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Energy intensity and convergence in Swedish industry: A combined econometric and decomposition analysis

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A B S T R A C T

How to reduce the carbon footprint associated with energy use is still a major concern for most decision-makers. Against this background, a better understanding of energy intensity—the ratio of energy use to output and its convergence could be important in the design of policies targeting the reduction in the carbon footprint related to energy use. This paper analyzes the determinants of energy intensity and tests for energy intensity convergence across 14 Swedish industrial sectors. This analysis builds on a nonparametric regression analysis of an intensity index constructed at the industry sector level as well as indices constructed from a decomposition of this index. The latter isolates two key determinants of changes in energy intensity and convergence patterns: the efficiency channel-fundamental improvement in the use of energy and activity channel-structural shifts in the economy. The empirical analysis relies on a detailed sectorial dataset covering the period 1990–2008. The findings indicate that input prices, including the price of energy, have been significant determinants of energy intensity in the Swedish industrial sectors. This effect can primarily be attributed to the efficiency channel and with a less profound influence from the activity channel. We also find evidence of energy intensity convergence among the industrial sectors, and this primarily stems from the activity channel rather than from the efficiency channel.

1. Introduction

Environmental and energy security concerns have generated great interest in issues related to the decoupling of environmental pollution, particularly carbon dioxide emissions, from economic growth. This has in turn resulted in a renewed interest in the relationship between energy and output, especially the use of fossil fuels and how to use energy resources efficiently. It is generally acknowledged that investments in new energy efficient technologies will play a significant role in achieving both environmental objectives and objectives concerning energy security. The industrial sector plays an important role in this context; it accounts for about one third of global final energy use and this share has grown over time (International Energy Agency, 2012). For this reason it is important to gain an in-depth understanding of the determinants of energy intensity – the ratio of energy use to output – in the industrial sector, not the least the extent to which changes in industrial energy intensity result from structural shifts in the industry or rather from more fundamental improvements in the industry's use of different energy carriers. This should provide important information for decision-makers on the design and evaluation of policy instruments aimed at achieving further energy efficiency improvements and the reduction of the carbon footprints associated with energy use.

Beyond this, a number of previous studies (e.g., Ezcurra, 2007; Liddle, 2010; Markandya et al., 2006; Miketa and Mulder, 2005) have illustrated the relevance of energy intensity convergence[1] across countries, either in the aggregate and/or across sectors between countries and/or across sectors within the same country. Cross-country convergence in energy (as well as carbon dioxide) intensity could influence the political economy of negotiating multilateral climate agreements (e.g., Pettersson et al., 2014). For instance, evidence of energy intensity convergence could indicate that specific countries would only need limited special consideration for global agreements to be considered fair (Liddle, 2010). A related argument may be valid also for the study of energy intensity convergence across industrial sectors in one country, especially concerning the consequences for different sectors of climate and energy policies. Such inter-sector convergence may

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[1] This is here defined as a decline in the cross-country and /or sector differences in energy intensity indices.

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arise due to different spillovers across sectors, both technological (e.g., improvements in the energy efficiency of generic production processes such as fuel combustion) as well as managerial (e.g., the use of energy management systems). There may be a need to provide evidence on the level of knowledge transfer across sectors, especially from leading sectors to backward sectors—sectors with a relatively high level of energy intensity, and use this information in targeting public support for energy efficient R&D activities. Finally, investigating energy intensity convergence between industrial sectors within a single country may also provide knowledge of what one may expect concerning future convergence at the international level (see also Brännlund et al., 2015). Countries with similar industry structures may be more likely to converge in terms of energy intensity, while the opposite could hold for countries with heterogeneous industrial compositions.

The objective of this study is twofold. The first is to provide evidence on the determinants of energy intensity across different manufacturing sectors in Sweden. The analysis addresses the roles of the energy price, R&D intensity, capacity utilization as well as the prices of capital and labor inputs, respectively. The second objective is to understand the differences in energy intensity dynamics across the manufacturing sectors in the country. Specifically, we are here interested in testing the so-called beta convergence hypothesis, and analyze the extent to which changes in energy intensity and convergence result from structural shifts in the industry (i.e., the activity channel) or rather from more fundamental improvements in the use of energy (i.e., the efficiency channel).

In contrast to most previous research in the field (e.g., Bernstein et al., 2003; Fisher-Vanden et al., 2004; Liu and Ang, 2007; Metcalf, 2008; Mulder and de Groot, 2012; Mulder et al., 2014; Sue Wing, 2008) the analysis builds on a nonparametric regression analysis of an intensity index constructed at the industry sector level as well as indices constructed from a decomposition of this index. The energy intensity indices are based on the Fisher ideal index analysis (Fisher, 1921), and these isolate two key determinants of changes in the energy intensity and convergence patterns: energy efficiency improvements and changes in economic output (activity). An important difference from most previous studies is that we combine decomposition analysis with regression analysis to examine the determinants of both energy intensity and energy intensity convergence.

Few previous studies combined decomposition and regression analyses in the energy literature (e.g., Metcalf, 2008; Mulder and de Groot, 2012; Sue Wing, 2008). Still, Metcalf (2008) and Sue Wing (2008) only focused on energy intensity determinants and trend analysis, respectively, whereas Mulder and de Groot (2012) focused on trend and energy convergence of similar sectors across countries. Our study differs from these in the sense that: (a) we examine both the efficiency and activity channels for the determinants of both energy intensity and convergence in energy intensity across sectors; (b) we consider manufacturing sectors within a given country; and (c) we implement a full nonparametric methodology to examine the drivers of energy intensity and test for convergence of energy intensity. The advantage of employing a nonparametric approach is that we avoid the imposition of functional specification bias.

The choice of Sweden for this study is motivated by the fact that in 2013, the Swedish industrial sector contributed to about 38% of total final energy consumption in the country (Swedish Energy Agency, 2015), and this puts Sweden among the top-five countries in the European Union (EU) in terms of industrial energy use as a share of final energy consumption. This also indicates the energy policy relevance of the industrial sector in Sweden, and the implications that this sector has for the country's contribution to the 27% energy efficiency EU-level target. Moreover, Sweden has had an active climate and energy policy for a fairly long time, including significant changes in carbon and energy taxes over the last three decades. For instance, the Swedish carbon dioxide tax (including some deductions for energy-intensive industrial sectors) was introduced already in 1991 (Brännlund et al., 2015). Against this background, Sweden should serve as an interesting case study to analyze industrial energy intensity dynamics and test for energy intensity convergence across different manufacturing sectors.

The remainder of the paper is structured as follows. In the next section a brief literature review on previous studies address the determinants of energy intensity and energy intensity convergence. We derive our energy factor demand model from production theory in Section 3, and relate this to energy intensity in order to establish some key determinants of energy intensity. This section also discusses the theoretical underpinnings of energy intensity convergence, especially the channels through which convergence (or divergence) may appear as suggested in previous research (e.g., see Grossman and Helpman, 1991, for economic growth convergence). The empirical model for the analysis is also presented in Section 3. The data used are presented and discussed in Section 4. In Section 5 we present the results, while Section 6 contains the conclusion of the study and points at some important implications.

2. A brief overview of the literature

The literature on energy demand and its determinants is vast, with most studies focusing on estimating price and income elasticities (see e.g., Fouquet, 2014 for a recent discussion); in this review we focus only on studies on energy intensity and its convergence, which is more related to the objective of our study. Empirical studies on energy use, output and the environment can be grouped into three main categories. The first category focuses on investigating trends in energy use, energy intensity and emission intensity, as well as on the determinants of energy intensity (e.g., Bernstein et al., 2003; Fisher-Vanden et al., 2004; Metcalf, 2008; Neelis et al., 2007; Nilsson, 1993; Schipper et al., 2001; Worrell, 2004). The general conclusion from much of this work is that energy intensity and energy use have tended to decline over time, although the specific trends have been contingent on the time periods, country and/or region and the industrial sectors under study. Studies that have focused on the determinants of energy intensity have typically pointed out the importance of energy price changes (e.g., Bernstein et al., 2003; Fisher-Vanden et al., 2004; Metcalf, 2008). Other important determinants of industrial energy intensity are capacity utilization, the climate, R&D expenditures, the structure of the economy, ownership patterns etc. (e.g., Bernstein et al., 2003; Fisher-Vanden et al., 2004).

Neelis et al. (2007) studied energy efficiency trends in Dutch manufacturing industry over the time period 1995–2003. These authors estimated the annual average energy efficiency development to be 1.3% and based on this concluded that, since the mid-1990s, significant energy efficiency improvements have been made in the sectors studied. They also indicated that efficiency improvement varies widely across sectors, years and various types of energy use. Schipper et al. (2001) reviewed energy indicators that have been developed to describe the link between energy use and human activity. They further reviewed decomposition methods, often used for analyzing trends in energy use. The authors utilize different energy indicators at a disaggregated level for industrial countries. An important purpose was to illustrate the applicability and ability of disaggregated energy indicators as a powerful analytical tool to uncover important trends in energy use, that are often obscured in traditional aggregate quantities such as the ratio of aggregate energy use to GDP. Findings from their analysis indicated a declining trend in energy intensity for the sampled countries.

The second category of studies focuses on index number decomposition analysis (e.g., Duro et al., 2010; Greening et al., 1997; Howarth et al., 1991; Huntington, 2010; Liu and Ang, 2007; Metcalf, 2008; Mulder and de Groot, 2012; Mulder et al., 2014; Sue Wing, 2008). The study by Howarth et al. (1991) used the Laspeyres method to examine trends in manufacturing energy use in eight OECD countries over the period 1973–1987. These authors decomposed changes in energy use into