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Estimating broad-brush rebound effects for household energy consumption in the EU 28 countries and Norway: some policy implications of Odyssee data

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HIGHLIGHTS

- Policymakers frequently link energy efficiency gains with energy consumption falls.
- Household energy rebound effects are calculated for EU lands using Odyssee data.
- Most older EU lands show results in the range of 0–50% but newer lands show 100–552%.
- Energy efficiency gains are not always a reliable predictor of energy consumption.
- Targeted research could explore why consumption is often so unrelated to efficiency.

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ABSTRACT

Currently there is a strong policy commitment in European Union (EU) and Organisation for Economic Co-operation and Development (OECD) countries to increase the energy efficiency of residential buildings, and it is widely assumed that this will naturally and automatically reduce domestic energy consumption. However, other factors such as fuel prices, wages, attitudes and lifestyles also influence energy consumption. This paper calculates broad-brush rebound effects based on changes in energy efficiency and energy consumption in each of the 28 EU countries plus Norway, for the years 2000–2011. In doing so, it tests how well the assumption of energy efficiency leading to energy reduction stands up to scrutiny in these lands. It uses the EU's Odyssee database for efficiency and consumption figures and a commonly employed econometric definition of the rebound effect as an energy-efficiency elasticity. Most older EU lands show rebound effects in the expected range of 0–50%. However, the range for newer EU countries is 100–550%, suggesting that energy efficiency increases are not a good predictor of energy consumption. A more in-depth look at one country, Germany, suggests these results underestimate the rebound effect significantly. This also identifies research needs for specific energy consumption determinants in each country, to find more precisely what is driving consumption levels.

1. Introduction

Policymakers are acutely aware that one of the main ways of reducing energy consumption and CO_2 emissions is to increase energy efficiency. From a purely technical standpoint, there should be a direct relationship between increased energy efficiency and a reduced quantity of energy required to produce the same amount of useful work. This applies to all sectors of the economy – households, transport, manufacturing, services, governance, research – even though 'useful work' can mean different things in each sector. In households, which are the concern of this paper, useful work consists of space heating and cooling, water heating, cooking, cleaning, refrigeration, lighting and the operation of electrical devices such as for ICT, home entertainment and hobbies. There is now considerable impetus globally to increase the efficiency of all such equipment to mitigate climate change and enhance energy security (Levine et al., 2007). At the European Union (EU) level, this is perhaps most directly addressed in the Energy Performance of Buildings directives (European Commission, 2010), though renewable energy plays a complementary role (European Commission, 2009).

This paper therefore investigates changes in household energy efficiency in the 28 EU countries and Norway from 2000 to 2011 and compares these with corresponding changes in household energy consumption.

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It asks whether there is any consistent relationship between these two, that is, does increasing energy efficiency in the household sector necessarily lead to reducing energy consumption in that sector? It also discusses what other factors are influencing this relationship and how their specific effects need to be accounted for in policy planning, so that we have a better chance of achieving stated goals – such as a 20% reduction in energy consumption. It also identifies avenues for detailed empirical work to obtain more precise results for such influences in each country. The principle data source for this paper is the EU's Odyssee database (Odyssee, 2013). As this database includes Norway along with the EU 28, this country is included in this study. For brevity, however, we will simply use the term 'EU' throughout.

While not all reductions in energy consumption are a direct consequence of energy efficiency increases, there is often a direct linkage between the two in policy statements. For example, the EU Commission's recent report on Nearly Zero-Energy Buildings (European Commission, 2013) states that buildings 'are central to the EU's energy efficiency policy'; that 'improving the energy performance of Europe's building stock is crucial' to meet climate goals; and that, to this end, 'Directive 2010/31/EU on the energy performance of buildings is the main legislative instrument at EU level for improving the energy efficiency of European buildings.' It is clear that a close connection between improving energy efficiency and reducing climate-damaging emissions (and therefore energy consumption) is assumed.

Similar linkages are found in policy literature of individual EU countries, such as the UK (e.g., DCLG (Department for Communities and Local Government) (2013)) and Germany (e.g., BMVBS (Bundesministerium für Verkehr, Bau und Stadtentwicklung), 2011). Similarly, the Intergovernmental Panel on Climate Change (IPCC), in its chapter on residential and commercial buildings, notes that improving the energy efficiency of buildings 'encompasses the most diverse, largest and most cost-effective mitigation opportunities in buildings' (Levine et al., 2007).

This is not to suggest policymakers think that energy efficiency is the only determinant of energy consumption or that energy efficiency improvements are a necessary and sufficient condition for energy reductions. However, these and many other examples indicate that there is often an assumption that increasing energy efficiency naturally and automatically leads to reductions in energy consumption or that efficiency is by far the dominant determinant.

Empirical studies consistently indicate that increases in energy efficiency do not regularly lead to one-to-one reductions in energy consumption. A proportion of the potential reductions are often 'taken back' as increases in useful work, a phenomenon generally termed the 'rebound effect' (Sorrell and Dimitropoulos, 2008). This phenomenon was identified as early as in the mid-19th century (Jevons, 1866) and its development in recent times can be traced through Brookes (1978), Khazzoom (1980) and Saunders (1992) and reviews such as in Hertwich (2005) and Sorrell (2007).

Berkhout et al. (2000) offered an econometric foundation for understanding the rebound effect, which has become a standard in economics literature and was further refined by Sorrell and Dimitropoulos (2008). Here, the rebound effect is defined as an 'elasticity', namely the 'energy efficiency elasticity of energy services'. This means the ratio of the proportionate change in energy services consumption to the proportionate change in energy efficiency, expressed as a differential function. In simplified, explanatory literature, this is often expressed as a ratio of percentage changes:

$$Rebound\ effect = \frac{percentage\ change\ in\ energy\ services\ consumption}{percentage\ change\ in\ energy\ efficiency}.$$

This can be a helpful prosaic explanation, but is not strictly correct because a percentage point is a very large change for a function that may be curvilinear. A more strict definition of the rebound effect is given using partial differentials:

$$R_{\varepsilon}(S) = \frac{\partial S/S}{\partial \varepsilon/\varepsilon}. \quad (1)$$

where S is the level of energy services and ε is the energy efficiency.

The mathematics of this relationship, for use in this investigation, is developed in Section 3. We use this definition here for several reasons. First, it is widely accepted in economics literature, where it can easily be related to other economic parameters such as price elasticity, income elasticity and changes in gross domestic product (GDP) indices (see, e.g., Berkhout et al., 2000; Sorrell and Dimitropoulos, 2008). Second, its two parameters, energy efficiency and energy services, are common to all sectors of the economy (see, e.g., Hertwich, 2005). Therefore, this definition enables us to speak a common language between these sectors and make credible comparisons of how energy consumption responds in each sector to changes in energy efficiency.

With regard to EU countries, estimates of the rebound effect in domestic energy consumption have been offered for Austria (Haas and Biermayr, 2000), Belgium (Hens et al., 2010), Germany (Madlener and Hauertmann, 2011), Norway (Nesbakken, 2001), the UK (Druckman et al., 2011) and Mediterranean countries (Tronchin and Fabbri (2007)), while Maxwell and McAndrew (2011) have offered an overview of the phenomenon in EU lands in general. As yet, there has not been a country-by-country comparison for the EU 28.

Further, there is a range of definitions of the rebound effect in the above-cited publications. Some of these make various comparisons between absolute values of energy consumption rather than proportionate changes between energy efficiency and energy services consumption. A review of these definitions is given in previous work by this author (Galvin, 2014). There it is also shown that much of the discrepancy in results for rebound effects, even within the same country's domestic sector, can be due to differences of definition rather than variations in the empirical data.

There is therefore a need for a country-by-country estimate of the rebound effect for domestic energy consumption in all 28 EU countries based on a consistent definition of the rebound effect, using data gathered by the same central agency, processed by the same consistent methodology.

We note, however, that even within this mainstream econometric definition of the rebound effect, there is a range of strictness as to the degree of cause and effect that is assumed to be at work between the two elements being compared. Under the strictest definition, only those increases in the consumption of energy services which are a direct consequence of consumers' responses to increased energy efficiency, would be counted in the calculations (Madlener and Hauertmann, 2011). However, in a study such as this, which uses national statistics rather than in-depth case studies, it is not possible to distinguish behavioural effects from other influences on consumption such as technical failures. We therefore speak of the 'broad-brush' rebound effect, as a straightforward energy efficiency elasticity of energy services, remaining agnostic as to what caused the energy services to increase when the efficiency increased.

The remainder of this paper proceeds as follows. Section 2 offers a critical explanation of the definition of energy efficiency used in the paper and in the Odyssee database. Section 3 presents the mathematical basis and methodology for the paper's comparison of energy efficiency and energy consumption. Section 4 gives the results for the EU countries and the EU as a whole, plus a more in-depth analysis for Germany as a case study, and a discussion of sources of error. The results and the methodology are discussed in Section 5 and Section 6 concludes.