The Coalition of Finance Ministers for Climate Action

ENVISAGE: a global CGE model covering 160 regions

World Bank

A contribution to the 'Compendium of Practice from a Global Community of Ministries of Finance and Leading Organizations: Economic analysis and modeling tools to assist Ministries of Finance in driving green and resilient transitions'

Topic: Modeling tools relevant to Ministries of Finance

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The Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) model is a global recursive dynamic computable general equilibrium (CGE) model designed to assess the interactions between economies and the global environment. A set of nonlinear behavioral equations is at the core of the ENVISAGE model, representing the production and consumption choices of all key economic agents. The model relies on the Global Trade Analysis Project (GTAP) Data Base, covering 160 regions, of which 141 are individual countries. Global production is divided into 76 sectors, with extensive details for agriculture, food, services, and energy. Due to numerical and algorithmic constraints, the level of disaggregation is typically limited to some 25–30 sectors and 20–25 regions.

The model provides a rich set of economic and environmental indicators, including changes in welfare, GDP, output, producer and consumer prices, exports and imports, value-added by sectors, emissions/carbon prices, energy balances, investments across sectors, tax revenues by types, etc. Greenhouse gas emissions, including CO_2 emissions from fossil-fuel combustion and industrial processes, and non-CO_2 emissions from various economic activities, are represented in the model. The model incorporates a flexible system for any combination of carbon taxes, emission caps, and tradable permits. It includes a climate module that links greenhouse gas emissions to atmospheric concentrations, combined with a carbon cycle that leads to radiative forcing and temperature changes. It is set up to incorporate a feedback loop that links changes in temperature to impacts on economic variables such as agricultural yields or damages created by sea-level rise (parameterization of the corresponding functions is required based on the regional or country-specific data). In addition, emissions of nine air pollutants are reported by the model, which could be further linked to the atmospheric source-receptor models, such as TM5-FASST.

Key strengths

The core strength of the ENVISAGE model is its consistent representation of interdependencies between sectors, agents, and markets within and between economies. By capturing both the supply and demand sides, the model captures adjustments in quantities and prices reacting to policy and other shocks (including climate ones). For instance, if a carbon price is imposed in the model, this leads to increasing energy prices, reducing energy supply and demand, accompanied by structural shifts in the economy—a declining share of energy-intensive sectors and an expansion in low-carbon activities (e.g., light manufacturing and services).

Limitations

While it provides an economy-wide coverage, the model might lack technological and/or spatial granularity available in more refined sectoral models, such as partial equilibrium energy-system models. In this regard, the ENVISAGE model is best suited for "'what-if'" type assessments of the macroeconomic and sectoral implications of the alternative climate policies (e.g., taxes, subsidies, carbon border adjustments, etc.), while a detailed technological analysis (e.g., implications of the energy transition for the electricity transmission networks across sub-regions) might require complementary modeling tools.

Relevance to Ministries of Finance

The ENVISAGE model is designed to analyze a variety of issues related to the economics of climate change to help design climate and macrofiscal policies:

- An assessment of the baseline emissions (CO_2, non-CO_2 greenhouse gas and air pollutant emissions) under business-as-usual scenario and various mitigation scenarios
- The impacts of climate change on the economy, including on sectoral output, international trade, and GDP, as well as adaptation by economic agents to climate change
- Greenhouse gas mitigation policies (taxes, caps and trade, border adjustment taxes)
- Different revenue recycling policy options for carbon taxes and/or other policy instruments (e.g., excise duties)

- Various industrial policies to support green transition (e.g., subsidies to renewable generation, fossil fuel subsidies reform).

The ENVISAGE model can help MoFs understand the implications of the above scenarios for GDP, Government balances, price change, wages, sectoral employment, and international trade/global value chains.

Key policy/analytical questions addressed

The tool can be used to assess the economy-wide implications of carbon pricing and other mitigation policies, carbon border adjustment measures, and industrial policies to develop specific industries and facilitate the green transition. It can also be used to assess the impacts of climate change on the economy through damage functions and evaluate different adaptation options. Various global and regional collaboration scenarios can be implemented in the model, e.g., regions achieve emissions reduction requirements through regional action, i.e., regionally uniform CO_2 prices, club trading with a number of countries linked through the ETS, etc. The ETS or sectoral focus of emission reduction can be adjusted as needed.

Use in practice

The detailed and up-to-date model documentation and the user manual are available via the GTAP-HUB.[1] The model is coded in the GAMS language, which requires a corresponding license in order to use the tool. In addition, users will require a subscription to the GTAP Data Base.[2]

Lessons and challenges:

- For its data, ENVISAGE relies on the GTAP Data Base, which covers 160 countries/regions. Some input-output (IO) tables are somewhat dated, and some inconsistency with national trade or fiscal statistics might occur.
- The data on emissions is not always based on country-specific data and sometimes relies on technologies deployed in other countries.

Future work

Ongoing data and model improvements include the incorporation of the non-CO_2 greenhouse gas marginal abatement cost curves into the model (e.g., representing costs of methane and nitrous oxide emission reductions across countries and sectors); the incorporation of the critical mineral value chains into the underlying database (e.g., mining, refining, and use of selected critical minerals in such applications as solar panels, wind turbines, and batteries for electric vehicles and electricity storage, etc.); the incorporation of additional technological details into the modeling framework (e.g., hydrogen, carbon capture and storage); a detailed representation of the abatement opportunities in the livestock sector and in food loss and waste management practices.

Analysis in action

The ENVISAGE model has been used in various World Bank reports and publications focusing on the trade and climate change nexus (see, for example, Brenton and Chemutai, 2021), a forthcoming report on trade and the climate emergency (Aldaz-Carroll et al., forthcoming) and inputs to CCDRs (e.g., for Brazil, Cambodia, China, Egypt, India, Morocco, Peru, the Philippines, South Africa, Tunisia, Türkiye, and Vietnam). Vietnam has published trade and climate analysis further to the CCDRs (World Bank, 2022a). Egypt, Türkiye, and Tunisia are due to include trade and climate analysis in their upcoming CCDR publications.

Recent examples of model applications include the analysis of climate policies in Azerbaijan (World Bank, 2023), an assessment of the circular economy transition in Europe (World Bank, 2022b), an

1 https://mygeohub.org/groups/gtap/envisage-docs
2 https://www.gtap.agecon.purdue.edu/databases/default.asp

analysis of the implications of greening global construction value chains (IFC, 2023), an assessment of the climate mitigation policies on stranded fossil fuel assets (World Bank, 2021), and an analysis of the EU climate mitigation policies (Jiaqian et al., 2020).

Conclusions

The ENVISAGE model is best suited for "'what-if'" type assessments of the macroeconomic and sectoral implications of the alternative climate policies (e.g., taxes, subsidies, carbon border adjustments, climate impact, carbon prices, etc.). The underlying database and model are undergoing continuous improvements and developments, with the most recent work focusing on the incorporation of critical mineral value chains within the developed framework.

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