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Electricity consumption and economic development: Are countries converging to a common trend?☆

Young Se Kim

Department of Economics, Sungkyunkwan University, 53 Myeongnyun-dong 3-ga, Jongno-go, Seoul 110-745, Republic of Korea

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ABSTRACT

This paper studies the dynamic behavior of electricity consumption with special emphasis on their convergence patterns. Individual electricity indicators are modeled by allowing for apparent heterogeneous transitions. Log t convergence test results indicate that all 109 countries converge to a common stochastic trend for electricity intensity while per capita electricity consumption is better explained by a multiple-component model. In the case of 24 advanced economies, there is a strong tendency towards a common component for both indicators. The application of clustering algorithm confirms the presence of club convergence for per capita electricity consumption. In terms of clustering pattern, per capita electricity consumption appears to be remarkably similar to per capita income, widely used measure of economic development.

1. Introduction

The importance of understanding both time-series and cross-sectional properties of energy-related measures illuminating the links between energy uses and human activity has been underscored by researchers as well as policymakers. This paper studies convergence in some important electricity-related measures, electricity intensity and per capita electricity consumption, using a variety of panel data. With special emphasis on heterogeneous transitional dynamics of the indicators, we take the convergence analysis in a different avenue than previous attempts in the literature. This is motivated by the observation that, even over several decades, there still exist substantial differences in electric power usage across countries. Since, in the presence of divergence, a traditional statistical model may not be felicitous to account for some salient features of the data, this paper utilizes an alternative approach, multiple-component model, to better understand their dynamic behavior.

Improving energy efficiency has become one of top priorities in most countries and, as a consequence, there has been significant progress in enhancing efficient use of energy resources. That is, primary energy use has been increasing more slowly than aggregate economic activity. Such a sharp reduction in energy intensity can be attributed to higher energy prices, technological progress, and government energy regulations. In particular, as shifting availabilities of energy resources and development of technologies change a country's energy structure, a number of studies, e.g., Liddle (2009), Nilsson (1993), and Rosenberg (1998), suggest that the shifts to electricity, which is considered to be one of dominant components of secondary energy, have contributed to the marked improvement in energy efficiency. In fact, the growth of electricity consumption has far outpaced primary energy consumption and world electricity intensity appears to exhibit the long-run upward trend.

Notwithstanding differences, both types of indicators, electricity intensity and per capita electricity consumption, are capable of accounting for how electricity consumption is associated with economic activity.

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E-mail address: youngsekim@skku.edu.

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Notably, per capita electricity consumption has attracted considerable attention in the literature as its role in determining economic welfare or development.[1] A number of studies propose that per capita electricity consumption is as tractable as per capita income and may better describe the nature of standard of living that depends not only on income but also on other factors influencing quality of life, such as education, health care, life expectancy, climate, and environment. However, empirical studies routinely find that there is no stable long run relationship between electricity consumption and income (Joyeux and Ripple, 2007). As such, income-based measures of standard of living may not be capable of capturing the long-run information content of electricity consumption.[2] Therefore it is of interest to explore which energy-related indicator would be the best candidate for evaluating economic development and how closely it is related to per capita income.

An issue that has attracted considerable attention in empirical work of energy economics is to investigate whether cross-sectional differences in energy-related measures across countries shrink over time. By examining the evolution of primary energy consumption, a number of studies have found the possibility of convergence among a set of countries that have relatively similar characteristics, such as OECD countries (Cornille and Fankhauser, 2004; Markandya et al., 2006; Mielnik and Goldemberg, 2000; Mulder and de Groot, 2012; Nilsson, 1993), whereas the evidence for convergence becomes weaker when the sample encompasses both developing and developed countries (Duro and Padilla, 2011; Ezcurra, 2007a; Miketa and Mulder, 2005).[3] On the other hand, the dynamic aspects of electricity consumption distribution have received relatively less attention. Recently, using a sample of IEA countries, Mohammadi and Ram (2012) and Liddle (2009) show the signs of electricity intensity convergence. With regard to per capita use of electricity, although there exists a weak form of convergence, large cross-sectional disparity seems to persist over time (Maza and Villaverde, 2008; Mohammadi and Ram, 2012).

Following the line of research, this paper aims to contribute to the literature on convergence in electricity consumption.[4] This study distinguishes from the previous works on the following grounds. First, as suggested by in Cornille and Fankhauser (2004) and Squalli (2007), this study takes into account apparent heterogeneous transitions making conventional convergence test results untrustworthy.[5] Specifically, we employ a nonlinear time-varying factor representation allowing for transitional dynamics and individual heterogeneity.[6] Using a sufficiently large time-series observations, 1971–2009, we show that relative convergence holds for electricity intensity among 109 countries, but not for per capita electricity consumption. Second, for a panel in which overall convergence is evidently rejected, we explore the possibility of club convergence, distinct clusters of countries with differentiating characteristics that set them apart from the rest of the sample. This is motivated by the fact that lack of convergence among all countries in a panel does not necessarily refute the idea that a subgroup of countries can be dominated by their own common component.[7] Our empirical application indicates that per capita electricity consumption can be better explained by a multi-component model rather than a single-component model that has been traditionally used in the literature. Third, the clustering analysis suggests that there is almost one-for-one relationship between per capita electricity consumption and per capita income and thus confirms the role of per capita electricity consumption as an alternative measure of economic development.[8]

This paper is organized as follows. Section 2 demonstrates some salient feature of electricity measures in the data and briefly reviews related studies regarding convergence analysis. In section 3, modeling individual electricity indicators is deliberated and log t convergence test results for a variety of panels are presented. Section 4 provides estimated convergence club classifications for per capita electricity consumption. The relationship between per capita electricity consumption and per capita income in terms of their clustering patterns is extensively discussed. Section 5 concludes the paper with future research directions.

2. Stylized facts of electricity intensity and consumption

To understand not only the differences in the level of electricity consumption across countries, but also their dynamic evolution, various indicators that are capable of elucidating the link between electricity usage and human activity have been developed. Over the past few decades, the most frequently used aggregate electricity indicators in the literature are electricity intensity and per capita electricity consumption. Despite the fact that these are two very different ways of looking at the link between electricity consumption and some of the most important underlying drivers, each indicator plays a crucial role in fostering energy efficiency policy development and evaluation since both types of indicators have proved to be extremely useful for a simple cross-country comparison. Before beginning a formal statistical analysis, this section documents some salient empirical features of electricity indicators regarding their time-series and cross-sectional properties with a special emphasis on dynamic behavior of cross-country dispersion.

Improving energy efficiency has become one of top priorities in many countries as governments have been increasingly aware of an imperative need to make better use of limited energy resources. As a consequence, substantial progress has been made to reduce the intensity of energy as primary energy consumption has been increasing more slowly than aggregate economic activity in most countries.[9] Contributing to the notable declines of energy intensity was often attributed to higher fuel prices and long-term technological progress. In addition, government policy plays a key role in limiting excessive use of energy resources, while meeting energy demand. However, some studies,

[1] Ferguson et al. (2000), Jakob et al. (2012), Joyeux and Ripple (2007), Nilsson (1993), and (Rosenberg (1998), among others, show that a rise in the proportion of energy used in the form of electricity is strongly associated with economic development. Specifically, the correlation between electric power usage and income tends to be much stronger, especially for advanced economies, than that between primary energy use and income. Thus electricity, rather than primary energy, yields more useful information in regard to differences in standard of living over time and across countries.

[2] For a more detailed discussion about the relative advantages of per capita electricity consumption over per capita income as the measure of economic well-being, see Maza and Villaverde (2008), and Rosenberg (1998), among others.

[3] Consequential indicators related to energy consumption, such as per capita carbon dioxide (CO_2) emission, have also been extensively studied to design appropriate policy response to potential global warming risks (Aldy, 2006), (Ezcurra, 2007b), (Ordás Criado and Grether, 2011), (Panopoulou and Pantelidis, 2009). In particular, Romero-Ávila (2008) argues that the finding of convergence in per capita CO_2 emission among advanced countries is important to encourage developing countries to accept a cap on their own emissions.

[4] It is important to note that, to provide a more complete explanation of electricity consumption development, more detailed end-use data concerning sectoral or activity levels may be inevitable (Hankinson and Rhys, 1983), (Miketa and Mulder, 2005), (Medlock and Soligo, 2001), (Schipper et al., 2001). However this analysis would take us well beyond the scope of the current paper.

[5] For example, in the notion of β-convergence, the estimation of speed of convergence parameter can be biased and inconsistent due to regression error correlated with explanatory variables. See Phillips and Sul (2009) for other pitfalls of traditional convergence tests in the presence of heterogeneous transition.

[6] An increasingly large number of studies have utilized log t convergence test and clustering procedure by Phillips and Sul (2007), for example Kim and Rous (2012), Phillips and Sul (2009), and Panopoulou and Pantelidis (2009), to overcome potential drawbacks to the convergence tests.

[7] In fact, the possibility of club convergence in energy-related indicators has been discussed by Hsu et al. (2008), Liddle (2009), Mielnik and Goldemberg (2000), Miketa and Mulder (2005), Ordás Criado and Grether (2011), and Zachmann (2008).

[8] Despite the strong link, it is hard to argue that the observed clustering pattern can be explained by per capita income due to evident endogeneity between them (Acaravci and Ozturk, 2010), (Asafu-Adjaye, 2000), (Ferguson et al., 2000), (Maza and Villaverde, 2008), (Payne, 2010).

[9] It is worth noting that energy intensity is only a proxy of energy efficiency, which is often difficult to measure (Verbruggen, 2006). Researchers routinely point out that energy efficiency is more general concept than the intensity of energy, as the former relies on various components, such as climate, population density, and output composition, that are not explicitly taken into account by the latter.