At the first meeting on the day of its establishment, a decision was made to establish the guiding principles of Japan's SDG implementation. Among these, climate change measures to mitigate global warming are implemented in a comprehensive and structured manner in accordance with the Plan for Global Warming Countermeasures (adopted by the Cabinet in May 2016). Clear numerical indicators were established for Targets 13.2 and 13.3 to reduce greenhouse gas emissions by 26% in fiscal year 2030 relative to fiscal year 2013. The 2016 plan was revised in 2021. Under the revised plan, Japan aims to achieve a 46% reduction in greenhouse gas emissions in fiscal year 2030 compared to fiscal year 2013 by Cabinet Office (2021).

Japan has set climate change SDG targets for greenhouse gases; however, the likelihood of achieving these targets has never been quantitatively verified. This pioneering study aims to quantify the feasibility of SDG targets for various greenhouse gases across sectors in a given target year.

The remainder of this paper is organized as follows. Section 2 provides an overview of the relevant literature and describes the status of Japan's SDG targets for climate change. Section 3 describes the study's methodology and the structure of the computable general equilibrium (CGE) model created through the environmentally extended social accounting matrix (SAM), an application of SEEA. Section 4 describes the official statistics and data, including the air emission accounts used to populate the model. Section 5 presents the results of the dynamic CGE model. Section 6 concludes with a summary and review of the significance of this study.

2. LITERATURE REVIEW

Johansen's (1960) extension of the input–output model is considered the forerunner of the CGE model. The model includes 20 production sectors and 1 household sector with fixed input coefficients, value-added production functions, and a market-clearing condition in the factor market intended for economic forecasting and policy evaluation. Following this, Harberger's (1962) two-sector model and Scarf's (1967) algorithm for computing a Walrasian general equilibrium are regarded as other starting points for CGE modeling. A CGE analysis using the Scarf algorithm was initiated by Shoven and Whalley (1984), two public finance scholars in the field of tax policy evaluation. It has since been applied to a variety of fields, including trade policy, energy policy, and environmental policy.

In the 1990s, a series of CGE models were developed for climate change policy. the GREEN model by Burniaux et al. (1992) for global climate change analysis by the Organisation of Economic Co-operation and Development is one of the most well-known examples. A number of single-country environmental CGE models have also been developed for environmental problems specific to each nation. Most of the single-country environmental

CGE models are regarded as externality CGE models because of the treatment of air pollution problems. For example, for carbon dioxide (CO_2), Jorgenson and Wilcoxen (1993) constructed a dynamic 35-sector model for the United States economy, and Harrison et al. (1997) developed a 117-sector model with static and dynamic models for Denmark. Furthermore, Bergman (1990) initiated a static 7-sector model of the Swedish economy dealing with sulfur dioxide (SO_2), nitrogen oxides (NOx), and CO_2. Alfsen et al. (1996) developed a dynamic 33-sector model with environmental elements such as SO_2, NOx, volatile organic compounds, ozone, carbon monoxide, CO_2, methane (CH_4), and nitrous oxide (N_2O) for Norway. In recent years, Takeda et al. (2021) have constructed a dynamic CGE model in Japan, however their analysis is limited to CO_2 emissions.

Studies have also applied the CGE model to millennium development goal (MDG) targets by Lofgren & Diaz-Bonilla (2006). SDGs, an extension of MDGs, have become an international standard, and analyses of CGE models for SDGs are underway. Related previous studies have also attempted to evaluate SDGs goals with Integrated Economic Environment Modeling (IEEM) based on CGE as Banerjeea et al. (2019). This study aims to verify realistic numerical values for emission reduction potential by applying CGE for policy evaluation, focusing on multiple air pollutants that have not been addressed in the past.

3. METHODS

3.1. Model

This study uses dynamic CGE modeling to analyze the empirical data. The model follows the methodology of Hosoe et al. (2016) but also incorporates environment-related extensions inspired by Banerjee et al. (2019). All markets are perfectly competitive, and all economic agents act as price takers. The following is a list of symbols, endogenous variables, and exogenous variables included in the CGE model used in this paper.

Symbols indicating indices
i, j: goods and firms
h, k: factors
h_mob: mobile factor (labor)
h_imm: immobile factor (capital)
t: time (t = 0, 1, 2, …)

Endogenous variables
$Y_{j,t}$: composite factors (value added)
$F_{h,j,t}$: the h-th factor used by the j-th firm
$X_{i,j,t}$: intermediate input of the i-th good used by the j-th firm
$Z_{j,t}$: gross domestic output of the j-th firm

$X^p_{i,t}$: household consumption of the i-th good
$X^v_{i,t}$: demand for the i-th investment good
$E_{i,t}$: exports of the i-th good
$M_{i,t}$: imports of the i-th good
$Q_{i,t}$: the i-th Armington composite good
$D_{i,t}$: the i-th domestic good
$FF_{h\_mob,t}$: factor endowment

$p^f_{h,j,t}$: price of the h-th factor

$p^y_{j,t}$: price of the j-th composite factor
$p^z_{j,t}$: price of the j-th gross domestic output
$p^q_{i,t}$: price of the i-th Armington's composite good
$p^e_{i,t}$: price of the i-th exported good (local currency)
$p^m_{i,t}$: price of the i-th imported good (local currency)
$p^d_{i,t}$: price of the i-th domestic good
p^k_t: composite investment goods price
ε_t: foreign exchange rate (domestic currency/foreign currency)
S^p_t: private savings
T^d_t: direct tax
$T^z_{j,t}$: production tax on the j-th good
$T^m_{i,t}$: import tariff on the i-th good
$KK_{j,t}$: capital stock
III_t: composite investment
$II_{j,t}$: sectoral investment
CC_t: composite consumption (felicity)
$GHG_{emi,i,t}$: GHG emissions from i-th good
$GHG_{emi,h,t}$: GHG emissions from household
$enceGHG_{emi,i,t}$: GHG emissions per unit i-th good
$enceGHG_{emi,h,t}$: GHG emissions per unit household

Exogenous variables and constants
pop: population growth rate
dep: capital depreciation rate
ror: rate of return of capital
ζ: elasticity parameter for investment allocation

$X^g_{i,t}$: government consumption of the i-th good
S^f_t: foreign savings (foreign currency)

τ_i^z: production tax rate on the j-th good
τ_i^m: import tariff rate on the i-th good
$p_{i,t}^{We}$: price of the i-th exported good (foreign currency)
$p_{i,t}^{Wm}$: price of the i-th imported good (foreign currency)
$exceGHG_{emi,i,t}$: exogenous component of GHG emissions per unit i-th good
$exceGHG_{emi,h,t}$: exogenous component of GHG emissions per unit household

σ_i: elasticity of substitution in the i-th Armington composite good production function
ψ_i: elasticity of transformation in the i-th good transformation function
η_i: parameter defined by the elasticity of substitution
ϕ_i: parameter defined by the elasticity of transformation
$ax_{i,j}$: 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
α_j: share parameter for the i-th good consumption in the composite consumption function
a: scale parameter in composite consumption function
$\beta_{h,j}$: share parameter for the h-th factor used by the j-th firm in the composite factor production function
b_j: scale parameter in the j-th composite factor production function
λ_i: expenditure share of the i-th good in total investment, investment demand share
ι: scale parameter in composite investment production function
ssp: propensity for savings by the private sector
γ_i: scale parameter in the i-th Armington composite good production function
δm_i: input share parameter in the i-th Armington composite good production function
δd_i: input share parameter in the i-th Armington composite good production function
θ_i: scale parameter in the i-th good transformation function
ξe_i: share parameter in the i-th good transformation function
ξd_i: share parameter in the i-th good transformation function
$sfeGHG_{emi,i,t}$: scaling factor for GHG emissions per unit i-th good
$sfeGHG_{emi,h,t}$: scaling factor for GHG emissions per unit household

3.2. Production

In this model, the production process is divided into two stages. In the first stage, capital and labor are used to produce composite production factors (or value added), and in the second stage, these synthetic production factors and intermediate inputs are used to produce domestic production goods. The optimal conditions for profit maximization in the first stage are expressed by Equations 1 and 2, the composite production function and the factor demand function, respectively, both assuming Cobb-Douglas-type technology.

$$\underset{Y_{j,t},F_{h,j,t}}{\text{maximize}}\ \pi^y_{j,t} = p^y_{j,t} Y_{j,t} - \sum_h p^f_{h,t} F_{h,j,t} \qquad \forall j,t$$

subject to

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

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

$$F_{h,j,t} = \frac{\beta_{h,j}}{p^f_{h,j,t}} p^y_{j,t} Y_{j,t} \qquad \forall h,j,t \qquad (2)$$

Furthermore, the optimal conditions for the second stage are shown in Equations 4–6, where Equations 4 and 5 are the intermediate input demand function and composite factor demand function, respectively, assuming Leontief-type technology. Equation 6 represents the unit price of gross output function, which can be obtained by substituting Equations 4 and 5 into the zero profit condition of the second stage and dividing both sides by $Z_{j,t}$.

$$\underset{Z_{j,t},Y_{j,t},X_{i,j,t}}{\text{maximize}}\ \pi^z_{j,t} = p^z_{j,t} Z_{j,t} - (p^y_{j,t} Y_{j,t} + \sum_i p^q_{i,t} X_{i,j,t}) \qquad \forall j,t$$

subject to

$$Z_{j,t} = \min\left(\frac{X_{i,j,t}}{ax_{i,j}}, \frac{Y_{j,t}}{ay_j}\right) \qquad \forall j,t \qquad (3)$$

$$X_{i,j,t} = ax_{i,j} Z_{j,t} \qquad \forall i,j,t \qquad (4)$$

$$Y_{j,t} = ay_j Z_{j,t} \qquad \forall j,t \qquad (5)$$

$$p^z_{j,t} = ay_j p^y_{j,t} + \sum_i ax_{i,j} p^q_{i,t} \qquad \forall j,t \qquad (6)$$

3.3. Institution

In this model, the government imposes a production tax on domestic production at a fixed rate τ^z_j using a specific tax system and an import tariff on imports at a fixed rate τ^m_i using a specific tax system. Equation 7 represents production tax revenue, and Equation 8 represents import tariff revenue. To balance the government's budget constraint, lump sum direct tax revenue is used to offset the difference, and this is represented by Equation 9. Note that government consumption $Xg_{i,t}$ is assumed to be exogenously determined, but this point will be explicitly stated in the subsequent dynamic model section.

$$T^z_{j,t} = \tau^z_j p^z_{j,t} Z_{j,t} \qquad \forall j,t \qquad (7)$$

$$T^m_{i,t} = \tau^m_i p^m_{i,t} M_{i,t} \qquad \forall i,t \qquad (8)$$

$$T^d_t = \sum_i p^q_{i,t} X^g_{i,t} - \sum_i (T^z_{i,t} + T^m_{i,t}) \qquad \forall t \qquad (9)$$

Next, to introduce investment and savings behavior, we assume that savings are determined by the average propensity to save ss^p (Equation 10). The investment demand function (Equation 11) shows the relationship in which fictitious investment entities, which are different from households and the government, accept savings from both domestic and overseas sources and make decisions in accordance with the expenditure ratio λ_i for investment goods. Note that this model deals with exogenous government consumption associated with dynamization, and government savings are not treated endogenously. The dynamic treatment of investment will be discussed in section xxx.

$$S^p_t = ss^p\left(\sum_{h,j} p^f_{h,j,t} F_{h,j,t} - T^d_t\right) \quad \forall t \tag{10}$$

$$X^v_{i,t} = \frac{\lambda_i}{p^q_{i,t}}\left(S^p_t + \varepsilon_t S^f_t\right) \quad \forall i,t \tag{11}$$

Maximize?

$$X^p_{i,t} = \frac{\alpha_i}{p^q_{i,t}}\left(\sum_{h,j} p^f_{h,j,t} FF_{h,j,t} - S^p_t - T^d_t\right) \quad \forall i,t \tag{12}$$

The utility of a representative household depends on its consumption and savings. To maximize utility, a household allocates the income earned from labor and its factors of production to consumption and savings. This household demand function for the i-th good by Cobb-Douglas type is expressed in Equation 12.

3.4. International trade

If a small country engages in international trade, the foreign currency prices of exported and imported goods are fixed for the domestic economy. Therefore, the domestic currency prices of exported and imported goods are expressed using the exchange rate ε_t in Equations 13 and 14. Furthermore, using the foreign currency-denominated international prices of export and import goods, the balance of payments constraints are shown in Equation 15.

$$p^e_{i,t} = \varepsilon_t p^{We}_{i,t} \quad \forall i,t \tag{13}$$

$$p^m_{i,t} = \varepsilon_t p^{Wm}_{i,t} \quad \forall i,t \tag{14}$$

$$\sum_i p^{We}_{i,t} E_{i,t} + S^f_t = \sum_i p^{Wm}_{i,t} M_{i,t} \quad \forall t \tag{15}$$

In line with Armington's (1969) assumption that imported and domestic goods are imperfect substitutes, we first consider the production of composite goods using imported goods and domestic goods in a fixed ratio. The profit maximization problem for firms producing such composite goods can be formulated as follows. The CES-type i-th Armington composite goods production function, demand function for imports, and demand function for domestic goods obtained from the first-order conditions of this optimization problem are shown in Equations 16–18, respectively.

$$\underset{Q_{i,t},M_{i,t},D_{i,t}}{\text{maximize}}\ \pi^q_{i,t} = p^q_{i,t} Q_{i,t} - \left((1+\tau^m_i) p^m_i M_{i,t} + p^d_{i,t} D_{i,t}\right) \quad \forall i,t$$

subject to

$$Q_{i,t} = \gamma_i \left(\delta m_i M_{i,t}^{\eta_i} + \delta d_i D_{i,t}^{\eta_i}\right)^{\frac{1}{\eta_i}} \quad \forall i,t \tag{16}$$

$$Q_{i,t} = \gamma_i \left(\delta m_i M_{i,t}^{\eta_i} + \delta d_i D_{i,t}^{\eta_i}\right)^{\frac{1}{\eta_i}} \quad \forall i,t \tag{16}$$

$$M_{i,t} = \left(\frac{\gamma_i^{\eta_i} \delta m_i p^q_{i,t}}{(1+\tau^m_i) p^m_{i,t}}\right)^{\frac{1}{1-\eta_i}} Q_{i,t} \quad \forall i,t \tag{17}$$

$$D_{i,t} = \left(\frac{\gamma_i^{\eta_i} \delta d_i p^q_{i,t}}{p^d_{i,t}}\right)^{\frac{1}{1-\eta_i}} Q_{i,t} \quad \forall i \tag{18}$$

Assuming that the relationship between export goods and domestic goods is imperfect transformation, the profit maximization problem for companies selling or transforming such goods can be expressed as follows. From the first-order conditions of this optimization problem, in addition to the CET-type gross domestic output disaggregation function, a function for exports and functions for domestic goods are obtained, which are expressed in Equations 19–21.

$$\underset{D_{i,t},E_{i,t},Z_{i,t}}{\text{maximize}}\ \pi^z_{i,t} = \left(p^e_{i,t} E_{i,t} + p^d_{i,t} D_{i,t}\right) - (1+\tau^z_i) p^z_{i,t} Z_{i,t} \quad \forall i,t$$

subject to

$$Z_{i,t} = \theta_i \left(\xi e_i E_{i,t}^{\phi_i} + \xi d_i D_{i,t}^{\phi_i}\right)^{\frac{1}{\phi_i}} \quad \forall i,t \tag{19}$$

$$Z_{i,t} = \theta_i \left(\xi e_i E_{i,t}^{\phi_i} + \xi d_i D_{i,t}^{\phi_i}\right)^{\frac{1}{\phi_i}} \quad \forall i,t \tag{19}$$

$$E_{i,t} = \left(\frac{\theta_i^{\phi_i} \xi e_i (1+\tau^z_i) p^z_{i,t}}{p^e_{i,t}}\right)^{\frac{1}{1-\phi_i}} Z_{i,t} \quad \forall i,t \tag{20}$$

$$D_{i,t} = \left(\frac{\theta_i^{\phi_i} \xi d_i (1+\tau^z_i) p^z_{i,t}}{p^d_{i,t}}\right)^{\frac{1}{1-\phi_i}} Z_{i,t} \quad \forall i,t \tag{21}$$

3.5. Environment

For the environmental module, we follow the climate change model of Banerjee et al. (2019), which is closely related to SEEA. In the following environmental modules, emi refers to emissions of each greenhouse gas originating from production processes and consumption. Equations (22) – (26) show that changes in exogenous emission coefficients by greenhouse gas and by sector affect the emissions of each gas, which in turn affect the levels of intermediate inputs and final consumption.

$$enceGHG_{emi,i,t} = exceGHG_{emi,i,t} sfeGHG_{emi,i,t} \tag{22}$$

$$enceGHG_{emi,h,t} = exceGHG_{emi,h,t} sfeGHG_{emi,h,t} \tag{23}$$

$$GHG_{emi,i,t} = enceGHG_{emi,i,t} \sum_j X_{i,j,t} \tag{24}$$

$$GHG_{emi,h,t} = enceGHG_{emi,h,t} \sum_i X^p_{i,t} \tag{25}$$

caliblation parameters

3.6. Market-clearing conditions and Dynamics

In this section, we introduce several market-clearing conditions. Equation (26) shows the market-clearing condition for Armington composite goods, and Equations (27)–(29) show, in order, the labor market-clearing condition by quantity, the labor market-clearing condition by price, and the capital market-clearing condition. With regard to the supply and demand prices of goods, this model does not require market-clearing conditions for goods prices because the substitution between imported goods and domestic goods and the transformation relationship between exported goods and domestic goods are represented by the CES/CET functions described above.

$$Q_{i,t} = X^p_{i,t} + X^g_{i,t} + X^v_{i,t} + \sum_j X_{i,j,t} \quad \forall i, t \tag{26}$$

$$\sum_j F_{h_{mob},j,t} = FF_{h_{mob},t} \quad \forall h_{mob}, t \tag{27}$$

$$p^f_{h_{mob},j,t} = p^f_{h_{mob},i,t} \quad \forall h_{mob}, j, i, t \tag{28}$$

$$F_{CAP,j,t} = rorKK_{j,t} \quad \forall j, t \tag{29}$$

Furthermore, this model incorporates dynamization through capital accumulation, and Equations (30), (31) and (34) are, in order, the investment goods market-clearing condition, sectoral investment allocation and composite investment production function for treatment of capital. Equations (32) and (33) represent composite consumption goods function (felicity function) and price level (numeraire), respectively.

$$\sum_j II_{j,t} = III_t \quad \forall t \tag{30}$$

$$p^k_t II_{j,t} = \frac{{p^f_{CAP,j,t}}^{\zeta} F_{CAP,j,t}}{\sum_i {p^f_{CAP,j,t}}^{\zeta} F_{CAP,i,t}} (S^p_t + \varepsilon_t S^f_t) \quad \forall j, t \tag{31}$$

$$CC_t = a \prod_i {X^p_{i,t}}^{\alpha_i} \quad \forall t \tag{32}$$

$$PRICE_t = \sum_j p^q_{j,t} \left(\frac{Q^0_{j,t}}{\sum_i Q^0_{i,t}}\right) \quad \forall t \tag{33}$$

$$III_t = \iota \prod_i {X^v_{i,t}}^{\lambda i} \quad \forall t \tag{34}$$

Finally, Equations (35), (36) show the change of mobile factor (labor), capital stock accumulation production function as a function for dynamization. Furthermore, in this model, government consumption by Equations (37) and foreign savings by Equations (38) are given as exogenous variables, and dynamic changes.

$$FF_{h_{mob},t+1} = (1 + pop)FF_{h_{mob},t} \quad \forall h_{mob},\, t \tag{35}$$

$$KK_{j,t+1} = (1 - dep)KK_{j,t} + II_{j,t} \quad \forall j, t \tag{36}$$

$$X^{g}_{i,t+1} = (1 + pop)X^{g}_{i,t} \quad \forall i, t \tag{37}$$

$$S^{f}_{t+1} = (1 + pop)S^{f}_{t} \quad \forall t \tag{38}$$

$$FF_{h_{mob},o} = FF^{00}_{h\_mob} \quad \forall h\_mob \tag{39}$$

$$KK_{j,0} = KK^{00}_{j} \quad \forall j \tag{40}$$

3.7. SAM

When performing simulations using the above model, calibration data are compiled using an SAM. Specifically, the study compiles an environmentally extended SAM consistent with the international SNA and SEEA standards. In this SAM, the basic economic activity and environmental extension parts are described in monetary and physical terms to ensure overall balance. Depending on the model type, an input–output model (product × product) is used for intermediate inputs. Additionally, a greenhouse gas emissions module is incorporated based on the analytical requirement.

4. EMPIRICAL DATA

For the benchmark data, we used official economic statistics for 2020, the most recent year for Japan's national accounts, supply–use tables, and input–output tables from the Economic and Social Research Institute et al. (2021) and the Ministry of Internal Affairs and Communications (2024a, 2024b). Japan's sector classification comprises 108 sectors, which were merged into 51 sectors (4 primary sectors, 19 manufacturing sectors, and 28 service sectors) to align with the classification of air emission accounts.

For the environmental data, air emission accounts were used based on the SNA/SEEA framework. The Economic and Social Research Institute, a part of the Cabinet Office of the Government of Japan, has been researching indicators that reflect the environmental impact of economic activities on gross domestic product from the perspective of decarbonization. We participated as members of a commissioned study conducted by the Economic and Social Research Institute in 2021. The results of the study were published in August 2022 as an estimate of air emissions accounts based on industry classifications, consistent with the Japanese SNA, by the Economic and Social Research Institute et al. (2022).

Air emissions account for estimated greenhouse gas emissions based on the United Nations standards for pollutants with available official data. These pollutants include CO_2,

CH_4, dinitrogen monoxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The latest estimated data for 2020 were used, with industry classifications comprising 51 industrial sectors and 1 household sector, consistent with the economic data in the SNA. 13 sectors?

caliblation parameters

5. EMPIRICAL RESULTS

Japan's SDGs target concerning climate change aims to reduce greenhouse gas emissions by 46% in fiscal year 2030 compared to fiscal year 2013. The plan specifies numerical targets for 2030 based on greenhouse gas emissions and sectors. The targets set for fiscal year 2030 include 345 million t-CO_2 from the industrial sector (including energy conversion), 146 million t-CO_2 from the transportation sector, and 116 million t-CO_2 from commercial and other sectors. Households? Additionally, the targets include 26.7 million t-CO_2 of CH_4, 17.8 million t-CO_2 of N_2O, 14.5 million t-CO_2 of HFCs, 4.2 million t-CO_2 of PFCs, and 2.7 million t-CO_2 of SF_6.

Although Japan has set numerical SDG targets for climate change, quantitative policy measures to achieve these targets have traditionally not been established or analyzed. An environmental CGE scenario analysis, which enables a quantitative analysis, typically uses environmental or carbon tax assumptions that affect all markets and sectors. Japan introduced a global warming tax in 2012, which increased in 2014 and 2016. The current tax rate is 289 Japanese yen per ton of CO_2 emissions, which is considerably low. The effect of the tax is not expected to be significant in the future.

対策　排出係数　資本蓄積　シナリオ　環境効果　経済効果

Figure-X. Dynamic change of CO_2 Emissions (t-CO_2)

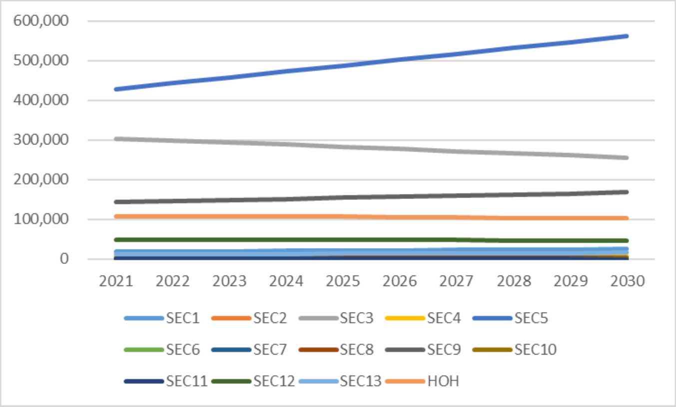


Figure-X. Dynamic change of CH_4 Emissions (t-CO_2)

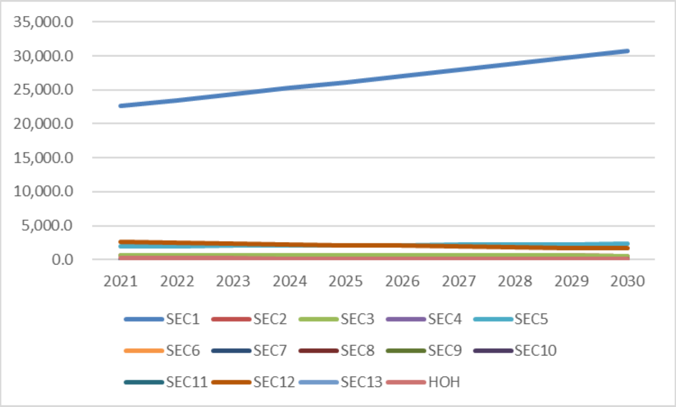


Figure-X. Dynamic change of N_2OEmissions (t-CO_2)

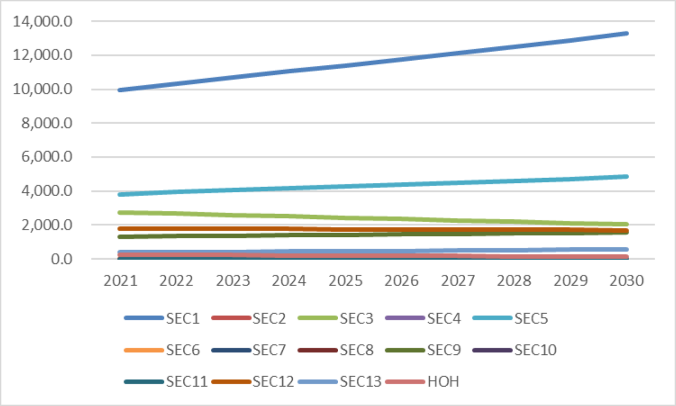


Figure-X. Dynamic change of HFC_s Emissions (t-CO_2)

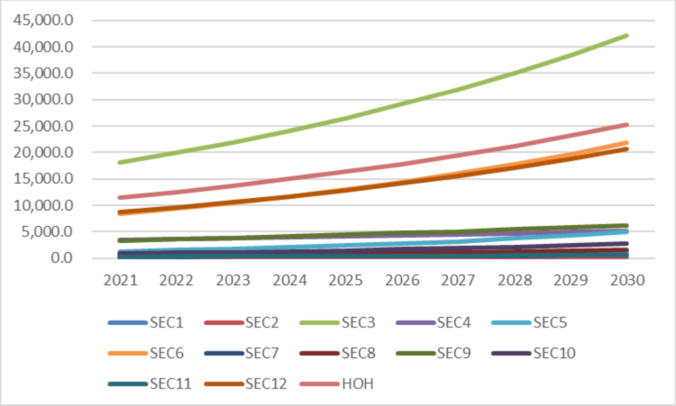


Figure-X. Dynamic change of PFC_s Emissions (t-CO_2)

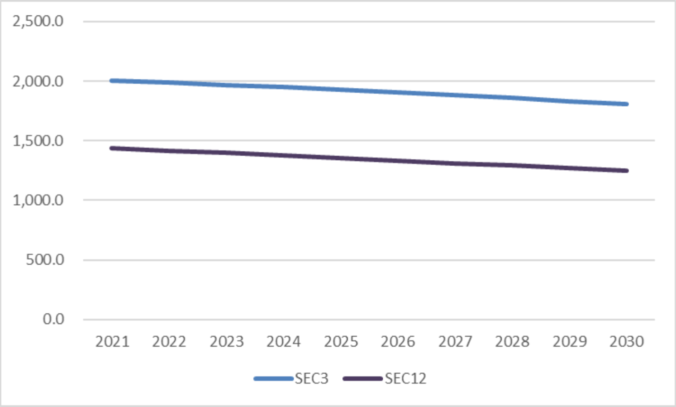
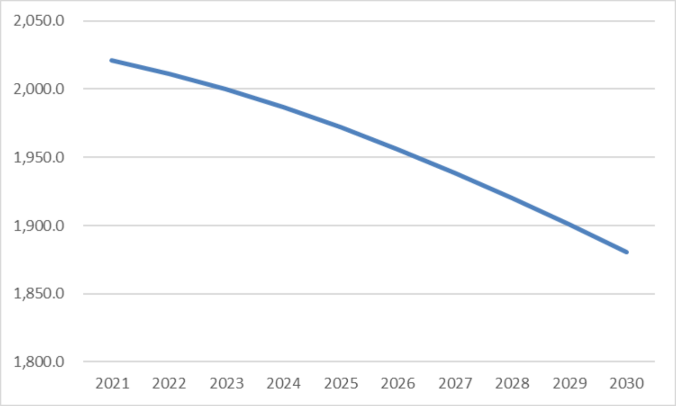


Figure-X. Dynamic change of SF_6 Emissions (SEC3, t-CO_2)



Figures X–X show the long-term changes in emissions through 2030 for the 6 greenhouse gas pollutants covered by the SDGs, assuming that indirect tax rates increase. In addition, while Japan's climate change-related SDG targets are set for CO_2 emissions by sector, this study presents quantitative data for all gas pollutants by sector based on official estimates. Notably, PFCs are emitted only by the industrial, commercial, and other sectors, and SF_6 is emitted only from the industrial sector. In Figures 1 through 6, SEC1 through SEC3 correspond to the industrial sector, transportation sector, and commercial and other sectors, respectively.

Table -X. Change of GHGs by capital stock (2030, t-CO_2)

	CO_2			CH_4			N_2O			HFC_S			PFC_S			SF_6		
	BAU	-25%	+25%	BAU	-25%	+25%	BAU	-25%	+25%	BAU	-25%	+25%	BAU	-25%	+25%	BAU	-25%	+25%
SEC1	24,373.7	21,903.4	26,752.6	30,784.7	27,664.5	33,789.3	13,270.9	11,925.9	14,566.2	1,084.5	974.6	1,190.3	-	-	-	-	-	-
SEC2	1,061.7	945.5	1,174.1	679.7	605.3	751.6	6.1	5.4	6.7	185.5	165.2	205.2	-	-	-	-	-	-
SEC3	254,989.3	231,914.4	276,906.1	565.7	514.5	614.3	2,041.0	1,856.3	2,216.4	42,113.5	38,302.5	45,733.3	1,805.2	1,641.8	1,960.3	1,880.5	1,710.3	2,042.1
SEC4	6,569.9	6,010.3	7,097.2	94.2	86.2	101.8	42.5	38.9	46.0	5,174.5	4,733.8	5,589.8	-	-	-	-	-	-
SEC5	561,196.1	509,898.3	609,952.8	2,305.5	2,094.8	2,505.8	4,833.3	4,391.5	5,253.2	4,984.6	4,528.9	5,417.6	-	-	-	-	-	-
SEC6	2,968.4	2,777.1	3,148.3	0.2	0.2	0.2	71.1	66.5	75.4	21,885.4	20,474.7	23,212.0	-	-	-	-	-	-
SEC7	185.5	168.2	202.5	0.0	0.0	0.0	1.0	0.9	1.1	517.8	469.6	565.2	-	-	-	-	-	-
SEC8	1,928.1	1,639.4	2,223.8	0.1	0.1	0.1	21.4	18.2	24.6	1,510.4	1,284.2	1,742.1	-	-	-	-	-	-
SEC9	167,708.7	157,300.0	177,535.9	102.0	95.7	108.0	1,552.1	1,455.8	1,643.1	6,211.1	5,825.6	6,575.0	-	-	-	-	-	-
SEC10	486.5	440.6	530.9	3.7	3.3	4.0	2.4	2.2	2.6	2,759.9	2,499.3	3,011.5	-	-	-	-	-	-
SEC11	670.3	664.6	676.4	0.0	0.0	0.0	12.2	12.1	12.3	544.7	540.1	549.7	-	-	-	-	-	-
SEC12	45,976.7	43,815.4	48,013.5	1,661.2	1,583.1	1,734.8	1,698.9	1,619.1	1,774.2	20,737.7	19,762.9	21,656.4	1,247.1	1,188.5	1,302.3	-	-	-
SEC13	15,559.8	12,497.8	19,129.8	7.1	5.7	8.7	561.3	450.8	690.1	-	-	-	-	-	-	-	-	-
HOH	101,801.9	92,419.3	111,029.3	157.7	143.2	172.0	131.2	119.1	143.1	25,225.1	22,900.3	27,511.6	-	-	-	-	-	-
Total	1,185,476.8	1,082,394.4	1,284,373.3	36,361.8	32,796.6	39,790.7	24,245.4	21,962.7	26,455.0	132,934.8	122,461.7	142,959.6	3,052.3	2,830.3	3,262.7	1,880.5	1,710.3	2,042.1

The results of the analysis for each pollutant emission in 2030 are presented in the context of numerical targets. Table X-X. First, in terms of changes over time, the energy conversion sector will continue to grow its share, but emissions will remain within targets, while the manufacturing sector will decline, particularly owing to a decline in its share of production. In 2030, CO_2 emissions in the industrial sector (SEC1–SEC4) and energy transmission sector (SEC5) are expected to reach 260.8, 287.9, and 311.9 million t-CO_2, respectively, at 51.0, 56.1, and 61.0 million t-CO_2, respectively, and the target of 289 million t-CO_2 and 56 million t-CO_2. If the capital accumulation rate increases more than the balanced growth rate, there will be an excess of emissions. Furthermore, emissions from the commercial and other sectors (SEC6–8, 10–13) are 62.0, 67.8, and 73.9 t-CO_2, respectively, which will not exceed the target of 116 million t-CO_2. CO_2 emissions in the transportation sector (SEC9), household sector are expected to be 157.3, 167.7, and 177.5 million t-CO_2, respectively, and 92.4, 101.8, and 111.0 million t-CO_2, respectively, which will exceed the target of 146 million t-CO_2 and 70 million t-CO_2.

Subsequently, emissions of CH_4 and N_2O are estimated to be 32.8, 36.3, 39.8 million t-CO_2 and 22.0, 24.2, 26.5 million t-CO_2, respectively, higher than the targets of 26.7 million t-CO_2 and 17.8 million t-CO_2. In terms of changes over time, most emissions for both gas pollutants originate from the agricultural sector (SEC1), contributing 27.7, 30.7, 33.8 million t-CO_2 and 12.0, 13.3, 14.6 million t-CO_2, in 2030, respectively.

For HFCs, the projected emissions for 2030 are estimated at 12.2, 13.3, 14.3 million t-CO_2. Even if the capital accumulation rate increases, emissions will not exceed the emission target of 14.5 million t-CO_2. Over time, emissions from manufacturing, specific service sectors, and households will continue to increase in line with changes in production, but the 2030 emission target is expected to be achieved.

Finally, PFCs and SF_6 are estimated to be 2.8, 3.1, 3.3 million t-CO_2 and 1.7, 1.9, 2.0 million t-CO_2, respectively, both below the numerical targets of 4.2 million t-CO_2 and 2.7 million t-CO_2 emissions. These substances are generated only by manufacturing and certain service industries, but calculations show that they will continue to decrease over time as a result of emission reductions.

6. CONCLUSION

The results of the above analysis suggest that CO_2 emissions originating from manufacturing, energy transmission, commercial and other sectors, HFCs emissions, PFC_S emissions, and SF_6 emissions will decline over time, and that the 2030 targets will be achieved. If the capital accumulation rate increases, CO_2 emissions from the manufacturing, commercial, and other sectors may exceed the targets. However, CO_2 emissions from the transportation and household sectors, particularly CH_4 and N_2O emissions mainly from agriculture, forestry, and fisheries, are expected to fall short of emission reduction targets by the target year even if capital accumulation rates slow down.

Based on the analysis, this study's policy recommendations include the implementation of measures to reduce emissions of these greenhouse gases in the relevant sectors. In addition, it is important to continue to pay attention to CO_2 emissions from the manufacturing and service sectors in accordance with the capital accumulation rate and degree of economic growth.

In this study, we set emission reduction rates based on historical data for greenhouse gases and by sector; however, owing to space limitations, the analysis of the effects of technical measures for each substance and sector will be conducted in a separate paper. Recovery technologies exist for some substances, and it may be possible to specify the effects of these technological innovations on the economy using another model.

The significance of this study lies in its use of SEEA-integrated environmental and economic modeling to test the viability of SDG targets, which are official United Nations indicators. This study examines the feasibility of SDG targets for several greenhouse gases that countries are required to report using data from the SEEA Air Emissions Account, the official national statistics. Moreover, tracking changes in pollutant emissions over time using a dynamic CGE model is crucial to examine emission reduction responses by sector. This study is a pioneering quantitative analysis that evaluates SDG targets using SEEA and applied models, as required by the United Nations member countries.

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