Renewable and Sustainable Energy Reviews 65 (2016) 902–914

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Is the share of renewable energy sources determining the CO2 kWh and income relation in electricity generation?

Victor Moutinho [a,b], Margarita Robaina [a,b,*]

[a] Department of Economics, Management, Industrial Engineering and Tourism, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal
[b] GOVCOPP - Research Unit in Governance, Competitiveness and Public Policy, Portugal

ARTICLE INFO

Article history:
Received 29 January 2015
Received in revised form
27 April 2016
Accepted 4 July 2016

Jel Classification:
Q430
Q400
Q530
Q560

Keywords:
Carbon dioxide emissions per kW h
Electricity generation
Environmental Kuznets Curve
Innovative accounting approach
Panel cointegration tests
Renewable energy

ABSTRACT

The present study examines the long and short-run causality of the share of renewable energy sources (RES) in the relation between Carbon Dioxide emissions of electricity generation (CO2 kW h) and real income (GDP) for 20 European countries over 1991–2010, and in sub period 2001–2010. We used Co-integration Analysis and the Innovative Accounting Approach that includes Forecast Error Variance Decomposition and Impulse Response Functions (IRFs). Our results provide supportive evidence for the validity of the Environmental Kuznets Curve (EKC), and suggest that renewable energy can be a potential determining driver of the difference in the emissions-income relations across European countries and a significant way of reducing CO2 kW h. Moreover, in this particular 2001–2010 subperiod the share of renewable energy in electricity output will have significant influence on the shape of the EKC, which will shift downward as RES increases, suggesting lower (environmental) costs of development. In these sub period, 2001–2010, all the results show a common pattern expected of CO2 emissions in electricity generation after the European Directive 2001/77/EC, and reveal the importance of the interactive impact of renewable energy sources and GDP to reduce the CO2 emissions in electricity generation.

Contents

* Corresponding author at: Department of Economics, Management, Industrial Engineering and Tourism, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal.
E-mail addresses: vmoutinho@ua.pt (V. Moutinho), mrobaina@ua.pt (M. Robaina).

http://dx.doi.org/10.1016/j.rser.2016.07.007
1364-0321/

1. Introduction

European countries have shown a special concern in reducing emissions of greenhouse gases (GHG) that materialized in a practical way with the signing of Kyoto Protocol, with the implementation of the European Union Emissions Trade System (EUETS) and more recently with the adoption of the "20-20-20" targets. In 2020, these targets specifically aim for a 20% cut in GHG emissions from 1990 levels; for an increase of renewable energy sources to 20%; and for a 20% improvement in the energy efficiency.

The use of fossil fuels is the biggest culprit of anthropogenic air pollution (in particular by the emission of Carbon Dioxide (CO2)), being responsible for about 90% of total global CO2 emissions. Despite the recent economic crisis, it is expected that the use of fossil fuels will continue to increase in the future (Olivier et al. [1]).

In the European electricity sector, more than 50% of the primary energy used is based on fossil fuels, coal representing approximately 30%. This translated into CO2 emissions represents 70% of total emissions in electricity production and 24% of the emissions of all European sectors (Commission of European Communities [2]).

This makes the European Union (EU) have a growing concern in creating and implementing policies to limit CO2 emissions, primarily through the reduction of the use of coal in the electricity sector. For instance, through the EUETS, EU limited the allowances allocated to installations that produce electricity as well as to energy-intensive industries, in order to cut 21% compared to 2005 levels (European Commission [3]).

There are several articles that have studied the connection between economic growth and emissions, testing the hypothesis of the Environmental Kuznets Curve (EKC). This hypothesis suggests that there is an inverse U-shaped relationship between income and environmental pollution, which means that there is an increase in pollution as the economy grows, but from a certain point, the economy can grow decreasing environmental degradation. Some studies validate the hypothesis like Hettige et al. [4], Martinez-Zarzoso and Bengochea-Morancho [5] for OCDE countries, Acaravci and Ozturk [6] for Europe, Cropper and Griffiths [7] for non-OECD countries in Africa, Asia, and Central and South America, Pao et al. [8] for Russia, Apergis and Payne [9] for Central America, Iwata et al. [10], for 28 countries (OECD countries, and non-OECD countries), Mongelli et al. [11], for Brazil, Ang [12,13] for France and Malaysia, Jalil and Mahmud [14] for China, Halicioglu [15] for Turkey, Alam et al. [16] for India, Fodha and Zaghdoud [17] for Tunisia and Nasir and Rehman [18] for Pakistan, are some examples.

The relation between emissions from electricity production and GDP is not focused on literature. Those studies that include electricity are based on the amount of energy consumed, which is inherently linked to a volume of emissions, but don't directly include the emissions resulting from its production. Representative studies are for instance: Aqeel and Butt [19], Shiu and Lam [20], Lee and Chang [21], Altinay and Karagol [22], Yuan et al. [23], Halicioglu [24]. They concluded that electricity consumption causes economic growth and as a result supports the growth hypothesis. The opposite causality is also found running from economic growth to electricity consumption, supporting the conservation hypothesis, by Narayan and Smith [25], Yuan et al. [26], Squalli [27], Mozamder and Marathe [28], Hu and Lin [29], Reynolds and Kolodziej [30], Sari et al. [31], Halicioglu [24]. Akbostanci et al. [32], Dhakal [33], Jalil and Mahmud [14], Fodha and Zaghdoud [17], Gosh [34], Payne [35]. Other studies like Lean and Smith [36], found a unidirectional relationship, and support the growth effect for the period 1980–2006 in Asian countries.

Those studies focus specifically on the relationship between economic growth and energy consumption, in particular electricity consumption. The study of the latter relationship is important because electricity production is, as we have seen, a major source of emissions, but on the other hand it is also an important way to reduce them, if there is a replacement of fossil fuels with renewable energy in electricity production. It is then important to analyze, how the reduction of emissions in this sector may undermine the economic growth of European countries.

Moreover, it is important to analyze how the percentage of renewable energy used for electricity production affects the relationship between economic growth and emissions from this sector. The study of these relationships is important from the point of view of environmental and energy policy as it gives us information on the costs in terms of economic growth, on the application of restrictive levels of emissions and also on the effects of the policies concerning the use of renewable energy in the electricity sector (see for instance European Commission Directive 2001/77/EC, [37]).

In this line, some studies include renewable energy in the relation of causality with GDP. There is a wide variety of research for different countries and groups of countries, of which we shall give some examples. The following studies obtained positive results in what concerns causal relationships between the referred variables. Bidirectional causality between GDP and renewable energy consumption was found for Eurasian countries (Apergis and Payne [38]), for OECD countries (Apergis and Payne [39]), for emerging economies (Sadorsky [40]), for six Central American countries (Apergis and Payne [41]), for 80 countries (Apergis and Payne [42]) and for Brazil (Pao and Fu [43]). Al-mulali et al. [44], Silva et al. [45], Bowden and Payne [46], Tiwari [47], Menyah and Wolde-Rufael [48], Menegaki [49], Tugcu et al. [50] are other examples where renewable energy is a relevant variable on the growth path-environment relation of several countries or group of countries.

As shown, in the literature it is often studied the relation between the electricity generation and GDP, or between the total CO2 emissions and GDP. What we study in this paper is the relationship between CO2 emissions from the electricity sector and the GDP, and that was not addressed in the literature. The interest of this is that the focus is on the electricity production, that is, on the way it is produced and the resultant emissions and its relation with GDP. When relating the emissions of the sector with the GDP, it is intended to see how different electricity production technologies, with different environmental impacts, affect the GDP. This is different from the purpose of studies linking the final consumption of electricity to the GDP, or total CO2 emissions to the GDP.

In this study we use Cointegration Analysis on the set of cross-country panel data between CO_2 emissions from electricity generation (CO2 kW h), real income (GDP) and the share of renewable energy for 20 European countries. We estimated the long–run equilibrium to validate the EKC with a new approach specification.

Additionally, we have implemented the Innovative Accounting Approach (IAA) that includes Forecast Error Variance Decomposition and Impulse Response Functions (IRFs), applied to those variables. This can allow us, for example, to know (i) how CO2 kW h responds to an impulse in GDP and (ii) how CO2 kW h responds to an impulse in the share of renewable sources.

By combining these two methodologies, we will not only give an outline of what has been a past reality for CO2 kW h emissions and their relation to economic growth and to the use of renewable energy in European countries, but also how the last two variables can influence CO2 kW h emissions in the future.

This paper is divided into four sections including this introduction. In Section 2 we present the data, the model and the econometric methodology, in Section 3 we expose and discuss the main results and in Section 4 are the conclusions and policy recommendations.