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Hydroelectricity consumption and economic growth nexus: Evidence from a panel of ten largest hydroelectricity consumers ☆

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ABSTRACT

This paper explores the long-run and causal relationships between hydroelectricity consumption and economic growth for a panel of the 10 largest hydroelectricity consuming countries over the period 1965–2012. The countries include Brazil, Canada, China, France, India, Japan, Norway, Sweden, Turkey and the U.S.A. Using the Bai and Perron (2003) [9] tests for cointegration, the results indicate that real GDP per capita and hydroelectricity consumption per capita appear to be cointegrated around a broken intercept. Granger causality results from a nonlinear panel smooth transition vector error correction model suggest different results depending on the regimes, which we identified based on structural break tests. The test identified three breaks at 1988, 2000 and 2009. For the pre-1988 period, there is evidence of unidirectional causality running from real GDP per capita to hydroelectricity per capita in both the short- and long-run. Over the post-1988 period, there exists evidence of bidirectional causality between hydroelectricity energy consumption per capita and real GDP per capita in both the short- and the long-run. The results imply the existence of a feedback hypothesis with both hydroelectricity consumption and growth promoting each other in more recent periods, as the importance of hydroelectricity as a renewable energy, has become more prominent.

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1. Introduction

A number of studies have analysed the causal relationship between renewable energy consumption and economic growth across different countries or sets of countries ([1–3,5–8,13], among others). There is also a growing literature on the causal relationship between renewable energy consumption and economic growth. Most of these studies use aggregate energy sources (with the exceptions of [1,19,49,13]). With the world facing global warming, mainly as a result of the consumption of fossil fuels, it

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might be important to consider hydroelectricity which is non-polluting. The role of hydroelectricity on agricultural production and hence, the GDP growth is undeniable, as have been described in detail in [34,35,37,38] and Valipour et al., [36]. There is a growing literature on energy intensity and carbon emissions. Such studies include Bentzen [10], Jin [15], Sorrell and Dimitropoulos [31], Zhang [39], Zhang and Wang. [40–42], Wang et al. [43,44], Wang et al. [45], Wang, Chao [46–48], among others. The role of individual sources of renewable energy is important, given countries' challenges in determining the optimal mix of energy.

The goal of this paper is to assess the causal relationships between hydroelectricity consumption and economic growth in a panel of the 10 largest consumers of hydroelectricity. The empirical analysis employs annual data spanning the period 1965–2012. The countries include Brazil, Canada, China, France, India, Japan, Norway, Sweden, Turkey and the U.S.A. Note that, Venezuela is also a very prominent user of hydroelectricity (2.1 percent of world share, BP's Statistical Review of World Energy, 2013) and ranks in the top 10 countries, however, due to the lack of data on per capita real GDP going as far back as 1965, we had to exclude it from the analysis. The ten countries included in the analysis covers 67.4 percent of world hydroelectricity consumption, with China coming in first with 27.4 percent and Turkey with 1.0 percent of world share (BP's Statistical Review of World Energy, 2013). Canada, Brazil and the U.S. follows China with 9.8 percent, 9.5 percent and 6.7 percent of world share (BP's Statistical Review of World Energy, 2013). Given these figures, and the lack of per capita real GDP data for Venezuela, the choice of the ten countries were quite obvious in our analysis. This paper contributes to the literature on the nexus between renewable energy consumption and economic growth by examining a particular energy source, hydroelectricity. Also note that, among these ten countries four of them are in the world's top five polluting countries. Of all ten sample countries, only Sweden is among the leading countries in the use of renewable energies. The use of hydroelectricity is important as it reduced carbon emissions.

This study is among a few studies, third to be precise, that make use of a nonlinear panel smooth transition vector error correction model to study the relationship between energy consumption and growth. The other two studies by Omay and Kan [20] and Apergis and Payne [7] have looked at aggregate energy and aggregate renewable energy respectively. However, none of the studies dealing with hydroelectricity (as will be seen from the literature review below), have used nonlinear panel smooth transition vector error correction model. While aggregate energy analyses are helpful, but these studies cannot be necessarily used for energy sector-specific analysis, since policy recommendations for aggregate energy could possibly not hold for a specific-type of energy in question, which in our case is hydroelectricity. The importance of hydroelectricity on the growth process via agricultural output has already been discussed above, and given that we show nonlinearity and structural breaks in the relationship exists between the two variables (growth and hydroelectricity in the empirical segment), makes our analysis even more important, since using linear frameworks (as utilised in the hydroelectricity literature) are likely to provide incorrect results and policy conclusions due to model-misspecification.

The remainder of the paper is organised as follows: the next section gives the testable hypotheses in the energy consumption-economic growth relationship and an overview of the empirical literature on the nexus between renewable and non-renewable energy consumption and economic growth. Section 3 outlines the data employed in this study. Section 4 outlines the empirical analysis and the obtained results. The econometric methodologies which are employed in this study are also discussed in the same section. Section 5 presents the panel Granger causality test results. Finally, Section 6 provides concluding remarks.

2. Energy consumption – growth hypotheses and literature overview

The relationship between energy consumption and economic growth can be classified into four testable hypotheses: growth, conservation, feedback, and neutrality [2]. The growth hypothesis suggests that energy consumption contributes to economic growth, both directly and indirectly, as a complement to other inputs in the production process. Support for this hypothesis requires unidirectional causality from energy consumption to income. The conservation hypothesis states that energy conservation policies that curtail energy consumption would not adversely affect real income. Unidirectional causality running from income to energy consumption provides support for this hypothesis. The feedback hypothesis argues that energy consumption and income are interdependent and complimentary to each other. Support for this hypothesis requires the presence of bi-directional causality between the two variables under consideration. Finally, the neutrality hypothesis implies that energy consumption has a minor role in the determination of real income [22]. This hypothesis is supported in the case where there is no Granger-causality between energy consumption and economic growth.

Numerous studies have examined the causal dynamics between renewable energy consumption and economic growth. Empirical evidence has been rather mixed [22]. Unlike most studies, Ohlers and Fetters [19] examine the causal relationship between renewable electricity generation and economic growth. One of the earliest studies to assess the causal relationship between hydroelectricity consumption and economic growth has been that by Abakah [1]. The author assesses the relationship between economic growth and three sources of energy-charcoal, petroleum and hydroelectricity in Ghana over the period 1976–1990. The results indicate a significant negative correlation for charcoal and positive correlation with respect to the consumption of hydroelectricity and petroleum.

Apergis and Payne [2] examine the causal relationship between renewable energy consumption and economic growth for thirteen countries within Eurasia over the period 1992–2007. They use a multivariate panel data framework which includes such variables such as real gross domestic product (GDP), renewable energy consumption, real gross fixed capital formation and labour force. Their panel cointegration test reveals a long-run equilibrium relationship among these variables. They also find bidirectional causality between renewable energy consumption and economic growth in both the short- and the long-run. Thus, their results lend support for the feedback hypothesis in the panel of countries.

In another study on a panel of 20 OECD countries, Apergis and Payne [3] examine the relationship between renewable energy consumption and economic growth spanning the period 1985–2005. Capital and labour are included as control variables in the multivariate framework. They use the Im et al. [14] unit root test and they find that all variables to be integrated of order one. They also employ the heterogeneous panel cointegration test advanced by Pedroni [23,25] to examine the long-run relationship among the variables across the panel of countries. Their findings document a long-run equilibrium relationship, while their Granger causality test results indicate the presence of bidirectional causality between renewable energy consumption and economic growth.

Apergis, Payne, Menyah and Wolde-Rufael [4] examine the causal relationship between carbon emissions, nuclear energy consumption, renewable energy consumption and economic growth in a panel of 19 developed and developing countries over