Title: **An interdisciplinary understanding of macro rebound effects**


## Key words

Rebound effects, critical realism, Interdisciplinary, socio technological structures



## Short abstract

This paper, delivered to the special session about rebound effects "Energy, Efficiency, and Growth - Analyzing Rebound Effects", addresses three different positions found within the rebound debate to explain what causes rebound effects at the macro level. It outlines an energy-economic perspective in which the actors, consumers and producers in the market adjust to lower energy prices by producing and consuming more than they did before the efficiency improvement. It then addresses how rebound effects have been understood in light of evolutionary theory and thermodynamics, in which it is key that society is under constant development and that there are two forms of efficiency: energy efficiency and time efficiency. There has been a preference for time efficiency, that is, for increasing the speed of consumption and production society wide. Finally, by applying a critical-realist perspective, it looks at how social science has dealt with rebound effects at various levels.



## Long abstract

In this paper we outline different explanations for the reasons for macro rebound effects. Why does something that seems sound at the micro level act differently at the macro level? What could be learned across and between disciplines to better understand macro rebound effects?

What exactly is the rebound effect? According to the New Oxford American Dictionary kindle edition (2010), rebound is something that bounces back after hitting a hard surface or object, recovers in value, amount and strength after a previous decrease or decline, or has an unexpected adverse consequence for the person responsible for it. From this, it seems that rebound sends you back in relation to what you have been trying to achieve (Levett, 2009). In energy economics, the rebound effect is understood as a behavioral change that follows an efficiency improvement. Consumption and production after an efficiency improvement will not necessarily follow the "engineering estimate" (that is, be less than expected according to a pure engineering estimate), because according to simple micro economic theory, consumers and producers will adapt to price changes following energy efficiency improvements (Sorrell, 2007).

Looking more deeply into the issue from an energy economics perspective, on the micro level, improved energy or material efficiency might enable firms to raise wages, to increase dividends or to lower prices, all of which lead to increased net consumption. Similarly, induced technological savings by individuals are redirected to other forms of consumption, cancelling some of the initial gains (Wackernagel and Rees, 1996). At the macro level, the effects of efficiency gains could increase energy consumption by making energy cheaper than other inputs and by increasing economic growth. Technical efficiency gains that produce increased return on capital will attract investment and ripple through the economy; this was exactly the point that Jevons (1865) made. It should be noted that there is a dispute between conventional economists and ecological economists about the role that energy plays in economic growth and the resulting size of the macro rebound effect. The works of several ecological economists have challenged the prevailing economic view, contending that increases in the availability of high-quality energy inputs have been a primary driver of economic

growth since the Industrial Revolution (Jenkins et al., 2011). These economists argue that capital, labor and energy inputs have synergistic and multiplicative effects on economic output and that the increased availability of low-cost, high-quality energy sources has provided a necessary condition and been a key driver of most historical improvements in economic productivity (Sorrell, 2009). Although different methods (including price elasticities and general equilibrium models) and theories (from micro economics to neoclassical growth theory) are applied, it could be argued that the energy economic understanding of macro rebound effects takes its point of departure in methodological individualism: The sum of the actors' actions on the micro level constitutes what is called macro-economic and economy-wide rebound effects, leaving no room to explain rebound effects outside the market.

Giampietro and Mayumi (2008) provide a different perspective by analyzing the rebound effect in the light of evolutionary theory and thermodynamics. They address the problem of how to separate the effect of changes due to extensive variables (an increase in population, for example) from the effect of changes due to intensive variables (an improvement in energy efficiency, for example). They point to the fact that the Jevons Paradox or the rebound effect just reflects natural patterns associated with evolution that entail contrasting goals in relation to different objectives, which can only be defined at different hierarchical levels and scales. Conventional scientists and their tools have a problem dealing with the perception and representation of the process of evolution. Their point is that an increase in efficiency would lead to resource savings only if the process of evolution did not modify the existing portifolio of behaviors in response to efficiency improvements. In dealing with evolution, they claim that because of emergence (the process of coming into being) the original formal identity used in a model loses its validity and will be replaced by another formal identity. Therefore, the phenomenon makes it impossible to predict the effect of an increase in efficiency while still using the original formalization of the concept of efficiency. By making a process more efficient, we are unintentionally increasing the likehood of emergence.

To explain the rebound effect, the thermodynamic hierarchy theory (Kawamiya 1983 as cited in Giampietro and Mayumi 2008) distinguishes between two types of efficiencies:

- Efficiency of type 1 (EFT1)—the output/input ratio—which does not consider the time required for the output. An example of this is kilometers obtained with a litre of fuel, in which the time required for the travel is not considered.
- Efficiency of type 2 (EFT2)—the output obtained per unit of time—which does not consider the required amount of input. An example is the cruising speed of a car, which does not consider the related fuel consumption.

That is, EFT1 focuses on energy efficiency and EFT2 focuses on time efficiency.

EFT1 is related to the scale issue of the socio-economic system. It is concerned with the suitable size of the biophysical metabolism of a given society, compared with the biophysical metabolism of the ecosystems embedding it.

A higher speed of throughput, implied by an increase in EFT2, has beneficial effects on the ability of the socio-economic system to express more complex behaviors and enlarge its domain of action. This higher speed of the biophysical throughput associated with the economic process is benign, because it can relate to a higher level of production and consumption of goods and services. The tendency in the past has been towards EFT2's greater speed of throughoutput in terms of production and consumption. Unfortunately, in the case of economic systems, there is a tendency to put excessive emphasis on the short-term increases of EFT2.

Another approach can be found in a social-science understanding by applying a perspective from the theory of science position critical realism. According to Archer (2003) structures emerge from the interaction of actors. Structures have qualities that actors do not possess. Actors do have qualities in the form of social structures qualities, but also qualities that no social structure possesses. This allows the studying of the interaction of structures and actors over time by an endless cycle of developing structural conditions, social interaction and structural development. Structural conditions do not enforce or determine an actor's actions, but they do have an objective influence that reduces their degree of freedom. A central point is that actors and structures do not stand in a one-to-one relationship, but that society consists of several levels and emergent structures. Actors are not only confronted with one structure but with a network of interlinked political, economical, scientific, cultural, and other structures. Because structures exist prior to social interactions, actors do not create social structures; they recreate or change structures through their activities (Buch-Hansen and Nielsen, 2005)

How have social sciences treated the rebound effect on the micro, meso, and macro levels. At the micro level applying a physiological explanations for rebound effects, it could be that more efficient products or ecofriendly products in effect salves people's conscience. When an environmentally benign product has been purchased, demand for environmentally damaging products increases (Santarius, 2012):Further at the micro level optimism in green technology could weakens the individual's sense of responsibility to act pro-environmentally (Soland, 2013). Peters et al. (2012) have suggested combining  a psychological perspective with a lifestyle perspective of rebound effects to allow for explanation of rebound effects at the micro level and meso levels. Rebound effects and consumption patterns are not only determined by individuals' level of income, but also by their values and attitudes and those of their peers. Lifestyle groups might differ from each other with regard to changes in behavior after an energy efficiency improvement. The lifestyle concept integrates differences both in resource levels and in value orientations and attitudes, and so connects these levels and dimensions to explain social differences. Peters et al. (2012) found that a holistic lifestyle concept would enable comparison across different behavioral areas (namely mobility and housing) and cover aspects that are outside psychological models. Lifestyle concepts are a feasible means to broaden the focus of psychological models to the meso level of social groups and milieus.

Actors are also embedded in fundamental socio-technical structures. We live in a society that is connected with the high mobility that allows people to adapt to it, one in which efficiency, technical and comfort development have contributed to increased mobility. This affects people's everyday life organization; it affects how the car is used for daily activities; and it is related to the location of housing, schools and kindergartens, and to employment and procurement opportunities. The conventional car has also spurred transport when there has been a greater demand for mobility during leisure time. The political-institutional framework looks at society in a high-mobility context by the desire for economic growth and mobility over environmental concerns. Business interests, including international agreements, have also helped generate growth in mobility, both nationally and internationally (COWI, 2000).

At the macro level our quest for growth through our economical and political system outstrips the efficiency gains. In growing economies, the savings achieved by eco-efficient technologies will be used for other consumption (Schneider et al., 2010).

### What could be learned across disciplines?

The rebound problem could be identified as stemming from the belief in the efficiency strategy for solving environmental problems. This strategy proposes developing new and more efficient technologies to replace the old, inefficient, and polluting materials and methods (Høyer and Holden, 2007). The sustainable development debate has focused on transforming production to become more efficient in terms of resource use, and hence less environmentally harmful. The final output through reduction in absolute volume through simply consuming less are overlooked in current policy (Aall and Husabø, 2010).

Outcomes on the macro scale do not reflect what is expected from an action at the micro level: Because there is a profound difference between efficiency and reduction in absolute volume, relying on the efficiency strategy and failing to understand how the micro and macro levels are connected leads to misguided environmental policies. An analysis that understands the rebound effect(s) needs to account for different dimensions and scales and to be constituted on the basis of integrating a number of disciplines into a research cluster that provides (or purports to provide) a new framework of understanding; rebound effects are not limited to any disciplinary boundaries (Høyer and Næss, 2008).

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