Biomass and Bioenergy 90 (2016) 202–208

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Biomass energy, technological progress and the environmental Kuznets curve: Evidence from selected European countries

Ali Ahmed [a], Gazi Salah Uddin [a, *], Kazi Sohag [b]

[a] *Linköping University, Department of Management and Engineering, SE-581 83, Linköping, Sweden*
[b] *Institute of Climate Change, Universiti Kebangsaan, Malaysia*

ARTICLE INFO

Article history:
Received 16 July 2015
Received in revised form
8 March 2016
Accepted 11 April 2016
Available online 28 April 2016

Keywords:
Biomass
GDP
CO_2 emissions
European countries
Panel ARDL

ABSTRACT

We examine the causal relationship between economic growth and CO_2 emissions in a panel of 24 European countries from 1980 to 2010. Using an analytical framework that considers pooled mean group estimations in a dynamic heterogeneous panel setting, we show that there is an inverted U-shaped relationship between CO_2 emissions and economic growth in the long run and that there is no such relationship in the short run. In particular, we find that biomass energy is insignificantly linked to CO_2 emission. However, technological innovation significantly facilitates reduction of CO_2 emissions in the investigated countries. Altogether, our study implies that economic growth and environmental quality can be achieved simultaneously, which opens up new insights for policy-makers for sustainable economic development via implementation of renewable energy consumption through technological innovation.

1. Introduction

Energy is one of the essential ingredients of the modern economic growth paradigm. Using the energy in the production process is the primary reason for high carbon dioxide (CO_2) emission and consequently global warming. Thus, environmental sustainability becomes a global concern in the strategy to reduce the negative consequences of economic growth [1]. The global economy still uses about 80% fossil fuel in the total energy mix to produce major goods and services. Therefore, if the composition of output and the means of production are inseparable, then harm to the environment due to economic activities will be unavoidable. Such a problem can be somewhat mitigated through structural reformation, mainly in terms of the energy use and environmental regulation. However, the goals of higher economic growth and better environmental preservation are sometimes mutually exclusive.

According to Grossman and Krueger [2], the nexus between CO_2 emission and economic growth are non-monotonically related and are embodied by an inverted U-shaped relationship known as the *environmental Kuznets curve* (EKC). EKC refers to a first stage of economic development where a small increment of income achieved by industrialization is positively associated with environmental problems. However, when income takes an upturn and exceeds a certain threshold point, the level of CO_2 emission declines. Hence, whether or not EKC is valid for a country or region largely depends on the quality of the economic growth, environmental preservation, and type of energy used. Renewable energy is one of the prime instruments to address the negative externalities of economic growth, evaluate environmental vulnerability, and ensure energy security [3,4]. These issues were emphasized in the recent convention, "The United Nations Climate Change Conference," in December 2015 in Paris where energy efficiency was recognized as the prime instrument to fight climate-change problems.

Globalization, the depletion of natural resources and geopolitical turbulence in the world economy has drawn attention to energy security in the energy market. Energy security is essential for European energy policy. In this connection, the European Union (EU) listed countries are mandated to meet by 2020 a target of 20% renewable resources in the energy supply and 10% renewable resources in energy in the transport sector in order to meet the joint sustainable energy intensity goal of the EU regional market [5]. A recent development in the EU was biomass and renewable waste,

* Corresponding author.
E-mail addresses: ali.ahmed@liu.se (A. Ahmed), gazi.salah.uddin@liu.se (G.S. Uddin), sohagkaziewu@gmail.com (K. Sohag).

http://dx.doi.org/10.1016/j.biombioe.2016.04.004
0961-9534/

accounting for 65.5% of primary renewables production in 2012, which is the highest in the world.[1,2] The potential benefits of the utilization of the biomass energy include a reduction in CO_2 emissions and a reduced dependency on fossil fuel markets.

Previous research on renewable energy in general and its implication on economy are extensively discussed in energy and ecological economics. We will review this literature in the next section. However, the literature specifically focused on biomass energy consumption and income is not extensive due to the limited availability of data. Pane [6] used annual data from 1949 to 2007 and examined the causal relationship between biomass energy consumption and real gross domestic product (GDP) within a multivariate framework in the United States. The analytical framework was based on the Toda-Yamamoto causality tests and results showed a unidirectional causality from biomass energy consumption to real GDP supporting the growth hypothesis in which biomass energy consumption has a positive effect on economic growth. Bildirici [7] applied the autoregressive distributed lag bounds testing approach of co-integration and error-correction models and examined the short- and long-run causality between biomass energy consumption and economic growth for 10 selected developing and emerging countries from 1980 to 2009. The results showed cointegration between biomass energy consumption and economic growth in all of the countries except for Paraguay. Using panel information for biomass energy consumption and GDP growth for G7 countries, Bilgili and Ozturk [8] provide support for the growth hypothesis. In another study, Ozturk and Bilgili [9] applied a dynamic panel analysis on data consisting of 51 Sub-Sahara African countries over a period of 1980–2009. Their results showed a significant effect of biomass consumption on GDP.

In this paper, we examine the causal relationship between CO_2 emissions, biomass energy consumption, and GDP per capita using a panel of 24 European countries from 1980 to 2010 after controlling for technology innovation in the model. Our study contributes to the literature in several dimensions. First, we consider an analytical framework that involves pooled mean group (PMG) estimations in a dynamic heterogeneous panel setting that is not captured in previous studies on renewable energy consumption-CO_2 emission nexus. PMG is applicable for mixed order of integration in panel time series data: it provides short and long run parameter along with error correction coefficient, and this approach solves the endogeneity bias by taking sufficient lag difference. Second, we show that there is an inverted U-shaped relationship between CO_2 emissions and economic growth in the long run, but the relationship is insignificant in the short run. In particular, we find that biomass energy consumption is insignificantly linked to CO_2 emissions but that technological innovation significantly facilitates the reduction of CO_2 emissions in the investigated countries. Third, this study generates new insights for policy makers to sustain economic development by encouraging renewable energy consumption through technological innovation.

2. Literature review

Besides the limited literature on biomass energy consumption and income that we discussed in the introduction, there is also a related body of research on renewable energy consumption, in general, and income.[3] Using a panel of 20 OECD countries, Apergis and Payne [10] examined the relationship between renewable energy consumption and economic growth from 1985 to 2005. The application of the heterogeneous panel cointegration test and Granger-causality results indicated a bidirectional causality between renewable energy consumption and economic growth in both the short and long runs. Using a similar panel framework for emerging economies, Sadorsky [11] showed that increases in real per capita income have a positive and statistically significant impact on per capita renewable energy consumption. In another study of the G7 countries' renewable energy consumption, Sadorsky [12] showed that the increases in real GDP per capita and CO_2 per capita are major drivers of per capita consumption of renewable energy.

Using autoregressive distributed lag bounds testing approach of cointegration on data for nineteen European countries, Acaravci and Ozturk [13] observed a causal relationship between CO_2 emissions, energy consumption, and economic growth. Results supported the legitimacy of EKC hypothesis in Denmark and Italy. Applying a similar approach and bootstrapping causality, Tugcu et al. [14] investigated the long run and causal relationships between renewable and non-renewable energy consumption and economic growth in G7 countries. The long-run estimates showed that neither renewable nor non-renewable energy consumption mattered for economic growth. Shahbaz et al. [15] found that EKC hypothesis is sustained in both the short run and long run for Portugal by applying autoregressive distributed lag bounds testing approach. Ozturk and Al-Mulali [16] found no support for the EKC hypothesis in data for Cambodia when controlling for governess and corruption and using the generalized method of moments and the two-stage least squares. Apergis and Ozturk [17] studied the validity of the environmental Kuznets curve (EKC) hypothesis for 14 Asian economies using a panel GMM in a multivariate framework. The empirical results supported the presence of an EKC when controlling for the institutional quality.

Al-Mulali et al. [18] focus on the effect of economic growth, renewable energy consumption and financial development on CO_2 emission in Latin America and Caribbean countries using the Kao cointegration test. The application of the Fully Modified OLS results indicated an inverted U-shape supporting the EKC hypothesis. Working on a panel of 25 OECD countries, Jebli et al. [19] found a link between per capita CO_2 emissions, GDP, renewable and non-renewable energy consumption, and international trade. Results show that the inverted U-shaped EKC hypothesis is supported for this sample of OECD countries using long-run fully modified ordinary least squares and dynamic ordinary least squares. Using the similar specification for a panel of 24 sub-Saharan Africa countries, Jebli et al. [20] found no support for the EKC hypothesis.

3. Conceptual framework of the model

In this section, we propose a conceptual framework based on the standard neoclassical production function with constant returns to scales. In this framework the aggregate output function can be presented at time t as follows:

$$Y_t = F(K_t, A_t, L_t), \quad (1)$$

where Y_t is GDP, K_t is capital, A_t is the given technology, and L_t is the effective labor. Similar to Begum et al. [1], we consider the CO_2

[1] See, e.g., Eurostats Renewable Energy Statistics at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics.

[2] It is becoming common to make a distinction between traditional and modern bioenergy (see, e.g., International Renewable Energy Agency at https://www.irena.org/remap/REmap-FactSheet-3-Modern%20Bioenergy.pdf). Traditional use includes fuelwood, animal waste and charcoal. Modern use includes liquid biofuels, industrial cogeneration, and biorefineries, biogas etc. Throughout this paper we focus on modern bioenergy use.

[3] We thank one of the anonymous referees pointing out the relevance of this related literature.