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Analysis

How Technological Efficiency Improvements Change Consumer Preferences: Towards a Psychological Theory of Rebound Effects

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ABSTRACT

The use of technologies can influence consumer preferences and demand and hence, impact on environmental sustainability. This article contributes to research on 'rebound effects', which focus on how energy efficiency improvements (EEI) increase energy service demand. Most of 35 years of rebound research has been analyzed from micro- and macro-economic perspectives. Yet, micro-economic rebound research has so far investigated human behavior only on grounds of simple rational choice models and static assumptions about consumer preferences. This article exposes the existing rebound discourse to psychological theories. Building on considerations of how EEI can interfere with processes of decision-making, it develops a model of how EEI – via psychological processes – may lead to 'motivational rebound effects' as well as to 'beneficial effects', which countervail rebounds. The article then advances a typology of such rebound and beneficial effects that not only integrates the typology currently used in the micro-economic rebound literature, but goes beyond it. Model and typology explain how economic rebound research could benefit from psychological theory, provide the basis for empirically investigating rebound effects on more solid theoretical grounds, and empower a comprehensive discussion about policies and measures that aim at a sustainable use of technologies.

1. Introduction

Saving energy is an important strategy to achieve sustainability policy goals (IPCC, 2014; IEA, 2013). One of the key strategies to reduce energy consumption is to increase energy efficiency in production and consumption. However, an increase in energy efficiency by, say, 30% does not necessarily equal a decrease of *absolute* energy demand by 30%, respectively (Wilhite and Norgard, 2004). Most notably, from an environmental perspective, the efficiency strategy brings about 'undesired side effects': energy efficiency improvements (in the following: EEI) may indeed lead to a reduced use of energy per unit of production or service, but at the same time they may raise demand of these services – which runs counter to the goal of saving energy. Such increased demand of energy services enabled by increased energy efficiency is termed a 'rebound effect' (Herring, 1998; Herring and Sorrell, 2009; Santarius et al., 2016). Rebound effects can nullify a proportion of the savings potential of energy efficiency technologies and policy measures or – in the extreme case – can even drive energy demand above levels before the efficiency improvement has taken place, which is called 'backfire'.

Literature on the rebound effect can be differentiated in publications on micro-economic and on macro-economic rebounds. Macro-economic rebound effects, which describe the impact of EEI on a country's overall economic growth (Jevons, 1906; Brookes, 1978, 1990, 2000; Saunders, 1992, 2000), will not be further considered in this article. Instead, this article will engage in the debate on micro-economic rebound effects.

Research on micro-economic rebound effects investigates consumer reactions to EEI. This strain of analysis was initiated by Khazzoom (1980, 1987) and was intensively debated throughout the 1980s (e.g., Lovins, 1988; Grubb, 1990). Since then a significant number of theoretical elaborations has been performed to fine-tune Khazzoom's initial argumentation (e.g., Berkhout et al., 2000; Birol and Keppler, 2000; Binswanger, 2001; van den Bergh, 2011; Borenstein, 2013), while dozens of quantitative studies have calculated the scope of micro-economic rebounds, including five meta-analyses (see Azevedo et al., 2012; Maxwell et al., 2011; Jenkins et al., 2011; Sorrell et al., 2009; Greening et al., 2000). The meta-analyses suggest that, on average, direct rebound effects range between 10% and 30%; the percentage indicates that about 10% to 30% of the *theoretical savings potential* from an efficiency improvement will be 'eaten up' by increased demand. In addition, indirect rebound effects will amount to at least 5% to 10%, but can

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be much higher if embodied energy emissions and a changing consumer basket are considered (see Druckman et al., 2011; Chitnis et al., 2014). This article focusses on the mechanisms that generate direct rebound effects.

Given the large number of studies, micro-economic rebound effects are no longer questioned in principle today (for currently open research questions see Madlener and Alcott, 2009; Santarius, 2015; Madlener and Turner, 2016); debate remains mainly on their aggregate quantitative dimension. However, this article will show that the model assumptions of practically all of micro-economic rebound research, as well as the explanatory variables used in those models, significantly limit the ability to comprehend how rebound effects actually arise, and hence, how they should be empirically investigated. The contributions of this paper are i) to highlight these deficiencies of micro-economic research (Section 2), ii) to develop a more comprehensive and behavioral science-based theoretical model and typology that explains various mechanisms leading to rebound effects (Sections 3 to 5), and on this basis, iii) to prepare the ground for more inclusive empirical rebound research in the future (Section 5). The conclusions (Section 6) deliver some interpretations of the rebound theory developed here, draw some insights for environmental policy-making, and highlight avenues for further research.

So far, literature on rebounds from a behavioral-science perspective can be counted on one hand. Girod and de Haan (2009) were the first to analyze motivational rebound effects, but remain in micro-economic rational choice thinking as they conceptualize what they term 'mental rebounds' with Thaler's mental accounting framework (Thaler, 1980, 1985, 1999). Paech (2011) and Santarius (2012) provide essayistic introductions into social and behavioral science perspectives on rebound effects. Otto et al. (2014) discuss rebounds from a psychological perspective, but mainly draw on a critique of *homo oeconomicus* assumptions' of the profit-maximizing individual. Suffolk and Poortinga (2016) try to empirically investigate behavioral changes after the introduction of energy efficiency improvements in housing, mainly focussing on effects on self-identity. Peters et al. (2012a) and Peters and Dütschke (2016) deliver the most valuable approach to motivational rebounds so far and suggest a theoretical framework of how to empirically investigate them. We draw on this approach and further advance it through additional theoretical considerations. Besides, Peters et al. (2012b) have conducted focus groups on motivational rebounds with the general public in Germany. Yet Peters et al. lack to advance their findings into an approach that theorizes motivational rebound effects and that develops an extended and more comprehensive rebound typology, which is the main aim of this article.

2. Deficiencies of Micro-economic Rebound Analysis

Micro-economic rebound research highlights two effects that explain how rebound effects are generated by consumers: the income effect, and the substitution effect (see Khazzoom, 1980; Binswanger, 2001 and many others). Whenever an EEI has a price content, this will generate an income effect. The substitution effect describes how an EEI's price content can alter a person's consumption portfolio as a result of a change in the relative value of products and services. The additional amount of energy related to using more of the very service that has improved its efficiency is termed a 'direct rebound effect'. The energy used when consuming alternative services generates so-called 'indirect rebound effect'.

The economics of rebound effects can be criticized on epistemological grounds because economic rebound literature generally assumes that consumers act according to a simple rational choice model. Rational choice assumes perfect information and implies that a person's sole intention to act is subjective utility maximization, including most notably profit maximization (Russell, 2000; Scott, 2000). There is a considerable body of sociological, philosophical, psychological, but also behavioral economics literature that questions this simple rational choice model, particularly on grounds of bounded rationality (Simon, 1947, 1957; Tversky and Kahnemann, 1974; Kahnemann, 2003), methodological individualism (Granovetter, 1985; see also Zey, 1992), and the utilitarian notion of insatiability of needs (Maslow, 1954, 1968; see also Max-Neef, 1992). While these behavioral science critiques on economic rational choice thinking will not be covered here (for a condensed overview, see Sen, 1977; Jackson, 2005), this article deems it important to highlight that only very few economic rebound papers mention the assumptions of the rational choice model (e.g., Berkhout et al., 2000; Schettkatt, 2009), while none of the studies we are aware of critically reflect them.

Yet, the assumptions of the rational choice model determine the scope of rebound effects to a large extent, and they explain the polarized debate about the significance of rebound effects for sustainability policy-making. On the one side, 'rebound supporters' tend to assume that consumers conform to the idea of '*homo oeconomicus*', for whom needs (or whishes) are insatiable, means ever scarce and therefore, the satisfaction of needs is solely determined by an economically rational cost-benefit analysis. Under these assumptions, any financial benefits from energy efficiency improvements (EEI) will eventually be reinvested in increased demand, which means that rebound effects are generally large. On the other side, 'rebound skeptics' tend to assume that consumers need certain kinds of energy services, that these needs remain more or less constant over time, and therefore, that they can either be satisfied with more efficient or less efficient technologies. In this view, EEI directly transfer into absolute reductions of energy use, and hence rebounds are small if not negligible (for rebound skepticism and critique, see Lovins, 1988; Henly et al., 1988; Grubb, 1990; Greenalgh, 1990; Goldstein et al., 2011; Nadel, 2011). Obviously, both of these broad-brushed assumptions are somewhat simplistic and need to be informed by a more profound understanding of the determinants of human behavior.

3. Definition and Deliberation of 'Motivational Rebound Effects'

In their seminal rebound review, Greening et al. (2000) state that "Changes in technology also have the potential to change consumers' preferences", but they deplore that "there is no all-inclusive theory for predicting those effects, which could result in more or less energy consumption" (p. 391 f.). In the same vein, Midden et al. (2007) encourage scientists to find "a psychological account of the rebound phenomenon" (p. 170). Against this background, we define: A 'motivational rebound effect' is an increase in energy service demand due to a change in consumer preferences that can be attributed to an increase in technological energy efficiency. Note that in this definition, and throughout this article, we use the term consumer 'preference' as it is most widely applied in the economic literature, where it describes the set of underlying assumptions about a consumer's motivation to purchase or use a particular good or service vis-à-vis alternatives (Grüne-Yanoff and Hansson, 2012; Fehige and Wessels, 1998). Most notably, much of the micro-economic literature assumes that preferences remain stable over time (cf. 'stationarity in preferences', see e.g., Houthakker, 2010), while no micro-economic rebound model examines how 'consumer preferences' actually come about. In the following paragraphs, we draw on behavioral science theories to shed light on this notion of preferences as a 'black box'. More specifically, we analyze how EEI may lead to motivational changes, that is to say to changes regarding the evaluation of goals, which in turn may increase a consumer's preference to demand a certain energy service. The core question for this deliberation will be: how does the purchase of an efficient technology subsequently change consumer preferences to use this technology and, ultimately, the de facto consumer behavior?

In broadest terms, theories on environmental behavior focus on either self-interests or moral norms as the central motivation for human behavior (Bamberg and Möser, 2007). For our following considerations, we use two of the most widely applied theories that reflect these broad