Energy-economy modeling under emission constraints using TIMES-MACRO: The Case of Turkey[1]

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Overview

Turkey's total energy demand is predicted to reach 218 Mtoe by the year 2023 from its current level of 125 Mtoe. Currently, Turkey's primary energy demand is basically met by natural gas (35%), followed by coal (29%), oil (27%), hydro (7%) and other renewable energies. As a result, CO2 emission values are predicted to reach 1540 Mton by the year 2050 from its current value of 400Mton. Therefore, it is important to explore the underlying factors of emission growth in Turkey, and quantify economic impacts of reducing the growth of greenhouse gas emissions.

In today's dynamically changing and energy sensitive environment, there is a need to build a comprehensive energy model and analyze various scenarios, such as new technology adaption and alternative supply options.

Recently, a bottom-up energy modeling system representing 1765 process technologies within the TIMES modeling system has been developed for Turkey. As an extension to this study, the macroeconomic module of TIMES has been utilized linking the energy submodel with an aggregate representation of the macroeconomics by means of a nested CES production function. The integrated energy-economy model TIMES-MACRO is calibrated under a base scenario employing the same resource availability, macroeconomic and technology assumptions as in the stand-alone TIMES case. Afterwards different CO2 emission targets were defined under scenario analyses.

Methods

The MACRO model, which is a general equilibrium model, maximizes the national utility for a single representative producer-consumer. The aim of merging the energy systems model, TIMES, with MACRO is the integrated modeling of macroeconomics impacts within the TIMES outline. The energy demand is covered by the TIMES model which represents the energy sector and annual production is partially used to cover the energy demand's cost. The other part is used for investment and consumption by the consumers.

The equilibrium is determined by maximizing the regional utility and solving the non-linear problem.

After carrying out the TIMES run, TIMES-MACRO goes through a calibration procedure to determine Demand Decoupling Factors (DDF) that links the trends in the economy (represented by GDP) and the demand sectors. This Demand Decoupling Factors (DDF) are used to set the TIMES-MACRO base scenario which matches both the user specified GDP growth rates and the demand levels of each demand category. The DDFs set the demand decoupling factors and reference prices of each demand category, the potential GDP growth rates and the initial energy system cost needed by TIMES-MACRO database. In other words, through the calibration process, demand decoupling

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factors, growth rates and energy costs are generated, which match the projected GDP growth rates and demands of each demand category.

After calibration, policy scenarios (in this study bounds on CO2 emissions) are added and by carrying out "MACRO Policy Runs" results of the various policy options with attention to the new MACRO results parameters are examined.

Results

Results of the base scenario are compared with the results of policy scenarios (different CO2 emission bounds) and differences between various scenarios are analyzed.

And as a result, the impacts of carbon mitigation on GDP, investment and consumption are evaluated. The changes in both final and primary energy mix, changes in technologies, and marginal abatement costs are analyzed. Results indicate significant reduction in coal use, substituted primarily by renewables, under moderate economic loss. For example 30.4% reduction in industrial coal use is observed by 2030 together with a 15.43% increase in renewables and 16.58% increase in natural gas as a result of a 10% reduction in emissions.

Detailed sectoral findings are presented in this study.

Conclusions

This study illustrates how energy demand is supplied and consumed under alternative scenarios, and how emissions and system costs change with respect to the defined scenarios. The results suggest various useful policy implications for an environmentally and economically sustainable development of Turkey and provide long-term prospects for effective and applicable energy policy solutions to foster investment into new technologies. This is particularly important under a carbon-constrained economy as implied by the Intended Nationally Determined Contribution towards the Paris agreement.

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