A comprehensive, partial equilibrium energy rebound analysis framework

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Abstract

Widespread implementation of energy efficiency measures is an important global strategy to meet Paris greenhouse gas emissions reduction targets. However, energy rebound can "take back" efficiency-based energy reductions via behavior changes and economic effects. If rebound effects are larger than typically assumed, efficiency-based efforts to reduce carbon emissions will be less effective than supposed. Therefore, the investigation of rebound effects is a high priority. An operationalized rebound analysis framework is needed to study energy efficiency upgrades for specific energy conversion devices, one that discriminates among all rebound effects in energy, expenditure, and consumption spaces with a detailed model of consumer responses for non-marginal energy efficiency changes. In response, we develop a comprehensive, partial equilibrium rebound analysis framework to describe direct and indirect locations for emplacement, substitution, and income rebound effects. We utilize a macro factor to link microeconomic to macroeconomic rebound scales. A sequence of novel graphs shows rebound paths through energy, expenditure, and consumption spaces. The framework is applied to two case studies: upgrades of a car and an electric lamp. After calibrating the macro factor, we find total rebound of 48% and 80% for the car and lamp examples, respectively. Sensitivity studies are performed, showing the effects of energy efficiency, capital cost, energy price, energy service price elasticity of energy demand, and the macro factor on rebound components. Implications of rebound for three common energy policies are considered: energy efficiency standards, rebates or subsidies, and carbon pricing or energy taxes.

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