# *EVALUATING MULTIPLE EMISSION PATHWAYS FOR FIXED CUMULATIVE $CO_2$ EMISSIONS FROM SOCIOECONOMIC PERSPECTIVES*

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## Overview

To avoid dangerous climate change, reducing $CO_2$ emissions is necessary. Previous studies (e.g., Allen et al., 2009; IPCC, 2013; Meinshausen et al., 2009) indicate that cumulative $CO_2$ (or carbon) emissions are a good indicator for the climate stabilization level. This indicator has been used to analyze the relationship between emission reduction in the short term (e.g., 2020 targets) and technological/economic feasibility of achieving the certain climate target in the long term (e.g., 2ºC target; Rogelj et al., 2013). Those studies, however, did not focus on socioeconomic impact of taking different emission pathways for fixed cumulative $CO_2$ emissions, although understanding such impact is important for society since capacity of reducing $CO_2$ emissions might be different by year because of technological feasibility, economic situations, and so on. The purpose of this study is to analyze socioeconomic feasibility and impact to achieve various emission pathways under a constraint that the cumulative $CO_2$ emissions are unchanged.

## Methods

The model used in this study is a multi-regional and multi-sectoral, recursive dynamic, computable general equilibrium (CGE) model with 24 geographical regions each producing 21 types of economic goods/services (Matsumoto and Andriosopoulos, accepted). In the model, electric power can be generated using thermal, hydro, and nuclear, as well as several types of renewable energy. In addition, carbon capture and storage technology is considered for thermal and biomass power generation. Each sector in the economy is represented by a nested constant elasticity of substitution production function. The time period of the simulation analysis is between 2001 (base year) and 2100.

The CGE model is calibrated to reproduce economic and energy activity levels in the base year using the GTAP database for economic activity levels, the International Energy Agency's Energy Balances for energy, and the EDGAR database for greenhouse gas emissions. To make the model dynamic, future gross domestic production (GDP) values for the reference scenario are taken from the Sustainability First scenario in the Global Environmental Outlook 4 of the United Nations Environmental Programme. Future population growth rates are taken from the medium variant of the World Population Prospectsof the United Nations. The rate of energy efficiency improvement is also set exogenous using the SRES B2 scenario (Nakicenovic and Swart, 2000).

The model is constrained to follow the global $CO_2$ emission pathways shown in Figure 1a. The cumulative emissions of these pathways are same during the 21st century. These emission pathways (five emission pathways named s1-s5) are to start declining from the reference level in 2040 and finally attain zero emissions in 2100. The cumulative emissions in the 21st century are 812 GtC, which is similar to the cumulative emissions of the Representative Concentation Pathways 4.5W/m$^2$ scenario in the same period (819 GtC).

## Results

Calculated carbon prices (Figure 1b) indicate that the smaller the emissions, the higher the carbon prices in each year. In 2100 when emission levels are same among the pathways, however, the price of the s1 is slightly higher than the others. It might be due to its larger emission reduction from 2090 to 2100 than the others. The changes in the global GDP (Figure 1c) indicate that the differences among the emission pathways are small. In each year, the smaller the emissions, the larger the impact will be. In 2100, the global GDP for the five emission pathways is between \$206 trillion (s1) and \$208 trillion (s5). In addition, the differences in the cumulative GDP between 2010 and 2100 among the pathways are 1% at most (discount rate = 3%).

The differences in the global primary energy demand among the pathways (Figure 1d) are more noticeable than those in the GDP, but the largest difference in the cumulative primary energy demand among the pathways is about 4%. Similar to the changes in the GDP, the smaller the emissions, the smaller the energy demand will be in each year.

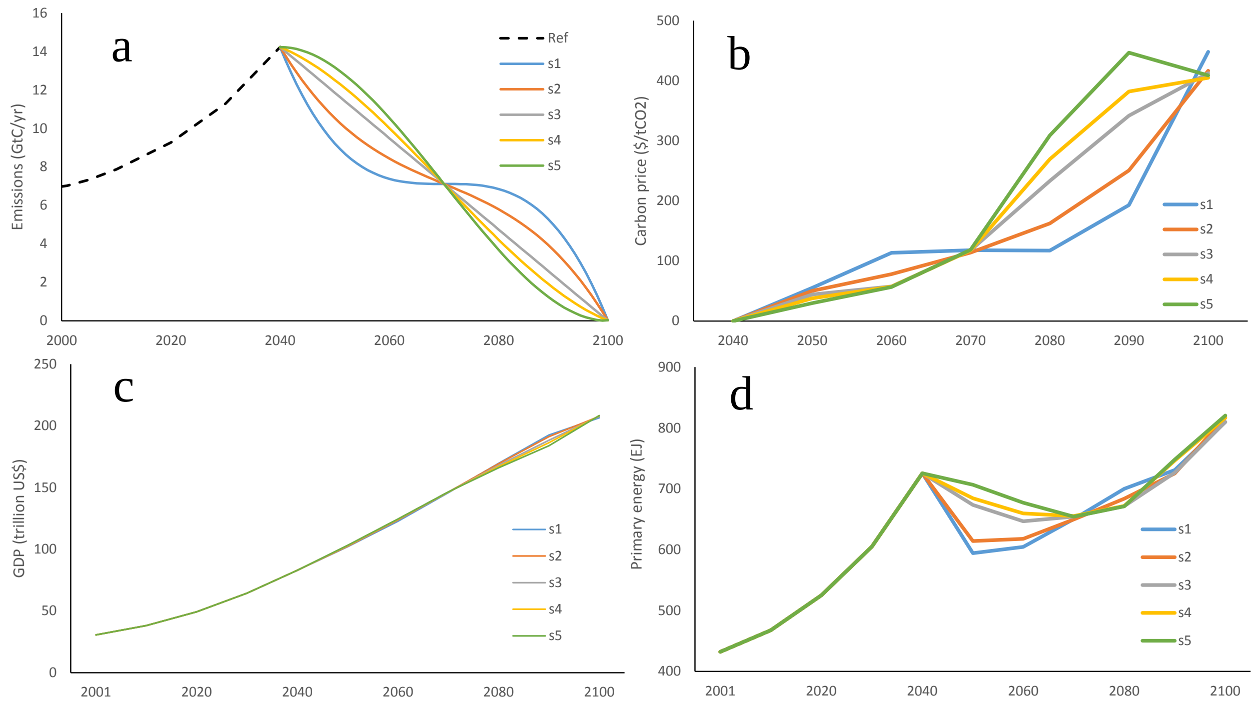


Figure 1 Emission pathways (a), and changes in carbon price (b), global GDP (c), and primary energy (d)

## Conclusions

The results suggest that the differences in the global GDP by emission pathway are relatively smaller than the differences in the emission pathways. It is also found that the impact on the GDP is similar regardless of when emissions are reduced if the cumulative $CO_2$ emission budget in this century is fixed. However, this result might be affected by the choice of the discount rate. The differences in the primary energy demand are larger, but the differences did not seem to affect the GDP significantly.

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