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Methodological and Ideological Options

The foundations of the environmental rebound effect and its contribution towards a general framework

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ABSTRACT

The study of the so-called rebound effect has traditionally pertained to the domain of neoclassical energy economics. In recent years, other disciplines have applied this concept in the context of the environmental assessment of products and policies, and multiple perspectives have unfolded more or less in parallel. Among these, the environmental rebound effect (ERE) perspective, focused on efficiency changes and indicators that go beyond energy to multiple environmental issues, has remained relatively unnoticed. This article thus asks the following questions: What are the foundational aspects of the ERE and how these relate to other perspectives? Are there irreconcilable differences between perspectives? And what is the value of the ERE towards a general framework? We map the fundamental ideas behind the ERE and find that the lack of articulation has resulted in inconsistent usage and lack of clarity. We also argue that the ERE offers many valuable insights for rebound assessment, such as the study of broader efficiency changes and of innovations aimed at tackling multiple environmental issues. Perhaps most importantly, the ERE helps bringing together the existing rebound perspectives, as its application shows that it is both possible and valuable to articulate broader definitions for the rebound effect.

1. Introduction

Efforts to reduce environmental burdens by fostering energy or resource efficiency have often fallen short of expectations. One important reason for this is known as the 'rebound effect', which occurs through behavioural and economic demand responses to efficiency changes from technical improvements that are ignored by engineering-based models that apply *ceteris paribus* conditions (Binswanger, 2001; Brookes, 1990; Greening et al., 2000; Khazzoom, 1980; Saunders, 2005). The rebound effect is generally defined as the difference between the expected and the actual environmental savings from efficiency improvements once a number of economic mechanisms have been considered, that is, the savings that are 'taken back'. An illustrative example is that of improvements in car fuel efficiency, which make driving cheaper and so the liberated income will be spent to drive further distances as well as consuming other products, which in turn will increase energy and fuel consumption.

The rebound effect concept can be traced back to the seminal works of William Stanley Jevons, particularly his much-cited book 'The Coal Question' (Jevons, 1865), from which the so-called 'Jevons Paradox' was derived later on (Alcott, 2005; Giampietro and Mayumi, 1998; Wirl, 1997). Jevon's ideas were later embraced by energy economists during the 1980s and 1990s in the context first of a looming energy crisis (1973 oil crisis and 1979 energy crisis) and then concerns over climate change, where the rebound effect was provided with a robust theoretical and analytical framework (Binswanger, 2001; Brookes, 1990; Greening et al., 2000; Khazzoom, 1980; Lovins, 1988; Saunders, 1992). Since then, the rebound effect has gained popularity both in the academic and policy arenas (Maxwell et al., 2011), and academic research and debate of more than 30 years have resulted in a general agreement on its existence as well as a panoply of views about its magnitude and causes (Jenkins et al., 2011; Sorrell, 2007).

The multiple possibilities for analysis that the rebound effect offers also lured other disciplines to adopt it, and each enriched the concept with their own insights. A number of authors have identified different disciplinary perspectives on rebound effects, such as Binswanger (2001); Sorrell (2007); de Haan et al. (2005); Madjar and Ozawa (2006) and Walnum et al. (2014). After carrying out a comprehensive review, Walnum et al. (2014) identify six perspectives that would offer unique understandings of the assumptions and the drivers behind the rebound effect: energy economics, ecological economics, socio-psychological, socio-technological, urban, planning and evolutionary. Moreover, other authors point out the existence of an additional perspective from industrial ecology and sustainability sciences (Font Vivanco and van der Voet, 2014; Hertwich, 2005), known as the

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'environmental rebound effect' (ERE) (Goedkoop et al., 1999; Murray, 2013; Spielmann et al., 2008; Takahashi et al., 2004).

The ERE mainly differs from other perspectives in that the rebound effect concept is generalised to encompass efficiency changes and indicators of interest that go beyond energy and energy-related emissions (mainly CO_2 emissions from fuel combustion) to a wide range of environmental issues. This perspective thus incorporates broader efficiency changes as well as the representation of the rebound effect as a multidimensional value into rebound assessments (Font Vivanco et al., 2015). The ERE can be thus defined as the environmental consequences from changes in demand in response to efficiency changes from technical improvement. The ERE also offers other advantages in the context of sustainability assessment, namely, the high technology detail and the life cycle perspective, which are used to calculate more comprehensive estimates of the technology effect driving environmental consequences (see Section 2.2 for a more detailed description). However, a complete investigation of the value of the ERE perspective in rebound effect assessment is missing.

The increasing inclusion of economic and behavioural feedbacks into the analysis of the full environmental impacts of particular technologies has led sometimes to a rather loose use of the term 'rebound effect' (Font Vivanco and van der Voet, 2014). Applications of such type of analysis include economy–environment and economy–energy models as well as life cycle assessment (LCA) and consequential LCA in particular, through which causal effects from marginal changes in technical systems can be appraised (Ekvall, 2002). The progressive broadening of the rebound effect concept thus raises the question of where one draws the line between calling something a rebound effect and simply identifying feedback effects that occur in response to changes in some product or system, and whether such broadening can jeopardise the analytic coherence of the term.

Taking full advantage of the ERE concept thus largely depends on the clear delineation of boundaries for this emerging perspective, and clarifying how it relates to the more narrowly defined 'classic rebound effect', familiar to energy economics. For this, it is key to understand its foundational aspects, including its relationship with other existing perspectives and specific research questions in the context of sustainability assessment. Furthermore, another unresolved issue concerns whether irreconcilable differences exists between the different rebound perspectives, including the ERE, and whether a general, all-inclusive conceptual framework can be delineated. Such a general framework would delineate clear boundaries for the rebound effect rather than offer analytical guidance and aims at favouring learning and co-evolution between disciplines.

In summary, this article addresses two sets of research questions (SRQ):

- SRQ 1: What are the foundational aspects of the ERE? How do these aspects relate to other perspectives and specific research questions?
- SRQ 2: Are there irreconcilable differences between perspectives? What is the value of the ERE towards a general framework?

This paper situates the traditionally defined 'classic rebound effect' within a wider rebound framework, in which we also articulate the strengths and limitations of the ERE concept. In short, that the classical rebound effect relates to changes in energy use (a 'driver' indicator) arising from energy efficiency changes, while the ERE is concerned with the environmental pressure consequences (using 'pressure' indicators) of broader efficiency changes from technical improvements. The distinction between drivers and pressures follows the DPSIR framework of environmental indicators (EEA, 1999), which describes the interactions between society and the environment through driving forces (e.g., energy use), pressures (e.g., CO_2 emissions), states (e.g., atmospheric CO2 concentration), impacts (e.g., temperature rise) and responses (e.g., climate change mitigation policies). The values may greatly differ from one another, even when the key mechanisms are the same: a direct effect, an indirect effect and a macroeconomic systems effect.

The article is organised as follows. Section 2 introduces both the classical and the environmental rebound effect. Section 3 describes the foundations of the ERE perspective by (1) mapping the influences from alternative disciplinary perspectives as well as the novel contributions and (2) justifying such influences and novel contributions in the context of environmental assessment. Section 4 shows the differences and synergies between all rebound perspectives with the aim to explore the feasibility and value of an integrated conceptual framework. Section 5 concludes the paper by discussing the value, limitations and potential impact of the findings.

2. Origins of the (Environmental) Rebound Effect

This section is dedicated to the introduction of the mainstream understanding of the rebound effect as well as the environmental rebound effect (ERE) concept and is divided into two subsections. The first subsection provides a basic theoretical framework of the rebound effect as described by energy economics from a neoclassical perspective (from here on referred only as energy economics). The second subsection describes the origins of the environmental rebound effect (ERE) concept, drawing from the works within industrial ecology and other sustainability sciences. The later subsection addresses partly the first set of research questions regarding the foundational aspects of the ERE.

2.1. The Rebound Effect from Energy Economics

Energy economics is widely regarded as the cradle of the rebound effect concept. The oil crisis of 1973 and the emergence of worldwide energy efficiency policies revived the insightful yet generally ignored theories of William Stanley Jevons (1865), which postulated that improved energy efficiency would lead to increased economy-wide energy consumption. These ideas were reviewed with renewed enthusiasm through the works of various scholars, among which the contributions of Khazzoom (1980) and Brookes (1990) stood out. The so-called Khazzoom–Brookes postulate (Saunders, 1992) then spurred a panoply of theoretical and empirical contributions within energy economics, which translated into a debate about the theoretical foundations and the importance of the rebound effect that still continues to the present day (Sorrell, 2007). In short, energy economics defines the rebound effect as the reduction in the expected energy savings when the introduction of a technology that increases the energy efficiency of providing an energy service is followed by behavioural and systemic responses to changes in consumption and production factors, mainly prices, income and factors of production (Greening et al., 2000). Such responses can be captured using various analytical approaches, which can be classified into two main groups: those based on direct observation (evaluation studies) and those based on secondary data (mostly based on econometrics) (Sorrell, 2007). Among these, the latter is undoubtedly the most popular among energy rebound analysts, with elasticities playing a key role in rebound effect studies. In short, elasticities use statistical data to measure the responsiveness of economic actors in terms of demand for energy services to changes in the efficiency of providing such energy services. Thus, the more responsive or 'elastic' are economic actors to efficiency changes, the bigger the rebound effect (Berkhout et al., 2000). In mathematical notation, the energy rebound effect (R) can thus be represented as

$$R = 1 + \eta^{E}_{\varepsilon_E} \quad (1)$$

with

$$\eta^{E}_{\varepsilon_E} = \frac{\varepsilon_E}{E}\frac{\partial E}{\partial \varepsilon_E} \quad (2)$$