Renewable and Sustainable Energy Reviews 52 (2015) 325–332

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Business cycle co-movements between renewables consumption and industrial production: A continuous wavelet coherence approach

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ARTICLE INFO

Article history:
Received 29 January 2015
Received in revised form
18 May 2015
Accepted 25 July 2015
Available online 14 August 2015

Keywords:
Renewables
Industrial production
Continuous wavelet coherency
Continuous wavelet partial coherency

ABSTRACT

One may observe that there exist many seminal papers in energy literature to investigate intensively the energy consumption–growth nexus. The majority of these papers employ time series and/or panel data methodologies to explore, if exists, the impact of energy and/or renewable energy usage on economic growth. While time series or panel data methodologies, on the other hand, can capture time and/or cross sectional dimensions of variables, they are not able to observe frequency dimension of the related variables. This paper, thus, aims at considering both time series and frequency properties of relevant data through wavelet coherence methodology to follow the possible influences of US renewable energy consumption on the US economy in both the short run and the long run cycles.

This paper, hence, considers short run and long run co-movements between renewables consumption and industrial production through wavelet coherence and wavelet partial coherence analyses. Wavelet analyses are able to capture the co-movements in time and frequency domains. Hence, wavelet analyses are able to observe structural breaks within transitory and permanent cycles through time in analyzing the dependency between two variables. This paper specifically launches continuous wavelet transform methodology since it is more selective with time parameters in comparison with discrete wavelet transform function. Employing the US monthly data of renewables and industrial production with the controlled variables of coal consumption, natural gas consumption and petroleum consumption, this paper observes, first, continuous wavelet coherency analyses and, later, considers continuous wavelet partial coherence analyses with phase differences. In conclusion, paper yields that renewables consumption has positive significant impacts on industrial production, hence, on economic growth, in both lower and higher frequencies in the US.

Contents

1. Introduction

The literature of energy and/or economics considers recently, especially within last two decades, the impact of energy consumption on economic growth. Detailed literature surveys on economic growth–energy consumption nexus can be found in [1–4]. Some papers find positive impact of electricity consumption on growth as in [5–7], and some other papers result in positive impulse of total energy consumption on economic growth as in [8–11].

Akinlo [5], following Nigerian data, employs cointegration and causality analyses, and reaches that GDP and electricity consumption are cointegrated and that there exists Granger causality from electricity consumption to GDP. Hossain and Saeki [6], observing 76 countries'

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http://dx.doi.org/10.1016/j.rser.2015.07.116
1364-0321/

Nomenclature

ψ	mother wavelet
ψ_τ^s	wavelet daughters
s	a scaling or dilation factor that controls the width of the wavelet
τ	a translation parameter controlling the location of the wavelet
t	time
f	set of all functions
$X(t)$	a time series variable
$Y(t)$	a time series variable
WPS_x	wavelet power spectrum for $X(t)$
WPS_Y	wavelet power spectrum for $Y(t)$
W_X	wavelet transform of X
W_Y	wavelet transform of Y
W_{XY}	cross wavelet power
$CWPS_{XY}$	cross wavelet power
R_{XY}	wavelet coherency
S	smoothing operator
$\varnothing_{xy}$	phase difference
$\varphi(S(W_{XY}))$	imaginary part of smoothed cross wavelet power
$\Re(S(W_{XY}))$	real part of smoothed cross wavelet power
$R^2_{1(23\ldots p)}$	squared multiple wavelet coherency
$\sigma_{1j.qj}$	complex partial wavelet coherency of x_1 and x_j
γ^d	determinant of matrix of all the complex wavelet coherencies
γ^d_{j1}	determinant of γ matrix when jth row and 1st column are deleted
γ^d_{11}	determinant of γ matrix when 1st row and 1st column are deleted
γ^d_{jj}	determinant of γ matrix when jth row and jth column are deleted
AR	autoregressive
MA	moving average
m	constant term
γ	AR coefficient
p	lagged values of X_t
e_t	error term from ARMA model
δ	MA coefficient
q	lagged values of e_t
ψ_M	Morlet wavelet function
ψ_P	Paul wavelet function
ψ_{DOG}	DOG wavelet function
π	pi
e	exponential
i	imaginary (complex) number
w_0	frequency parameter
n	time parameter (or time index)
m	order
Γ	parameter gamma
d	derivative

panel data, follow dynamic causality analyses, and yield bidirectional causality between electricity consumption and economic growth. Tang et al. [7], employing Portugal data, launch cointegration and causality estimations, and confirm Akinlo [5] and Hossain and Saeki [6]. Sari and Soytas [8], utilizing Turkish data, conduct the methodology of generalized forecast error variance decompositions, and claim that energy consumption has positive impact on GDP. Bowden and Payne [9], considering the US data, conduct Toda–Yamamoto causality tests, and concludes that industrial primary energy consumption Granger causes GDP. Wang et al. [10], observing Chinese data, launch multivariate cointegration model and auto-regressive distributed lag model (ARDL), and explore that energy consumption affects economic growth positively both in the short and the long-run. Alam et al. [11], employing Bangladesh data, run the tests of Johansen cointegration model, ARDL and Granger causality model, and verify the findings of Wang et al. [10]. Akhmat and Zaman [12], following Asian Countries' data, employ bootstrap Granger causality tests, and find significant impact of commercial energy consumption (i.e. oil) on economic growth in Bangladesh, Bhutan, Maldives, Nepal and Srilanka, and reveal significant influence of coal consumption on economic growth in Bangladesh, Bhutan, Nepal and Srilanka.

On the other hand, the related literature comprises also some other papers revealing insignificant impact of energy consumption on economic growth as in [13–16].

Altinay and Karagol [13], following Turkish data, employ Hsiao's version of Granger causality test, and reveal no evidence of causality between energy consumption and GDP. Zhang and Cheng [14], concerning Chinese data, apply multivariate model of economic growth, and confirm Altinay and Karagol [13]. Payne [15], following the US data, launches Toda–Yamamoto causality tests and verifies the findings of Altinay and Karagol [13] and Zhang and Cheng [14]. Yıldırım et al. [16], employing NEXT 11 countries' data, consider bootstrapped autoregressive metric causality methodology, and, except Turkish data, yield no evidence of causality from energy consumption to economic growth. On the other hand, Śmiech and Papież [17], monitoring EU data, pursue the methodology of bootstrap panel Granger causality, and reveal both significant (in 15 countries) and insignificant (in 5 countries) impacts of energy consumption on economic growth.

Energy literature consists of papers investigating renewable energy and economic growth nexus, as well. Throughout related literature, the renewable energy gets prominent attention due to its replenishable resources such as biomass, biofuels, geothermal, hydropower, solar, wind and waves, and, because of its potential favorable impact on environment. The detailed literature surveys on economic growth–renewable energy consumption nexus can be found in [3,4].

Apergis and Payne [18], employing panel cointegration and error correction model with panel data for 20 OECD countries, explored bi-directional causality for long and short run between renewable energy and growth. Apergis and Payne [19] reached similar results throughout estimations of multivariate panel data model for 13 countries within Eurasia. Apergis and Payne [20], considering 16 emerging market economies within a multivariate panel framework, yield bidirectional causality between economic growth and renewable electricity consumption in the long-run. Tugcu et al. [21], following ARDL model with the data for G7 countries, exhibit bidirectional causality economic growth and renewable energy consumption. Pao and Fu [22], Ohler and Fetters [23], Apergis and Payne [24], Coban and Yorgancılar [25], Magnani and Vaona [26] and Rafiq and Salim [27] found similar positive impact of renewable energy consumption on economic growth.

Throughout literature, one may consider, as well, the papers yielding negative impact of renewable consumption on growth as in [28,29]. Ocal and Aslan [28] considered Turkish data through ARDL approach and result in negative impact of renewable consumption on economic growth. Fang [29] follows Chinese data with multivariate OLS methodology and reveals that the share of renewable energy has negative effect on economic welfare growth.

Some other studies yield insignificant effect of total renewables on GDP growth as is in [30,31,15]. Yıldırım et al. [31] follow Toda–