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Does moving towards renewable energy causes water and land inefficiency? An empirical investigation

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HIGHLIGHTS

- The effect of renewable energy production on water and land footprint is studied.
- 58 developed and developing countries were examined for the period of 1980–2009.
- Eight different models were constructed to achieve robustness in the outcomes.
- GDP, urbanization, and trade openness increase the water and land footprint.
- Renewable energy production increases the water and land inefficiency.

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ABSTRACT

This study investigates the effect of renewable energy production on water and land footprint in 58 developed and developing countries for the period of 1980–2009. Utilizing the ecological footprint as an indicator, the fixed effects, difference and system generalized method of moment (GMM) approaches were employed and eight different models were constructed to achieve robustness in the empirical outcomes. Despite the use of different methods and models, the outcome was the same whereby GDP growth, urbanization, and trade openness increase the water and land footprint. Moreover, renewable energy production increases the water and land inefficiency because of its positive effect on ecological footprint. Additionally, based on the square of GDP it is concluded that the EKC hypothesis does not exist while the square of renewable energy production indicates that renewable energy production will continue to increase water and land footprint in the future. From the outcome of this study, a number of recommendations were provided to the investigated countries.

1. Introduction

The increase in environmental pressure that the globe is witnessing (due to the consumption of fossil fuels in the world) is forcing countries to adopt renewable energy as an alternative to fossil fuels. It is well known that renewable energy can play a significant role in reducing air pollution and increasing the countries' energy security by reducing their dependency on fossil fuels. On the other hand, if the world replaces fossil fuels energy with renewables, it is important to take into consideration the use of water and land. Similar to fossil fuels, renewable energy sources, such as biofuels, solar, wind and geothermal energy, require substantial amount of water and land. The rapid increase in world population increased the scarcity of water and land availability, thus the global move towards renewable energy sources may escalate water and land insufficiency (Hoekstra, 2015). Since renewable energy sources require substantial amounts of land and water resources, given the limitation of land and water availability, therefore, these energy scenarios may be feasible and important in the long run.

There is a considerable number of empirical literature regarding the influence of renewable energy consumption on the gross domestic product (GDP) (Aguirre and Ibikunle, 2014; Apergis and Payne, 2011a, 2011b; Shahbaz et al., 2015; Inglesi-Lotz, 2015; Tugcu et al., 2012; Omri et al., 2015; Lin and Moubarak, 2014; Bloch et al., 2015; and so forth) and air pollution (Sebri and Ben-Salha, 2014; Menyah and Wolde-Rufael, 2010a, 2010b; Jaforullah

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and King, 2015; Özbuğday and Erbas, 2015; Shafiei and Salim, 2014; Jebli and Youssef, 2015; and so forth). The outcome of these studies reached the conclusion that renewable energy consumption plays a significant effect in increasing GDP growth and reducing air pollution. However, there is a lack of empirical literature that examined the influence of renewable energy production on water and land footprint.

The global production of renewable energy escalated especially after the first adoption of Kyoto Protocol in Japan in 1997. The researchers of this study believe that this large escalation in renewable energy production that the world is witnessing over the last three decades may cause water and land inefficiency. Therefore, this study will examine the influence of renewable energy production on water and land footprint. Table 1 reviews the literature that investigated the relationship between environmental degradation, economic activities, and energy consumption. Most of the previous studies found that GDP growth and energy consumption are the main factors that increase air pollution (Zhang and Cheng, 2009; Menyah and Wolde-Rufael, 2010a, 2010b; Pao and Tsai, 2011a, 2011b; Hossain, 2011; Chandran and Tang, 2013; Kohler, 2013; Saboori and Sulaiman, 2013a, 2013b; Shahbaz et al., 2013a, 2013b; Ozturk and Al-Mulali (2015); Al-Mulali et al., 2015a, 2015b, 2015c, 2015d, 2015e; Ajmi et al., 2015; Heidari et al., 2015; Bastola and Sapkota, 2015; Kasman and Duman, 2015; and so forth). Moreover, other important air pollution determinants were found such as urbanization (Hossain, 2011; Omri, 2013; Al-Mulali, 2014; Al-Mulali et al., 2015a, 2015b, 2015c, 2015d, 2015e; and Kasman and Duman, 2015), trade openness (Jayanthakumaran et al., 2012; Omri, 2013; Kohler, 2013; Shahbaz et al., 2013a, 2013b; Farhani et al. 2014; Ozturk and Al-Mulali, 2015; Kasman and Duman, 2015; and Halicioglu, 2009), financial development (Al-Mulali et al., 2015a, 2015a; Shahbaz et al., 2013a, 2013b), foreign direct investment (FDI) (Al-Mulali, 2012; Chandran and Tang, 2013; Al-Mulali and Tang, 2013; and Pao and Tsai, 2011a, 2011b), and so forth.

In addition, most of the studies used CO_2 emission as an indicator of environmental degradation (see Table 1). However, there is a lack of studies that investigated the effect of renewable energy on the environmental degradation. The aim of this study is to address this gap in the energy economics literature.

This study, therefore, examines the effect of renewable energy production on water and land footprint in 58 developed and developing countries for the period of 1980–2009. The ecological footprint as an indicator, the fixed effects, as well as difference and system generalized method of moment (GMM) approaches were employed and eight different models were constructed to achieve robustness in the empirical outcomes. The rest of the paper is organized as follows: methodology and data are presented in Section 2, empirical results are presented in Sections 3 and 4 provides the conclusion and policy implication.

2. Methodology

The same factors responsible for CO_2 emissions are also the determinants of ecological footprint. Since the main goal of this study is to examine the influence of renewable energy on water and air footprint, the ecological footprint is the optimal choice because water and land footprint are included in this variable. The existing literature has modelled the determinants of emission by using several variables; for instance, aggregate and disaggregate energy production (or consumption) series have been used by the existing literature as determinants of emission (Ang, 2007, 2008). Also, standard theories such as STRIPAT (which stands for *Stochastic Impacts by Regression on Population, Affluence and Technology)* have argued that the level of environmental degradation is determined by a nation's level of affluence, its demographic characteristics, and the available technology (Dietz and Rosa, 1994, 1997; Suh, 2013). While affluence and demography can be easily represented by macroeconomic indicators, representing technology is not straight forward. Real GDP can proxy affluence, while urbanization can be utilized to proxy the demographic characteristics of a country. The technology term represents all other factors other than population and affluence (Suh, 2013). Therefore, we use trade openness to represent the level of technology in a country. Moreover, we examine the determinants of ecological footprints with the following model:

$$Y = f(RE, GDP, URB, TRA) \tag{1}$$

Here, Y is ecological footprints, RE is electricity production from renewable sources, excluding hydroelectricity, GDP is real GDP, URB is the total urban population, and TRA is real trade openness (real exports of goods and services plus real imports of goods and services). The data of ecological footprint were retrieved from the Global Footprint Network (2015), while the data for the remaining variables were obtained from the World Development Indicators (WDI) (2015) for the period of 1980–2009. The number of investigated countries in this paper is 58.[1] We transformed all the variables into logarithmic form, which produces better result compared to the linear functional form (Shahbaz and Lean, 2012). The empirical equation of the model is given as follows:

$$\ln Y_{it} = \alpha_1 + \alpha_2 \ln RE_{it} + \alpha_3 \ln GDP_{it} + \alpha_4 \ln URB_{it} + \alpha_5 \ln TRA_{it} + \varepsilon_{it} \tag{2}$$

where, $\ln Y$ is natural log of ecological footprints, $\ln RE$ is natural log of electricity production from renewable sources, excluding hydroelectricity, $\ln GDP$ is natural log of real GDP, $\ln URB$ is natural log of total urban population, $\ln TRA$ is natural log of real trade openness, and ε is error term with the assumption of normal distribution.

We utilize the system generalized method of moment (GMM) procedure to estimate the determinants of ecological footprints. Introduced by Hansen (1982), GMM is perceived as an internal instrument estimator because it relies on previous values of the regressors. The method offers several advantages over the traditional panel estimation techniques. As contrary to the older panel techniques, GMM relaxes the assumptions of both serial correlation and heteroscedasticity. Therefore, under weak distributional assumptions, the methods of moments are ideal in obtaining parameter estimators that are unbiased and consistent. The estimator is known to produce unreliable estimates when employed in dynamic models. Extant papers illustrate that in dynamic panels, within group method may produce coefficients that are likely to be biased downwards, while OLS may produce coefficients that are likely to be biased upwards. According to Baum et al. (2003), GMM estimator produces more efficient output than the simple instrumental variable technique. Given the dimension of the data, the econometric method is also suitable. This research use a panel data with finite time span *(T)* and a sizeable number of cross-sectional units *(N)*. The system GMM estimator is appropriate to this kind of data structure (Arellano and Bover, 1995; Blundell and Bond, 1998). The method works with the notion that regressors

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