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Stochastic convergence in per capita energy use in world☆

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ABSTRACT

This paper examines the pattern of convergence in per capita energy use in a sample of 109-country covering the period 1971–2013. In addition to the full sample of countries, existence of convergence is also examined in seven subsets of countries: OECD countries, OPEC countries, and also countries in America, Africa, Asia and Oceania, Europe, and the Middle East. In contrast to the previous studies which mainly used unit root or stationarity tests, we use the results from subsampling confidence intervals. Furthermore, instead of considering convergence to a particular country benchmark, we explore all the possible pair-wise convergences. The findings, based on 7962 pairs of countries, are more favorable to the existence of the convergence. Another finding of the paper is that the per capita energy use, despite being convergent, is highly persistent.

1. Introduction

Energy is one of the most important challenges of our time and it has attracted a lot of attention from researchers all over the world. Important global issues such as energy security, energy efficiency, economic growth, sustainability, greenhouse gas emissions and climate change are all related to the energy sector. Due to its importance in the economy, researchers have investigated different aspects of energy consumption. In this paper we study the stochastic convergence of per capita energy consumption (PEC) around the world to examine the evolution of the energy use path during the past five decades. Stochastic convergence deals with the effect of shocks and it means that the per capita energy use in country i relative to the average of the PEC or the PEC in the country j would be stationary. Therefore, stationarity of the relative PEC would be considered as evidence of convergence.[1]

Most of the previous studies have used point estimation methods, mostly unit root (or stationarity) tests, to explore the existence of stochastic convergence. However, in this paper we use interval estimates (confidence intervals), which provides more information about the evolution of the series. Interval estimates are superior to the point estimates because not only they show the stationarity of the relative (differential) PECs but also they show how close they are to stationarity. In addition, we know that the stochastic convergence is equivalent to the stationarity of the gap, so when the differential is stationary, $I(0)$, we would conclude that the series is convergent. However, we might have a series with a root close but not equal to the unity[2], then shocks will have a long lasting but temporary effects. Most of the point estimates or unit root tests cannot distinguish these two, but the confidence interval can differentiate a unit root process from a stationary but highly persistent one.

Another point that has been emphasized in the literature is that the $I(0)$ and $I(1)$ dichotomy is too restrictive because it excludes the possibility of presence of long memory[3] in the process (Caggiano and Leonida, 2010). When the differential is stationary with long memory, two series would converge with a hyperbolic rate, which is

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[1] It is worth noting that convergence does not necessarily mean that the PECs are tending to be equal, rather it means that the series will move together over time and the long-term differences between the PECs are deterministic and predictable.

[2] A unit root case versus a near to unit root case.

[3] That is, the series might be fractionally integrated of order d, denoted I(d), where $0 < d < 1$.

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slower than the stationary AR process. In this case, when $0 < d < 0.5$ the convergence would be strong but when $0.5 < d < 1$ the convergence would be weak (Caggiano and Leonida, 2010).

Considering these problems, we attempt to study the convergence in PECs using confidence intervals. Using confidence intervals frees us from the dichotomy of I(0)-I(1) or I(d). Therefore, we can start our investigation without making any assumptions about the existence or non-existence of long memory. We construct confidence intervals for the sum of the coefficients in an AR(p) model, denoted by ρ, which summarizes the whole impulse response function into a single scalar measure. To construct the confidence intervals for ρ we use the subsampling approach of Romano and Wolf (2001), which provides correct first order coverage.

Almost all of the previous studies have examined convergence to the average or convergence to a specific country. But in this study we use the approach of Pesaran (2007) to investigate the pair-wise convergence. This approach considers all possible differentials (gaps) between the energy use of the countries and avoids the pitfalls of choosing a benchmark. To the best of our knowledge, this study is the first attempt to use this approach to examine the convergence of energy consumption.

Most of the previous studies have investigated convergence in energy intensities or the greenhouse gas emissions (see Panopoulou and Pantelidis, 2009; Le Pen and Sévi, 2Liddle, 2010; Barassi et al., 2011; Criado and Grether, 2011; Mulder and De Groot, 2012; Herrerias and Liu, 2013; Li and Lin, 2013; Zhang and Broadstock, 2016; Burnett and Madariaga, 2017) among others. Convergence of energy consumption has attracted attention recently. Maza and Villaverde (2008) using data for the period 1980–2007 studied the convergence of per capita residential electricity consumption in a sample of 98 countries. The results supported the existence of σ and β convergence among these countries. In addition, using a non-parametric approach they have shown that the process of convergence is weak. Mohammadi and Ram (2012) studied a sample of 108 countries. Using data from 1971 to 2007 and quantile regression analysis, they came to the same conclusion and showed that the global convergence in energy use is generally weak. Meng et al. (2013) examined existence of convergence in per capita energy consumption among 25 OECD countries over the period 1960–2010. The results from the residual augmented least square unit root tests that allow for two break points showed that the null of a unit root can be rejected for 17 countries; so the results suggest the presence of convergence in 17 countries. Mishra and Smyth (2014) is another study that supports existence of convergence in per capita energy consumption. Using panel unit root tests, they showed that the per capita energy use in the ASEAN countries over the period 1971–2011 exhibits a convergent pattern. Anoruo and DiPietro (2014) studied the convergence of per capita energy consumption among African countries. Their analyses indicated that 15 of the 22 countries considered in this study have converged to the average of the group.

Fallahi and Voia (2015) studied a group of 25 OECD countries over the period 1960–2012. Unlike the previous studies, they have used subsampling confidence intervals and concluded that the per capita energy consumption in 13 countries shows a convergent behavior towards the average per capita energy use. Reboredo (2015) examined the convergence of renewable energy as a share of energy supply for a sample of 39 developed and emerging countries over the period 1990–2010. The results from the pooled mean group method suggested the existence of convergence in only eight countries. Herrerias et al. (2017) using regional data over the period 1995–2011 studied the convergence of residential energy consumption in China. Based on the results from the approach of Phillips and Sul (2007), they found four convergence clubs in coal consumption and two convergence clubs in residential electricity consumption. Ozcan and Ozturk (2016) examined the time series properties of the per capita energy consumption in the OECD countries during the period 1971–2013. The results showed that the per capita energy consumption is stationary in 16 countries. Conditional convergence of US disaggregated petroleum consumption at the sector level has examined by Lean et al. (2016). Using monthly data on petroleum consumption in residential, commercial, industrial, transportation and electric power sectors, they have shown that over half of the series have a convergent pattern. Payne et al. (2017) investigated stochastic convergence in per capita fossil fuel consumption in the US states. They have used different LM unit root tests with allowance for structural breaks and rejected the null of a unit root. Therefore, they concluded in favor of convergence in the relative per capita fossil fuel consumption in the US states. Mohammadi and Ram (2017) explored convergence in per capita energy consumption across the US states during the period 1970–2013. The results from different parametric and non-parametric approaches were in favor of non-stationarity of the series and lack of convergence. Mishra and Smyth (2017) examined the conditional convergence in Australia's energy consumption at the sector level and found convergent pattern in six of seven sectors in Australia during the period 1973–74 to 2013–14.

In this paper we use a sample of 109-country to examine the pair-wise convergence of per capita energy consumption.[4] We also examine the existence of convergence in seven subsets of countries: OECD countries, OPEC countries, and also countries in America, Africa, Asia and Oceania, Europe, and the Middle East. The findings, based on 7962 pairs of countries, are more favorable to the existence of the convergence. Another finding of the paper is that the per capita energy use, despite being convergent, is highly persistent.

The remainder of this paper is structured as follows. Section 2 outlines the methodologies for constructing the confidence intervals and pair-wise convergence. In Section 3, we report the data and empirical findings and finally Section 4 concludes.

2. Methodology

Based on the definition of Carlino and Mills (1993) stochastic convergence occurs when per capita energy use of a country relative to the benchmark country or the average of the per capita energy use is stationary. In other words, stochastic convergence implies that the shocks to the per capita energy use gaps (differentials) are temporary. Two important elements of this definition should be emphasized: 1) the selection of a benchmark and 2) the selection of a test to examine the stationarity property of the differentials. In the literature on convergence, it is common to choose one of the series under investigation or the average of all countries as the benchmark. The selected benchmark plays a very crucial role and it could provide misleading results; therefore, it is necessary to seek a way to resolve this issue. Pesaran (2007) proposed a solution for this problem called the pair-wise approach. The idea of the Pesaran's pair-wise approach is that it calculates all possible differentials, so it does not rely on the selection of a single benchmark.[5] Thus, this approach avoids the pitfalls of using a series or the average of the series as the benchmark. Therefore, for a sample of N countries we need to calculate $N(N-1)/2$ possible per capita energy use gaps and test them for stationarity.

As mentioned above, besides the selection of a benchmark, choosing a test of stationarity is also very important. Most of the previous studies used point estimate approaches and examined the existence of convergence using unit root or stationarity tests with or without structural breaks. However, it is a well-known fact that these tests have low power especially in small samples and near unit root cases. So, it is necessary to adopt different approaches to address

[4] Our paper differs from Fallahi and Voia (2015) in that we use a larger sample of countries and also rather than studying convergence towards the average, we use pair-wise approach to examine the convergence.

[5] See Holmes et al. (2011) for more advantages the pair-wise method.