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Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from OECD countries ☆

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ABSTRACT

This paper uses a panel threshold regression (PTR) model to investigate the influence that energy prices have on renewable energy development under different economic growth rate regimes. The empirical data are obtained from each of the OECD member-countries over the period from 1997 to 2006. We show that there is one threshold in the regression relationship, which is 4.13% of a one-period lag in the annual gross domestic product (GDP) growth rate. The consumer price index (CPI), in so far as it relates to variations in energy, is significantly positively correlated with the contribution of renewables to energy supply in the regime with higher-economic growth, but there is no relationship in the regime with lower economic growth. Therefore, countries characterized by high-economic growth are able to respond to high energy prices with increases in renewable energy use, while countries characterized by low-economic growth countries tend to be unresponsive to energy price changes when they come to their level of renewable energy.

1. Introduction

Greenhouse gases, such as carbon dioxide (CO_2) emissions, have resulted in a serious global-warming problem that is believed to have caused extreme changes in the world's climate. In addition, the world is dealing with the dual problems of fossil energy exhaustion and the impact of inflation on economic growth. In the historical statistics on energy CPI and crude oil prices, energy CPI grew rapidly (from 137.4 to 159.7 in 2004), while the West Texas Intermediate Cushing Oil spot price rocketed from $32.81 to $56.17.[1] In addition, the IEA (2004) reported that a $10 oil price increase would reduce global GDP by 0.5% thereby giving rise to $225 billion in losses over several years. These shocks have seriously affected macroeconomic growth by raising inflation and unemployment.[2] Policy-makers have therefore attempted to implement various fiscal and monetary policies around the world to stabilize macroeconomic conditions. In particular, the promotion of renewable energy has become one of the important strategies introduced in order to mitigate CO_2 emissions and find substitutes for fossil energy in the transportation and power generation sectors. Moreover, renewable energy can help serve as a substitute for fossil fuels and thereby reduce man-made emissions of greenhouse gases upon meeting the future energy needs of developing countries.

On January 23, 2008, the European Commission put forth an integrated proposal for climate action, which includes a directive that sets an overall binding target for the European Union of 20% renewable energy and a 10% minimum target for the share of biofuels in overall gasoline and diesel consumption in the transportation sector by 2020. However, because the utilization of renewable energy resources (e.g., wind power, solar or photovoltaic cells, and biomass) has often given rise to cost disadvantages, their successful performance frequently depends on support schemes. Therefore, most advanced countries have introduced various incentive mechanisms to increase their production and utilization of renewable energy. These mechanisms include feed-in tariffs, renewable portfolio standards, financing preferences, tax credits, and investment and research subsidies.

As far as past studies are concerned, investments in renewable energy technologies will result in an increase in GDP. However, the exploitation of massive renewable energy resources will dampen economic activities through the mechanism of the consumer price index, which will be pushed upwards by higher energy prices. Awerbuch and Sauter (2006) argue that the wealth released by avoiding the negative relationship between oil prices

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[1] The energy consumer price index is the weighted average of energy prices purchased by a typical household. It is a widely-cited index number for price levels. The statistics for the West Texas Intermediate Cushing Oil spot price change were collected from the United States Department of Labor and the Bloomberg data stream.

[2] The IEA (2004) information was obtained from Awerbuch and Sauter (2006).

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and GDP provides sources of deployment of renewable energy. If this statement is true, low-growth countries are incapable of maintaining renewable energy incentive policies when economic circumstances become unfavorable over a long period of time. The statement also implies that high-growth countries can more easily handle the pressure from steep increases in energy prices than can low-growth countries when meeting their obligations to reduce greenhouse gas emissions.

From the above discussion, another question arises. What kinds of economic growth measures are necessary to change renewable energy development in the future? It is important for policy-makers to have access to knowledge regarding the critical value of energy development. Our empirical results are helpful in interpreting why policy-makers ignore powerful cost reductions and other benefits associated with renewable energy and efficiency. In its empirical work, this paper adopts the panel threshold regression (PTR) method proposed by Hansen (1999) to examine whether the threshold effect of GDP influences renewable energy supply when countries face greater oil price volatility and higher energy prices.

The PTR model is developed for non-dynamic panels with individual-specific fixed-effects, which is advantageous to our work in several ways. First, traditional regression functions do not capture variations between OECD countries in terms of renewable energy policies. In particular, every OECD country is a significantly developed economy in its respective region, and every one exists in a different geographic location with different policy-maker attitudes. Therefore, the PTR model can help us to understand that individual observations can be grouped into classes based on the values of a key variable. Second, we also employ a non-standard asymptotic theory of inference and a bootstrap method, which allow for the construction of confidence intervals in assessing the statistical significance of the threshold effect and the testing of hypotheses. The PTR model illustrates that errors tend to be heteroskedastic. This implies that adopting conventional OLS models may lead to incorrect inferences. Finally, the PTR model's sample can be split and thereby more accurately examine whether OECD countries possess significantly different threshold effects. Thus, the PTR model helps us to effectively understand issues related to the problem of renewable energy policy.

The panel dataset is drawn from data for the OECD member-countries,[3] and the research period extends from 1997 to 2006. From the estimated results, the overall findings show that: (1) a single threshold effect exists, where the optimal threshold effect value is found to be 4.13% for a one-period lag of annual growth, measured as a percentage of GDP; and (2) the threshold effect segments countries into groups with lower- and higher-growth rates. A complete reversal in the estimated slope coefficient exists in the two regimes, such that the CPI of energy variation is significantly and positively correlated with the contribution of renewables to energy supply in the higher-growth regimes, but is insignificantly and negatively correlated with the contribution of renewables to energy supply in the lower-growth regimes. These results also indicate that the different countries' economic growth during the previous period plays an important role in reforming energy policy.

In other words, because of cost considerations, the low-economic growth countries are less willing to enhance their renewable energy development. Conversely, if the previous economic growth rate reaches 4.13% or more, those countries will have an economic surplus to deploy their renewable energy resources. As a consequence, the high-economic growth countries are able to respond to energy price impacts by changing their use of renewable energy, while the low-economic growth countries cannot.

Our findings are also consistent with Awerbuch and Sauter (2006) view that, in high-growth countries, a substitution effect arises from renewable energy use so as to avoid the negative relationship between oil prices and GDP. Less-restricted countries, on the other hand, have the ability to adjust to the impact of abrupt changes in energy prices and to maintain sustainable renewable energy development. Furthermore, if a country's wealth is limited, it may tend to concentrate its resources on other fiscal policies and on decreasing renewable energy consumption in order to mitigate the impact of rising energy prices.

The remainder of this paper is organized as follows. The next section reviews previous studies on the relationships among renewable energy, economic growth, and energy prices. Section 3 describes the PTR model's estimation methodology. Section 4 describes how the panel data are constructed. Section 5 presents the empirical results of the estimation, which are robust with respect to the threshold effect. The final section summarizes our empirical findings and enables us to draw conclusions.

2. Literature review

In a recent study, Awerbuch and Sauter (2006) noted that although a relationship between oil and GDP has been established over the last 20 years (e.g., Jones et al., 2004), energy policy-makers have shown little interest in the potential implications that the observed negative relationship has for a renewables policy. Awerbuch and Sauter argued that oil price increases will affect both GDP and financial markets, and suggested that renewable energy investments can effectively help nations avoid the costly macroeconomic losses that arise because of the oil-gross domestic product (GDP) effect. In particular, Nakicenovic and Swart (2000) noted that the extent of primary energy consumption must surely depends on technological and economic growth assumptions. Their conclusions imply that speedy development may increase energy demands. In addition, Askari and Krichene (2008) show that the upward pressure on oil prices in recent years result from rigid crude oil supply and expanding world demand for crude oil. In other words, the change in supply and demand has pushed up energy prices and thereby affected the global economic environment. Therefore, the costs and benefits of renewable energy utilization must be considered if policy-makers wish to lower CO_2 emissions, reduce national losses, and stabilize economic development.

It is important to understand the benefits of renewable energy policies and when they should be implemented. Past studies such as Domac et al. (2005) noted that renewable energy increases macroeconomic efficiency through business expansion and ample employment opportunities as a result of developing renewable energy industries. Furthermore, finding substitutes for energy imports has both direct and indirect positive effects on an economy's GDP and current account balance. Similarly, Chien and Hu (2008) examine the impact of renewable energy on GDP using an expenditure approach. Their findings suggest that there is a positive relationship between renewable energy and GDP that occurs through increased capital formation rather than by increasing the trade balance, which indicates that renewable energy does not lead to an import substitution effect.

In addition, Awerbuch and Sauter (2006) reference prior work showing that a 10% rise in the oil price results in losses of around 0.5% of GDP. In particular, in absolute terms, the GDP losses

[3] The member-countries of the OECD are Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.