Dissertation Outline:

Rebound Effects in Industry and Service Sectors: Conceptual framework, empirical evidence and policy implications

(work in progress)

Submitted by

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1 Overview

In Germany, the services and industrial sectors in 2011 were responsible for almost half of the country's total primary energy consumption, according to the national energy balance. In terms of electricity consumption, the two sectors even add up to more than 70% of total consumption. Therefore, it is obvious that any effort to reduce energy related carbon dioxide emissions and fossil fuel consumption must incorporate these sectors. Measures include switching from fossil fuels to renewable energy sources, realising significant energy efficiency measures and thus reducing primary energy consumption.

Both theoretical and empirical literature suggests that energy efficiency measures do not necessarily lead to the full energy and emission savings projected by ex-ante engineering-economic estimates (Berkhout et al. 2000; Bentzen 2004). One of the reasons for this observation is the so-called rebound effect (Jevons 1865; Brookes 1979; Khazzoom 1980). This effect denotes the phenomenon that the implementation of energy efficiency measures leads to a change in consumer behaviour that may result in an increased use of energy, countering the initial impact of the measure. The literature commonly distinguishes between direct, indirect and economy-wide rebound effects (Maxwell et al. 2011).

- Direct rebound effect: use of energy inputs increases after service/product/process have become more energy-efficient due to reduced energy costs
- Indirect rebound effect: use of energy inputs for other products/services/processes increases due to reduced energy consumption following efficiency measures
- Economy-wide rebound effect: increase in economy-wide use of energy inputs in response to changes in demand, production and distribution patterns (e.g., decreasing costs for energy efficient products may lead to new applications (for example steam engine (Jevons 1865), and LED lighting (Bessho und Shimizu 2012))

While the general existence of rebound effects can be regarded as scientifically accepted, their quantification, underlying mechanisms such as drivers and barriers, and countermeasures are still under debate. Also, rebound effects in commercial and industrial enterprises comprise a much less well explored field of research.

Numerous studies have conceptually identified and empirically explored rebound effects for individual consumers and are summarised in two comprehensive meta studies (Sorrell 2007; Maxwell et al. 2011). In contrast, for lack of data, only few studies have analysed rebound effects in industrial sectors, including (Saunders 2013) and (Allan et al. 2007), with results varying widely in terms of magnitude of the effect, scope of industry sectors investigated and methodologies applied.

Further empirical literature on rebound effects relies on a variety of methodologies, typically acknowledges the existence of rebound effects, but differs in terms of explanations and quantification (Sorrell 2007) – even for the least complex type of rebound effects, i.e. the di-

rect effect. Among others, the direct effect observed for energy consumption by private households is tried to be explained by changes in relative costs of energy inputs/services (lower variable/marginal per unit costs), bounded rationality (Turrentine und Kurani 2007) and mental accounting (Girod und de Haan 2009).

Most of these concepts, however, are only applicable to explain individual consumption behaviour. Current research results are insufficient in terms of investigating the relevance and causes of rebound effects for industrial and commercial energy consumers (Turner 2013). This group of consumers is targeted by numerous energy efficiency programmes. So far, it has not been established if, and to what extent, rebound effects can be expected when policy driven or autonomous energy efficiency measures are taken. Van den Bergh (2011) identifies and describes 14 different drivers leading to the existence of rebound effects. For commercial and industrial sectors, a number of these are relevant, including changes in factor input mixes and trade and relocation effects. Besides promoting the understanding of rebound effects, these drivers are also of crucial importance for questions of industrial and economic competitiveness.

On a macroeconomic level, the occurrence of rebound effects in industrial sectors is demonstrated (e.g. Barker et al. 2009). However, it remains unclear what drives these macroeconomic effects, which sectors are affected to what extent, and what countermeasures – if any – should and can be taken. In conclusion, more research on rebound effects in service and industry sectors is required to adequately assess the effects of technological and political energy efficiency measures to reduce energy use and greenhouse gas emissions (Ryan und Campbell 2012). If this can be achieved and mechanisms underlying rebound effects can be understood better, energy efficiency policies can be expected to have an even more significant impact on energy saving and climate protection targets.

It must also be mentioned that the debate of rebound effects does not go without critical voices. Gillingham et al. (2013) argue that the magnitude of rebound effects is small, compared to energy savings achieved by policy measures. The authors conclude that the rebound debate should not be an excuse for inaction in the field of energy efficiency policy. Turner (2013) also critically reflects the “huge surge in empirical studies claiming rebound effects of hugely varying magnitudes”, lacking a common conceptual foundation and therefore resulting in an equivocal debate which is not leading towards a convincing resolution.

A thorough analysis of rebound effects not only requires conceptual foundation, but also technical understanding of production processes and related energy efficiency measures. This greatly helps in comprehending the adaptation behaviour of organisations (Fleiter 2012).

2 Research objective and structure

The proposed dissertation aims to contribute to the field of research on rebound effects by elaborating a conceptual framework for the investigation in the tertiary sector and in energy intensive industry sectors in Germany, collecting empirical data on energy efficiency and consumption patterns and deriving policy implications to strengthen energy efficiency measures. The conceptual framework will be built on van den Bergh's (2011) identification of relevant drivers for rebound effects. The objective of this dissertation therefore is to improve the understanding of rebound effects and their underlying mechanisms in the German services and industrial sector by

a) Conceptualising a framework that is suitable for the discussion of rebound effects in the German services and industrial sector

b) Identifying the influence of energy prices on the factor input mix of German energy intensive industries and investigating the effect on their competitiveness

c) Evaluating energy efficiency performance data from the German service sector and determining whether energy efficient production units exhibit changes in their factor input mix signalling the existence of rebound effects.

The conceptual framework will be the basis for the analysis of rebound effects in service and industry sectors. Based on the evaluation of empirical evidence, policy implications will then be derived. For this objective, three sets of sub-questions are addressed in separate work packages:

1) What drivers of rebound effects at the level of companies and within individual energy intensive industry sectors can be identified? How can these drivers be conceptualised for an assessment of rebound effects in the German industry and services sector?
2) For energy intensive metalliferous industries, what is the influence of energy costs on factor input mix and trade patterns? How do energy prices influence competitiveness? Does the data provide a base for the assumption that energy efficiency measures lead to a shift in consumption behaviour?
3) For the service sector, does consumption data justify the assumption that organisations shift their input factor mix following the implementation of energy efficiency measures?

In the following section, an overview of the applied methodologies is given, and then the structure of the second work package is discussed in more detail.

3 Methods

3.1 General approach

To address the broad nature of energy efficiency measures, competitiveness and the occurrence of rebound effects in the services and industrial sectors, the proposed dissertation employs a multi-faceted approach. This approach is consisting of the development of a theoretical framework and the implementation of empirical analyses based on firm-level and sectoral-level data. Micro- and sectoral-level analyses will be combined to capture key effects and mechanisms identified in the conceptual framework. According to the three subquestions formulated in the previous section, a set of methods is applied in the three work packages accordingly and described in the following sections.

First work package: Conceptual framework

In a first stage, a theoretical framework is developed which will serve as basis for the subsequent empirical studies. Research will be based on a broad literature review, and include primarily concepts from neoclassical economics, evolutionary economics, and where applicable behavioural economics (Armstrong und Huck 2010). Hence, the theoretical framework will also acknowledge the implications of path dependencies (Dosi 1982) and limited factor substitutability (Lutz et al. 2005). Taking into account the call for a clear conceptualisation by (Turner 2013), the framework for the following two work packages will be developed along the following key aspects:

- Clear formulation of the type of rebound effects relevant for the respective work package
- Identification of rebound mechanisms according to van den Bergh (2011) which may trigger rebound effects following the implementation of efficiency measures identified in the first step
- Definition of the understanding of the term energy efficiency (measures) for the scope of the respective work package
- Evaluation of relevant energy efficiency measures and quantification of expected energy savings

Only after conceptualising the framework for the respective work packages, the identification and quantification of rebound effects conjoined with further analyses is carried out.

Second work package: Sectoral level analysis

See detailed description in section 3.2.

Third work package: Micro-level analysis

Data from a survey on energy efficiency and energy use by companies in the German service sector will be assessed to quantify the effect of energy efficiency measures and evaluate whether there is evidence for the existence of rebound effects in terms of factor input shifts

following energy efficiency measures. For this survey, roughly 2000 companies in the German service sector will be questioned inter alia on their energy consumption and supply structure and the implementation of energy efficiency measures.

On the resulting data, a multi-dimensional Data Envelopment Analysis (DEA) will be performed to relate energy consumption data among other input factors to output data of service sector companies, resulting in the determination of an efficient production frontier. This allows for the comparison of energy consumption of individual companies and the rating of their efficiency performance. Also, by determining the position of energy efficient companies towards the efficient frontier, it is possible to derive evidence on the factor input shift following the implementation of efficiency measures.

3.2 Sectoral competitiveness analysis (work package 2)

Within the second work package, the competitiveness situation of German energy intensive industries is analysed. First, an overview of competitiveness definitions and derivable indicators is given. Based on this set of indicators, the current situation and historic development of metalliferous industry sectors (steel, aluminium, copper) is assessed. Next, the input cost structure of selected production processes is depicted to analyse the effect of energy price changes on the price of final products and thus on the competitiveness of these sectors. However, competitiveness can hardly be expressed in one single indicator. Besides price competition for homogeneous goods, a set of non-price related factors is crucial for the success or failure of companies. These include

- **Structure of production and use of products:** By determining focuses of investment and existing production capacities as well as important customer locations, information on industry structures can be gained. Also, by analyzing labour and capital intensity of the respective branches, and taking into account Leontief's Paradox, the production structure is assessed with regards to comparative advantages.
- **Trade patterns:** Trade volumes (imports and exports) as well as destinations (countries, sectors, and companies) allow for the determination of trade intensities, comparative cost advantages (Ricardo) and intra-industrial trade (Verdoorn). Trade data can be gathered from databases such as UN Comtrade.
- **Price mechanisms:** Depending on the geographic scope and structure (monopoly, oligopoly, and perfect competition) of product markets, different pricing mechanisms can be observed, giving indications to the competition structure. Also, the market structure allows for conclusions as to whether price signals can be passed on to customers along the value chain.
- **Other competitiveness factors:** These include quality and accessibility of infrastructur, training level of work force, access to capital markets and others. Most of these factors are difficult to quantify and will therefore only be included in a qualitative discussion.

These factors will be incorporated into the development of an analysis framework that allows for the assessment of sectoral competitiveness. Data collection will be performed based on statistics from the German Federal Statistics Office, statistical offices of the federal states,

Eurostat and industry associations. Additionally, national and international energy statistics will be analysed. The results are used to gain an overview of the significance of the respective branches for the German industrial sector.

Following the analysis of sectoral competitiveness data, an investigation into the influence of energy prices and other production factors on the production cost structure of the industries will be performed. This will be based on a production cost model that can display the effects of input factor price changes on the price of selected final products, incorporating technological knowledge of according production processes. Production costs are influenced by material, labour, and capital costs. These include research and development expenditure, and spending for compensatory environmental measures which may vary considerably in international comparison. Also, subsidies, allowances and trade barriers such as customs must be taken into account. The variation of energy costs can thus be contrasted against the influence of other input factor prices taking into account the energy intensity of individual products.

Subsequently, a four factor (capital, labour, materials, energy) analysis performed by Saunders (2013) is adapted to investigate the historic occurrence and possible magnitude of rebound effects in the according energy intensive industrial sectors in Germany. The analysis will again focus on energy intensive branches that have a high relevance for the German economy. By analysing the development of the usage of the above mentioned factors over time and against a frozen efficiency scenario, it is possible to evaluate the extent of efficiency gains. By also evaluating the development against a “100% efficiency scenario”, in which theoretical ex-ante efficiency gains are included, it is possible to derive implications on the existence and magnitude of rebound effects within energy intensive industry sectors.

4 Results

The conceptual framework developed in work package 1 will provide the scientific basis for a robust assessment of rebound effects. It serves as foundation for the following work packages. This is required to correctly classify and discuss effects that are identified in the empirical analysis and put them into a scientific perspective. Thus, the correct interpretation of data will be ensured.

For the competitiveness analysis in work package 2, factor input mix changes are addressed on a detailed technical level. Thus, the influence of factor price changes (the focus will be on energy and mainly on electricity) can be quantified. By looking at individual production processes rather than more aggregated sectoral data, the energy intensity of products and thus the criticality of the input factor energy can be assessed much more precisely. Re-aggregating this data will allow the identification of the overall influence of energy costs on sectoral competitiveness and thus the competitiveness situation of relevant energy intensive industries in Germany. By employing the four factor analysis, the existence and magnitude of rebound effects in selected energy intensive industry sectors is determined, based on thorough technical understanding of energy efficiency options and historic development of factor input mix, using synergy effects with the competitiveness analysis in technically analysing production processes.

In the third and final work package, novel consumption data from a comprehensive survey in the German service sector is evaluated. This data gives insights into the effects of energy efficiency measures on the productivity and input factor structure of companies. The Data Envelopment Analysis will help determining efficient production frontiers in different branches of the service sector, allowing for a detailed investigation into their productivity and allowing for the identification of areas that need further political attention in relation to the reduction of inefficient energy usage. The data gathered can also be used to decide whether there is evidence for the existence of rebound effects within the service sector by assessing how companies modify their factor allocation after implementing energy efficiency measures.

5 Conclusions

The proposed dissertation can provide insights into the mechanisms underlying the occurrence of rebound effects in energy intensive industry sectors and the service sector in Germany. This is required to be able to base decisions on energy efficiency policy measures on a robust knowledge of these effects, possibly contributing to the strengthening of energy efficiency policies. Unique data can be accessed to gain insights into factor input composition, and technological knowledge is combined with conceptualised economic expertise to advance the debate of rebound effects.

Systematic clarification with regards to drivers of rebound effects will be added for an area of energy consumption that has so far seen little attention with regard to the investigation of these effects. For this, technological knowledge of individual production processes and efficiency measures is combined with the detailed economic analysis of the development of relevant indicators to provide robust results.

The combination of multi-faceted approaches on sectoral as well as individual company levels leads to a broad picture in terms of an exploratory attempt to conceptualise and capture rebound and competitiveness effects in sectors of substantial economic importance and environmental impact. By understanding how energy efficiency measures, competitiveness and factor inputs are interrelated, it may be possible to better steer the effect of future policy measures to reduce energy consumption and its environmental impact. Also, an insight into the occurrence and possible magnitude of rebound effects in the investigated sectors will shed light on the question whether political action is required to reduce these effects or whether energy efficiency measures can unfold their full potential without additional intervention.

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