Mitigating rebound effects: A CGE model analysis of sustainable consumption and production

Topic: CGE and Econometric Input-output Modelling (3)
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The 12th Sustainable Development Goal of the United Nations, "Ensure sustainable consumption and production patterns," promotes combining eco-efficiency in production with consumer efficiency in consumption. Producers can reduce production-driven greenhouse gas (GHG) emissions by enhancing technological efficiency. Consumers can either decrease overall consumption or shift their consumption patterns towards products with lower GHG emissions. However, these actions often lead to the reallocation of resources to other goods and services or to savings, potentially triggering rebound effects (RE). RE can arise from efficiency improvements or changes in consumption patterns that reduce the cost of goods or services, leading to increased demand. There are three main types of RE: direct (re-spending on the same good or service), indirect (re-spending on other goods and services), and macroeconomic (distribution of effects throughout the economy).

Computable General Equilibrium (CGE) models, which account for inter-industry interactions, are widely used for energy and climate policy assessments. These models simulate changes in industry prices and quantities due to policy shocks by including general equilibrium effects. They can incorporate more complex behavioural equations of economic agents than approaches using fixed coefficients, like input-output analysis (IOA). When equipped with energy and environmental information, CGE models allow tracking general equilibrium and inter-industry effects for estimating carbon and energy RE from technological efficiency improvements and shifts in consumption patterns. Previous studies on assessing carbon and energy RE using CGE models often focus on either production or consumption patterns, failing to capture the dual perspective offered by combining both measures. Additionally, previous studies are limited to analysing specific behavioural actions rather than lifestyle changes and provide limited evidence on measures to offset RE.

This study aims to comprehensively evaluate the efficacy of changes in production and consumption patterns in mitigating climate change, considering RE while maintaining economic stability. A recursive-dynamic CGE model tailored to the Belgian economy is developed to estimate economy-wide energy and carbon RE for various scenarios. Economic instruments, such as carbon taxes needed to counteract the triggered RE, are assessed.

The model integrates 65 economic sectors and commodities, linking economic flows with energy use and carbon emissions through an energy-environmental module. A social accounting matrix constructed from input-output tables and national statistics is used to calibrate the model, providing the foundation for modelling economic interactions among firms, households, government, and foreign trade. Production functions employ a nested constant elasticity substitution structure, where value added, energy, and non-energy inputs are aggregated to represent sectoral outputs. The energy module incorporates data on fossil fuel consumption, electricity use, and renewable energy shares from Belgian statistics and the Belgian energy balance, projecting their growth trajectories. Carbon emissions are estimated through coefficients calibrated with data from the Belgian air emission accounts. Simulations span a 20-year period, capturing the dynamic and long-term impacts of policy strategies. For each scenario, the model quantifies RE by comparing expected energy and emissions reductions from partial equilibrium analysis with general equilibrium outcomes.

The first set of production-based scenarios considers energy efficiency improvements across energy and non-energy sectors. The second set of scenarios pertains to shifts in spending among commodities, distinguishing shifts among main consumption baskets, from energy to non-energy consumption and savings, from energy to individual non-energy commodities, and from individual energy commodities to other types of energy.

Results show the effects of each scenario on GDP, energy use, CO2 emissions, and labour, revealing the performance of production- vs. consumption-based measures and their total effect on the economy. Furthermore, results unveil the magnitude of RE induced by each scenario, explain how RE varies across scenarios, and examine how much a carbon tax could counteract the carbon RE. These findings provide valuable insights for policymakers on effective strategies that integrate production- and consumption-based measures with economic instruments, such as carbon taxes, to mitigate climate change without compromising economic stability. They underscore the necessity for multifaceted approaches that balance production and consumption measures alongside economic instruments to annihilate RE and achieve optimal performance.