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THE REBOUND EFFECT: MICROECONOMIC DEFINITIONS, LIMITATIONS AND EXTENSIONS

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Overview

The rebound effect results in part from an increased consumption of energy services following an improvement in the technical efficiency of delivering those services. This increased consumption may offset the energy savings that may otherwise be achieved and potentially undermine the rationale for policy measures to encourage energy efficiency.

The nature, definition and magnitude of the rebound effect are the focus of long-running disputes with energy economics. This paper brings together previous theoretical work to provide a rigorous definition of the rebound effect, clarify key conceptual issues and highlight the consequences of various assumptions for empirical estimation of the effect. The focus is on the direct rebound effect for a single energy service; since this definition has been used for approaching indirect and economy-wide rebound effects, which are not discussed here.

Beginning with Khazzoom's (1980) original definition of the rebound effect, we expose the limitations of three simplifying assumptions, on which this definition is based. First, we argue that potentially capital costs form an important part of the total cost of providing energy services and will limit the magnitude of the rebound effect in many instances. Second, we argue that energy efficiency should be treated as endogenous, since higher energy prices induce the innovation and adoption of more energy efficient technologies. Third, we explore the implications of opportunity costs of time and highlight the consequences for energy consumption of increasing 'time efficiency' that frequently requires more energy. These three modifications lead to a more general version of the 'Khazzoom equation', of which the original formulation can be considered a special case. This formulation identifies some of the factors that need to be controlled for in order to obtain a less biased estimate of the magnitude of the rebound effect. We discuss the implications of these findings for econometric studies and argue that several existing empirical studies may overestimate the magnitude of the effect.

Methods and Results

Our approach is to develop and extend an equation originally introduced by Khazzoom (1980). This relates the elasticity of energy demand (*E*) with respect to energy efficiency (ε) to the elasticity of energy service demand (*S*) with respect to the total cost of the energy service (P_S):

$$\eta_{\varepsilon}(E) = -\eta_{P_S}(S) - 1$$

The efficiency elasticity of energy demand ($\eta_{\varepsilon}(E)$) is a direct measure of the rebound effect, but it is difficult to isolate empirically. Hence, some empirical studies estimate the rebound effect *indirectly* from estimates of the own price elasticity of energy service demand ($\eta_{P_S}(S)$). However, most relevant empirical studies use the own price elasticity of energy demand ($\eta_{P_E}(E)$) in place of the own price elasticity of demand for a composite energy service ($\eta_{P_S}(S)$). We argue that such approaches can lead to significant bias because they fail to take into account other determinants of energy service demand.

Our first extension of the equation follows Henly *et al.* (1988) in including capital costs in the total cost of energy services (P_S). In the (typical) circumstance where energy efficient equipment is more expensive, we show that the magnitude of the rebound effect is reduced.

Our second modification follows Small & VanDender (2005) in treating energy efficiency as endogenous. We argue that periods of increased energy prices can trigger 'irreversible' energy efficiency improvements and thereby reduce, with a hysteresis, energy demand. Ceteris paribus, energy demand will not reverse even when energy prices return to pre-hike levels. Estimates of the rebound effect that do not account for the effect of prices on energy efficiency, will not be consistent because energy demand will not respond symmetrically to changes in prices and efficiency. We show that rebound definitions need to account efficiency as endogenous, corrected if needed, for mandated efficiency during model specification.

Our final modification follows Becker (1965), Binswanger (2001) and other authors in considering the importance of time costs and time scarcity. With the increasing opportunity cost of time in industrial societies (relative to energy costs), there is a strong incentive to improve the efficiency of time use through technological improvements. This may increase energy consumption in three ways: first by substituting energy-intensive, time-efficient services for time-intensive services in household consumption; second by allowing time for consumption of more energy services and third through the creation of new time-saving, energy-consuming needs. Following this literature, we include time costs in the total costs of energy services and provide a wider definition for microeconomic rebounds that includes both energy efficiency and time efficiency. We argue that improvements in time efficiency may be a significant driver for increasing energy consumption and that such effects need to be controlled for in econometric estimation.

Conclusions

In conclusion, we argue that the use of the limited Khazzoom definition in empirical approaches can lead to biased estimates of the magnitude of the direct rebound effect. Demand for energy services is a function of more factors than just energy prices and energy efficiency and these should be controlled for in econometric estimation. Hence, the findings from several empirical studies of the direct rebound effect should be reconsidered.

References

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