Title: Economic impacts of achieving Korea's mitigation targets: Integrating transportation and power sector's net-zero transition into CGE Model

Jongwoo Moon, Hyungwoo Lim, Jungeun Lee, Hyungsik Choi, Yukyung Yang, Sungjin Kim, Hoon Chang

Keyword:

Computable General Equilibrium, Economic Impacts, Integrated Modeling Framework

Abstract

The study incorporates the national computable general equilibrium (CGE) model in Korea with the detailed transport and power sector models in the KICAT framework to assess the macroeconomic impacts of mitigation pathways of Korea. The CGE model is established based on the 2019 social accounting matrix and extended to separate renewable generation technologies and passenger vehicle types. Based on the information from the recent input-output table and other literature, the study reflects the production structure of internal combustion engine vehicles and electric vehicles. Moreover, the study considers the projections of vehicle purchases and fuel consumption from the transport model through household demand. The study compares the current policy pathway with a 2040 target pathway, which follows Korea's 2030 NDC target and goes further to net zero by 2050. Preliminary results indicate that the 2040 Target pathway reduces the real GDP by about 2.3% in 2040 compared to the Current Policy scenario and increases the carbon price roughly to USD 220.

Korea has been accelerating its national efforts in reducing its greenhouse gas emissions and has been strengthening its ambitious target enough to achieve the net-zero transition by 2050. The country established its enhanced Nationally Determined Contributions (NDCs), which aim to reduce its greenhouse gas emissions by 40% by 2030 from the 2018 emission level. Recently, the government further enhanced its ambition to reduce greenhouse gas emissions by 53~61% by 2035. This transition requires a systematic transformation of the national economy, and all sectors, including power, industry, and transport, need to accelerate their efforts. As a country with emission and energy-intensive industries, such as steel, petrochemical, and semiconductor, understanding the economic impacts of achieving mitigation targets has been an important issue. While the CGE (Computable General Equilibrium) model is widely used to analyze such impacts, it has limitations in incorporating sector-specific characteristics. For instance, the transport sector's emissions are closely related to vehicles' fuel consumption, and the type and number of new vehicles purchased and operating vehicles in the economy will be key drivers. Also, for the power sector, the transition requires considering the stability of the electricity system, which should take into account various techno-economic characteristics of each technology. However, those sectoral aspects or policies are limitedly incorporated into the CGE model, in general. This analysis develops and applies a hybrid-modeling framework, named KICAT (KEI Integrated Climate-Atmospheric model), which incorporates other sectoral model inputs into a national CGE model. The national CGE model in the KICAT modeling framework is built upon the UNICON-K-CGE model.

The KICAT modeling framework includes a national CGE model, power sector model, transport sector model, impact model, and air quality model. This analysis mainly develops and advances the national CGE model to incorporate the key results of the power and transport models to evaluate Korea's long-term decarbonization pathways.

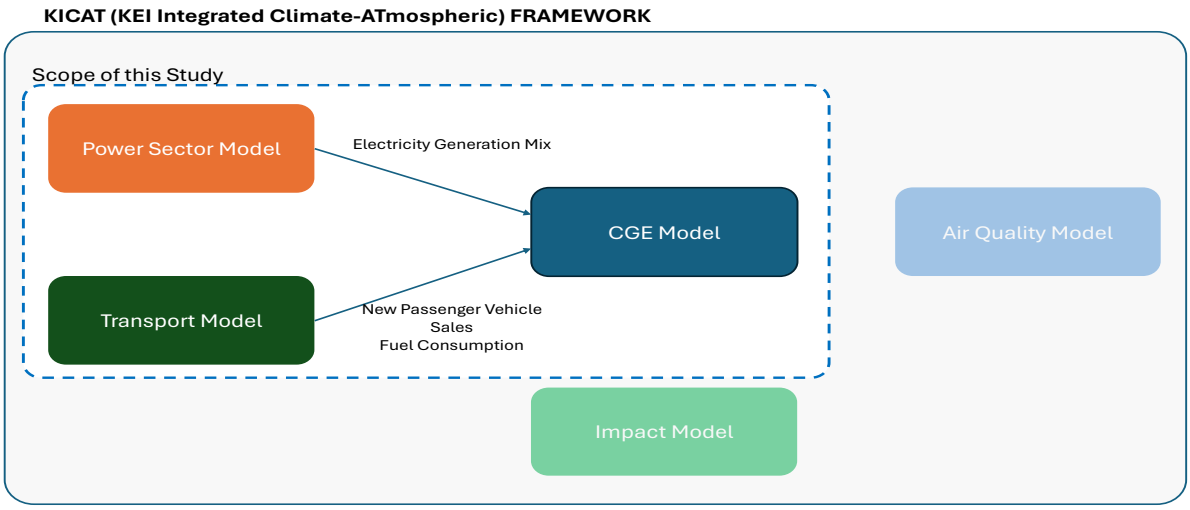

Figure 1. KICAT Framework and the Scope of the Study

The CGE model is established on a 2019 Social Accounting Matrix, constructed from the national 2019 input-output table, with a detailed representation of energy. Production is represented using CES (Constant Elasticity of Substitution) functions, which allow substitution between factors under relative price changes due to policy impacts.

The Basic SAM is built on the 2019 Input-Output table, where renewable technologies are aggregated into a single sector category. Also, this Input-Output table does not disaggregate the internal combustion engine vehicle and the electric vehicle. To link the key outputs of the transport and power sector model results, these should be further disaggregated. To address this, we reviewed the 2020-2022 input-output table, in which new energy (fuel cell, hydrogen, etc.) and renewable energy are more explicitly distinguished. Renewable energy, including solar and wind, shows relatively stable input patterns across years and lacks a fuel-input channel compared to thermal generation. Based on the expert consultation and literature, we further disaggregated solar, wind, and other renewable energy, and assumed their input structure for linkage purposes. Moreover, 2019 IO table represents a single passenger vehicle sector, but 2020 IO separates the internal combustion engine (ICEV) and electric vehicles (EV). Thus, we examined the recent IOs (2020-2022) and assumed the input structure of the electric vehicle sector. The evidence indicates that EV production has a notably different intermediate input composition compared to ICEV, with the battery representing a higher share of inputs alongside auto parts. Since EV types have become diverse after 2021, the analysis calibrates the EV input structure using the latest 2022 IO evidence. To map the transport model's outputs into the CGE model, we decomposed household energy consumption into transport and non-transport components based on the Energy Consumption Survey and the Household Income and

Expenditure Survey. In the base year 2019, those surveys indicate that gasoline is transport-only, city gas and kerosene are non-transport, and electricity, diesel, and LPG are mixed use. For the mixed-use fuel categories, the study used the household income and expenditure survey information to separate those like electricity-transport, electricity-non-transport.

For model linkage, the current structure applies a one-way linkage method. The transport model provides projections for new passenger vehicle purchases by fuel category (gasoline, diesel, LPG, and EV) and fuel consumption by fuel type over time. The current CGE model does not include hydrogen, so the purchase of the hydrogen vehicle and fuel consumption are excluded. These projections are imposed as an exogenous change in household consumption composition in the CGE model. The power sector model determines the electricity generation mix. The CGE model's electricity sector operates in monetary units, so we identified the conversion coefficient that maps the production values in the CGE model to physical generation in the base year and use this coefficient to translate between the two model spaces. The electricity generation mix determined by the power model is integrated exogenously in the CGE model.

For the scenario analysis, the study considers the emission pathways as (1) the current policy and (2) the 2040 Target pathway. The current policy pathway is constructed by extrapolating the recent national emission trends, and it shows that the national GHG emissions decline gradually from the peak in 2018. The 2040 target pathway follows the 2030 NDC trajectory until 2030 and then accelerates toward a net-zero scenario by 2050.

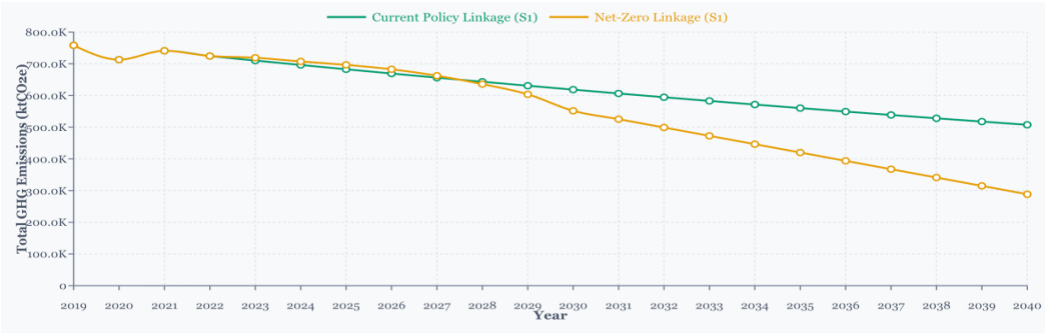

Figure 2. Scenario Emission Pathways (unit: MtCO2eq)

For model consistency, both the CGE and the power model utilize the IEA STEPS scenario's energy price forecast. The preliminary results show that the 2040 Target Pathway reduces real GDP in 2040 by about 2.3% compared to the Current Policy scenario, and the carbon price can increase up to USD 220 in 2040.

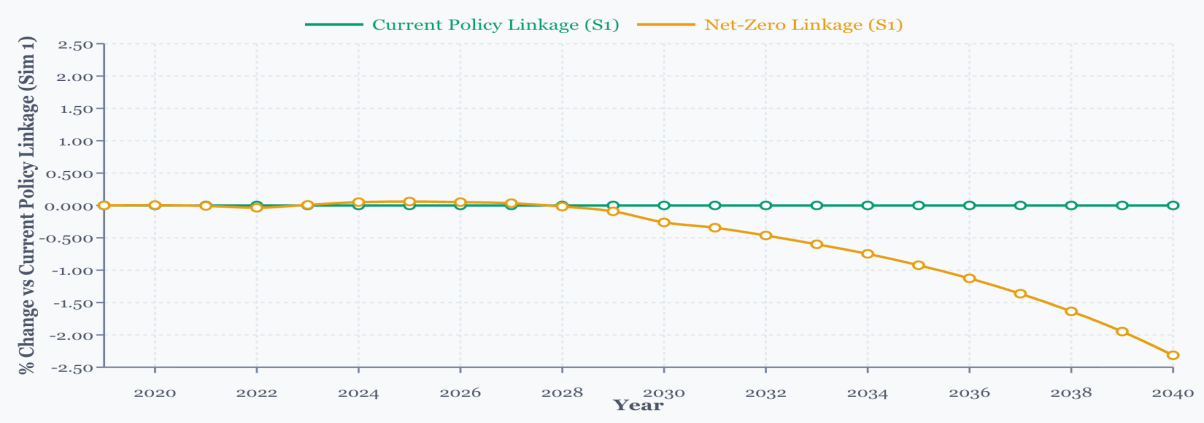

Figure 3. Changes in Real GDP (% relative to BAU)

Acknowledgement

This work was supported by Korea Environment Industry & Technology Institute (KEITI) through "Climate Change R&D Project for New Climate Regime.", funded by Korea Ministry of Environment (MOE) (RS-2022-KE002489).

This work was written following the research work "Development of an Integrated Modeling Framework for Assessing Climate and Air Quality (III)" (RE2025-17), funded by the Korea Environment Institute (KEI)