Renewable and Sustainable Energy Reviews 89 (2018) 216–227

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Underlying causal factors of the European Union energy intensity: Econometric evidence

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ARTICLE INFO

Keywords:
Energy intensity
GDP per capita
Foreign direct investments
Energy prices
EU

ABSTRACT

The aim of the research is to determine the main factors that define the level of energy intensity in the countries of the European Union. The research was conducted by estimation of six baseline and six auxiliary regressions, with and without time lags, in form of one-way fixed and random effects error component models, on different unbalanced panel data samples covering the period 1995–2015. The obtained baseline regressions results generate three sets of findings. The first set consists of extremely robust findings relating to the positive influence of gross fixed capital formation and industrial gross value added, and negative effects of real per capita gross domestic product and oil products retail price. These variables are statistically significant in all 36 baseline empirical models. The second set of results consists of quite robust findings relating to insignificant influence of foreign direct investment and negative influence of coal price. According to the results, it cannot be confirm the hypothesis of energy-saving technology transfer via foreign direct investments in European Union member states. The third set of results shows that the research has failed to generate any robust findings for economic openness (import ratio), urbanization and natural gas price, which means that the effect of these determinants on energy intensity in European Union member states is unspecified. Finally, auxiliary regressions estimation results show that changes in the sectorial composition within the European Union member states' economies have not enhanced energy-saving technological transfer via foreign direct investments.

1. Introduction

In November 2016, the European Commission presented a new package of measures in energy policy. Strategic document entitled The Clean Energy for All Europeans [1] covers energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union (EU). Putting energy efficiency first is specified as a priority strategic goal. The European Commission increased energy efficiency target from 27%, as was agreed in October 2014 [2], to 30% by 2030. Improving the energy efficiency should ensure gross domestic product (GDP) growth of additional EUR 70 billion, open an additional 400,000 jobs and reduce the EU's fossil fuel dependence. Achieving these ambitious goals will depend on the consistent implementation of energy policy. Streimikiene and Šivickas [3] studied the effect of the implementation of EU policy and directives on reducing energy intensity, and they showed that consistent implementation of the regulation and support to structural funds was crucial for reducing energy intensity in the Baltic States after 2005. In order to achieve a continuous reduction in energy intensity, many factors are significant, but the goal of this paper is to determine its key determinants in EU member states.

One of the widely confirmed assumptions is that technological advancement has positive impact on reducing energy intensity. There are a lot of empirical evidence especially in iron and steel industry which are closely connected to other industries [4–6]. Application of new technologies or management practices, which imply high level of accumulated knowledge, contributes to higher level of productivity and energy efficiency [7,8]. Literature contains a number of research examples, based on different methods and empirical data, which confirm direct link between productivity and energy efficiency [9–11].

Abbreviations: EU, European Union; IM, import ratio; GDP, gross domestic product; PCY, real per capita GDP; FDI, foreign direct investment net inflows; UR, urban population; IND, industrial gross value added in GDP; OILP, oil products retail price; e(A), energy intensity of non-industry sector; COALP, coal price; YPC, per capita income; GASP, natural gas price; G, cumulated values; GLS, generalised least squares; AID, foreign aid; BLUE, best linear unbiased estimations; EI, energy intensity; SA, Swamy - Arora estimator; I, gross fixed capital formation; WH, Wallace - Hussain estimator; IVA, industrial gross value added; WK, Wansbeek - Kapteyn estimator; OP, economic openness; FE, fixed effects error component mode

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https://doi.org/10.1016/j.rser.2018.03.061
Received 16 June 2017; Received in revised form 10 March 2018; Accepted 17 March 2018
1364-0321/

According to Arrow [12] and Hübler and Keller [13], cumulative knowledge is the function of cumulative gross fixed investment, meaning that overall knowledge pool increases with every new available capital good. Engaging new capital goods and increased knowledge results in reducing energy intensity.

As transfer of technology is directly associated with foreign direct investment (FDI), FDI is expected to have positive impact on energy efficiency. However, there is empirical evidence that in low income countries FDI would not promote investment in technology due to capital deficiency and low level of technology literacy [14]. Mielnik and Goldemberg [15] hypothesized that, through technology transfer, FDIs in developing countries have stronger energy-saving influence than new domestic investments. Therefore, Hübler and Keller [13] treated domestic and foreign investments as separate explanatory variables. Although EU member states can in no case be categorized as developing countries, the said difference in energy-saving effect could exist in some member states from the region of Central and Eastern Europe. Technology transfer through FDI, which should reduce energy intensity, can be achieved in two ways. The first is direct, through greater energy efficiency of foreign companies compared to domestic ones. This implies that foreign companies are to use more superior technology than the technology currently used in the observed countries, thus causing lower relative energy consumption. The second is indirect, through technological spillovers from foreign to domestic companies. This impact is achieved by means of three transmission channels: (a) demonstration effects, (b) labor turnover and (c) vertical linkages. Demonstration effects predominately relate to absorbing the knowledge by following the examples of more efficient and effective foreign companies. Labor turnover effect is the transfer of knowledge achieved through fluctuation of workers. Vertical linkages imply transfer of technology and knowledge from foreign companies to their suppliers and customers. In addition, FDI inflow also affects intensifying of competition in the domestic market, thus putting the pressure on domestic opponents to increase their productivity and, consequently, energy efficiency.

The economy structure largely determines energy intensity of the country. Industry, particularly certain sectors such as iron and steel sector, are large energy consumers. Literature contains numerous research in the field of energy intensity in various sectors of industry [16–18]. Phylipsen et al. [19] conducted international comparisons of energy efficiency and found structural differences in energy-intensive industrial sectors, as well as the way to incorporate these differences in international comparisons of energy efficiency. Makridou et al. [20] researched energy efficiency in the countries of EU, in 5 energy-intensive sectors (construction, electricity, manufacturing, mining and quarrying, and transport). The research showed that in the analyzed period 2000–2009, all sectors recorded energy efficiency growth due to technological changes. The results of the research showed, inter alia, that high prices of electricity and energy taxes have negative impact on industrial energy efficiency.

Energy intensity is closely and directly related to economic development. Literature contains a number of studies in which direct link between energy consumption and economic development was empirically tested and proved [21–24]. Taking into account different level of economic development at the EU level, Markandya et al. [25] analyzed energy intensity for 12 transition countries in Eastern Europe and for 15 EU countries and showed that, along with the economic development, energy intensities of the 12 transition countries will significantly converge toward energy intensities of the 15 EU countries. Streimikiene et al. [26] analyzed energy intensity for three Baltic Sea States: Lithuania, Latvia, and Estonia. They noted that energy intensity in these three Baltic Sea States sharply fell in the course of a deep economic recession starting in 1992. After 1996, the decline in their energy intensity was caused by the economic transition process.

A link between energy consumption growth and urban population growth can be viewed from the perspective of two potential channels of impact. The first channel is direct and is reflected in the fact that urban zones are by far busier and well-connected with other regions, which implies significantly denser traffic and greater energy consumption. Also, higher degree of urbanization implies higher level of development of urban institutions and infrastructure (street lighting, schools, universities, hospitals), but also greater use of other energy-using appliances that are not widely used in rural areas. The second channel is indirect and refers to the fact that urbanization promotes industrialization and thus greater energy consumption (which will be particularly controlled in this paper through introduction of industrial gross value added in regression equations). Pacione [27] estimated that cities account for 75% of the world's consumption of natural resources and, at the same time, only 2% of the world's surface. Literature contains a great number of papers dealing, in empirical terms, with impact of urban population growth on energy efficiency, primarily in China and in other countries with accelerated growth of urbanization [28,29].

The main objective of this paper is to determine the main drivers of energy intensity and test their impact on energy intensity in EU-28. There are many determinants that affect energy intensity, but their mutual relationship is so complex that makes it hard to determine the direction (direct or indirect) and the intensity of impact of each individual determinant on energy intensity. Starting from the results of other empirical studies, the authors selected and tested the impact of the following variables (gross fixed capital formation, FDI net inflows, industrial gross value added, economic openness or import ratio, real per capita GDP, urban population and energy prices) on energy intensity in EU-28. Considering the existing literature for selected six variables, it was found that the research is focused mostly on developing countries while the empirical results for developed countries are limited. It would be for the first time to test the impact of these factors on energy intensity in EU-28 member states. EU region is specific due to common energy policy, where reducing energy intensity is one of the priorities. All countries have harmonized regulations striving to promote energy efficiency, so it is very important to analyse all the determinants included in regulation in the appropriate manner. The single European market is based on "four freedoms" (free movement of goods, capital, services, and labor) where FDI inflows should be consistent with energy efficiency policy. As energy efficiency is on EU priority list, FDI should promote energy efficiency. The focus of this paper is to analyse whether FDI in this region promotes energy efficiency technologies. This research represents the only study on EU energy intensity, known to the authors, that incorporates such a broad set of potential determinants and, at the same time, does not confirm the hypothesis of energy-saving technology transfer via FDI.

The paper is organized into four sections. Section 2 discusses the theoretical and empirical model and data. The results and discussion is developed in Section 3, while Section 4 refers to the main conclusion and proposed direction for future research.

2. Material and methods

2.1. Model

A basic theoretical model was developed by Hübler and Keller [13], starting from the assumption that economic activity can be decomposed into industry and non-industry sectors, quite different in terms of energy intensity. Energy intensity of non-industry sector is marked as $e(A)$, where A stands for average technology in use, and where $e(A) > 0$, and $e'(A) < 0$. It is assumed that energy intensity of industry sector is μ times higher than $e(A)$. If share of industrial gross value added in GDP is marked as IND, total energy consumption can be formulated as follows:

$$E = GDP^{*}(\mu^{*}IND + 1 - IND)^{*}e(A), \quad (1)$$

which gives that total energy consumption is a function of three key factors: scope of economic activity (GDP), relative significance effected