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Persistence of policy shocks to an environmental degradation index: The case of ecological footprint in 128 developed and developing countries

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ABSTRACT

The objective of this study is to examine the stationarity of ecological footprint for 128 countries for the period 1961–2013. We have been motivated by the seeming inadequacy of CO_2 emission as an index for environmental degradation, the rising importance of ecological footprint as an aggregate environmental indicator and the lack of studies on the stochastic behaviour of ecological footprint. After separating the series into linear and nonlinear categories, we have used recent unit root test to examine the stationarity of the series. The overall results show evidence of a non-reverting mean in the series for 96 countries or 81% of the sample. This implies that ecological footprint is a nonstationary series and as such policies such as imposition of carbon tax, subsidy on cleaner energy and appropriate land use act will have long-term and permanent effects on it in many countries. The policy designs should also take into consideration the individual economic characteristics of each country as ecological footprint is found to be region invariant.

1. Introduction

The menace of climate change and its impacts are so severe that urgent action against it constitutes one of the core goals of attaining sustainable development (United Nations, 2015). This has also drawn a great deal of interest of academics and policy makers on the need to have a full grasp of the influence of human activities on natural environment in the quest for economic growth and development. Environmental economists have, over the years, sought to explain the driving forces of the environment within the framework of the famous Environmental Kuznets Curve (EKC) hypothesis, which postulates an inverted U-shaped relationship between economic growth and environmental degradation. In this regard, several pollutants such as CH_4, N_2O, and SF_6 among others, have been adopted in the literature but CO_2 clearly stands out as the most widely used measure of environmental degradation partly due to its reputation as the dominant form of Greenhouse Gasses (GHGs) emission and partly due to availability of data. However, CO_2, being only an air pollution, may not be an adequate index of environmental degradation in some instances as environmental degradation may also be stock embodied such as soil, forestry, mining, and water stocks. For instance, Ulucak and Lin (2017) stated that inference based on the use of CO_2 emission may be weak in some cases especially with regards to resource stock and as such the relevant series should also focus on resource stocks such as soil stock, forestry stock, mining stock, and oil stock. This claim is also supported by Stern (2014) that though technological innovations and increasingly stringent environmental regulations have, over time, led to the decline in the levels of many pollutants per unit of output in specific processes in developed countries, the effluent mix has changed with mounting solid waste. Thus, the foregoing argument suggests the inadequacy of partial indicators of environment degradation and the need for the adoption of an aggregate indicator.

An aggregate indicator of environmental degradation is the ecological footprint. It is a metric that measures the amount of nature that is available and the amount that is consumed. It represents a comprehensive indicator of anthropogenic pressure on the environment. Conceived in 1990 by William Rees and Mathis Wackernagel in 1990 at the university of British Columbia and later developed by Rees (1992), Wackernagel (1994) and Rees and Wackernagel (1996), different aspect of the index has been studied by Charfeddine and Mrabet (2017), Ozturk et al. (2016), Al-mulali et al. (2015), Ozturk and Al-mulali (2015), Al-mulali and Ozturk (2015), Wang et al. (2013), Caviglia-Harris et al. (2009), Bagliani et al. (2008), and Marco et al. (2006). Ecological footprint basically compares environmental degradation caused by human consumption with the regenerative capacity of the biosphere. This is determined by estimating the quantity of natural capital necessary to sustain the resource demand and waste absorption requirements of a population expressed in global hectares or hectares of globally standardized bio-productivity (Rees and Wackernagel, 2004). It is tracked by the sum of six different components of surface areas that

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are productive namely land for crops, land for grazing, grounds for fishing, built-up land, forest and land for carbon demand. In most of the countries, land for carbon demand is the dominant component of ecological footprint. Ecological footprint is an important aggregate indicator for the environment as it helps countries, local leaders, and individuals to respectively understand and enhance well-being, get the best from public project investments, and comprehend their influences on the globe (National Footprint Accounts, 2016). The ecological footprint serves as a potential tool to estimate planetary boundaries and the degree to which humanity is exerting pressure on them. The ecological footprint shows that we are using ecological services at a faster rate than the planet can replenish. Apart from its importance as a measure of environmental degradation from which appropriate policy decisions can be made, ecological footprint can also broaden the discussion on sustainability beyond only the climate change problem because it tracks human demand on a wide range of natural resources and ecosystem services rather than only atmospheric carbon accumulation and sequestration (Charfeddine and Mrabet, 2017). It provides the basis for setting goals, identifying options for action, and tracking progress toward stated goals (Ulucak and Apergis, 2018). Ecological footprint accounts can be utilized as reference benchmark that encompasses all of humanity's demands on nature that compete for biologically productive area. It is an accounting system that compares human demand on earth's ecosystems to what these ecosystems are able to renew. It demonstrates how much of the regenerative capacity of the biosphere is accounted for by human activities (Galli et al., 2016). It can be used to provide a first quantitative assessment of the two sustainability principles including the principle that states that waste emission rates should not be more than the natural assimilative capacity (Mancini et al., 2016).

The objective of this paper is to examine the unit root properties of ecological indicators in 128 countries in 1961–2013. We add to the present literature on stationarity of environmental series in four separate ways. First, we incorporate several countries in the process of analysing the unit root properties of ecological footprint. To our knowledge, the only known study on the stationarity of ecological footprint has concentrated on U.S (Ulucak and Lin, 2017). The characteristics of ecological footprint such as contribution of each of its components vary across different countries and as such, policies that are suitable for the U.S may not automatically be effective in other nations. For instance, the share of carbon footprint in the total ecological footprint is dominant in U.S than in Norway and Chile, among several countries. Secondly, we test for nonlinearity in the series before we conduct the unit root tests. Most of the existing papers on the stationarity of environmental series have out rightly applied either linear or nonlinear unit root tests without initially looking at the nonlinearity of the series under examination. The use of linear models is only reliable, when the linearity tests have not detected evidence for nonlinearity in the variables (Solarin, 2017). According to Kilian and Vigfusson (2009) the estimates are asymptotically biased, if a linear series is analysed within a nonlinear framework. Conversely, the parameter estimates will be asymptotically biased, if a nonlinear series is analysed within a linear framework (Hamilton, 2011).

Thirdly, we introduce the nonlinear unit root test of Kruse (2011) to investigate the stationarity of the nonlinear series. The beauty of this test is that it relaxes the strong assumptions that the location parameter being zero, which is a characteristic of several nonlinear unit root tests. The inability to waive this assumption will cause unreliable and weak inferences, when nonlinearity, possibly the exponential smooth transition autoregressive (ESTAR)-type with nonzero location, is evident in the series (Kruse, 2011). Kapetanios et al. (2003). The use of this method is also consistent with the argument of Ulucak and Lin (2017) that suggested that future research should use alternative methods to examine the stationarity of ecological footprint. Fourthly, we adopt the linear unit root test of Narayan and Popp (2010) to examine the stationarity of the linear series. The unit root test proposed by Narayan and Popp (2010) does not only account for two structural breaks it allows the breaks to be determined endogenously within the model thereby avoiding the possible bias of having to predetermine the breaks. It is also efficient and consistent in attaining empirical evidence about the integrating properties of the series (Tiwari et al., 2013).

The remaining sections of this paper are patterned as follows: Section 2 reviews the existing literature, while Section 3 involves the data and methodology adopted in this study. The results are reported and the discussion of the results are contained in Section 4. Section 5 concludes the paper.

2. Literature review

Modelling the dynamic behaviour of the environmental indicators is fast becoming a relevant research area. With several of its major sources and solutions to be found within the energy industry, environmental degradation is a key source of public health concern as its impacts include respiratory problems, cardiac arrest, learning deficiencies and lowered IQ, high blood pressure, lung diseases, and heart disease in adults (Gil-Alana and Solarin, 2017). Many papers have focussed on the time series properties of CO2 emissions, especially the convergence of CO2 emissions[1]. A detailed literature review of the convergence has been conducted by Pettersson et al. (2014). Unlike the convergence of environmental indicators, the stationarity of environmental indicators is very limited in the literature and the few papers have mostly concentrated on the stationarity properties of CO2 emissions. Knowing the stationarity properties of an environmental indicator is imperative for the following reasons. One, the existence of unit roots means shocks to the pollutions resulting from the introduction of better fuel-efficient technologies are permanent (McKitrick, 2007). Two, the nonstationarity of the environmental indicator has important implications for the papers on the Environmental Kuznets Curve (EKC), which estimate the relationship between the income and pollution levels of a country. The EKC studies rely on the assumption that pollution is trend stationary. Meanwhile, an EKC study that adopts a nonstationary pollution series in levels as the dependent series might generate spurious inference if the independent series including income or output, are also nonstationary (Sidneva and Zivot, 2014). Three, if the environmental indicators of several countries at level are difference stationary, there is no possibility of convergence between them and therefore, any inference of convergence on the relative per capita CO2 levels is not valid (Carlino and Mills, 1993; Solarin, 2014). Four, the division between trend stationary and difference processes is vital for analysing the potential long-term effect of environmental blueprints, which depend on the ability to forecast future emissions and evaluating the accuracy of these forecasts. The long-term impacts of a policy are much more certain when the series are stationary than when they are nonstationary.

The studies on the stationarity of CO2 emissions include Heil and Selden (1999) that test for unit roots in 135 countries for the period, 1950–1992. The results confirm stationarity of CO2 emissions in 20 countries. McKitrick and Strazicich (2005) examined unit root properties in CO2 emissions in 121 countries for the period 1950–2000. It is observed that nonstationarity exists in majority of the countries. Christidou et al. (2013) investigated the stationarity of CO2 emissions in 36 nations for period, 1870–2006. Using the Kapetanios et al. (2003) method among other nonlinear unit root tests, the results indicate that stationarity exists in 33 out of 36 countries. Chen et al. (2016) used the fractional integration method of Robinson (1994) to test for the stationarity of air pollution of four key Chinese metropolises, for the period, September 28 of 2013 to December 12 of 2015. The findings

[1] A related field is the literature on the stationarity of energy consumption and its components. For instance, Aslan (2011), Smyth (2013), Yilanci and Tunali (2014) and Dogan (2016) have investigated the stationarity of natural consumption, energy consumption and electricity consumption, respectively. A detailed literature on the stationarity of energy consumption has been documented in Smyth (2013).