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An empirical study on the rebound effect considering capital costs ☆

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Abstract

Technological progress is one of the means of reducing energy usage and carbon dioxide (CO_2) emissions. However, this reduction, in turn, leads to a reduction in the real cost of energy services per unit, which results in an increase in the demand for energy services. Therefore, a reduction in the anticipated CO_2 emissions caused by a technological improvement might be partially offset in response to the cost reduction. Previous studies have referred to this effect as the "rebound effect." A large amount of empirical evidence on the rebound effect exists; however, most of these studies assume an exogenous improvement in energy efficiency, and thus, capital costs that may decrease the magnitude of the rebound effect are not taken into account expressly. This paper extends the scope of the research conducted by Brannlund et al. [Brannlund, R., Ghalwash, T., Nordstrom, J., 2007. Increased energy efficiency and the rebound effect: effects on consumption and emissions. Energy Economics 29, 1–17] in terms of two aspects: (i) considering capital costs explicitly as additional capital costs and (ii) adapting an iterating procedure, and estimating the rebound effect, using Japanese household data. As a result of our empirical analysis, we conclude that the rebound is approximately 27%. However, we also find that ignoring additional capital costs leads to an increase in the rebound effect. In the case of Japanese households, the magnitude of the rebound effect increases to approximately 115%. Moreover, our simulation study shows that only a one-time iteration of Brannlund et al. [Brannlund, R., Ghalwash, T., Nordstrom, J., 2007. Increased energy efficiency and the rebound effect: effects on consumption and emissions. Energy Economics 29, 1–17] may lead to a biased result.

Keywords: Rebound effect; Energy efficiency; CO_2 emissions; Capital costs; Japanese households; Bayesian estimation

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1. Introduction

The Kyoto Protocol came into effect on February 16, 2005. As of January 2006, the number of signatory countries was over 158, and these countries had already begun developing strategies to curb carbon dioxide (CO_2) emissions. Japan has also ratified the Kyoto Protocol and carried out some related projects.[1] Amongst these projects, one of the core strategies to reduce CO_2 emissions is the improvement of energy efficiency.[2] In recent years, a large number of firms have started developing energy-efficient appliances, and the number of people purchasing these appliances has increased rapidly. However, it is possible that the potential energy savings from this energy conservation strategy might be reduced by a rebound effect.

The rebound effect is essentially a behavioral response to an improvement in energy efficiency. Typically, if we improve energy efficiency, a decrease in energy consumption is expected. However, improvements in energy efficiency not only reduce energy consumption but also cause a reduction in the real per unit cost of energy services, and accordingly, improvements in energy efficiency result in an increase in the demand for energy services. Thus, the anticipated energy savings from technological improvement are cancelled out by the increment of energy services. For example, let us consider the case of purchasing a new air conditioner that consumes less energy than an older one does. If the hours of operation and the preset temperature of the new air conditioner are identical to those of the older model, the amount of energy consumption is decreased by this technological improvement. However, this improvement also reduces operating costs and results in an additional demand for air-conditioning. Increased use of energy services induced by the reduction in their costs due to greater energy efficiency is called the direct rebound effect (Greening et al., 2000). The mechanism underlying this effect is identical to that underlying the effects of the reduction in the price of commodity. It induces an income effect in favor of the commodity whose price has fallen, and an income effect, due to the fact that the lower price confers an increase in real income on the consumer. Holding the prices of other commodities constant, the reduction in the cost of energy services implies that the consumer has a little more money to spend on not only relevant energy goods and services but also other goods and services. Other goods and services also require energy, and thus, total energy use will increase in areas not directly affected by the energy efficiency improvement. This is called the indirect rebound effect. As a result, the anticipated energy savings from the new technology are cancelled out by these additional demands.[3] Following the pioneering study by Khazzoom (Khazzoom (1980), a considerable number of studies have been conducted on the rebound effect; these have focused on theoretical and empirical aspects (Lovins, 1988; Henly et al., 1988; Greene, 1992; Berkhout et al., 2000; Reinhard and Peter, 2000; Roy, 2000; Binswanger, 2001; Bentzen, 2004; Sorrell and Dimitropoulos, in press; Brannlund et al., 2007). See Greening et al. (2000) for a comprehensive survey on the rebound effect.

An additional aspect of the rebound effect can be viewed in the context of the climate change problem. A reduction in carbon intensive energy use implies a reduction in GHG emissions. If the

[1] Some examples of these projects are voluntary emission trading, a law for the rationalization of energy use, and the development of new energy resources.

[2] In most cases, greenhouse gas (hereafter, GHG) is generated by the combustion of fossil fuels such as coal, oil, and natural gas (Energy data Modeling Center (EDMC) (2004)).

[3] A third type of rebound effect is called the general equilibrium effect. Changes in the demand patterns for goods and services affect the supply side of these products, and this effect spreads throughout the economy, resulting in adjustments in supply and demand in all sectors (see Greening et al., 2000 and Washida, 2006).