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Analysis of the importance of structural change in non-energy intensive industry for prospective modelling: The French case

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HIGHLIGHTS

- Defining NEI industries with a quantitative approach from relevant indicators in France.
- Developing new decomposition method given in additive form with no residual in NEI.
- Structural change is the overwhelming factor in improving energy performance within NEI.
- Revealed consistent trend with level of sector disaggregation if homogeneous industries.

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ABSTRACT

A large number of studies have been conducted on the contribution of technological progress and structural change to the evolution of aggregate energy intensity in the industrial sector. However, no analyses have been done to examine theses changes in the non-energy intensive industry in France. We analyzed their importance in French industry with respect to their energy intensity, energy costs, value added, labour and the diffusion of production sites by using data at the 3-digit level with 236 sectors. Using a new decomposition method that gives no residual, this paper attempted to examine, over 10 years from 1996 to 2005, the changes that occurred in an area that has been neglected in energy analysis. We found that structural change had an overwhelming effect on the decline of aggregate energy intensity. Furthermore, we found that the higher the level of sector disaggregation, the more significant the changes that can be attributed to structural change, due to the homogeneity of this industrial group. The results of our study show that it is important to take into account the effects of structural change in "bottom-up" modelling exercises so as to improve the accuracy of energy demand forecasting for policy-makers and scientists.

1. Introduction

It is well known that change in aggregate energy intensity is caused by structural and technological effects. In recent years, a considerable number of analyses have studied their impacts on industrial energy intensity over time (Cortuk and Singh, 2011; Chen et al., 2011; Sauramo and Maliranta, 2011; Al-Salman, 2008; Ma and Stern, 2008; Chòliz and Duarte, 2006; Ramirez et al., 2005; Enevoldsen et al., 2007; Ussanarassamee and Bhattacharryya, 2005; Zhang, 2003; Fagerberg, 2000; Farla et al., 1998; Gardner and Elkhafif, 1998; Sinton and Levine, 1994; Gardner, 1993; Huang, 1993; Li et al., 1990; Ang, 1987; Boyd et al., 1987; Motamen and Schaller, 1985; Sterner, 1985; Jenne and Cattell, 1983). In France, the non-energy intensive industry (NEI) group represented almost 40% of total energy consumption in industry in 2005, compared to 30% for 1993. For both electricity and natural gas, we observe a respective increase in consumption from 45% to 55% and from 40% to 45% (Seck, 2012). Thus, NEIs possess a large share of the technical pool for energy savings.

Under the ESC mechanism (Energy Savings Certificate), energy operators are required to achieve a certain amount of energy savings per 3-year period. A failure to achieve these objectives incurs penalties. To avoid double counting with the European ETS (Emission Trading Scheme, or mechanism for trading emissions of CO_2), the ESC cannot be applied to sites that come under the national quota allocation plan (PNAQ, which are generally the energy intensive industries (EIs)). NEIs are thus a priority target for energy operators. They are expected to play an important role in reducing the aggregate energy intensity of industry in the long term because of their economic importance (80% of value added in French

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industry) and have relatively high growth rate. However, these sectors have been neglected in energy analyses, despite the continuing policy focus on energy efficiency and the many reports and books written on the topic. This oversight encouraged us to do long-term modelling exercises with a bottom-up model like MARKAL/TIMES (The Integrated MARKAL-EFOM System developed by ETSAP (Energy Technology Systems Analysis Programme) under the aegis of the International Energy Agency (IEA)) (Seck, 2012; Seck et al., 2013, 2015; Djemaa, 2009; Gargiulo, 2009; Loulou and Labriet, 2007; Loulou et al., 2004, 2005; Fishbone and Abilock, 1981, Fishbone et al., 1983).

These models will aim to inform energy companies on how much to invest in new technology so as to facilitate its incorporation and achieve the expected energy savings. Thus, it would be wise to analyze the importance of structural effects in energy efficiency studies in order to take them into account in modelling exercises and avoid skewed results. A deeper understanding of the sources of aggregate intensity change can help to improve the quality of energy demand forecasting. Energy demand forecasts that can explicitly take into account important effects of structural change will be more useful in policy making than those that cannot (Sinton and Levine, 1994). Past trends in aggregate energy intensity can help us better understand the current situation and have an influence on future decisions aimed at reducing energy use. This paper examines the relative contributions of technological and structural effects on change in aggregate energy intensity in the NEI group in France from 1996 to 2005. The paper is broken down as follows: Section 1 shows the level of disaggregation detail considered, the data and sources used in the analysis, along with a presentation of the decomposition method, which allows us to analyze the influence of structural and technological effects on changes in aggregate energy intensity; Section 2 deals with a way to distinguish between non-energy intensive and energy intensive industries in the industrial perimeter by using criteria which could explain their difference through a data mining approach; Section 3 presents the results of the analysis of the influence played by structural change on the evolution of the aggregate energy intensity.

2. Data and methodology

This article uses economic data published by EUROSTAT on the industrial sector (manufacturing industry) for France (value added, production value, energy costs). The data on energy consumption, employment and number of production sites came from the internal database ENERVISION of EDF R&D departments designed by EPI (Eco-Efficiency and Industrial Processes) and ICAME (Business Innovation, Market Analysis and their Environment) at the 4-digit level of NACE rev 1.1 (Statistical Classification of Economic Activities in the European Community) classification. The heart of the data used is from the capitalization of investigations on the energy use on industrial sites. The database is thus constructed from approximately more than 300,000 data by incorporating energy knowledge of industrial sectors from CEREN (Centre of analysis and research on energy), SESSI (Industrial statistics and analysis), AGRESTE (Statistical organism on agriculture, Food and drink industry, and fishing), and INSEE (National Institute of Statistics and Economics Studies) (Berthou et al., 2009)

We base our analysis on a 3-digit level of disaggregation of the NACE rev 1.1 classification with 236 subsectors. The choice of this level of disaggregation can be explained by the fact that the most precise level of subsectoral detail is adequate in order to accurately disentangle the structural effect from the intensity effect, but data availability also has an impact. Thus, the recycling sector was not considered in the analysis due to lack of data. The data extend over a period of approximately 10 years from 1996 to 2005.

2.1. The choice of activity indicator for energy intensity

Energy intensity is defined as the ratio of energy consumed and the indicator of activity. The latter may be an economic or a physical indicator.

In the NEI industry, there are a considerable number of goods that do not necessarily have physical links that can form the basis of aggregation. As illustrated by Bernard and Côté (2002), the Food and Drink industry provides a clear example. Liquid foods are by nature sold on the basis of volume, while solid foods are sold by weight, and some products such as eggs or oranges are sold by natural units. Physical measures are useful and meaningful when considering a particular product in the case of an energy-intensive industry (e.g. in the cement industry, a ton of cement is a relevant and useful measure of output), but the more heterogeneous the products produced by an industry like in the NEI, the more difficult it is to measure the volume of production. Thus, physical measures are not relevant here (Seck, 2012; IEA, 1997). In this case, economic measures relating to the volume of output are preferable due to the difficulty of precisely measuring the volume of output across very diverse products (Freeman et al., 1997). Moreover, they are generally available and comparisons are often easy. The value added and value of production measures are widely referred to the literature.

The choice of one of these parameters can have an impact on information related to changes in energy intensity, which may involve a very different energy efficiency policy, as illustrated by Côté (2002) with the example of the US manufacturing sector between 1988 and 1991 observed by the DOE (Department of Energy) (US DOE, 1995b). Intensity indicators based on value added are somewhat more sensitive to changes in an economic environment than those based on production value (Li et al., 1990). However, NEIs include a large number of sectors which require aggregation in order to strike a compromise between detailed modelling, cost in time and acquisition of data. Thus, value added has the advantage of not only representing the economic benefit associated with the energy consumed, but also of allowing consistent aggregation between different levels, which is not the case for the value of production (IEA, 1997). Moreover, the use of value of production could be problematic because of double counting (Ramirez et al., 2005; INSEE, 2003). We consider that it is important to remove this problem of multiple counting because of the high number of links between subsector products in the NEI industry in terms of intermediate products, and we compare the efficiency ratios between them. In conclusion, our choice is to use value added as our indicator of activity for the rest of our study, and to keep it in mind as our final goal in order not to bias our energy modelling analysis (Seck, 2012; Hita et al., 2011).

2.2. Decomposition method

The aim of our analysis in this section is to measure the impact of structural and technological changes in the aggregate energy intensity of the non-energy intensive industry over a period of 10 years from 1996 to 2005 through a decomposition analysis.

A review of decomposition methodology in energy studies can be found in Ang (1993, 1995a, 1995b, 2004, 2005), Ang et al. (1992, 1998, 2002, 2003, 2004), Ang and Liu (2001), Ang and Liu (2007a, 2007b), Ang and Skea (1994), Ang and Zhang (2000), Boyd and Roop (2004), Boyd et al. (1987, 1988), Choi and Ang (2003, 2012), Hirst et al. (1983), Hoekstra and Van der Bergh (2003), Liu and Ang (2003, 2007), Shrestha and Timilsina (1996), Sun (1998), Su and Ang (2012, 2014, 2015) and Zhang and Ang (2001).

In this paper we considered an index decomposition analysis