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RENEWABLE ENERGY AND RENEWABLE R&D IN EU COUNTRIES: A COINTEGRATION ANALYSIS

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ABSTRACT

In recent years, increased attention has been directed towards carbon dioxide emissions and environmental impacts, as industrialized countries have had to find ways of reducing energy use in order to meet Kyoto targets. One way in which such a reduction in energy use could be achieved would be to develop renewable energy. In comparison with that generated from fossil fuels, electricity generated from renewable energy sources would give rise to lower greenhouse gas emissions. An increased share of renewable electricity would thus help to reduce the impact of greenhouse gas emissions on the environment and human health (European Environment Agency). The relationships between the increased share of renewable electricity in gross electricity consumption and renewable energy-related R&D for countries in the EU region is an important topic to investigate for several reasons. First, in comparison with other regions, EU countries are the most committed to the development of renewable energy and to reducing their carbon dioxide emissions. Second, the EU is a very promising area for energy-related R&D. Studying the influence of renewable energy-related R&D on the share of renewable energy can help policy-makers make appropriate investments. This paper investigates the relationships among the share of renewable electricity in gross electricity consumption, GDP, the oil price as well as the R&D of renewable energy for EU countries, using a newly-developed panel unit root and cointegration framework. We find that higher income and oil prices in the future will help EU countries to boost the share of renewable electricity in gross electricity consumption. Moreover, governments in EU countries could use the so-called technology-push climate policy to persistently stimulate the share of renewable electricity in gross electricity consumption and meet the targets laid down by the EU commission.

Keywords: Renewable energy, Oil price, Renewable energy R&D, Panel co-integration, Panel unit root, Cross-section dependence.

INTRODUCTION

In recent years, increased attention has been directed towards carbon dioxide emissions and environmental impacts, as industrialized countries have had to find ways of reducing energy use in order to meet Kyoto targets. One way in which such a reduction in energy use could be achieved would be to develop renewable energy. In comparison with that generated from fossil fuels, electricity generated from renewable energy sources would give rise to lower greenhouse gas emissions. An increased share of renewable electricity would thus help to reduce the impact of greenhouse gas emissions on the environment and human health (European Environment Agency).

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A number of existing studies examine the role of renewable energy demand (see, for example, Sadorsky, 2009a,b). Sadorsky (2009) found that renewable energy consumption is explained by GDP per capita and carbon dioxide emissions. However, no published research has looked into the relationships between the share of renewable electricity in gross electricity consumption and the R&D of renewable energy for countries in the EU region, using the new panel approach (cross-sectional dependence). One reason for using R&D as a factor affecting the share of renewable energy is that the government R&D (based on the so-called upstream or technology-push climate policy) may improve technology and enhance quality, and thus has a significant effect on productivity growth (Guellec et al., 2004).

The relationships between the increased share of renewable electricity in gross electricity consumption and renewable energy-related R&D for countries in the EU region is an important topic to investigate for several reasons. First, in comparison with other regions, EU countries are the most committed to the development of renewable energy and to reducing their carbon dioxide emissions. For instance, the EU Commission set itself a target which was to have a share of 20% for renewable electricity in gross electricity consumption by 2020. Second, the EU is a very promising area for energy-related R&D. According to the EU Seventh Framework Programme (FP7), covering 2007-2013, more than €2.35 billion is being allocated to improving energy efficiency and the share of renewable energy. Studying the influence of renewable energy-related R&D on the share of renewable energy can help policy-makers make appropriate investments. As was mentioned above, it is interesting to examine whether or not the share of renewable energy in the EU will be increased through the use of renewable energy-related R&D.

In recent years, the problem of the cross-sectional dependence of the data has been highlighted in many macroeconomic studies. Thus, in this paper we employ the newly-developed panel unit root and panel cointegration tests. To the best of our knowledge, such an analysis has not been performed to investigate the links between the share of renewable electricity in gross electricity consumption and the R&D of renewable energy.

The remainder of this paper is organized as follows. Section 2 provides information regarding the data set. Section 3 introduces the panel approach adopted in this paper. Section 4 discusses the empirical results. Finally, Section 5 concludes.

MODEL AND DATA

In order to investigate the relationships among the share of renewable electricity in gross electricity consumption (SRE), GDP (Y), the oil price (OP) and renewable energy-related R&D ($R\&D$), the log equation is expressed as follows:

$$\ln SRE_{it} = \alpha_{0i} + \beta_{1i} lnY_{it} + \beta_{2i} \ln OP_{it} + \beta_{3i} \ln R\&D_{it} + \varepsilon_{it} \qquad (1)$$

Where Eq. (1) is estimated using the panel approach that considers both country i and year t. The term ε_{it} is an error term. The sign of β_{3i} is expected to be positive.

In this paper we consider four variables, namely, the share of renewable electricity in gross electricity consumption (%), real GDP per capita (measured at 2000 prices), the real price of crude oil (measured at 2000 prices) and national public sector expenditures on the R&D of renewable energy (measured in millions of US dollars at 2000 prices). As for the data, the annual data in the sample are obtained for EU-11 countries (Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom). The sample is limited to the 1995-2006 period because data on the national public sector expenditures on renewable energy-related $R\&D$ are not available.

The variable for the share of renewable electricity in gross electricity consumption was supplied by Eurostat, those on real GDP per capita were supplied by the World Bank Development Indicators' CD-ROM, the real price of crude oil was obtained from the Energy Information Administration (EIA), and the national public sector expenditures on renewable energy-related R&D were obtained from the IEA Energy Technology Research and Development Database (IEA 2006c).

METHODOLOGY

The analysis of the data was performed by means of a panel approach, so as to avoid small sample bias and also take individual heterogeneity into account. Moreover, the cross section dependence problem has attracted considerable research attention in recent years. In order to address this problem, second generation unit root and cointegration tests were conducted.

Two kinds of panel unit root tests were utilized in this paper. One of the unit root tests was developed by Im et al. (IPS) (2003). The main advantage of the IPS panel unit root test is that it attempts to relax the Levin et al. (2002) alternative hypothesis which requires that all series be stationary. The IPS test requires that only some of the series be stationary. In addition, the IPS test converges to a normal distribution with mean and variance through the use of the Monte Carlo approach. The other panel unit root test is the cross-sectionally augmented Dickey-Fuller (CADF) unit root testing approach proposed by Pesaran (2007) who used cross-sectional averages of the lagged levels as a common factor. It should be noted that OLS yields biased results if the common factor is not captured in the equation.

The next step is to examine the existence of a long-run relationship among the variables. Pedroni (2000, 2004) developed cointegrated panels characterized by heterogeneity and fixed effects. Seven statistics were proposed by Pedroni (2000, 2004) in order to test the null of no cointegration. In addition, the Pedroni (2000, 2004) cointegration test required only one of those series to be cointegrated as an alternative hypothesis. The seven statistics used in Pedroni (2000, 2004)'s cointegration tests for heterogeneous panels were those within-dimension statistics (the Panel PP, Panel ADF, Panel v and Panel rho statistics) and between-dimension statistics (the Group PP, Group ADF and Group rho statistics). Westerlund (2007) developed cointegration panels characterized by ECM. In comparison with common factor restrictions, the ECM panel cointegration tests focus on structural dynamics. The two statistics used in Westerlund (2007) test for the pooling of the information along the cross-sectional unit (the P_α statistic) and that in relation to the between-dimension statistic (the G_α statistic). The third panel cointegration test was proposed by Westerlund and Edgerton (2007) and was based on the popular Lagrange multiplier (LM) test of McCoskey and Kao (1998) and took into consideration cross-sectional dependence in the sample. Moreover, the bootstrap approach was applied to deal with cross cross-sectional dependence and improve the LM test performance.

Having found a cointegration relationship among these variables, we then estimate the coefficient for a cointegrated panel using the SUR technique. The SUR technique for error cross-sectional dependence is proposed by Zellner (1962). In each of the SUR models, all of the regressors are found to be strongly exogenous. Thus, the SUR estimators are still consistent regardless of whether cross-sectional dependence is taken into account. Moreover, the SUR estimators as feasible GLS estimators are consistent and asymptotically efficient.

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EMPIRICAL RESULTS

In order to test the long-run relationships and avoid spurious regression among the crude oil price and income variables, the IPS and CAPS panel unit root tests were applied and the results are presented in Table 1. The null hypothesis of the IPS and CAPS unit root tests were not rejected by all variables. We therefore conclude that all variables are non-stationary.

Table 1. Panel unit root tests

Variable	*Method*	*Model with constant*	*Model with constant and trend*
SRE	IPS	-0.466(0.320)	-1.483(0.070)
	CADF	-2.143	-0.704
Y	IPS	-0.204(0.420)	1.457(0.927)
	CADF	-1.314	-1.19
OP	IPS	4.134(0.999)	1.734(0.958)
	CADF	-2.328	-0.492
R & D	IPS	-0.502(0.308)	-1.501(0.068)
	CADF	-1.038	-1.786

Notes: In the first generation tests, the values in brackets are the p-values. For the case with a constant only, the critical values for the Pesaran CADF test are -2.97 and -2.52 at the 1% and 5% significance levels, respectively. For the case with a constant and trend, the critical values for the Pesaran CADF test are -3.88 and -3.27 for the 1% and 5% significance levels, respectively.

After finding all variables that were characterized by a unit root, we tested the heterogeneous cointegration relationships among the SRE_{it} and the explanatory variables as shown in Table 2. It can be seen in Table 2 that only the Group ADF and Group PP statistics were all statistically significant at the 5 percent level. Thus, the null hypothesis was not rejected in most cases and a long-run relationship was not found to exist among all variables in the first-generation cointegration model.

Table 2. Pedroni panel cointegration tests

Test Statistics	*Statistics value*
Panel v	-2.020 (0.978)
Panel rho	0.938 (0.826)
Panel PP	-1.498 (0.067)
Panel ADF	-0.887 (0.188)
Group rho	1.928 (0.973)
Group PP	-3.995*** (0.000)
Group ADF	-5.736*** (0.000)

Note: The p values are reported in the parentheses; *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

In terms of second-generation cointegration tests, the Westerlund (2007) and Westerlund and Edgerton (2007) cointegration test results for a model including either a constant term or a constant and a trend are shown in Table 3 and Table 4. The results of the Westerlund (2007) test indicate that all statistics are statistically significant at the 5 per cent level and that there are long-run relationships among all the variables in both the constant and constant and trend cases. As for the Westerlund and Edgerton (2007) test, the cases of a constant and a constant and trend have significant LM statistics with a low asymptotic p-value leading us to reject the null of cointegration. However, this result is based on conventional asymptotic critical values which assume the cross-sectional independence of countries. Thus, Westerlund and Edgerton (2007) employ a bootstrap technique to deal with dependence among individuals and to determine the bootstrap p-value. In this case we conclude that there is a long-run cointegration relationship among all variables.

Table 3: Westerlund (2007) panel cointegration tests

	Test statistics	*Model with constant*	*Model with constant and trend*
	value	3.017	3.121
G_α	Z-value	6.593	7.679
	robust p value	0.000	0.000
	value	4.671	5.522
P_α	Z-value	6.136	7.704
	robust p value	0.000	0.000

Note: For Westerlund (2007), the null hypothesis of the tests is no cointegration among all the variables and the bootstrap is based on 500 replications.

Table 4. Westerlund and Edgerton (2007) panel cointegration tests

Test statistics	*Model with constant*	*Model with constant and trend*
LM-stat	10.080	28.614
Asymptotic p-value	0.000	0.000
Bootstrap p-value	0.746	0.595

Note: The null hypothesis of the tests is cointegration among all the variables and the bootstrap is based on 1,000 replications.

Table 5. Panel SUR tests

Method	*Dependent variable*		
	Y_{it}	OP_{it}	$R\&D_{it}$
Panel SUR	1.467^{***} (0.046)	0.088^{***} (0.007)	0.014^{***} (0.002)

Note: The standard errors are reported in the parentheses; *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

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Having established the long-run cointegration relationship, in the next part of the analysis we derive panel SUR estimates to obtain coefficients for cointegrated panels. The results of the panel SUR statistics are given in Table 5. It can be seen from Table 5 that all variables are statistically significant at the 5% level. The coefficient of income is 1.467, which indicates that real GDP plays an important role in EU countries to improve the share of renewable electricity in gross electricity consumption. Furthermore, a positive coefficient of the oil price is obtained. Thus, an oil price surge will help EU countries to adjust the amount of SRE. In terms of the effect of renewable research and development on SRE, it is found that $R\&D$ has a positive impact on SRE. Thus, increasing $R\&D$ will help EU countries meet the targets laid down by the EU Commission.

CONCLUSION

In this paper, we have attempted to examine the relationships among the share of renewable electricity in gross electricity consumption, GDP, the oil price as well as the R&D of renewable energy for 11 countries over the 1995-2006 period, using a newly-developed panel unit root and cointegration framework. The panel cross-section dependence cointegration approach (e.g., Westerlund, 2007; Westerlund and Edgerton, 2007) has good small sample properties and high power compared to residual-based panel cointegration tests (e.g., Pedroni, 2004). Our empirical evidence showed that after taking cross-section dependence into account, a long-run cointegration relationship between all variables was found to exist.

In addition, the main conclusion from the study is that the income and oil price variables are positively associated with SRE. Thus, higher income and oil prices in the future will help EU countries to boost the share of renewable electricity in gross electricity consumption. Moreover, the share of renewable energy in renewable R&D investment was found to be positive and statistically significant. Thus, governments in EU countries could use the so-called technology-push climate policy to persistently stimulate the share of renewable electricity in gross electricity consumption and meet the targets laid down by the EU commission.

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