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Energy Innovations-GHG Emissions Nexus: Fresh Empirical Evidence from OECD Countries

Agustín Álvarez-Herránz[a], Daniel Balsalobre[b,*], José María Cantos[b], Muhammad Shahbaz[c]

[a] Department of Spanish and International Economics, Econometrics and Economic History and Institutions.University of Castilla-La Mancha
[b] Department of Political Economy and Public Finance, Economic and Business Statistics and Economic Policy. University of Castilla-La Mancha
[c] Montpellier Business School, Montpellier, France

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ABSTRACT

This study explores the impact of improvements in energy research development (ERD) on greenhouse gas (GHG) emissions using environmental Kuznets curve hypothesis for 28 OECD countries over the period of 1990–2014. In doing so, we have employed a panel data where public budget in energy research development and demonstration (ERD & D) has transformed into a finite inverted V-lag distribution model developed by De Leeuw (1962). This model considers that energy innovation accumulates in time and presents empirical evidence, how energy innovation contributes in reducing energy intensity and environmental pollution as well.

Our results indicate that energy innovation measures require lapses of time to reach their full effect i.e. innovation applied to measures for environmental correction does not reach its whole effect immediately, requiring instead a certain amount of time to pass. Innovation policies have recommended for improving environmental quality.

1. Introduction

Many studies have investigated the relationship between economic growth and environmental pollution, but in recent decades, environmental problems have been the epicentre of economic growth processes, assuming that greenhouse gas (GHG) emissions produce irreversible damage to economic systems (Ulgiati et al., 1995; Ukidwe and Bakshi, 2007; UNFCCC, 2015). Carbon dioxide emissions produce large amounts of greenhouse gases, which significantly contribute to increase in global temperatures, and associated with climatic instability (IPCC 1997, Fischer et al., 1999, Caillon et al., 2003, Wen et al., 2011, Tiwari et al., 2013). Against the traditional economic theory which considers the existence of trade-off between economic growth and environmental quality (Meadows et al., 1972). Otherwise, recent literature suggests the existence of a relationship between economic growth and environmental degradation changes with the economic cycle. This relationship could be positive when economies cross a certain level of income (Grossman and Krueger, 1991; Panayotou, 1993, among others). It is further argued that to reach a 'sustainable development' is possible, where economic growth is compatible with environmental quality (Arrow et al., 1995; Munasinghe, 1999; Wang et al., 2012, Wang and Lin 2015).

After certain income levels, nations are allowed to provide the necessary resources aiming to improve environmental quality. Existing empirical literature on environmental Kuznets curve (EKC) illustrates how a nation's environment makes an environmental transition: in the first stage of economic growth, environmental pollutants would increase up to a certain level of income and after that, energy pollutants start to decrease (Selden and Song, 1994; Torras and Boyce, 1998; Dinda, 2004, Martınez-Zarzoso and Bengochea-Morancho, 2004). The EKC hypothesis was coined in early 1990 s 'almost simultaneously' by Grossman and Krueger (1991) and later on by Panayotou (1993). By analogy with Kuznets (1955), this hypothesis explains that there is a relationship between income per capita and pollution levels i.e. an inverted U-shaped relationship. This relationship shows how in early stages of industrialization, pollution grows rapidly, because a higher priority is given to increase material output, an interest in increasing rather than environmental quality. In a longer term, however, pollution levels will decrease and this relationship reveals that economic growth can be compatible with environmental improvements (Hu et al., 2011; Zuo and Ai, 2011).

This study attempts to explain the EKC relationship between economic growth and environmental degradation in the framework of endogenous growth model (Dinda, 2005), considering ERD & D as the

* Corresponding author.
E-mail addresses: Agustin.Alvarez@uclm.es (A. Álvarez-Herránz), Daniel.Balsalobre@uclm.es (D. Balsalobre), Josemaria.Cantos@uclm.es (J.M. Cantos), shahbazmohd@live.com (M. Shahbaz).

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main variable to delay technological obsolescence in the economies, reducing the scale effect: process of environmental pollution is delayed in terms of greenhouse gas emissions. This study makes use of the empirical analysis of EKC hypothesis by incorporating energy innovations as potential determinants of carbon emissions. This further shows the dire need of analyzing energy intensity, which affects environmental quality (Sun, 2002; Dowlatabadi and Oravetz, 2005, Alcántara and Duro 2004, Mendiluce and Linares, 2007). Higher energy intensity implies higher energy consumption and hence, increases GHG emissions per capita (Peker and Yücel 2006; Ang, 2007, Hughes et al., 2008, Ozturk and Acaravci, 2010, Pao and Tsai, 2011, Ozturk and Uddin, 2012, Shahbaz et al., 2014, Khan et al., 2014). Various researchers have analyzed the effect of technology and structural changes on greenhouse gas emissions during a lapse of time and have considered their evolution (de Bruyn 2000, Damanpour et al., 2006, Balsalobre et al., 2015). In resulting, the structure of oil-dependent economies would have been altered by the adoption of new techniques that lower energy intensity per unit of output, strengthening service sectors is based on a lighter productive structure (Lindmark, 2002; Kander, 2005; Lantz and Feng, 2006; Tol et al., 2009).

This study contributes to the existing literature by investigating that how technological innovations play a role in environmental quality processes. It is assumed that public budget in energy RD & D contributes to the containment of per capita GHG emissions (Carrión-Flores and Innes, 2010; Heyes and Kapur, 2011; Balsalobre et al., 2015). The empirical evidence confirms that the relationship income levels and environmental pollution attend to EKC effect but we divide EKC hypothesis into several factors, trying to prove that improvements in energy innovation have a direct relationship with the processes of reduction of environmental pollution (Robalino-López et al., 2015; Li and Lin, 2016). Technological improvements are a direct result of efforts previously made in RD & D, where, in turn, public participation is essential in this type of intervention. The way in which the RD & D positively affects the levels of greenhouse gas emissions, is twofold: first, it reduces the amount of embodied energy per unit of output (energy efficiency); on other hand, the amount of greenhouse gas emissions resulting per energetic unit reduces. This hypothesis allows us to establish that energy innovation measures enacted by administration could create a positive effect on GHG emissions.(Fig. 1).

2. Methods and Theoretical Analysis

The latest observations show that global GHG emissions have not stabilized, experiencing instead a significant growth during the last century. The adoption of environmentally sustainable technologies, improving energy efficiency, or saving energy are some of the most effective ways to address the climate change issue (Masui et al., 2006; Rafindadi, 2016).

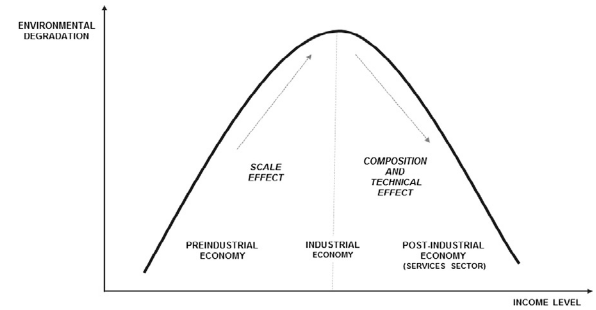

Fig. 2. Scale, Technical and Composition Effects.
Source: Self extract and Halkos (2011)

2.1. Scale, Composition and Technical effect in the EKC

Since the 1990 s, the analysis of the relationship between economic growth and environmental quality has taken attention of academicians and practitioners but provided ambiguous empirical results. For example, Grossman and Krueger (1991) provided a systematic explanation for the relation between economic growth and environmental quality. Fig. 2 shows a dynamic process where structural changes appears connected with economic growth which suggests that economic growth affects environmental quality through three channels (Grossman and Krueger, 1991; Dinda, 2004).

*The scale effect asserts that even if the structure of an economy and technology do not change, an increase in production impedes environmental quality; therefore, in such stage of economic development, economic growth has positive effect on environmental degradation. However, the composition effect may have a positive impact on environment quality. In earlier stages of economic development, pollution increases as economic structure changes from agriculture to more energy intensive heavy manufacturing industries but in later stages of economic development, pollution decreases as structure of an economy moves towards services and light manufacturing industries. Therefore, composition effect, through this change in production structure, could decrease the harmful effects of economic growth on environment pollution. Finally, technique effect captures improvements in productivity and adaptation of cleaner technologies, which will lead to an increase in environmental quality (*Zhang, 2004,Blesl et al., 2007, Wang et al., 2012,Balsalobre et al., 2015*).*

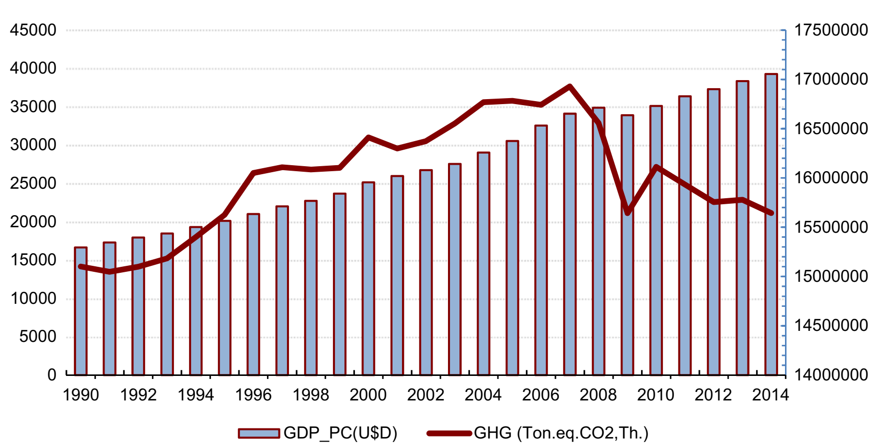

Fig. 1. Evolution of GDP per capita and GHG in OECD countries (1990–2014) . Note: The principal axis shows accumulative GDP per capita (U$D) in OECD countries; the secondary axis shows GHG (Tonnes of CO_2 equivalent, Thousands), in OECD countries.
Source: OECD (2016)