A Reexamination Of Causal Nexus Between Economic Growth And Renewable Enegy Consumption For Us: Further Evidence From Bootstrap-Corrected Causality Test

Şenay Saraç, Ertugrul Yıldırım

Bulent Ecevit University, Department of Economics, Zonguldak, Turkey.

E-mails: *senaysarac@hotmail.com, yildirimertugrul@hotmail.com*

Abstract

Recent debates about renewable energy consumption manifest two main expectations. Firstly, renewable energy consumption should contribute to economic growth and secondly, it should not cause a damage on environment. This study focuses on the first issue by applying bootstrap-corrected causality test for the US since empirical literature criticizes the Toda-Yamamoto test which bases on asymptotic distribution. The models consist of real GDP, employment, investment and kinds of renewable energy consumption. Only one causal relationship was found from biomass-waste-drived energy consumption to real GDP. No causal relationship was found between real GDP and all of the other renewable energy kinds – total renewable energy consumption, geothermal energy consumption, hydro-electric energy consumption, biomass energy consumption and biomass-wood-drived energy consumption. That is using of energy from waste cause not only solving the dumping problems but also it contributes to real GDP. For policy purpose, the results of this study suggest that countries should concentrate on energy producing from waste as an alternative energy resource.

Keywords: Sustainable development, Economic growth, Renewable energy consumption, US.

JEL: O13, Q42, O51

1. INTRODUCTION

Sustainable development can be defined as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Many factors can contribute to achieving sustainable development goal. One of the most important factors is the sustainable supply of energy resources (Rosen, 1996; Dincer and Rosen, 1998; Dincer, 1999). A secure supply of energy resources is a necessary condition but not sufficient requirement for sustainable development within an economic society. Furthermore, sustainable development needs a sustainable supply of energy resources and an effective and efficient utilization of energy resources. In this context, renewable energy is one of the crucial elements for sustainable development. A number of factors lead to increase attention on renewable energy sources such as the volatility of oil prices, the dependency on foreign energy sources, and the environmental consequences of carbon emissions and government policies that promote renewable energy production (Bowden and Payne, 2010; Apergis and Payne, 2010a).

Recent debates about renewable energy consumption manifest two main expectations. Firstly, renewable energy consumption should contribute to economic growth and the secondly, it should not cause a damage on environment. This study focuses on first issue. There are four hypotheses about causal nexus between economic growth and energy consumption. According to the growth hypothesis energy consumption contributes to economic growth both directly and/or indirectly by complementing to labor and capital in the production process. Validity of the growth hypothesis implies that energy conservation policies could reduce real GDP. The conservation hypothesis implies that energy conservation policies would not reduce real GDP. Achieving unidirectional Granger-causality from real GDP to energy consumption supports the conservation hypothesis. Interdependent causal nexus between energy consumption and real GDP is suggested by the feedback hypothesis. It is supported by the validity of bidirectional Granger-causality between energy consumption and real GDP. Finally, the neutrality hypothesis proposes that energy consumption serves a relatively minor role in the determination of real GDP while energy conservation policies would not reduce real GDP. The absence of Granger-causality between energy consumption and real GDP supports the neutrality hypothesis.

Ozturk (2010) reviews the literature about energy consumption-economic growth nexus. Empirical evidence about causal nexus between energy consumption and real GDP are mixed. Furthermore very few studies investigate the relationship between renewable energy consumption and real GDP. Table 1 summarizes empirical literature about renewable energy consumption-economic growth nexus.

Table 1: Literature review: Renewable energy consumption and Economic Growth

Study	**Methodology**	**Period**	**Subject**	**Relationship**
Sari and Soytas (2004)	Variance decomposition	1969-1999	Turkey	REC increases GDP
Ewing et al. (2007)	Variance decomposition	2000:1-2005:6	US	REC increases IP
Sari et al. (2008)	ARDL	2000:1-2005:6	US	IP→REC
Sadorsky (2009)	Panel Cointegration	1994-2003	18 emerging countries	GDP→REC
Apergis and Payne (2010a)	Panel Cointegration	1985-2005	20 OECD countries	GDP↔REC
Apergis and Payne (2010b)	Panel Cointegration	1992–2007	13 countries within Eurasia	GDP↔REC
Payne (2009)	Toda-Yamamoto	1949-2006	US	GDP≠REC
Bowden and Payne (2010)	Toda-Yamamoto	1949-2006	US (sectoral level)	GDP↔REC

Note: Abbreviations are defined as follows: REC= renewable energy consumption, GDP=real gross domestic product, IP=industrial production. EC→GDP means that the causality runs from energy consumption to growth. GDP→EC means that the causality runs from growth to energy consumption. EC↔GDP means that bi-directional causality exists between energy consumption and growth. EC≠GDP means that no causality exists between energy consumption and growth.

Only Payne (2009) and Bowden and Payne (2010) use Toda-Yamamoto causality test. But Toda-Yamamoto test which bases upon lag-augmented VAR model has assumption of the normality of the error term. Hacker and Hatemi (2006) indicate that if the error term of the model is characterized by non-normality, asymptotic distribution can be poor approximation. In this case findings of Toda-Yamamoto test are invalid.

The contribution of our empirical study is threefold. First this study uses a multivariate causality test by including employment and investment variables into the model between renewable energy consumption and real GDP since the omission of relevant variables leads to econometric problems. Second, this study employs bootstrap-corrected causality technique suggested by Hacker and Hatemi (2006) to avoid unclear results due to the assumption of normality and the third one is to pick the true lag order by combining Schwarz (1978) Bayesian information criterion and the Hannan and Quinn (1979) information criterion as suggested by Hatemi (2003).

The rest of the paper is organized as follows: The next section describes the data, methodology and the results from empirical analysis are presented in third section. Section four presents conclusion and policy implications of the paper.

2. Data

Employment, real gross fixed capital formation and real GDP variables are taken from OECD National Accounts data that is attained from source OECD data base and time series of renewable energy consumption variables are obtained from the US Energy Information Administration as billion Btu. Tim span of the renewable energy consumption variables are as follows: 1949-2010 for total renewable energy consumption, biomass energy consumption, hydropower energy consumption and biomass-wood-drived energy consumption, 1960-2010 for geothermal energy consumption and 1970-2010 for biomass-waste-drived energy consumption.

3. Methodology and Results

Toda-Yamamoto augmented VAR(p+d) model can be described in the following a compact way (Hacker and Hatemi-J, 2006):

$$K = FZ + \psi. \qquad (1)$$

Where:

$K = (x_1, \ldots, x_T)(n \times T)$ matrix,

$F = (v, A_1, \ldots, A_p, \ldots, A_{p+d})(n \times (1 + n(p+d)))$ matrix,

$$Z_t = \begin{bmatrix} 1 \\ x_t \\ x_{t-1} \\ \cdot \\ \cdot \\ \cdot \\ x_{t-p-d+1} \end{bmatrix} ((1 + n(p+d)) \times 1) \text{ matrix, for t=1,...,T,}$$

matrix,

$Z = (Z_0, \cdots, Z_{T-1})((1 + n(p+d)) \times T)$ matrix,

$\psi = (\varepsilon_1, \cdots, \varepsilon_T)(n \times T)$ matrix,

Toda and Yamamoto (1995) introduce the following modified Wald (MWALD) test statistic for testing the null hypothesis of non-Granger causality:

$$MWALD = (Y\phi)' \left[Y\left((Z'Z)^{-1} \otimes V_U \right) Y' \right]^{-1} (Y\phi) \sim \chi^2_P. \qquad (2)$$

Where:

$\otimes$ = the Kronecker product.

$Y = ap \times n(1 + n(p + d))$.

V_U = the estimated variance – covariance matrix of residuals in Eq. (1).

$\phi = vec\ (F)$, where vec represents the column stacking operator.

The MWALD test statistic is asymptotically $\chi 2$ distributed, conditional on the assumption that the error terms are normally distributed, with the number of degrees of freedom equal to the number of restrictions to be tested. According to Toda and Yamamoto (1995), their function (Eq.2) guarantees the use of asymptotical distribution theory. However, using Monte Carlo simulations Hacker and Hatemi-J (2006) showed that the MWALD test statistic over rejects the null hypothesis, especially if the error term is characterized by autoregressive conditional heteroscedasticity (ARCH) and non-normality. Furthermore, Hacker and Hatemi-J urged that the asymptotic distribution can be a poor approximation, especially for the small samples that are common in empirical studies.

Hacker and Hatemi-J (2006) found that the bootstrapped empirical size for the modified Wald test is close to the correct size in the different cases when the extra lags are greater than or equal to the integration order of both variables, and it is generally closer to the correct size than the asymptotic distribution empirical size.

To perform the bootstrap simulations, firstly regression (Eq. 1) is estimated with the null hypothesis of no Granger causality. For each bootstrap simulation it is generated the simulated data, K*.

$$K^* = \hat{F}Z + \psi^* \qquad (3)$$

where $\hat{F}$ is the estimated value of the parameters in Eq. (1). That is. $\hat{F} = KZ'(ZZ')^{-1}$ The bootstrap residuals (Ψ*) are based on T random draws with replacement from the regression's modified residuals, each with equal probability of 1/T. The mean of the resulting set of drawn modified residuals is subtracted from each of the modified residuals in that set. The modified residuals are the regression's raw residuals modified to have constant variance, through the use of leverages. Eq.(4) defines the modified residual through leverage adjustment for xit.

$$\varepsilon_{it}^m = \frac{\varepsilon_{it}}{\sqrt{1 - h_{it}}} \qquad (4)$$

In order to calculate the bootstrap critical values, the bootstrap simulation is run 100,000 times and calculated the MWALD test statistic each time. In this way, it is able to produce the empirical distribution for the MWALD test statistic.

The analyses consist of three stage, In the first stage, to ensure robustness for the common components of the variables, we use several unit root tests, including the augmented Dickey and Fuller (1979) (ADF) test, the Phillips and Perron (1988) (PP) test, as well as the

Kwiatkowski et al. (1992) (KPPS) test. According to our results, not represented here, the common components of the all variables turn out to be integrated of order one, I(1).

The next step is to pick optimal lag order. Two of the most successful criteria according to the simulation results presented in the literature are Schwarz (1978) Bayesian information criterion (SBC) and the Hannan and Quinn (1979) information criterion (HQC). However, the earlier studies illustrate that each of these two different criteria can perform better than the other depending on the properties of the true VAR model. Hatemi-J Criteria (HJC), displayed in Table 2, is employed to pick true lag order which is suggested by Hatemi-J (2003).

Table 3: Selection of Lag Length

Models	AIC	SBC	HQC	HJC
Model 1:Real GDP=Employment+Investment+Total REC	2	1	2	2
Model 2:Real GDP=Employment+Investment+Biomass Total EC	2	2	2	2
Model 3:Real GDP=Employment+Investment+ Hydropower EC	2	1	2	2
Model 4:Real GDP=Employment+Investment+Biomass Wood-drived EC	2	2	2	2
Model 5:Real GDP=Employment+Investment+Biomass Waste-drived EC	2	2	6	2
Model 6:Real GDP=Employment+Investment+Geothermal EC	2	2	2	2

Note: Abbreviations are defined as follows: AIC=Akaike information criteria, SBC= Schwarz Bayesian information criteria, HQC=Hannan-Quinn information criteria, HJC=Hatemi-J information criteria, REC=Renewable energy consumption and EC= Energy consumption. First number is selected lag length and second one is min test stats of relevant criteria.

Note: Abbreviations are defined as follows: AIC=Akaike information criteria, SBC= Schwarz Bayesian information criteria, HQC=Hannan-Quinn information criteria, HJC=Hatemi-J information criteria, REC=Renewable energy consumption and EC= Energy consumption. First number is selected lag length and second one is min test stats of relevant criteria.

In the last step bootstrap-corrected causality test was applied. Table 4 illustrates the MWALD stats and critical values.

Table 4: Causality Test Results

	H0: REC does not Granger cause GDP				H0: GDP does not Granger cause REC			
	MWALD	%1 CV	%5 CV	%10 CV	MWALD	%1 CV	%5 CV	%10 CV
Model 1	0.069	10.505	6.590	4.974	2.288	10.727	6.764	5.087
Model 2	2.226	11.078	6.833	5.162	1.602	10.847	6.764	5.108
Model 3	0.966	10.272	6.447	4.915	1.261	10.754	6.758	5.090
Model 4	1.637	10.610	6.623	4.996	1.684	10.965	6.839	5.181
Model 5	**12.422***	11.681	6.969	5.160	4.482	11.872	7.003	5.186
Model 6	1.228	11.064	6.871	5.148	0.332	11.603	6.994	5.255

Note: * represents rejection of null hypothesis at 1% significance level. REC=Renewable energy consumption. For definitions of the models see Table 3.

According to Table 4 only one causal relationship was found from biomass-waste-drived energy consumption to real GDP. This finding supports the growth hypothesis. No causal relationship was found between all of the other renewable energy kinds and real GDP. All of the findings, except for biomass-waste-drived energy consumption, support the neutrality hypothesis.

4.CONCLUSION

Recent debates about relationship between renewable energy consumption and economic growth manifest two main expectations. Firstly, renewable energy consumption should contribute to economic growth and secondly, it should not cause a damage on environment. This study focuses on the first issue by applying bootstrap-corrected causality test for the US since empirical literature criticizes the Toda-Yamamoto test which bases on asymptotic distribution.

According to bootstrap-corrected causality test results only one causal relationship was found from biomass-waste-drived energy consumption to real GDP. No causal relationship was found between all of the other renewable energy kinds and real GDP. These findings are interesting since biomass-waste-drived energy consumption has a low percentage (6%) of total renewable energy consumption.

Many developed countries are trying to dump their garbage on the lands of lesser developed countries. However dumping garbage on other places spreads pollutions and diseases instead of solving the problem. In fact it is more dangerous to dump garbage in the less developed countries since there are neither technologies available to process it nor enough awareness. Even creating landfills wastes precious resources. Lastly our findings indicate that there is a causality from waste-drived energy to real GDP. Using of energy from waste cause not only to resolve the dumping problems but also it contributes to real GDP. The countries that are using other energy resources do not take advantage from using waste-drived energy. For policy purpose, the results of this study suggest that countries should concentrate on energy producing from waste as an alternative energy resource.

REFERENCES

Akaike, H. (1974) A new look at the statistical model identification, IEEE Transactions on Automatic Control, 19 (6), 716-723.

Apergis, N. and Payne J.E. (2010a) Renewable energy consumption and economic growth: Evidence from a panel of OECD countries, Energy Policy, 38, 656-660.

Apergis, N. and Payne J.E. (2010b) Renewable enrgy consumption and growth in Eurosia, Energy Economics, 32, 1392-1397.

Bowden, N. and Payne, J.E. (2010) Sectoral Analysis of the Causal Relationship Between Renewable and Non-Renewable Energy Consumption and Real Output in the US, Energy Sources, Part B: Economics, Planning, and Policy, 5:4, 400-408.

Dickey, D.A. and Fuller W.A. (1979) Distribution of the estimators for autoregressive time series with a unit root, Journal of the American Statistical Association, 74, 427-431.

Dincer, I. (1999) Environmental impacts of energy, Energy Policy, 27, 845-854.

Dincer, I. and Rosen M.A. (1998) A worldwide perspective on energy, environment and sustainable development, International Journal of Energy Research, 15, 1305-1321.

Ewing, B.T., Sari, R. and Soytas U. (2007) Disaggregate energy consumption and industrial output in the United States, Energy Policy, 35, 1274–1281.

Hacker, R.S. and Hatemi-J A. (2006) Tests for causality between integrated variables using asymptotic and bootstrap distributions: theory and application, Applied Economics, 38, 1489-500.

Hannan, E. J. and Quinn B.G. (1979) The determination of the order of an autoregressive, Journal of the Royal Statistical Society, 41, 190-195.

Hatemi-J, A. (2003) A new method to choose optimal lag order in stable and unstable VAR models, Applied Economics Letters, 10, 135-137.

Kwiatkowski D., Phillips P.C.B., Schmidt P. and Shin. Y. (1992) Testing for the null of stationarity against the alternative of a unit root, Journal of Econometrics, 54, 159-178.

Ozturk, I. (2010) A literatüre survey on energy-growth nexus, Energy Policy, 38, 340-349.

Payne, J.E. (2009) On the dynamics of energy consumption and output in the US, Applied Energy, 86, 575–577.

Phillips, P.C. and Perron P. (1988) Testing for a unit root in time series regression, Biometrika, 75, 335-346.

Rosen, M.A. (1996) The role of energy efficiency in sustainable development, Technology and Society, 15(4), 21-26.

Sadorsky, P. (2009) Renewable energy consumption and income in emerging economies, Energy Policy, 37, 4021-4028.

Sarı, R. and Soytas U. (2004) Disaggregate energy consumption, employment, and income in Turkey, Energy Economics, 26, 335–344.

Sarı, R., Ewing, B.T. and Soytas, U. (2008) The relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach, Energy Economics, 30, 2302–2313.

Schwarz, G. (1978), Estimating the dimension of a model, Annals of Statistics, 6, 461-464.

Toda, H.Y. and Yamamoto T. (1995), Statistical inference in vector autoregressions with possibly integrated processes, Journal of Econometrics, 66, 225-250.