Progress in Technology and Long-Term Development

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ABSTRACT: Technology-induced resource- or energy-efficiency improvements tend to overstate prospective saving benefits because they often overlook the behavioral reactions elicited by technical advances. A 1% gain in efficiency frequently results in a 1% decrease in resource consumption, or even an increase in resource use. The rebound effect is well-known among energy economists, but has received little attention in ecological economics. Starting with a conventional neoclassical study of the rebound effect in a partial equilibrium framework that focuses on one specific energy service like mobility or room temperature. It also summarizes some of the major empirical research that support the rebound effect's existence but debate its significance. But we need to go beyond the neoclassical single-service model to address the many potential energy usage feedback loops. The article offers two significant extensions of the single-service model to demonstrate the rebound effect's potential ecological significance. First, it is demonstrated that generalizing about the rebound effect in a multi-services paradigm is problematic. In this instance, the overall impact of increased energy efficiency on total energy consumption is dependent on assumptions about service substitutability and the income effect. It also attempts to account for the reality that changes in resource or energy use are often 'side-effects' of other technological advancements. Many time-saving technologies (for example, quicker means of transportation) involve an increase in energy consumption, which is often reinforced by a 'time-rebound effect'. This impact is amplified when salaries are high and energy costs are low, as is presently the situation in most developed nations. As a result, the study strongly supports energy taxes.

KEYWORD: Development, Energy Efficiency, Rebound Effect, Resource, Technology.

1. INTRODUCTION

Numerous ideas of sustainable development stress the significance of efficiency gains brought about by technology advancement. Technology is intended to aid us in the promotion of a society in which it is feasible to maintain or even improve our current quality of living while consuming less resources, particularly energy, than we now do. These ideas are based on the premise that a one percent improvement in efficiency would, on average, result in a one percent reduction in resource consumption[1]. This is not always the case, however, since technology advancements elicit behavioral reactions from users and consumers. Increasing efficiency by one percent will often result in a decrease in resource consumption that is much below one percent, or it may even result in an increase in resource consumption in certain cases. The rebound effect1 is a term used by energy economists to describe this phenomena, which has not yet been thoroughly investigated by ecological economists in depth.

The precise concept of the rebound effect differs from one piece of literature to another. A very broad definition of the word may be found here. It is used to describe the functioning of market economies where gains in efficiency are often overcompensated by a phenomenon known as 'growth effects.' A rise in the ratio of GDP to energy or resource usage does not always imply a decrease in energy or resource use since there will be an increase in economic activity at the same time that the ratio of GDP increases. Increases in resource or energy efficiency may not always translate into equivalent decreases in energy or resource use, which is known as the rebound effect. However, when seen from a broader perspective, the expansion of economic activity is not always associated with the increase in efficiency brought about by new technology[2]. Because of structural changes and the general growth tendency of market economies, the growth impacts may be temporary. This immediately leads to the question of whether a constantly expanding economy can ever be sustained and if the growth tendency can be reversed.

However, despite the fact that these are significant issues, we will not go into more detail about them here since we are more concerned with the more particular question of how efficiency gains as a result of technological development impact the demand for natural resources and energy. Since its inception, the rebound effect has been primarily linked to energy consumption and the issue of whether or not increases in energy efficiency have an impact on energy consumption. Energy economists have developed specific definitions of the rebound effect, which can be extended to the usage of renewable energy sources in general with relative ease[3].

In order to provide a clear definition of the rebound effect, the following factors were taken into account. Increasing the efficiency of machinery via technical advancement reduces the quantity of energy necessary for the same amount of product or service to be produced. The quantity of the product or service, on the other hand, is seldom the same from year to year. In part as a result of improvements in energy efficiency, the cost per unit of product or service produced with this equipment is decreasing, which in turn boosts demand for the product or service. If technology advancements improve the energy efficiency of a vehicle, the 100 km may be travelled with less gasoline and, as a result, at a cheaper cost[4]. As a result, individuals are more likely to travel more and longer distances since transportation has become more affordable.

Several empirical studies conducted in the 1980s and 1990s confirm the existence of a narrowly defined rebound effect in the context of improvements in energy efficiency in heating systems and insulation, as well as improvements in energy efficiency in transportation activities, in the 1980s and 1990s. In general, economists seem to agree that there is a rebound effect, although they differ on the significance of the impact in certain circumstances. The discrepancy is mostly due to the very strong assumptions made by the single-service model, which is the basis for deriving the rebound impact from the first assumption[5].

Due to the fact that it ignores the numerous possibilities of substitution effects among services, as well as the income impact, econometric research based on the single-service model may be deceptive. In this paper, we will argue that the rebound effect is indeed empirically significant and that behavioral responses elicited by efficiency improvements can have a significant impact on energy consumption even when we go beyond the single-service model in order to account for the variety of possible feedbacks affecting energy consumption.

Furthermore, the article makes an effort to account for the reality that shifts in resource use or energy consumption are often just "side effects" of other types of technical advancement. Technological development, particularly of a time-saving type, has the potential to have a significant impact on energy consumption since many time-saving technologies need an increase in energy usage[6]. One that, as will be shown, is reinforced by an often significant rebound effect, which is measured not in terms of energy but in terms of time, thus providing a fresh viewpoint on the topic of the rebound effect.

In particular, when salaries are high and energy costs are low at the same time, as is presently the situation in most industrialized nations, this' rebound impact with regard to time' will be particularly significant. In combination with low energy prices, which represent the opportunity costs of time, high wages, which represent the opportunity costs of time, encourage the increasing use of time-saving but energy-intensive devices, resulting in an overall increase in energy consumption as people constantly attempt to ‘save' time[7].

1.1 Scope of The Single-Service Model:

During the 1980s, there was a spirited discussion in the Energy Journal over the true importance of the rebound effect and if it was a cyclical phenomenon. Based on the findings of his own and other empirical investigations, researchers have claimed that the rebound effect is experimentally meaningful and has a substantial impact on energy consumption in general. Furthermore, the researchers concluded that "the demand recovery has generally not been substantial," with the theoretical maximum demand recovery being on the order of 2 percent in most cases. However, the majority of the researchers' assertions are not supported by any actual data.

According to the researchers' reasoning, there is still one argument against the empirical validity of the rebound effect that may be relevant since it relates to the limitations of the single-service model, which they have not addressed in their study to this point. According to the researchers, the rebound effect is more likely to be an income impact than a price effect, which would result in a much lower response rate[8]. To put it another way, the potential substitution impacts between various services must be addressed in conjunction with the resultant revenue benefit of increased energy-efficiency improvements.

If you have a multi-services model, the total impact of an improvement in energy efficiency on energy consumption is dependent on the substitutability between various services, as well as on which way the income effect is going. A two-services model may be used to demonstrate this point visually. After considering the scenario where there are two services with high substitutability, we turn our attention to the situation when there are two services with low substitutability, which is the case that the researchers allude to in their article. In this setting, the financial restriction of the household cannot be ignored any more, as was the case with the single-service model before. We suppose that the utility $u(s1, s2)$ of a typical family is dependent on two services, s1 and s2, and that the household is subject to a budget constraint $B = p1s1 + p2s2$, where p1 and p2 are the costs of the two services[9].

Assume that B is a set travel budget for a household that may be spent either for rail travel (s1) or for vehicle travel (s2), and that 1 km travelled by train consumes less energy per person than 1 km travelled by car in the first scenario. Because we want to keep things simple, we also assume that there is an exogenously provided improvement in fuel efficiency, which enables for a mile to be travelled by vehicle with less fuel, but still results in a lower efficiency than travelling by train.

The amount of change in total fuel consumption that results from the income and substitution effects is dependent on the magnitude of the income and substitution impacts. As shown in the single service example, an improvement in fuel economy lowers the cost of a service while simultaneously increasing the demand for the service. For the sake of this scenario, driving becomes less expensive, and driving will partly replace travelling by rail in certain situations. This is the replacement impact, which is expected to be significant in our situation since a family can typically readily swap travelling by vehicle for travelling by rail[10].

Additionally, there is now a revenue impact, which was not there in the single service scenario before. The income impact is expected to result in an increase in the number of passenger kilometers travelled by vehicle, since the same travel budget B now allows for more kilometers driven than before allowed. When considering this case, both the income impact and the substitution effect have a tendency to raise fuel demand, and the overall ‘rebound effect' is much greater than indicated by the single-service model.

For example, where there is little substitutability between the two services under consideration, the second example illustrates the impact of an exogenously provided improvement in energy efficiency. To demonstrate this point, let us suppose that B now represents a household's leisure budget, which may be spent on either leisure activity that can be completed without the use of a vehicle (s1) or leisure activities that need the use of a car (s2) (s2). Because of this, s1 requires less energy than s2 as measured, for example, by the amount of energy used per hour of recreational activity.

It is possible that the substitutability of the two services is so low that the substitution impact is of insignificant size. This assumption is correct if reduced costs as a consequence of increased fuel efficiency do not lead to a shift in family leisure activities to more transportation-intensive activities. The researcher's reasons further indicate that the income impact would mainly boost demand for activities that do not need more vehicle journeys, since travelling by automobile becomes an inferior benefit once a certain level of wealth is achieved. Due to the income impact working in favor of reducing energy consumption and the substitution effect being extremely low, the rebound effect obtained from the single-service model would be negligible in practice in this situation.

Whether or not what academics say is accurate is dependent on whether or not there is a critical level of income below which energy-intensive activities become inferior, and whether or not the majority of households in developed nations have already passed that critical level of income. This is a question that can only be answered in the negative, despite the fact that direct empirical information in this area is limited. Household energy consumption statistics in industrialized nations has shown no discernible changes since the early 1970s, according to aggregate data.

However, decomposition of changes in energy use in different sectors in ten OECD countries over the period 1973 to 1992 strongly suggests that the production of energy-intensive services continues to increase with household income, which may be taken as evidence against researchers' claims that energy-intensive services are inferior to other types of services at the current level of household income in most cases. Putting it all together, the two examples of a two-services model presented in this section demonstrate how difficult it is to make broad generalizations regarding the significance of the rebound effect.

An improvement in energy efficiency will have a greater overall impact on total energy consumption if the services examined are more efficient. It will also have a greater overall impact if the assumptions regarding substitutability between these services are more conservative. As a result, depending on the services that are included in the model, the feedback in energy use may actually be greater or less than indicated by the single-service model. In general, if consumers spend extra money on services with a low energy intensity, the feedback will be less or even negative in nature. It should be noted that there is no compelling empirical evidence to support the existence of such a trend.

2. DISCUSSION

According to the reasons given in this article, the rebound effect with regard to households is, in fact, a significant phenomenon that is far too frequently overlooked in discussions about sustainable development. Technical development has resulted in resource and energy gains, however sustainability ideas based on this notion overstate the real saving benefits since they fail to account for the behavioral reactions elicited by technological progress that contribute to the rebound effect. It goes without saying that resource-saving technology development is a pre-requisite for a reduction in the resource intensity of economic activity. However, because of the rebound effect with regard to energy as well as, and maybe even more importantly, the rebound effect with respect to time, it is not a sufficient condition.

For as long as substitution between various services and the income impact remain of insignificant magnitude, the single-service model offers an appropriate explanation of the rebound effect. Although this is often the case, it is not always true, and in this case, the estimated rebound effects based on single-service models may either underestimate or overestimate the actual feedback in energy use induced by higher energy efficiency. In particular, researchers suggested that the rebound impact was more likely to be an income effect rather than a price effect, and that this was supported by empirical evidence. It would be inaccurate to use just one service as a basis for comparison; instead, it would be necessary to take into account the revenue and substitution effects between various services.

It is difficult to make broad generalizations regarding the importance of the rebound effect in a multi-services paradigm because of the complexity of the system. Overall, the impact of increased energy efficiency on total energy consumption is dependent on the specific services examined as well as the assumptions made regarding substitutability between these services and the direction of the income effect on total energy consumption. However, there is no evidence to cast doubt on the significance of the rebound effect, even in a multi-services paradigm, as a result of this study. On the contrary, if substitutability across services is great and if the demand for energy services rises as a function of income, the feedback will be even larger than predicted by the single-service model (positive income effect).

However, since it focuses on energy as the sole important input in the creation of a service, the conventional single-service model of the rebound effect may also show to be too limiting in another regard. Particularly essential as an input to the provision of services in the home is time, and time-saving technologies have the potential to have a significant impact on the energy consumption of families. As a result, the article provides a new viewpoint on the rebound effect, with the emphasis on time-saving technologies as the primary focus.

Time-saving technologies often need more energy, as is most apparent in the transportation industry, where an improvement in the efficiency of time usage (as is the case with quicker means of transportation) is typically linked with a greater requirement for energy input. It is possible to produce a particular service (for example, mobility) in less time if a time-saving innovation is introduced into the manufacturing process. As a result of this, households will demand more of the service (a rebound effect with respect to time) and it will be substituted for other services that are more time intensive but typically less energy intensive. As a result, the total impact of time-saving technology advancement will be an increase in the use of energy.

3. CONCLUSION

Because of the induced feedback in energy or resource demand, all of the views on the rebound effect given in the article support the assertion that resource-saving or energy-saving technical development will not be adequate to ensure the long-term viability of the economy. This is due to the fact that the conventional single-service model of the rebound effect does not capture the entire spectrum of feedbacks. Furthermore, improvements that are designed to save time have a significant impact on energy use. The greater the opportunity costs of time (wage rate) and the lower the price of energy, the more likely it is that these advances will result in an increase in total energy consumption. So an ecological tax reform that increases the relative price of energy in comparison to the wage rate would be a significant step toward actually reducing energy consumption in the household sector because it dampens the "rebound effect with respect to energy" as well the "rebound effect with respect to time" as long as time-saving devices are energy intensive would be an important step toward actually reducing energy consumption in the household sector.

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