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Electricity Consumption, Technological Innovation, Economic Growth and Energy Prices: Does Energy Export Dependency and Development Levels Matter?

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Abstract

Empirical evidences appear to substantiate the hypothesis that electricity consumption is casually linked to economic growth in both the short and the long run. Nevertheless, incorporating new variables on examining the traditional electricity-growth nexus is relatively underdeveloped. This study uses annual data from 1974 to 2011 to examine the long-term and short-term relationship among electricity consumption, economic growth, energy prices and technological innovation for Canada, Ecuador, Norway and South Africa. These countries were selected on the basis of energy export dependency and development level. Based on the results derived from the methodology of ARDL and VECM, they suggest that developing economies should not simply reduce their consumption on fossil fuel powered electricity. Although technological innovation does not significantly influence the long-term variation in fossil fuel powered electricity, it is bilaterally tied with economic growth for all countries. This result indicates the applicability of the endogenous growth theory on the electricity-growth nexus.

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1. Introduction

There is growing concern over fuel scarcity, which has attracted discussion over the economic necessity of applying electricity conservation policies on different countries. Although new results of the electricity-growth nexus have continued to emerge, there is a lack of consensus on the supplementary determinants of this relationship (Ozturk, 2010). According to Narayan and Prasad (2008), two-thirds of available studies published in *Energy Policy* and *Energy Economics* find that electricity consumption Granger causes economic growth in both developed and developing countries suggesting that the implementation of electricity conservation policies will slow down economic growth. This is because most countries are economically dependent on electricity-intensive industries, such as information technology and manufacturing (Murry and Nan, 1996; Wolde-Rufael, 2006; Chen *et al.*, 2007; Narayan and Prasad, 2008).

This study seeks to provide three main contributions to the energy literature. Firstly, it incorporates the effect of technological innovation on the electricity-growth nexus using four countries drawn on the basis of economic development and energy exporting dependency. Given the global focus on averting the tragedy of commons and global warming issues, technological innovation can be viewed as a driver of

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long-term growth (Solow, 1956, Romer, 1990) and energy-saving technologies (Tang and Tan, 2013). The developed countries comprise Canada and Norway and the developing countries comprise Ecuador and South Africa. The selection of countries only focuses within the list of net energy exporting countries since the level of energy-exporting dependence may have a strong impact to influence the electricity-growth nexus. Canada and South Africa show relatively low reliance on energy exporting activities to support economic growth compared to Norway and Ecuador. Hence, Canada and South Africa are categorized as low energy-export dependent countries, while Ecuador and Norway are classified as high energy-export dependent countries. Secondly, this paper deploys the Granger causality test to evaluate the electricity-growth nexus for four the four countries using a matrix that differentiates these countries by the degree of economic development and energy-export dependency. Instead of using total electricity consumption, this paper employs fossil fuel powered electricity consumption to investigate the necessity of using fossil fuel powered electricity.

2. Methodology

This paper employs annual data of Canada, Ecuador, Norway and South Africa over the period from 1974 to 2010. The multivariate model contains the variables of per capita fossil fuel powered electricity consumption (EC), per capita real GDP (GDP), the relative price of fossil fuel to non-energy goods (EP) and the number of patenting activities (TI). All secondary data were extracted from World Bank (2013). Following the suggestions by Schmoch (2007) and Popp (2005), this paper measures the degree of technological innovation by the number of patents filed by a country. This is because patents are the codified form of technology and an increase in patents would imply the interest of industries and private organizations in exploiting new technologies (Popp, 2001; Ang, 2010; Tang and Tan, 2013).

This paper adapts the model specification from Tang and Tan (2013) but with two modifications. We replace the indirect measure of energy prices (CPI) with relative price of fossil fuel to non-energy goods, while substituting total electricity consumption with fossil fuel powered electricity consumption. The relationship between electricity consumption, and energy prices, economic growth and technological innovation is expressed as follows:

$$EC_t = \alpha + \beta_1 GDP_t + \beta_2 EP_t + \beta_3 TI_t + \varepsilon_t \qquad (1)$$

where EC_t is per capita fossil fuel powered electricity consumption; GDP_t is per capita real GDP; EP_t is the relative price of fossil fuel to non-energy goods; TI_t is the proxy of technological innovation; ε is an error term.

To ensure the robustness of the model, three unit root tests have been employed to examine the integration order of the variables. These unit root tests include Augmented Dickey Fuller, KPSS and Zivot-Andrew tests. Payne (2010) noted that variables in the electricity-growth nexus are occasionally mixed in integration orders, mostly *I*(0)/*I*(1). Hence, this paper applies the autoregressive distributed lag model (Pesaran *et al.*, 2001) to investigate the presence of a long run relationship between electricity consumption, and economic growth, energy prices and technological innovation. Lag order selection follows the Akaike Information Criterion for the purpose of minimizing autocorrelation and heteroscedasticity problems (Liew, 2004). The autoregressive distributed lag (ARDL) model is specified below:

$$\Delta lnCE_t = \lambda_o + \gamma_1\, lnCE_{t-1} + \gamma_2\, lnGDP_{t-1} + \gamma_3\, lnCo2_{t-1} + \gamma_4\, lnTI_{t-1} + \sum_{i=1}^{p} \zeta_1\, \Delta lnCE_{t-i} + \sum_{i=0}^{q} \zeta_2\, \Delta lnGDP_{t-i} + \sum_{i=0}^{r} \zeta_3\, \Delta lnCo2_{t-i} + \sum_{i=0}^{s} \zeta_4\, \Delta lnTI_{t-i} + \varepsilon_t \qquad (2)$$

where Δ is a first difference operator and *ln* is a logarithmic function. ε_t denotes regression residuals, which follow the assumptions of homoscedasticity and normal distribution. *p, q, r* and *s* are the optimal lag for each variable in the ARDL model. This paper follows the critical bounds as suggested by Narayan (2005) to examine the cointegration properties among the variables. If the set of variables is cointegrated, the Granger causality test will be performed using the vector error correction model (VECM).

3. Findings

The results of the Augmented Dickey Fuller and Phillips Perron unit roots tests consistently reveal that the first differences of all variables (including electricity consumption) are stationary*. Further, by incorporating a structural break into the unit root tests, the results of the Zivot-Andrews test indicate that all variables are not purely integrated at *I*(1), traditional cointegration tests may be less useful to investigate the cointegration properties among the variables. The results are consistent with the claim that although most macroeconomic variables are stationary when first differenced, some could also be stationary at Levels (Perron, 1989). Besides, the small sample size used might yield less consistent results utilizing traditional cointegration tests. Thus, this paper adopts the ARDL test to investigate the presence of a long run equilibrium relationship between the variables.

Table 1: *F*-statistics for investigating the existence of long run equilibrium among the variables

Fec(EC I GDP EP PT)	Optimal lag	F-stat	Norm	Hete	ARCH	Func
Ecuador	5,5,6,6	4.2435*	0.6218	1.3243	1.3243	0.7848
South Africa	3,4,1,5	4.4924*	0.547	0.945	0.4029	0.6622
Canada	6,4,5,4	6.0957**	0.7723	0.0831	1.4873	0.5065
Norway	6,4,2,0	4.8665**	1.6797	1.3377	0.2888	0.0011

***, ** and * denote significance at 1%, 5% and 10% level, respectively. The critical values for bounds are abstracted from Narayan (2005), Case 3: unrestricted constant and no trend. Diagnostic test is presented as F stat.

The results of Equation (2) suggest that energy prices, economic growth and technological innovation are associated with fossil fuel powered electricity consumption in the long run for Ecuador, South Africa, Canada and Norway. The model specification for Ecuador and South Africa, i.e. F_{ec}(EC I GDP EP PT), is significant at the 10% significance level, while the same model specification for Norway and Canada is significant at the 5% significance level. The results of the diagnostic checking substantiate that the model specification is correct that the presence of cointegration is observable in all the examined countries (Perman, 1991). Hence, the null hypothesis of no cointegration can be rejected.

Table 2 – Results of long-term coefficient

	Constant	GDP	EP	TI
Ecuador	-21.317*	4.4607*	-1.1664*	-0.5511
South African	7.9526***	0.1542*	-0.0847*	-0.0493
Canada	3.4576***	0.3429***	-0.2614***	-0.2368
Norway	-27.973**	3.6179*	0.7247*	-0.1916

***, ** and * denote significance at 0.01, 0.05 and 0.10 levels respectively.

Dependent variable = EC

Since all the variables are cointegrated, an estimation of the long-term coefficients from the ARDL model can be carried out observe the long-term behaviour of the determinants of EC. Table 2 summarizes the results of the long-term coefficients of fossil fuel powered EC using the ARDL model.

Two unique trends are evident from the results. Firstly, the proxy of technological innovation does not significantly explain the variation in fossil fuel powered EC in the long run. Although technological innovation may have raised the efficiency of total EC as suggested by Tang and Tan (2013), it does not show any relationship with fossil fuel powered EC. One of the plausible explanations is that there could be a progressive shift from the use of fossil fuel to alternative energy in EC (Sagar and Holdren, 2002; Wonglimpiyarat, 2010). Secondly, energy-export dependent countries show a strong association between EC and GDP per capita, which is because energy-export dependent countries are not subjected to volatile fluctuations in energy supply generally. This crucial characteristic distinguishes a net energy-export dependent country from energy-importing countries in the electricity-growth nexus (Mehrara, 2007). Also, market prices significantly explain economic growth in Ecuador, South Africa and Canada as increases in fossil fuel prices lower fossil fuel powered EC in the long run (see also Tang and Tan, 2013; Tang *et al.*, 2013). Over the period of 1974-2011, the average fossil fuel powered EC in total consumption of Ecuador, South Africa, Canada and Norway was 42.2%, 95.1%, 23.2% and 0.5%,

*To save space, the full length of the unit root tests is not included in this summary. The results will be provided upon requested.

respectively. The unusual price-demand association in Norway could be a consequence of very low fossil fuel powered EC in the Norwegian economy.

Apart from the congruence in results between the ARDL approach and the Granger causality test, four further observations can be deduced from the results.† Firstly, the bidirectional relationship between fossil fuel powered EC and economic growth is observed only in Ecuador and Norway, which are low energy-export dependent countries. Secondly, EC has a bidirectional relationship with energy prices in South Africa, Canada and Norway, which is consistent with the findings on Pakistan (Jamil and Ahmad, 2010), Malaysia (Bekhet and Othman, 2011) and Cyprus (Egelioglu *et al.*, 2001). Thirdly, technological innovation is bilaterally tied to economic growth in all countries, which supports endogenous growth theory. Lastly, all error correction terms of the model specification of $F_{ec}(EC \mid GDP\ EP\ PT)$ are significant at either 1% or 5% significance levels with negative signs. The results show that any past year disequilibrium stemming from temporary shocks will be resolved in the following years so that the long run equilibrium relationship is maintained.

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†To save space, the full account of the Granger causality test results have been excluded from this summary. The results shall be provided upon request.