Granger Causality between Electricity Consumption and Economic Growth in Oil-Dependent Countries

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Abstract

This paper examines the causal relationship between the Electricity consumption and the GDP in a panel of 11 selected oil exporting countries by using panel unit root tests and panel cointegration analysis. A three variable model is formulated with oil revenues as the third variable. The results show a strong unidirectional causality from oil revenues and economic growth to electricity consumption in the oil exporting countries. Yet, electricity use does not have any significant effects on GDP in short- and long-run. Thus, in the oil exporting countries, given the generous subsidies for energy, there is relatively more scope for more drastic energy conservation measures without severe impacts on economic growth. In other words, it seems improbable that the elimination of energy price distortions restrain the economic growth in these countries.

JEL classifications: Q43; C32; O55

Keywords: Electricity consumption, Real GDP, Granger Causality, Panel Cointegration

1. Introduction

Economic growth is among the most important predictors to be considered in predicting world electricity consumption. In this regard, the analysis of the relationship between electricity consumption and economic growth has attracted a great deal of interest during last years (e.g. Kraft and Kraft, 1978; Erol and Yu, 1987; Cheng and Lai, 1997; Yang, 2000; Stern, 2000; Adjaye, 2000; Oh and Lee, 2004; Yoo, 2006; Lee, 2007; Chen et al. 2007; Narayan and Prasad, 2008; Chandran et al. 2009; Payne, 2010; Shahbaz et al. 2011; Shahbaz and Feridun, 2012). Indeed, whether the economic growth encourages electricity consumption or whether energy itself is a motivation for economic growth has triggered off interest among economists and policymakers.

The direction of causation between electricity consumption and economic growth has significant policy implications for oil dependent countries, enjoying implicit generous subsidies (low domestic prices) for energy. If, for example, there exists unidirectional Granger causality running from income to electricity consumption, it may be implied that electricity conservation policies such as phasing out energy subsidies or elimination of energy price distortions have little adverse or no effects on economic growth. On the other hand, if unidirectional causality runs from electricity consumption to income, reducing electricity consumption, for example through bringing domestic energy prices in line with market prices, could lead to a fall in income or employment.

In this study, we examine the causality issue between electricity use and income in a panel of 11 selected oil exporting countries by means of applying a dynamic panel framework allowing us to capture both inter-country and inter-temporal variation. In order to do this a three variable model is formulated comprising electricity consumption, GDP and oil revenues. Firstly, existence of a long-run relationship among these three variables is tested by using Pedroni (1995, 1999) panel cointegration approach. Panel Granger causality test is applied on the corresponding vector error correction model to examine short-run causal relationship between the variables. The paper is organized in four sections. Section 2 describes the data and the econometric methods of estimation and reports the
empirical results for cointegration and causality tests. Some concluding remarks are presented in the final section

2. Data and empirical results

We apply a three variable model to examine the causal relationship between electricity consumption and GDP with oil revenues included in model as conditioning variable along with these two variables. Data used in the analysis are annual time series during the period 1970-2010 on (logarithm of) per capita electricity consumption in KWH (denoted by EC), real GDP per capita (GDP) and real oil revenues per capita (OIL) in constant 2000 prices in local currency units for the 11 oil exporting countries including Iran, Kuwait, Saudi Arabia, United Arab Emirates, Bahrain, Oman, Algeria, Nigeria, Mexico, Venezuela and Ecuador. The data were obtained from World Development Indicators (WDI) 2011, published by the World Bank and OPEC Bulletins. The choice of the starting period was constrained by the availability of data.

To test the nature of association between the variables while avoiding any spurious correlation, the empirical investigation in this paper follows the three steps: We begin by testing for non-stationarity in the three variables of EC, GDP and OIL. Prompted by the existence of unit roots in the time series, we test for long run cointegrating relation between three variables at the second step of estimation using the panel cointegration technique developed by Pedroni (1995, 1999). Granted the long run relationship, we explore the causal link between the variables by testing for granger causality at the final step.

2.1. Panel Unit Roots Results

The panel data technique referred above has appealed to the researchers because of its weak restrictions. It captures country specific effects and allows for heterogeneity in the direction and magnitude of the parameters across the panel. In addition, it provides a great degree of flexibility in model selection. Following the methodology used in earlier works in the literature we test for trend stationarity the three variables of EC, GDP and OIL. With a null of non-stationary, the test is a residual based test that explores the performance of four different statistics. Together, these four statistics reflect a combination of the tests used by Levin-Lin (1993) and Im, Pesaran and Shin (1997). While the first two statistics are non-parametric rho-statistics, the last two are parametric ADF t-statistics. Sets of these four statistics have been reported in Table 1.

The first three rows report the panel unit root statistics for EC, GDP and OIL at the levels. As it can be inferred from this Table, we cannot reject the unit-root hypothesis when the variables are taken in levels and thus any causal inferences from the three series in levels are invalid. The last three rows report the panel unit root statistics for first differences of EC, GDP and OIL. The large negative values for the statistics indicate rejection of the null of non-stationary at 5% level for all variables. It may, therefore be concluded that the three variables of EC, GDP and OIL are unit root variables of order one, or, I (1) for short.

2.2. Panel Cointegration Results

At the second step of our estimation, we look for a long run relationship among EC, GDP and OIL using the panel cointegration technique developed by Pedroni (1995, 1999). This technique is a significant improvement over conventional cointegration tests applied on a single country series. While pooling data to determine the common long run relationship, it allows the cointegrating vectors to vary across the members of the panel. After including real OIL as an additional variable, the cointegration relationship we estimate is specified as follows:

\[ EC_{it} = \alpha_i + \delta_t + \beta_t GDP_{it} + \gamma_t OIL_{it} + \epsilon_{it} \] (1)
Where $\alpha_i$ refers to country effects and $\delta_i$ refers to trend effects. $\varepsilon_{it}$ is the estimated residual indicating deviations from the long run relationship. With a null of no cointegration, the panel cointegration test is essentially a test of unit roots in the estimated residuals of the panel. Pedroni (1999) refers to seven different statistics for this test. Of these seven statistics, the first four are known as panel cointegration statistics; the last three are group mean panel cointegration statistics. In the presence of a cointegrating relation, the residuals are expected to be stationary. These tests reject the null of no cointegration when they have large negative values except for the panel-v test which reject the null of cointegration when it has a large positive value. All of these seven statistics under different model specifications are reported in Table 2. The statistics for all different model specifications suggest rejection of the null of no cointegration for all tests. We, therefore, conclude that the three unit root variables EC, GDP and OIL are cointegrated in the long run.

2.3. Panel Causality Results

Cointegration implies that causality exists between the series but it does not indicate the direction of the causal relationship. With an affirmation of a long run relationship among EC, GDP and OIL, we test for Granger causality in the long run relationship at the third and final step of estimation. Granger causality itself is a two-step procedure. The first step relates to the estimation of the residual from the long run relationship. Incorporating the residual as a right hand side variable, the short run error correction model is estimated at the second step. Defining the error term from equation (1) to be $ECT_{it}$, the dynamic error correction model of our interest by focusing on electricity consumption (EC) and GDP is specified as follows:

\[
\begin{align*}
\Delta GDP_{it} &= \alpha_{yi} + \beta_{y2}ECT_{i, t-1} + \gamma_{y1i} \Delta EC_{i, t-1} + \gamma_{y2i} \Delta OIL_{i, t-1} + \gamma_{y3i} \Delta OIL_{i, t-2} + \varepsilon_{yt}, \\
\Delta EC_{it} &= \alpha_{hi} + \beta_{h2}ECT_{i, t-1} + \gamma_{h1i} \Delta EC_{i, t-1} + \gamma_{h2i} \Delta OIL_{i, t-1} + \gamma_{h3i} \Delta OIL_{i, t-2} + \varepsilon_{et},
\end{align*}
\]

Where $\Delta$ is a difference operator; $ECT$ is the lagged error-correction term derived from the long-run cointegrating relationship; the $\beta_{yi}$ and $\beta_{hi}$ are adjustment coefficients and the $\varepsilon_{yt}$ and $\varepsilon_{et}$ are disturbance terms assumed to be uncorrelated with mean zero.

Sources of causation can be identified by testing for significance of the coefficients on the lagged variables in Eqs (2) and (3). First, by testing $H_0 : \gamma_{y1i} = \gamma_{y2i} = 0$ for all $i$ in Eq. (2) or $H_0 : \gamma_{h1i} = \gamma_{h2i} = 0$ for all $i$ in Eq. (3), we evaluate Granger weak causality. Masih and Masih (1996) and Asafu-Adjaye (2000) interpreted the weak Granger causality as ‘short run’ causality in the sense that the dependent variable responds only to short-term shocks to the stochastic environment.

Another possible source of causation is the ECT in Eqs. (2) and (3). In other words, through the ECT, an error correction model offers an alternative test of causality (or weak exogeneity of the dependent variable). The coefficients on the ECTs represent how fast deviations from the long run equilibrium are eliminated following changes in each variable. If, for example, $\beta_{yi}$ is zero, then GDP does not respond to a deviation from the long run equilibrium in the previous period. Indeed
\( \beta_{yi} = 0 \) or \( \beta_{ei} = 0 \) for all \( i \) is equivalent to both the Granger non-causality in the long run and the weak exogeneity (Hatanaka, 1996).

It is also desirable to check whether the two sources of causation are jointly significant, in order to test Granger causality. This can be done by testing the joint hypotheses \( H_0 : \beta_{yi} = 0 \) and \( \gamma_{yi} = \gamma_{y2i} = 0 \) for all \( i \) in Eq. (2) or \( H_0 : \beta_{ei} = 0 \) and \( \delta_{yi} = \delta_{y2i} = 0 \) for all \( i \) in Eq. (3). This is referred to as a strong Granger causality test. The joint test indicates which variable(s) bear the burden of short run adjustment to re-establish long run equilibrium, following a shock to the system (Asafu-Adjaye, 2000).

The results of the F test for both long run and short run causality are reported in Table 3. As is apparent from the Table, the coefficients of the ECT, GDP and OIL are significant in the electricity equation which indicates that long-run and short-run causality run from GDP and OIL to electricity consumption. So, GDP and OIL strongly Granger-causes electricity use. OIL does Granger cause GDP at short run at 5% level, without any significant effect on output in long run. Weak exogeneity of GDP indicate that this variable does not adjust towards long-run equilibrium.

Moreover, the interaction terms in the electricity equation are significant at 1% level. These results imply that, there is Granger causality running from GDP and Oil to electricity use in the long-run and short run, while electricity have a neutral effect on GDP in both the short- and long-run. In other words, GDP is strongly exogenous and whenever a shock occurs in the system, electricity would make short-run adjustments to restore long-run equilibrium.

### 3. Conclusion

The purpose of this study was to test for Granger causality between electricity consumption and income for 11 oil-dependent developing countries over the period 1970-2010. Real oil revenues are also included in the model along with these two variables. The panel integration and cointegration techniques are applied to investigate the relationship between the three economic series: electricity consumption, output and oil revenues.

These eleven countries are heavily dependent on oil revenues and enjoying implicit generous subsidies for energy. To avoid lower rates of growth or stagnation in the non-oil sectors these countries make high demands on energy resources with cheap domestic energy particularly in times of high world energy prices. Utilizing Granger Causality within the framework of a panel cointegration model, our findings suggest that there is strong causality running from GDP and oil revenues to electricity use with no feedback effects from electricity to GDP for oil dependent countries. Moreover, oil revenues have significant effects on GDP just in short run. So it is the oil and GDP that drives the electricity, not vice versa. The findings have practical policy implications for decision makers in the area of macroeconomic planning, as energy conservation is a feasible policy with no damaging repercussions on economic growth for this group of countries.

### Acknowledgements

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### References


Table 1: Test of Unit Roots for EC, GDP and OIL

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<tr>
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***significant at 1%
** significant at 5%

Table 2: Results of Panel Cointegration test

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Panel v-stat</th>
<th>Rho-stat</th>
<th>PP-stat</th>
<th>ADF-stat</th>
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<td>Group ADF-stat</td>
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***significant at 1%
** significant at 5%

Table 3: Result of Panel causality tests

<table>
<thead>
<tr>
<th>Source of causation(independent variable)</th>
<th>Short-run</th>
<th>Long-run</th>
<th>Joint (short-run/long-run)</th>
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<td>ΔGDP</td>
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<td>F=4.51***</td>
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<td>F=5.01***</td>
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***significant at 1%
** significant at 5%