Energy Policy 66 (2014) 547–556

Contents lists available at ScienceDirect

Energy Policy

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

Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis

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HIGHLIGHTS

- Examine the relationship between disaggregated energy consumption and CO_2 emission.
- The STIRPAT econometric model is used for empirical analysis.
- Investigate the popular environmental Kuznets curve (EKC) hypothesis between urbanisation and CO_2 emissions.
- Non-renewable energy consumption increases CO_2 emissions whereas renewable energy consumption decreases CO_2 emissions.
- There is evidence of the existence of an environmental Kuznets curve between urbanisation and CO_2 emissions.

ARTICLE INFO

Article history:
Received 1 August 2013
Received in revised form
25 October 2013
Accepted 28 October 2013
Available online 21 November 2013

Keywords:
Renewable energy consumption
Non-renewable energy consumption
CO_2 emissions
Urbanisation
STIRPAT model

ABSTRACT

This paper attempts to explore the determinants of CO_2 emissions using the STIRPAT model and data from 1980 to 2011 for OECD countries. The empirical results show that non-renewable energy consumption increases CO_2 emissions, whereas renewable energy consumption decreases CO_2 emissions. Further, the results support the existence of an environmental Kuznets curve between urbanisation and CO_2 emissions, implying that at higher levels of urbanisation, the environmental impact decreases. Therefore, the overall evidence suggests that policy makers should focus on urban planning as well as clean energy development to make substantial contributions to both reducing non-renewable energy use and mitigating climate change.

1. Introduction

The OECD countries enjoy energy-led growth and remain the largest energy consuming countries with 41% of the total global energy consumption (Duffour, 2012). Major portion of this energy supply comes from conventional non-renewable sources such as coal, oil and natural gas. As a result, there is a sharp increase in carbon dioxide (CO_2) emission in the atmosphere which is considered to be the main source of greenhouse gas (GHG) effect that led to environmental degradation. Thus, the climate change intimidation and the increasing threat of global warming raise worldwide concerns and impose serious social and political pressure to curb emissions. Most OECD countries signed Kyoto Protocol to reduce their overall greenhouse gas emissions by an average of at least 5.2% below their 1990 levels in the five years after 2008 (IEA, 2011). Therefore, to combat climate change and to secure & diversify the supply of energy mix there has been heightened interest in renewable energy sources in OECD countries in recent years. This growing interest has been supported by various government incentive policies such as feed-in tariff, subsidies for renewable technologies, tax rebate and so on. As a result, the share of renewables in total power generation exceeds 20 per cent in OECD countries in 2011 (Duffour, 2012). Hence, identifying the relationship between renewable and non-renewable energy consumption and pollutant emission is worth academic investigation.

Human activities involving the combustion of fossil fuels and the burning of biomass, produce GHGs that affect the composition of the atmosphere and the global climate (IPCC, 2001). These activities constantly increase with the rapid pace of industrialisation and urbanisation in recent decades, which ultimately cause serious damage to environment through energy consumption. In addition, expansion in service industries, which is the result of economic development, can increase energy demand and consequently leads to pollutant emissions. Therefore, the aim of this article is to identify the determinants of pollutant emission by

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0301-4215/$ - see front matter
http://dx.doi.org/10.1016/j.enpol.2013.10.064

using a statistical model, namely STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) using data over the period of 1980–2011 from the OECD countries.

Numerous studies have dealt with the relationship between energy consumption and pollutant emissions. These studies have been performed in different countries and with various modelling methods, approaches and findings. However, only a few studies have investigated the relationship between disaggregated energy consumption and CO_2 emissions. No consensus has emerged from these studies. Therefore, the focus of this article is to contribute further to this literature by using disaggregated energy consumption (renewable and non-renewable) and comparing the effects of renewable and non-renewable energy consumption on CO_2 emissions. To the best of authors' knowledge, this is one of the first studies to simultaneously investigate the effects of renewable and non-renewable energy consumption on CO_2 emissions using the STIRPAT model. Additionally, this article also investigates the relationship between urbanisation and CO_2 emissions by emphasising the environmental Kuznets curve (EKC) hypothesis.

The rest of the article is organised as follows: Section 2 provides a critical review of the existing literature. Section 3 presents the research methodology, including model specification and the estimation strategy. The empirical results are reported in Section 4. Finally, Section 5 concludes the article.

2. A critical review of the literature

2.1. Renewable energy consumption, economic growth and CO_2 emissions

The relationships between economic growth and pollutant emissions and between economic growth and energy consumption, in addition to the combination of these two nexuses in a single framework, have been investigated extensively. However, limited research has been conducted on the nexus between renewable energy sources, economic growth and pollutant emissions.

Sadorsky (2009a) finds that in the long run, real GDP per capita and the CO_2 emissions per capita had positive effects on renewable energy consumption in the G7 countries from 1980 to 2005. Apergis et al. (2010) demonstrate that in the short run, nuclear energy consumption reduces CO_2 emissions, whereas renewable energy consumption does not contribute to reductions in emissions. These authors note that the latter result may be due to the limited proportion of renewable energy in total energy consumption. In the case of the US, Menyah and Wolde-Rufael (2010) find that although there was no causality from renewable energy consumption to CO_2 emissions, there was unidirectional causality from CO_2 emissions to renewable energy consumption over the period from 1960 to 2007. Salim and Rafiq (2012) investigate the relationship between CO_2 emissions and renewable energy consumption, controlling for income and oil prices. The long-run results obtained using the dynamic OLS and fully modified OLS methods show that CO_2 and income are the major determinants of renewable energy consumption in Brazil, China, India and Indonesia. For these countries, a bidirectional causal relationship is also found between renewable energy consumption and CO_2 emissions in the short run. The results also indicate that there is bidirectional relationship between income and CO_2 emissions in Brazil, China and Turkey. Using the Toda-Yamamoto procedure over the period from 1949 to 2009 for the US, Payne (2012) reveals that real GDP and CO_2 emissions do not have causal effects on renewable energy consumption. However, unexpected shocks to real GDP and CO_2 emissions positively affect renewable energy consumption over time.

2.2. Review of empirical works based on the STIRPAT model

The STIRPAT method has been applied by several scientists to investigate the effects of driving forces on pollutant emissions. For instance, York et al. (2003a) study a non-linear relationship between emissions and factors such as population, urbanisation and economic growth for 142 nations and find a positive relationship between emissions and the independent variables. In a similar study, York et al. (2003b) conclude that the elasticity of CO_2 emissions with respect to population is close to unity. Shi (2003) finds a direct relationship between population changes and emissions in 93 countries over the period from 1975 to 1996. Using a sample of 86 countries during the period from 1971 to 1998, Cole and Neumayer (2004) study the effects of population size and several other demographic factors, including age composition, the urbanisation rate and the average household size, on CO_2 and sulphur dioxide (SO_2) emissions. The results indicate that there is a *U*-shaped association between population size and SO_2 and a positive association between the urbanisation rate and CO_2 emissions. Moreover, a higher average household size is found to decrease emissions. In contrast, a negative relationship between urbanisation and CO_2 emissions is found by Fan et al. (2006) for developed countries over the period 1975 to 2000. The same result is obtained by Martínez-Zarzoso et al. (2007). These authors analyse the determinants of CO_2 emissions during the period of 1975 to 2003 and demonstrate that although the elasticity of emission-urbanisation is positive in low-income countries, it is negative in middle upper and high income countries.

Lin et al. (2009) add urbanisation and industrialisation factors to the basic model and name the new model STIRPUrlnAT. These authors use this revised model to analyse environmental impacts in China from 1978 to 2006 and find that the population had the largest potential effect on environmental impact, followed by the urbanisation level, the industrialisation level, GDP per capita and the energy intensity. Similar to the study of Fan et al. (2006), a study by Poumanyvong and Kaneko (2010) considers different development stages and provides evidence of positive effects of population, affluence and urbanisation on CO_2 emissions for all income groups, low, middle and high. Considering aggregate CO_2 emissions and CO_2 emissions from transport for 17 developed countries covering the period from 1960 to 2005, Liddle and Lung (2010) reveal that the total population and economic growth positively influence these two types of emissions. However, urbanisation has a positive and significant impact on only CO_2 emissions from transport. When improving this study by performing unit root and cointegration tests, Liddle (2011) finds positive associations between GDP per capita and CO_2 emissions from transport and between the total population and CO_2 from transport. Using a panel of 29 provinces in China from 1995 to 2010, Zhang and Lin (2012) show that population, affluence, industrialisation and energy intensity increase CO_2 emissions for the whole sample, whereas the results are different across the different regions.

2.3. CO_2 emissions, urbanisation and income: The environmental Kuznets curve (EKC) hypothesis

Empirical studies related to the link between environmental degradation and economic activities usually refer to the environmental Kuznets curve (EKC) hypothesis, which suggests that there is an inverted *U*-shaped relationship between pollutant emissions and income per capita. A large number of studies have tested the economic growth and environmental pollution nexus (Selden and Song, 1994; Grossman and Krueger, 1995; Galeotti and Lanza, 1999; Halicioglu, 2009; Kearsley and Riddel, 2010 and so on). Some of these studies have focused on developed countries. For