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Energy innovation and renewable energy consumption in the correction of air pollution levels

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ABSTRACT

This study analyses the relationship between economic growth and environmental pollution. Specifically, it investigates the presence of an environmental Kuznets curve (EKC) in 17 OECD countries over the period of 1990–2012. The results confirm the existence of an N-shaped EKC relationship between income and environmental degradation. The study offers a novel methodological contribution that makes it possible to explain the environmental pollution process through the analysis of low-carbon technologies. This demonstrates how income levels affect energy consumption and how higher energy demand leads to a larger share of fossil sources in the energy mix and, thus, increased greenhouse gas (GHG) emissions. The effect on per capita GHG emissions is explored in a model containing a dampening variable that moderates the relationship between energy consumption and income. This empirical evidence helps to explain the interaction between energy regulation, economic growth and carbon emissions. This study also confirms the positive effect that energy innovation process exerts on environmental pollution. Finally, it is noted that renewable energy sources help to improve air quality.

1. Introduction

Although the Club of Rome raised awareness of the need for economic systems to preserve environmental sustainability in the 1970s (Meadows et al., 1972), it was not until the early1990s that environmental pollution problems began to be more frequently addressed in the theoretical economic literature (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Selden and Song, 1994). These studies proposed the existence of an inverted-U relationship between economic growth and environmental degradation, which was studied through the empirical hypothesis of the environmental Kuznets curve (EKC). Increases in greenhouse gas (GHG) emissions, a fundamental problem for economic development, are encouraged by multiple variables, including economic growth, economic structure, energy dependency and energy efficiency (Velthuijsen and Worrell, 2002; Shi, 2003; Acaravci and Ozturk, 2010; Tugcu et al., 2012; Apergis and Ozturk, 2015; Ben Jebli et al., 2016; Mensah, 2014; Al-Mulali et al., 2016).

In addition to the burden of environmental pollution, developed economies also face the problem of energy dependency and high energy intensity. Climate change can, in theory, be addressed by limiting production that uses fossil fuels and improving the efficiency with which such fuels are used. However, a key driver of emissions reductions will be induced product and process innovation (Aghion et al., 2014). Thus, not only are energy policy instruments associated with the reduction of fossil energy sources, but public budget on energy research, development and demonstration (RD & D), procedures to improve energy efficiency, and measures intended to increase the share of renewable sources in the energy mix have also become central in environmental policy programmes. The present study used an EKC model[1] to examine the impact that economic growth, technology innovation measures, and consumption of renewable energy sources have on the evolution of per-capita carbon emissions in a selection of 17 OECD countries (Fig. 1).

The results of the regression, combined with economic growth, make it possible to determine the effectiveness of these energy measures in a context of sustainable economic growth.

Moreover, the results facilitate the analysis of the importance of

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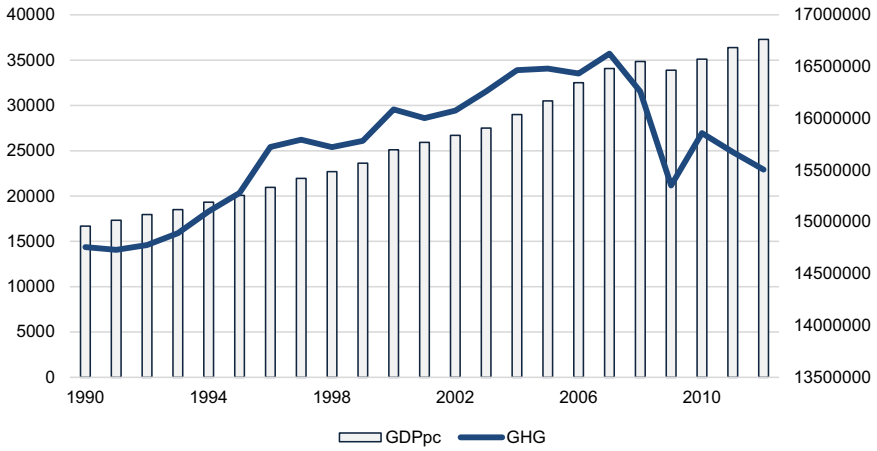

Fig. 1. Evolution of GHG emissions and GDPpc in OECD countries. Notes: Primary Axis: U$D GDP Per head, current prices, current PPPs. Secondary axis: GHG Thousands Tonnes of CO2 equivalent.
Source: OECD (2016).

energy sector and the impact of shares of fossil and renewable energy sources in the energy mix throughout the transition from developing (low-income) to developed (high-income) economy (Wackernagel et al., 1999; Turner and Hanley, 2011; UK Climate Change Committee, 2008). Fossil sources are known to predominate in most advanced countries' energy mixes. In developing economies, energy structure is based on over-exploitation of natural and fossil resources, although in recent decades this model has been altered by the increase in renewable sources and the implementation of innovations thought to be conducive to a more sustainable model in energy sector.[2] This new scenario reflects a consensus on the need to increase environmental sustainability through the use of low-carbon technologies. The implementation and effectiveness of environmental regulations will play a decisive role in thelong-term evolution of environmental pollution levels (Bilgili et al., 2016; Balsalobre et al., 2016).

Nowadays energy regulation measures have taken on special relevance in environmental correction processes; they are necessary to correct the global warming process and help to ensure sustainable economic growth (Dooley, 1998; Mendiluce et al., 2010; Costantini and Martini, 2010; Dogan and Seker, 2016). In addition, because of market-driven technological progress or government regulation economic sectors may adopt less polluting technologies (Cole et al., 2005).

To this end, the importance of energy regulation policies for the correction of environmental contamination processes must be clarified. The main objective of this study was to demonstrate the existence of EKC patterns for the selected countries and to show how energy regulation measures, together with energy innovation and energy substitution processes, impact GHG emissions.

2. Theoretical framework

The empirical environmental Kuznets curve (EKC) hypothesis suggests the existence of a relationship between economic growth and environmental pollution (Grossman and Krueger, 1991; Panayotou, 1993; Selden and Song, 1994).

This section will discuss the basic aspects of theoretical behaviour of the EKCmodel. This behaviour is reflected in the debate over the fundamental determinants of long-term improvements in environment correction, especially in the growing literature on the relationship between economic growth and pollution. The EKC postulate suggests a relationship between environmental quality and economic growth, but this relationship changes once a certain income threshold is attained. In their pioneering work, Grossman and Krueger (1991) proposed an inverted-U shaped relationship between environmental degradation and income level. According to this theory, in the early stages of economic growth, environmental pollution levels rise until reaching a certain turning point, beyond which economies experience a reduction in pollution levels (Fig. 2).

Fig. 2 shows an inverted-U shaped relationship between income level and environmental pollution, which supposes a dynamic process of structural changes connected with economic growth (Dinda, 2004). This behaviour also implies that economic growth affects environmental quality through three channels (Grossman and Krueger (1991)):

a) *Scale effect*: when economic systems achieve a given level of technology, increase in the inputs employed to obtain output, in the early stages of economic growth, entails an increase in environmental pollution levels. Specifically, the increased energy requirements of the production function lead to greater use of fossil sources and, consequently, increased pollution. The scale effect thus decreases environmental quality (Torras and Boyce, 1998; Prieur, 2009).
b) *Composition effect*: the evolution of economic growth appears to be linked to structural transformation, that is, the transition from a developing economy, with highly polluting production processes, to a more developed one, with a production pattern involving less-polluting activities. In other words, the composition effect refers to developing economies' transition from capital-intensive industrial sectors to service sectors and, ultimately, to technology-intensive knowledge economies that employ more efficient energy procedures and fewer fossil sources that directly impact environmental quality.
c) *Technical effect*: high-income (developed) economies allocate more resources to RD & D. Fisher-Vanden et al. (2004) found evidence that public budget on energy RD & D has a positive impact on reducing energy intensity (consumption per unit of gross domestic product) and, by extension, on the reduction of GHG emissions. Developed economies replace old, dirty and inefficient technologies with new, more efficient ones, thereby enhancing environmental quality (Copeland and Taylor, 2004).

When the total effect of the relationship between economic growth and environmental pollution is broken down, the technical effect is considered to be the main factor in the correction of environmental pollution process (Andreoni and Levinson, 1998; Markandya et al., 2006). In this regard, technical obsolescence will lead to re-emergence

[2] Energy practices have a direct impact on global warming processes. The global average temperature has already increased over the last three decades and the global surface temperature is likely to rise an additional 1.1–6.4°C (2.0–11.5°F) in the 21st century (IPCC2007). Global increases in CO_2 concentrations are primarily due to the burning of fossil fuels, which accounts for 56.6% of total emissions. According to an IPCC report, CO_2 alone accounts for 76.7% of total GHG (IPCC 2007).