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ANALYSIS

Technological progress and sustainable development: what about the rebound effect?

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Abstract

Sustainability concepts that rest on the idea of resource- or energy-efficiency improvements due to technological progress tend to overestimate the potential saving effects because they frequently ignore the behavioral responses evoked by technological improvements. Efficiency improvements also affect the demand for resources and energy, and often an increase in efficiency by 1% will cause a reduction in resource use that is far below 1% or, sometimes, it can even cause an increase in resource use. This phenomenon is commonly labeled the rebound effect, which is well-known among energy economists, but never attracted much attention in ecological economics. The paper starts with the traditional neoclassical analysis of the rebound effect in a partial equilibrium framework that concentrates on the demand of one particular energy service such as mobility or room temperature. It also provides an overview of some of the main empirical studies based on this model that mostly confirm the existence of the rebound effect, but are controversial about its actual importance. However, we have to go beyond the neoclassical single-service model in order to take care of the variety of possible feedback affecting energy use. The paper presents two important expansions of the single-service model in order to show the potential relevance of the rebound effect to ecological economics. First, it is shown that in a multi-services model it proves to be difficult to make general statements about the relevance of the rebound effect. In this case, the overall effect of an increase in energy efficiency on total energy use depends on the on the assumptions about the substitutability between the services considered and the direction of the income effect. Second, the paper also tries to take care of the fact that changes in resource use or energy use are frequently just 'side-effects' of other forms of technological progress. Especially technological change of a time-saving nature can have a large influence on energy use as many time-saving devices (for example, faster modes of transport) require an increase in energy consumption that is frequently reinforced by a 'rebound effect with respect to time'. This effect will be especially strong when wages are high and, at the same time, energy prices are low, as is currently the case in most industrialized countries. Consequently, the paper also provides a strong argument for the introduction of energy taxes.

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1. Introduction

Many concepts of sustainable development emphasize the importance of efficiency improvements by technological progress. Technology is supposed to help us in promoting a society where it is possible to keep our present standard of life or even increase it while at the same time using less resources and especially less energy (see, for example, von Weizsäcker et al., 1997). These concepts rest on the idea that an increase in efficiency by 1% will, more or less, also lead to a decrease in resource use by 1%. However, this is usually not the case because technological improvements evoke behavioral responses. Often an increase in efficiency by 1% will cause a reduction in resource use that is far below 1% or, sometimes, it can even cause an increase in resource use. Among energy economists this phenomenon is known as the rebound effect[1], which, however has not been studied in detail by ecological economists.

The exact definition of the rebound effect varies in the literature. Sometimes, the term is used in a very general sense as a description of the functioning of market economies where increases in efficiency are frequently overcompensated by 'growth effects' (for example, Radermacher, 1997). An increase in the ratio of GDP to energy or to resource use does not necessarily lead to a decrease in energy or resource use because, at the same time, there will also be growth in economic activities. In this general sense the rebound effect describes increases in resource or energy efficiency that do not result in a corresponding decrease in energy or resource use. However, from this broad perspective, the growth in economic activities is not necessarily connected to efficiency improvements due to new technologies. The growth effects may be due to structural changes and a general growth tendency of market economies, which immediately leads into the discussion whether a continuously growing economy ever can be sustainable (Binswanger, 1995; Daly, 1996) and whether the growth tendency may be reversed. Although these are important topics, they will not be further elaborated in this paper as, here, we are interested in the more specific question how efficiency improvements due to technological progress affect the demand for resources and energy.

So far, the rebound effect has been mainly associated with energy use and the question how energy efficiency improvements affect energy consumption. Energy economists (especially Khazzoom, 1980, 1987; Brookes, 1990; Wirl, 1997) have come up with precise definitions of the rebound effect, which can easily be applied to resource use in general. This narrow but precise definition of the rebound effect is based on the following considerations. If technological progress makes equipment more energy efficient, less energy is needed to produce the same amount of product or service. However, the amount of product or service usually does not stay the same. Because the equipment becomes more energy efficient, the cost per unit of product or service that is produced with this equipment falls which, in turn, increases the demand for the product or the service. If energy efficiency of a car is increased by technological innovations, the 100 km can be driven with less fuel and, therefore, at lower cost. Consequently, people may drive more and longer distances because mobility (for example expressed in passenger km) has become cheaper.

Several empirical studies of the 1980s and 1990s confirm the existence of the narrowly defined rebound effect with respect to improvements of energy efficiency in heating systems and insulation as well as with respect to transport activities. Generally, economists seem to agree that there exists a rebound effect, but they disagree about its actual importance. The disagreement, to a large degree, is the result of the very strong assump-

[1] Most articles on the rebound effect can be found in the *Energy Journal* and *Energy Policy*. Recently, *Energy Policy* published a special issue (issue 6–7, vol. 28, 2000) on the rebound effect that provides an overview of the current state of the debate.