Energy price, bandwagon effect, and the rebound effect*

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Abstract

Potential energy savings from energy efficiency improvements are partly or entirely offset by rebound effects. Rebound effects can be decomposed into two effects: direct rebound effect (DRE) and indirect rebound effect (IRE). The latter has not been studied as much as the former. This paper focuses on two types of IRE, which have not been studied previously. Firstly, the effect of a fall in energy prices because of energy efficiency improvements on energy consumption is examined. It is shown that the smaller the price elasticity of energy supply, the more significant is this type of IRE. Secondly, the paper tries to incorporate the bandwagon effect with the rebound effect. An energy service that has a large bandwagon effect can bring about a significant rebound effect.

JFL Classification: Q40; Q41; Q55.

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1. Introduction

In simple engineering models, it is often predicted that an increase in energy efficiency by 1% will cause a reduction in energy use by 1%. However, efficiency improvements result in a reduction in the effective price of the energy service, so demand of such a service will be stimulated. Hence, energy savings will not be as great as predicted by engineering models. This phenomenon is known as the rebound effect.

The rebound effect can be decomposed into two effects: the direct rebound effect (DRE) and the indirect rebound effect (IRE). DRE relates to an increase in the demand for an energy service because of a decrease in the service price by efficiency improvement ceteris paribus. Other mechanisms to explain why a reduction in energy consumption is less than predicted are classified as IREs.

Because the effective price of the energy service is defined as the ratio of energy price to energy efficiency, if the energy price is constant, an increase in efficiency by 1% will cause a reduction in the effective price of the service by 1%. Hence, the magnitude of DRE can be calculated by estimating the

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price elasticity of the energy service demand. Because it is not prohibited that the price elasticity of a service demand exceeds 1%, efficiency improvement can lead to increased energy consumption, that is, 'backfire' (Khazzoom, 1980, 1987, 1989).

Following Khazzoom's papers, several authors have tried to estimate the magnitude of DREs of individual energy services, such as automotive transportation, heating, and cooling. According to the results, although the magnitudes vary between the studies, the evidence suggests that DREs are not significant (Greene, 1992; Berkhout et al., 2000; Greening et al., 2000; Laitner, 2000; Schipper and Grubb, 2000). However, there have not been enough studies to conclude that the magnitude of DREs is of no significance, and technical problems associated with the estimation of DREs have been pointed out (UKERC, 2007). This paper makes concessions on the DRE question. Namely, I assume that the magnitude of DREs is not so significant as to exhaust the potential savings of energy by efficiency improvement. Therefore, this paper concentrates on IREs.

IREs can be classified into four categories. The first category relates to the initial energy input to equipment installed to improve energy efficiency. However, such energy use can be ignored as the equipment has a longer service life. If the initial energy use exceeds the potential savings by efficiency improvement, it is irrational to install the equipment in terms of cost-effective performance (UKERC, 2007).

The second category of IRE relates to the income effect (IE-IRE). Efficiency improvement of an energy service that has no significant DRE brings about an increase in each individual's disposable income. If this is spent on consumption of other goods and services, these will also stimulate energy consumption (Lobins, 1988; Binswanger, 2001). In practice, however, it is unlikely that all of such disposable income might be spent on energy for other services. Moreover, an energy service usually accounts for a small portion of total consumer expenditure. Hence, the magnitude of IE-IRE should not be huge (Schipper and Grubb, 2000). Similarly, it has been pointed out by Greening and Greene (1998) that the IE-IRE of intermediate goods is much smaller than the DRE.

The third category concerns the effect of an energy price change caused by efficiency improvement (Herring and Sorrell, 2009). This type of IRE (EP-IRE) is inextricably linked to DRE. It is natural to think that the smaller the magnitude of the DRE of an energy service, the greater the decrease in energy demand. However, the mechanism of EP-IRE has not been studied so far[1]. The reason is that existing studies about the rebound effect have mainly dealt with specified energy services separately; hence the impact of a relatively small decrease in energy consumption on the energy price could be ignored. Although this can be understood, in reality our target is to improve energy efficiency for every type of energy service, and to realize a dramatic reduction of energy consumption as a whole society. If so, in the future, we cannot ignore the relationship between efficiency improvement and change in the energy price. It could be of great significance in analyzing the situation. One of the

[1] One way of studying the rebound effect incorporating the adjustment process of energy prices is using a general equilibrium model (GEM). There have been several studies of the rebound effect based on GEMs, the results of which are still controversial. Moreover, there has been no study based on GEMs that focuses on the relation between the improvement in energy efficiency and the adjustment process of energy prices in energy market.

purposes of this paper is to examine this problem based on a comparison with DRE.

The fourth category of IRE corresponds to transformational effects so termed by Greening et al. (2000). To date, most studies of the rebound effect have focused on the effects of efficiency improvement on demands for energy services through price changes. However, a technological improvement could not only change the prices of several services, but also transform an individual's preferences, social institutions, and so on (Greening et al., 2000). Unfortunately, this type of IRE may be interpreted in many different ways because there is no comprehensive theory to deal with this effect. As an attempt, this paper focuses on the 'bandwagon effect', and examines theoretically how this effect relates to the rebound effect (BE-IRE).

The rest of this paper is organized as follows. Section 2 discusses EP-IRE based on a simple one-commodity model. Section 3 deals with BE-IRE. Finally, Section 4 concludes.

2. Energy efficiency and energy price

Intuitively, it is reasonable to think that EP-IRE is closely related to the price elasticity of energy supply. To show this precisely, suppose the aggregate demand function for an energy service, *S*, is given in the logarithmic form:

$$\ln S = -a \ln P_s + b,\ a \geq 0 \tag{1}$$

where P_s is the effective price of the energy service, which is defined as the ratio of energy price P_E to energy efficiency *e* (*e* is the ratio of service demand to energy consumption), and *a* and *b* are constants. Note that *a* is the price elasticity of the service demand, which corresponds to the magnitude of the DRE of the service. By rewriting equation (1) using the definition of energy efficiency, the demand for energy, E^d, is obtained as a function of energy price and energy efficiency.

$$\ln E^d = -a \ln P_E + (a-1)\ln e + b \tag{2}$$

On the other hand, the aggregate supply of energy, E^S, is supposed to be a function of energy price:

$$\ln E^s = c \ln P_E + d, c \geq 0 \tag{3}$$

where *c* and *d* are constants. Note that *c* corresponds to the price elasticity of energy supply. By setting equation (2) equal to equation (3), the equilibrium price of energy, P_E*, is obtained.

$$\ln P_E{}^* = \frac{a-1}{a+c}\ln e + \frac{b-d}{a+c} \tag{4}$$

Moreover, substituting equation (4) into (3), we obtain the efficiency elasticity of energy as follows:

$$\eta = \frac{d \ln E^*}{d \ln e} = \frac{a-1}{\frac{a}{c}+1}. \tag{5}$$

The magnitude of η is determined by the DRE of the service and price elasticity of energy supply. If *c* is sufficiently large, η can be approximated by $a-1$, that is, the energy reduction effect of efficiency improvement without EP-IRE (only with DRE). In other words, equation (5) tells how much DRE will be amplified by the existence of EP-IRE. For example, suppose that the DRE of an energy service is 0.2. If the price elasticity of energy supply is sufficiently large, η is approximately –0.8. In this case, an efficiency improvement of 1% will cause a reduction in energy consumption of 0.8%. However, if the price elasticity of energy supply is small (say 0.1), the percentage expected reduction in energy consumption will drop to 0.27% because of EP-IRE.

How large is the price elasticity of energy supply in practice? Among several types of energies, let us focus on oil because there is no doubt that oil remains the most important source of energy. Krichene (2005) estimated the short-run price elasticity of world crude oil supply since 1973 as –0.05, and the long-run elasticity as 0.25. Limiting the analysis to non-OPEC countries, several estimates have been presented including 0.08 (Krichene, 2006), 0.29 (Alhajji and Huettner, 2000), 0.15–0.58 (Gately, 2004), and 0.58 (Dahl and Duggan, 1996). As a whole, we can say that the price elasticity of oil is low. In fact, despite escalating oil prices in recent years, neither OPEC nor non-OPEC countries have increased oil production. Several reasons for this have been cited, including geophysical constraints as pointed out by Hubbert (1956), difficulties in acquiring human resources and equipment to develop wells, and increasing resource nationalism.

It is clear that EP-IRE is strongly related to the inelastic response of oil producers when oil price decreases. There is no reason to think that the response of oil suppliers for price increases and decreases is symmetric. As pointed out by Gately (2004), non-OPEC countries have shown less response to price decreases than to price increases. For behind this background there might be high vulnerability of economy in many oil countries (Noreng, 2006). Clearly, countries that heavily depend upon oil exports for most of their revenue cannot reduce oil production even if the market price of oil falls. Unless these countries divert spending to improvements in social infrastructure so that they will be able to transcend the oil-dependent economy in the future, the price elasticity of oil supply might remain low for years to come. If so, the efficiency improvement brought about by developed countries will be easily offset by the EP-IRE caused by 'slashed' oil prices.

Note that the above discussion is meaningless under the condition in which the improvement in energy efficiency occurs for a few limited kinds of energy services whose consumption of oil accounts for a small portion of total oil consumption. However, as the improvement in energy efficiency becomes more common in every energy service, the above discussion will become increasingly relevant.

3. Bandwagon effect and rebound effect

Greening et al. (2000) proposed a fourth type of rebound effect, the transformational effect, which has not been studied at all. This type of rebound effect considers the impact of technological changes on people's preferences. It is unsurprising that this study is not related to standard economics, because, in the framework of standard economics, i.e., neoclassical economics, the preferences of economic entities have been dealt with as a given exogenous element (Hodgson, 1988, 1999a, 1999b, 2004; O'Neill, 2007).

It is extremely difficult to set up an economic model that perfectly incorporates an individual's preferences as an endogenous factor. Hence, to simplify the discussion, this section attempts to examine the rebound effect from the viewpoint of the relationship between the social nature of goods and services. For some goods and services, the satisfaction obtained through their consumption is influenced by the level of consumption by others. The existence of such goods and services has been recognized for a long time (e.g., Smith (1776) pointed out the necessity of owning goods without which people felt ashamed when they met other people). Needs satisfied by such 'social goods' have strong symbolic meanings. Therefore, desire for such goods is insatiable (Keynes, 1930). If competition to obtain social goods becomes fiercer, resources that could be saved through resource efficiency improvement will be swallowed up completely. Hence, we should not ignore the social aspects of goods and services and admire environment-friendly technologies too much. Unfortunately, the social nature of goods and services has not been extensively examined by neoclassical economists (Mason, 1998). Thus, there are no studies about how the social characteristics of goods and services are associated with the rebound effect.

There are several ways to model an individual's demand for social goods and services as a function of consumption by others. This paper focuses attention on Leibenstein's bandwagon effect[2]. The bandwagon effect means that demands for goods and services are positively affected by the level of consumption by other people (Leibenstein, 1950). This consumption behavior is derived from the social desire of people not to lag behind other people, and it is an important aspect of status seeking. With respect to the demands for bandwagon goods, individuals react to information about the amount of goods others consume. Therefore, when energy efficiency is improved, the mechanism is phased. Firstly, consumers react to the decline in effective prices (DRE). Secondly, each consumer compares the level of his/her consumption with that of others and accordingly readjusts his/her demands for bandwagon goods (BE-IRE). Therefore, it is natural to consider that there is a time lag between the first stage and the second stage.

To simplify the discussion, let us consider a two-person model in which each person has the same demand function of an energy service. Equation (6) defines person *i*'s demand function at time *t* in logarithmic form as follows:

$$\ln S_i(t) = -a \ln P_s + b \ln S_j(t-1),\ i, j = 1,2 \tag{6}$$

where a (> 0) and b (> 0) are coefficients. Meanwhile, the energy price is assumed to be constant in this section. The value of b corresponds to the magnitude of the bandwagon effect of the service. To eliminate the possibility of divergence, the value of b is assumed to be less than unity. By subtracting person 2's demand function from person 1's, equation (7) is obtained.

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2 As the opposite effect, Leibenstein cites the snob effect, but this is not dealt with in this paper for the following reason. Considering items specific to an individual, there are several kinds of goods and services that indicate the snob effect. However, because expenditure items are a large category, it is natural to consider that status-seeking causes the bandwagon effect (e.g., a person who stops buying Chanel products because all surrounding people are wearing Chanel clothes will be encouraged to seek other brands. Thus, this will not reduce expenditure on 'expensive clothes').

$$\ln \frac{S_1(t)}{S_2(t)} = -b \ln \frac{S_1(t-1)}{S_2(t-1)} \tag{7}$$

By $|b| < 1$, the equilibrium demand $S^* = S_1^* = S_2^*$ is stable. By using equation (6), we have:

$$\ln S^* = -\frac{a}{1-b} \ln P_S \,. \tag{8}$$

From equation (8), it is clear that the rebound effect of DRE with BE-IRE is $1/(1 - b)$ times as large as that of DRE only.

In reality, it is difficult to investigate the degree of contribution of the bandwagon effect to the rebound effect. Although we cannot separate the bandwagon effect from existing estimations of the rebound effect, it is likely that existing results for which the long-term DRE tends to be larger than the short-term DRE (Berkhout et al., 2000; Greening et al., 2000) reflect the time lag of the bandwagon effect. However, the use of 'long term' or 'short term' in existing studies merely focuses on the period of time, so there is no evidence that the adjustment process of demand caused by the bandwagon effect had finished in even long-term estimation. The time lag between the first and second stages may be influenced by the nature of bandwagon goods, customs, general rules, trends, and other factors. It might range from several days to months or even several years. Hence, there is always a possibility that we underestimate the effect of the bandwagon effect on the rebound effect when using econometric methods.

4. Conclusion

The mechanism of indirect rebound effect has not been fully studied yet. There are several types of indirect rebound effect; this paper focused on two types of indirect rebound effect, which have not been studied previously. Firstly, the impact of improvement of energy efficiency on energy price was discussed. The smaller the price elasticity of energy supply is, the larger the reaction of the energy price to the demand reduction in energy. The energy price fall leads to a reduction in the effective price of energy services. This paper showed how the magnitude of the price elasticity of energy price relates to the rebound effect using a simple equilibrium model. It should be noted that even if the magnitude of the direct rebound effect and/or the indirect rebound effect caused by income effect is small, the price inelasticity of energy supply could amplify these effects as a whole.

Secondly, this paper analyzed the relationship between the bandwagon effect and the rebound effect. Consequently, it showed how the bandwagon effect amplifies the direct rebound effect.

To summarize, it should be noted that there is a possibility that we may underestimate the significance of the rebound effect if we estimate the rebound effect relating to only the improvement of energy efficiency ceteris paribus.

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