Energy Economics 42 (2014) 161–171

Contents lists available at ScienceDirect

Energy Economics

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

Energy intensity: A decomposition and counterfactual exercise for Latin American countries☆

Raul Jimenez *, Jorge Mercado

Inter-American Development Bank

ARTICLE INFO

Article history:
Received 7 June 2013
Received in revised form 21 December 2013
Accepted 21 December 2013
Available online 30 December 2013

JEL classification:
O5
O13
Q40
Q43

Keywords:
Energy intensity
Decomposition
Panel data
Synthetic control method

ABSTRACT

This paper investigates trends in energy intensity over the last 40 years. Based on a sample of 75 countries, it applies the Fisher Ideal Index to decompose the energy intensity into the relative contributions of energy efficiency and economic structure. Then, the determinants of these energy indexes are examined through panel data regression techniques. Special attention is lent to Latin American countries (LAC) by comparing its performance to that of a similar set of countries chosen through the synthetic control method. When analyzed by income level, energy intensity has decreased in a range between 40 and 54% in low and medium income countries respectively. Efficiency improvements drive these changes, while the structural effect does not represent a clear source of change. The regression analysis shows that per capita income, petroleum prices, fuel-energy mix, and GDP growth are main determinants of energy intensity and efficiency, while there are no clear correlations with the activity component. In the case of LAC the energy intensity decreased around 20% which could be interpreted as an under-performance. However, the counterfactual exercise suggests that LAC has closed the gap with respect to its synthetic control.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

As both energy prices and concerns about global warming continue to increase, measures to improve the energy use have become important components of public policy agenda. In particular, there is a focus on identifying factors that influence change in energy intensity and distinguishing the contribution of energy efficiency from other relevant factors. This information is useful as it provides a basis for policy decisions and evaluation. Further, energy efficiency represents a cost-effective strategy to address crosscutting issues such as energy security, climate change and competitiveness.

In this context, this paper aims to investigate trends in energy intensity based on a sample of 75 countries with annual data during the period 1971–2010. To this end, three specific objectives are addressed. First, analyze the evolution of the aggregate energy intensity and its main components. Then, identify the main determinants of these energy indexes. Finally, the article lends special interest to the Latin American region by evaluating its relative performance in terms of energy intensity and efficiency.

Following the World Energy Outlook (IEA, 2012) energy intensity would have decreased about 20% in the World and 35% in OECD countries between 1980 and 2010. Accordantly, empirical literature suggests a downward trend in energy intensity, with the efficiency effect as its most important source of variation. However, the magnitudes of those improvements tend to be heterogeneous depending on the case and period analyzed. Previous studies could be divided in two groups. One with a rich and large body decomposing and examining trends in energy intensity within a specific sector, where the manufacture has received great attention. The other group has been less explored and bases its analysis on more aggregate data mainly at multi-sector level within a country.

With respect to previous research in the industrial sector, some relevant figures emerge of the well-studied cases as China, India and United States. China represents a notable case of improvement decreasing its level of energy intensity more than 70% between 1980 and 2010. Sinton and Levine (1994), Zhang (2003), and Ma and Stern (2008) show that this was mostly a sustained decrease in industrial energy intensity, with efficiency explaining most of this variation. As reported by Ke et al. (2012), during the period 1996–2010, the efficiency effect explains 30%

☆ The opinions expressed in this article are strictly those of the authors and do not necessarily reflect those of the Inter-American Development Bank (IDB), its Board of Executive Directors or the countries they represent. A previous version was published as a working paper by the IDB. The authors are grateful for the support of Ramon Espinasa and the Research Department at the IDB, as well as for the helpful comments and suggestions of Lenin Balza, Diego Margot, Juan Jose Miranda, Tomas Serebrisky, Rodolfo Stucchi and four anonymous peer reviewers. All remaining errors are our own responsibility.

* Corresponding author at: 1300 New York Avenue, N.W. Washington, DC 20577, United States. Tel.: +1 202 623 2170. E-mail address: rjimenez@iadb.org.

0140-9883/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.eneco.2013.12.015

of the energy savings in industrial energy consumption. Another remarkable fact occurring in the industrial sector is that intensity actually increases in the period 2003 to 2005, related to a notably increase in the levels of energy consumption. Still, the industrial energy intensity continued to decrease.

In contrast, studies of the Indian industrial sector found mixed results from 1981 to 2005, showing only slight improvement in energy intensity (see Reddy and Ray, 2011). Interesting cases where both efficiency and activity have played a role in reducing the overall energy intensity index are found in studies of the United States. Hasanbeigi et al. (2012) show that in California, from 1997 to 2008, the energy intensity ratio decreased 43% is mainly explained by two events: (i) a shift in value added participation from the oil and gas extraction sector to the electric and electronic manufacturing sector, which uses less energy per value added; and (ii) an escalation in energy prices that led the industries to improve efficiency in order to reduce energy costs. Over a similar period, Huntington (2010) analyzes 65 U.S. industries in the commercial, industrial, and transportation sectors, showing that an estimated 40% of reduction in aggregate energy intensity was due to structural change.

In one of the first studies available on energy intensity at the state/country level, Metcalf (2008) performs a decomposition exercise at state level in the United States for the period between 1970 and 2001. He finds a reduction in energy intensity of approximately 75% as a result of efficiency improvements. Further, through a panel data analysis, he shows that rising per capita income and higher energy prices play an important part in lowering energy intensity. Bernstein et al. (2003) analyze a similar period using a sample of 48 states in the U.S., finding that population, energy prices, climate temperatures, and indicators of sector activities, are strongly correlated with energy intensity. In a recent study, Voigt et al. (2014) perform a decomposition analysis finding that intensity decreased by 18% on a sample of 40 major economies over the period 1995 and 2007. The results also suggest that this improvement is largely attributable to technological change.

Using a similar approach, Bhattacharya and Shyamal (2001) decompose the aggregate energy intensity of India into pure intensity or efficiency and the economic activity composition effect. They take broad sectors including agriculture, industry, and transport for the period between 1980 and 1986, finding that the efficiency effect contributed significantly to energy conservation.

This paper focuses on energy intensity indicators at broad end-use sectors at the country level. This implies the observation of (aggregate) energy indexes (i.e., the indicators of energy intensity and its decomposition into efficiency and the activity mix) at the country level. For this purpose, we adopt the monetary-based definition, where energy efficiency improvement generally means using less energy to produce the same amount (value added) of services or output (Ang, 2004; Nanduri et al., 2002).

In this context, the paper has three main contributions. Strengthen the literature by analyzing a greater sample over a longer period than previous studies. A further step is provided by the analysis of the determinants of energy intensity and its components. Second, the paper shows results by income level set of countries with a focus in Latin American region, where appears to be lacking of evidence. Finally, a methodological contribution to this specific literature is the comparison analysis using the synthetic control method in order to overcome heterogeneity issues in a benchmark exercise.

The paper is structured as follows. Next section provides methodological strategies for (i) the decomposition of aggregate energy intensity into activity and pure intensity, which is interpreted as efficiency, (ii) the specification of the panel data analysis in order to evaluate the determinant of those three indexes (intensity, efficiency and activity), and (iii) the synthetic control method used to construct a comparison set of countries to evaluate the relative performance of Latin America. Section 3 presents the empirical results of these methodologies, and Section 4 concludes.

2. Empirical strategies

2.1. Decomposition through the Fisher Ideal Index

A key limitation in empirical analysis is related with availability of data. Based on different levels of data disaggregation, methodological contributions have been made in order to estimate energy efficiency measures. Those methods are mostly based on decomposing energy intensity into different factors, including energy efficiency, economic structure, production levels, and/or fuel sources. The more disaggregate the data, the more accurate the efficiency contribution estimations would be. The election of the specific method to be used depends on the objectives and data availability. Some extensive methodological studies and surveys on decomposition methods can be found in Boyd et al. (1988), Ang and Lee (1994), Ang and Liu (2003), Ang (2004), Boyd and Roop (2004), and Ang et al. (2009). They suggest a certain degree of academic consensus that using price index numbers is preferred when dealing with aggregate data at the country level.

Following those recommendations, the method applied herein to perform the decomposition is the Fisher Ideal Index. Its main advantage is that it does not have residual term, referring to a portion of the change in intensity which is not assigned to a particular source; that is, a portion of energy intensity that remains unexplained (Boyd and Roop, 2004). The presence of residual term makes it difficult to interpret the relative importance of factors being evaluated. Specifically, Ang et al. (2010) emphasize that the perfect decomposition methods should be adopted in the case of cross-country/region studies. In addition, as mentioned by Ang (2004; 2006), Boyd and Roop (2004), and Ang and Liu (2003), these methods are also preferred in the case of two-factor decomposition due to their theoretical foundation and their adaptability, as well as the ease in interpreting their results. In our case, energy intensity is decomposed into its efficiency and activity components. Besides the references above Ang and Lee (1994), Greening et al. (1997), and Ang et al. (2010) provide a compressive review and applications of alternative decomposition methods.

In this context, the problem is set in terms of total energy consumption (E) and total production (Y), as well as sub-indexes for economic sector (i) and years (t). In our application i refers to the agricultural, industrial, services, and residential sectors. Thus, the aggregate energy intensity (e) can be written as:

$$e_t = \frac{E_t}{Y_t} = \sum_i^n \frac{E_{it}}{Y_{it}}\frac{Y_{it}}{Y_t} = \sum_i^n e_{it}s_{it}. \tag{1}$$

Expression 1 indicates that a change in e_t may be due to changes in the sector energy intensity (e_{it}) and/or the product mix or compositional effect (s_{it}). By construction, the energy uses in the different sectors need to form a partition (i.e., they must not overlap), but the measures of economic activities do not need to satisfy this condition. The last represents one of the main operative/practical advantages of this approach. What is more, they do not even need to be in the same units, facilitating the identification of good indicators to account for the activity mix (s_{it}).

Following the index number theory, we proceed to derive the two components of the Fischer index. Dividing Eq. (1) by the aggregate energy intensity for a base year ($e_0 = \sum_i^n e_{i0}s_{i0}$), and factorizing by $\frac{\sum_i^n e_{i0}s_{i0}}{\sum_i^n e_{i0}s_{i0}}$ and $\frac{\sum_i^n e_{it}s_{it}}{\sum_i^n e_{it}s_{it}}$, it obtained the Laspeyres and Paasche indexes, respectively.

$$\text{Laspeyres indexes:} \quad L_t^{act} = \frac{\sum_i^n e_{i0}s_{it}}{\sum_i^n e_{i0}s_{i0}} \quad L_t^{eff} = \frac{\sum_i^n e_{it}s_{i0}}{\sum_i^n e_{i0}s_{i0}}$$

$$\text{Paasche indexes:} \quad P_t^{act} = \frac{\sum_i^n e_{it}s_{it}}{\sum_i^n e_{it}s_{i0}} \quad P_t^{eff} = \frac{\sum_i^n e_{it}s_{it}}{\sum_i^n e_{i0}s_{it}}$$

Download English Version:

https://daneshyari.com/en/article/5064715

Download Persian Version:

https://daneshyari.com/article/5064715

Daneshyari.com