THE REBOUND EFFECT ON TRANSPORTATION SECTOR IN CHINA: A CGE ANALYSIS

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Overview

The objective of this study is to analyze the energy rebound effect from increased energy efficiency of transportation sector in China. A series of micro- and macroeconomic effects caused by energy efficiency improvement in transportation sector might hamper the positive effect on theoretical energy savings. We use a computable general equilibrium (CGE) model to evaluate the size of rebound effect and the impact on economic growth and sectoral performance in China. The findings show that the energy efficiency improved by 10% in each transportation sub-sector (i.e. rail, road, urban public transport, water, air transport sectors) induces an energy rebound effect and its magnitude is heterogeneous among different transport modes. Especially in air transport sector, there is a backfire effect because of the sharp increase of air transport service demand used for export. To offset positive energy rebound effect, some accompanying measures such as price mechanism adjustment (e.g. carbon tax) are necessary for air transport sector when its energy efficiency improves. While energy efficiency improves in the rail and road transport sectors, the energy consumption of the whole economy decreases, indicating a super-conservation effect on the whole economy despite of a positive energy rebound effect in rail and road transport sectors. Furthermore, the energy efficiency improvement in transportation sector promotes China’s economic growth and carbon reductions to some extent.

Methods

A static CGE model is developed in this study and the model includes 14 sectors. The purpose of this study is to explore the impacts of exogenous energy efficiency disturbance in transportation sector on all agents in the economy, thus we separated the transportation sector into five sub-sectors (i.e. rail transport, road transport, urban public transport, water transport, air transport). Fig. 1 shows the multi-level nested production structure of each sector in the economy. We divided the intermediate inputs into transportation and non-transportation and the top layer of the production structure comprise the transportation composite, non-transportation and the composite primary inputs (including labor, capital, and energy) using the Leontief production function. Other layers all adopt a constant elasticity of substitution (CES) function (Guo et al. 2014; Solaymani and Kari, 2014).

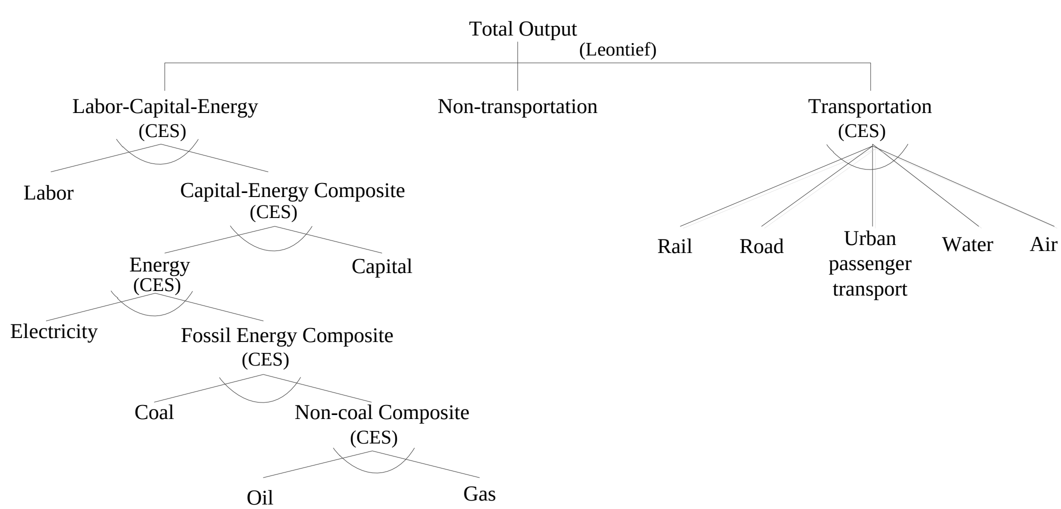

Figure. 1 the nested production structure

Results

Table 1 shows the energy rebound effect at macro level and production level. Obviously, there is large disparities of rebound effect caused by energy efficiency improvement in different transport service sectors. At macro level, the energy efficiency improvement in rail and road transport service sectors cause a negative rebound effect which called super-conservation effect. That is the energy saving of the whole economy caused by energy efficiency improvement in rail and road sectors exceeds the theoretical level. While the economy-wide rebound effects caused by other three transport service sectors are positive. That indicate the energy efficiency improvement in those three sectors cannot achieve theoretical energy saving level. It’s worth noting that there is a backfire effect at macro level when energy efficiency increases by 10% in air transport service sector, indicating that efficiency improvement increases energy use by 32%, rather than reduces it. At production level, there is a positive own-sector rebound effect in all transport service sectors when their energy efficiency improves. Especially in air transport service sector, its own-sector energy rebound effect is 154.52% meaning that energy efficiency improvement does not play its effectiveness on energy saving. However, the energy efficiency improvement in one transport service sector reduces total energy use of other sectors in the whole economy. The lower efficiency-induced price of unit transport service in epicenter sector makes people use it more to substitute for other expensive transport service, which reduces the energy use by other transport service sectors. Furthermore, the decreased energy demands form transport service sectors lower the output of energy related sectors which also reduces their energy use in the production progress. At consumption level, the total energy use decreases compared to the baseline but the energy use by households increases that mainly contribute to the increased demands for all commodities including energy by households due to their enhanced real purchasing power.

Table 1

Rebound effect and its decomposition from 10% energy efficiency improvement in each transport service sectors in China (%)

Simulation results	Scenario 1 Rail transport	Scenario 2 Road transport	Scenario 3 Urban public transport	Scenario 4 Water transport	Scenario 5 Air transport
Economy-wide rebound effect	-9.78	-1.88	0.85	33.23	131.17
Production side					
Production rebound effect	-7.94	0.27	2.97	35.48	133.38
Own-sector rebound effect	40.69	38.78	49.31	68.68	154.52
$\Delta E_{OP}/\gamma E_i$	-48.63	-38.51	-46.34	-33.20	-21.14
Consumption side					
$\Delta E_C/\gamma E_i$	-1.85	-2.16	-2.11	-2.25	-2.21
$\Delta E_H/\gamma E_i$	1.33	1.05	0.32	1.49	1.08
$\Delta E_I/\gamma E_i$	-1.10	-0.88	-0.34	-1.55	-1.62
$\Delta E_X/\gamma E_i$	-2.08	-2.33	-2.09	-2.18	-1.67

Conclusions

In this study, the we improved energy efficiency by 10% in five transport service sectors respectively and the results summarized as follows. First, the energy efficiency improvement in transportation sector promotes China’s economic growth to some extent. This measure increases the GDP, investment and social welfare, and decreases the CO2 emissions of the whole economy. Furthermore, there is an energy rebound effect in transportation sector when its energy efficiency improves, but the magnitude of rebound effects is heterogeneous among different transport modes. Second, when energy efficiency improves in the rail and road transport service sectors, the energy consumption of the whole economy decreases, indicating a super-conservation effect on the whole economy despite of a positive energy rebound effect in rail and road transport sectors. Particularly in rail transport sector, there is a large energy saving effect of the whole economy caused by the energy efficiency improvement of rail sector. With rapid development high-speed rail in China, rail sector gradually reduces the dependence on fossil fuel and transits to low carbon development. It is worth noting that high-speed rail mainly depends on electricity for getting power and the electricity production in China is dominated by coal-fired thermal power. To prevent spillover effect of carbon emissions, the rail sector should adopt more clean electricity to avoid the increase of carbon emissions in electric producing sectors. Third, improving energy efficiency in water and air transport sectors induce a positive economy-wide rebound effect. Particularly in air transport sector, there is a backfire effect because of the sharp increase of air transport service used for export. Compared with water and air transport sectors, the energy efficiency improvement of urban public transport sector induces a small rebound effect on the energy consumption of the whole economy. Simultaneously energy efficiency improvement in urban public transport sector stimulates the growth of demand for urban public transport service by households.