Testing Causality between ‘Electricity Consumption and GDP’ and ‘Petroleum Consumption and GDP’: Evidence from a Systematic Study of over 100 Countries

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Abstract

Energy consumption is seen as playing a vital role in economic development. In particular, it is often assumed that energy consumption causes economic growth. Several studies using a number of data sets and data periods, different methodologies and countries (either individually or in small groups) have been undertaken. No clear consensus about the evidence and the direction of causality emerges from these studies. Given the global environmental problems, it is essential that there is some understanding of the causal effects of energy consumption on development. In particular, if it is found that this effect is greater in the developing world, then any policy to reduce energy consumption (and hence emissions) would have a disproportionate effect on their development.

This paper, therefore, attempts for the first time (as far as is known) to systematically test for the existence and direction of causality between 1) electricity consumption and GDP; and 2) petroleum consumption and GDP. A consistent data set derived from the same source for 26 OECD and 78 non-OECD countries is used with a consistent methodology: VAR Johansen Cointegration coupled with the Hsiao Granger Causality technique.

It is found that causality from ‘petroleum to GDP’ and from ‘GDP to petroleum’ is more prevalent in the OECD/Developed countries compared to the non-OECD/Developing countries. This is not, however, the case for electricity. The results show that causality from ‘Electricity to GDP’ is similar for both groups whereas causality from ‘GDP to Electricity’ is more prevalent in the non-OECD/Developing countries (particular in mid-developed countries) compared with OECD/Developed countries.

Key Words: Energy; Electricity; Petroleum; GDP; Development; Causality; Modelling.
1. Introduction

Energy plays an essential role in an economy on both the demand side and the supply side. For demand, energy is one of the products a consumer decides to buy to maximize his or her utility. For supply, energy is a factor of production in addition to capital, labour, and materials. Within this energy is seen to play a vital role in the economic and social development of countries, a key factor increasing economic growth, and living standards. This implicitly assumes that there is a causal relationship between energy consumption and national income or GDP.

Many studies have attempted to test this assumption empirically. The results from these studies are summarized in Table 1. This shows that the causality from energy to GDP and GDP to energy is considered. On the demand side, causality from GDP to energy is an important consideration. However, on the supply side the causality from energy to GDP is an important issue for economic development since as recognized in many of the previous studies, if energy causes GDP then a policy of energy conservation will have detrimental effects on growth. Whereas if energy does not cause GDP, as Masih and Masih (1996) state, “energy conservation policies may be initiated without deteriorating economic side effects” (p. 166). It is important, therefore, to ascertain empirically whether there is a causal link from energy consumption to economic growth, in particular for developing countries.

Therefore the existence (or otherwise) of proof of causality between energy and GDP (as Table 1 illustrates) has been the subject of some investigation and debate by economists and econometricians. For example, if there is evidence that energy causes GDP then it has important implications for policy makers. In particular, in the area of global warming and the need to conserve energy since any constraints put on energy consumption to help reduce emissions, will have an effect on growth and development if causality exists. Moreover, if the link is greater for developing countries then any restraint on energy consumption will have a bigger effect on these countries compared to the more affluent industrialized countries. Therefore, it could be argued that any reduction in energy consumption should predominantly be undertaken by the developed world so as not to inhibit the development of the less developed nations.

In a previous paper, Chontanawat, et al (2004) attempted to analyze this issue by using a systematic and consistent methodology to test whether there is any evidence of causality from energy to GDP for 30 OECD countries and 78 non-OECD countries. This showed, contrary to prior expectations, that a greater proportion of OECD/Developed countries experienced causality both from energy to GDP and from GDP to energy than the Non-OECD/Developing countries. In order to further investigate this issue and in order to check the robustness of the previous results, this study disaggregates energy consumption into electricity and petroleum consumption and tests for the existence of causality between these energy types with GDP by using the same technique and countries and a similar data set. As in the previous study, the a-priori expectation is that the evidence of the link is strongest for the non-OECD developing countries. The next section therefore outlines the methodology used, followed by section 3 that presents the results. The final section summarizes and concludes.

2. Methodology

Table 1 shows there have been a number of studies investigating energy-GDP causality, all based upon the ‘Granger Causality’ principle (Granger, 1969). These studies have generally considered a single country or at most a small group of countries. Moreover, although Granger Causality is the key definition adopted, there have been a range of methodologies employed; partly explained by the development of new econometric techniques. Considering the different methodologies the studies may be categorized into three main groups:
The first use the conventional methodologies developed by Granger (1969) and Sims (1972), the majority being undertaken in the USA for developed countries covering the period 1947 to 1988.

The second use cointegration and the Error Correction Model (ECM) (Granger 1988); with several separate studies undertaken for a number of developed and some developing countries covering the period 1950 to 2002.

The third use the Hsiao (1981) technique that enhances Granger Causality by incorporating the use of the Akaike (1969) Final Prediction Error (FPE) criteria; with studies for the USA, Latin America and several Asian Countries covering the period 1947 to 2000.

Consequently, given the single country approach, the different methodologies and the different data sets and periods, no clear picture emerges without any clear direction for policy makers. This paper attempts to rectify this by using a consistent approach and data source for over 100 countries.

‘Granger Causality’ implies causality in the prediction (forecast) sense rather than in a structural sense. It starts with the premise that ‘the future cannot cause the past’; if event A occurs after event B, then A cannot cause B (Granger 1969). Therefore, for a bivariate model this gives the following two equations:

\[ y_t = \alpha_1 + \sum_{i=1}^{m} \beta_y y_{t-i} + \sum_{j=1}^{n} \lambda_j e_{t-j} + \upsilon_t \]  
(1)

and

\[ e_t = \alpha_2 + \sum_{i=1}^{m} \gamma_y e_{t-i} + \sum_{j=1}^{n} \delta_j y_{t-j} + \epsilon_t \]
(2)

Where: 
\[ e_t = \ln(E_t); \]
\[ y_t = \ln(Y_t); \]
\[ E_t = \text{electricity consumption per capita or petroleum consumption per capita}; \]
\[ Y_t = \text{real GDP per capita}. \]

From equation (1) ‘e is causing y if the current value of y is predicted better by using the past value of e than by not doing so’. In other words, if e causes y, then e helps to forecast y. And from equation (2) ‘y is causing e if the current value of e is predicted better by using the past value of y than by not doing so”. In other words, if y causes e, then y helps to forecast e.

This initial formulation by Granger used levels of variables as shown in equations (1) and (2). However, following the development of unit root testing and cointegration, for non-stationary integrated of order one [I(1)] variables, equation (1) and (2) are replaced by:

\[ \Delta y_t = \alpha_1 + \sum_{i=1}^{m} \beta_y \Delta y_{t-i} + \sum_{j=1}^{n} \lambda_j \Delta e_{t-j} + \upsilon_t \]  
(3)

and

\[ \Delta e_t = \alpha_2 + \sum_{i=1}^{m} \gamma_y \Delta e_{t-i} + \sum_{j=1}^{n} \delta_j \Delta y_{t-j} + \epsilon_t \]  
(4)

Where \( \Delta \) is the first difference operator, so that the terms are introduced in differences to ensure they are stationary or I(0). Here the presence of Granger causality depends on the significance of the \( \Delta e_{t-j} \) terms and \( \Delta y_{t-j} \) terms in equations (3) and (4) respectively.

Furthermore, if it is found that the two variables co-integrate then equations (3) and (4) can be augmented as follows:
\[ \Delta y_t = \alpha_1 + \sigma_1 EC_{t-1} + \sum_{i=1}^{m} \beta_i \Delta y_{t-i} + \sum_{j=1}^{n} \lambda_j \Delta e_{t-j} + \nu_t \]  

(5)

and

\[ \Delta e_t = \alpha_2 + \sigma_2 EC_{t-1} + \sum_{j=1}^{n} \gamma_j \Delta e_{t-j} + \sum_{j=1}^{n} \delta_j \Delta y_{t-j} + \epsilon_t \]  

(6)

where \( EC \) is the error correction term from the cointegrating equation and hence \( I(0) \). In this formulation there are two possible sources of causation: for the \( \Delta y \) equation it is either from the lagged \( \Delta e \) terms if \( \lambda_j \neq 0 \) or through the \( EC_{t-1} \) term, if \( \sigma_1 \neq 0 \) (implying a long run relationship); and for the \( \Delta e \) equation it is either from the lagged \( \Delta y \) terms if \( \delta_j \neq 0 \) or through the \( EC_{t-1} \) term, if \( \sigma_2 \neq 0 \). In essence, if a pair of \( I(1) \) series are co-integrated, there must be causation in at least one direction so it is necessary to add the EC term in the model otherwise the model will miss one source of causation and the model will be miss-specified and the possible values of lagged \( \Delta e \) (\( \Delta y \)) in forecasting \( \Delta y \) (\( \Delta e \)) will be missed.

Whichever formulation is used, past studies have shown that the result of causality is very sensitive to the lag length adopted in the models. However, Hsiao (1981) introduced a way to help determine the optimum lags to be used, combining the Granger (1969) definition of causality as outlined above and Akaike’s FPE criterion.

According to Akaike (1969a), the FPE is defined as the expected variance of the prediction error (asymptotic mean square of the prediction error) as follows:

\[
\text{FPE}_{y_i} = E(\hat{y}_i - y_i)^2 = \sigma_u^2 \left( 1 + \frac{m + n + 1}{T} \right)^2, \quad \sigma_u^2 = \frac{SSE(m,n)}{T - m - n - 1} \]  

(7)

Thus Akaike defines the estimate of \( \text{FPE}(m,n) \) by

\[
\text{FPE}(m,n) = \frac{T + m + n + 1}{T - m - n - 1} \frac{SSE(m,n)}{T} \]  

(8)

FPE is minimized in order to choose the number of lags, which is equivalent to applying an approximate (F-test) with varying significance levels. Hsiao (1981, 1982) points out that the major difference between applying Akaike’s FPE criterion and the conventional hypothesis testing procedure to decide if a variable should be included in the equation is in the choice of significance level. The conventional choice of a 5% or 1% significance level is ad hoc whilst the FPE criterion is based on an explicit optimality criterion (that of minimizing the mean square prediction error). Consequently, the FPE frees the model from the ambiguities inherent in the application of conventional procedures.

Akaike (1969a, 1969b) also suggests that a decision procedure about the order of a univariate stationary autoregressive process and/or on the inclusion or exclusion of a variable in the model based on the minimum FPE criterion is appealing. This is because it balances the risk due to bias when a lower order is selected and the risk due to an increase in the bias when a higher order is selected. In other words, the minimum FPE can provide the optimum number of lags for the model, since too many lags or too few lags may lead to bias estimates and hence misleading results.

Therefore Hsiao’s procedure requires two steps. To test whether \( e \) causes \( y \), a one-dimensional autoregressive process is first estimated as follows:

\[
\Delta y_t = \alpha_1 + \sum_{i=1}^{m} \beta_i \Delta y_{t-i} + \nu_t \]  

(9)
with varying values for m. The following is then computed for each of the regressions (1 to m):

$$FPE(m) = \frac{T + m + 1}{T + m - 1} \frac{SSE}{T}$$

(10)

Where T is sample size, SSE is sum of squared errors, and FPE is the final prediction error. The minimum value of FPE(m) determines the optimal lag length denoted by m*.

The second involves estimating the following:

$$\Delta y_t = \alpha_1 + \sum_{i=1}^{m^*} \beta_i \Delta y_{t-i} + \sum_{j=1}^{n^*} \lambda_j \Delta e_{t-j} + \nu_t$$

(11)

for various values for j, the lags on Δe, conditional on lag length m* for Δy. The following is then computed for each of the regressions (1 to n):

$$FPE(m^*, n) = \frac{T + m^* + n + 1}{T - m^* - n - 1} \frac{SSE(m^*, n)}{T}$$

(12)

The minimum value of FPE(m*, n) determines the optimal lag length denoted by n*. If FPE(m*, n*) < FPE(m*) then e (Granger) causes y. Whereas if FPE(m*, n*) > FPE(m*) then e does not (Granger) cause y.

The above explains the Hsiao method where no cointegration is found and therefore applied in the standard Granger methodology, equations (3) and (4). However, this equally applies when the EC term is included for a cointegrating relationship as in equations (5) and (6). That is, to test whether e causes y in this framework the EC term is also added at the second stage, equation (11) as follows:

$$\Delta y_t = \alpha_1 + \sigma_1 EC_{t-1} + \sum_{i=1}^{m^*} \beta_i \Delta y_{t-i} + \sum_{j=1}^{n} \lambda_j \Delta e_{t-j} + \nu_t$$

(13)

with similar decision criteria as given above.4,5

These tests determine whether e causes y. These can be confirmed by using a number of statistical tests. When using the standard Granger model (both in levels equation (1) and in differences equation (3)) causality can be confirmed by doing a joint F-test for the coefficients of the lagged e(Δe) variables. For the EC model, where causality comes from two sources, the EC term and the lagged Δe variables, causality can be confirmed by undertaking a joint F-test of the EC coefficient and the lagged Δe coefficients.6

Given the above, the methodology adopted for this paper is outlined in Figure 1.

This therefore involves the following stages:

**Stage 1**: Test the stationarity of the variables for each country using the Augmented Dickey Fuller (ADF) test.7 If both e and y are I(1) then proceed to Stage 2. If one or both are not I(1) proceed to Stage 3a.

**Stage 2**: Test for cointegration between e and y using the Johansen technique.8 If cointegration is not found proceed to Stage 3a. If cointegration is found, proceed to Stage 3b.

**Stage 3a**: Test for causality from e to y using the Hsiao (Granger coupled with FPE) procedure (i.e. estimate equation (11) and test accordingly).

**Stage 3b**: A long run relationship exists so there must be causality for at least one direction. Therefore test if it is from e to y using the Hsiao method for determining the order of lags for the EC equation (13) and test accordingly.9,10
Data
In order to ensure consistency, data for all countries comes from the same source the International Energy Agency (IEA) 2002 Energy Statistics for OECD and Non-OECD countries. For each country E is Electricity/Petroleum Consumption in thousand tones of oil equivalent (ktoe) divided by population and Y is real GDP in US dollars using Purchasing Power Parities (PPPs) divided by population. This gives a total of 26 OECD countries with data from 1960 to 2000 and 78 non-OECD countries with data from 1971 to 2000. In addition the Human Development Index (HDI) for 2001 has been used to rank the countries into 41 high-development countries, 44 medium-development countries, and 16 low-development countries.

3. Results

Given the vast amount of estimation undertaken, only a summary of the results are given here.

3.1 Causality between Electricity Consumption and GDP

Stage 1
When undertaking the testing procedure outlined in Figure 1 there are four possible conclusions for the direction of causality. Either type i) E causes Y; type ii) Y causes E; type
iii) E causes Y; and Y causes E; or type iv) no causality. Types i) and ii) represent uni-directional (i.e. one way without feedback) and type iii) represents bi-directional causality (i.e. both ways with feedback). The results from testing for stationery show that for the total 26 OECD countries, Electricity and GDP are generally found to be I(1) for 21 countries or 81% of the total. For the 78 Non-OECD countries, Electricity and GDP are both found to be I(1) for about 64 countries or 82% of the total.

Stage 2
The results for testing for cointegration show that for the OECD countries, cointegration is found for 12 countries or 46% whereas for non-OECD countries, cointegration is found for only 15 countries or 19%.

Stage 3
Figure 2a summarizes the overall results where causality exits of at least one type (i, ii or iii). Some 18 OECD countries (69% of the total) found evidence of some causality (one way or both ways). For non-OECD countries, some causality is found for 58 countries (74%). This gives 76 countries (73%) overall. According to the HDI classification, illustrated in Figure 2b, some causality is found for 28 countries (68%), 34 countries (77%), and 12 countries (75%) in high development group, medium development group, and low development group respectively.

Figure 2a: Evidence of Causality between Electricity Consumption and GDP in OECD and Non-OECD Countries

Figure 2b: Evidence of Causality between Electricity Consumption and GDP in High-, Mid-,and Low-Development Countries
The Direction of causality

Electricity causes GDP:

The proportion of countries in the OECD and Non-OECD where it is found that Electricity consumption causes GDP is illustrated in Figure 3a. The ratio is not much different between the two groups. This shows, that 11 OECD countries from 26 (42%) and 32 non-OECD countries from 78 (41%) show evidence of causality from Electricity to GDP. According to the HDI classification, shown in Figure 3b, gives a clearer picture; 18 high-development countries out of 41 (44%) show evidence of Electricity to GDP causality, whereas only 18 mid-development countries out of 44 (41%) and 5 low-development countries out of 16 (31%) show Electricity to GDP causality.

GDP causes Electricity:

The proportion of countries in the OECD and Non-OECD where it is found that GDP causes Electricity consumption is illustrated in Figure 4a. This shows the surprising results that 10 OECD countries from 26 (38%) show evidence of causality from GDP to Electricity whereas, somewhat surprisingly, 42 non-OECD countries from 78 (54%) show similar causality. The proportions from the rankings according to the HDI are shown in Figure 4b. The results are consistent; 16 high-development countries out of 41 (39%) show evidence of GDP to Electricity causality, whereas 26 mid-development countries out of 44 (59%) and 9 low-development countries out of 16 (56%) show GDP to Electricity causality. However, the mid-development group yields the biggest portion.
3.2 Causality between Petroleum Consumption and GDP

Stage 1
The results from testing for stationery show that for the 26 OECD countries Petroleum and GDP are generally found to be I(1) for 19 countries or 73% of the total. For the 78 Non-OECD countries E and Y are both found to be I(1) for 61 cases or 78% of the total.

Stage 2
The results for testing for cointegration show that for the OECD, cointegration is found for 12 countries or 46% whereas for non-OECD, cointegration is found for only 15 countries or 19%.

Stage 3
Figure 5a summarizes the overall results where causality exits of at least one type (i, ii or iii). Some 20 OECD countries (77% of the total) found evidence of some causality (one way or both ways). For non-OECD countries, some causality is found for 49 countries (63%). This gives 69 countries (66%) overall. According to the HDI classification which is illustrated in Figure 5b, some causality is found for 30 countries (73% of the total), 28 countries (64%), and 9 countries (56%) in high development group, medium development group, and low development group respectively.

Figure 5a: Evidence of Causality between Petroleum consumption and GDP in OECD and Non-OECD Countries

Figure 5b: Evidence of Causality between Petroleum Consumption and GDP in High-, Mid-, and Low-Development Countries
Direction of Causality

**Petroleum causes GDP:**
The proportion of countries in the OECD and Non-OECD where it is found that Petroleum consumption causes GDP is illustrated in Figure 6a. This shows, that 17 OECD countries from 26 (65%) show evidence of causality from Petroleum to GDP whereas, 34 non-OECD countries from 78 (44%) show this evidence. The proportions from the rankings according to the HDI are shown in Figure 6b. This confirms the previous figures; 24 high-development countries out of 41 (59%) show evidence of petroleum consumption to GDP causality, whereas only 20 mid-development countries out of 44 (45%) and 5 low-development countries out of 16 (31%) show Petroleum to GDP causality.

**Causality from GDP to Petroleum:**
The proportion of countries in the OECD and Non-OECD where it is found that GDP causes petroleum consumption is illustrated in Figure 7a. This shows, that 12 OECD countries from 26 (46%) and 27 non-OECD countries from 78 (35%) show evidence of causality from GDP to Petroleum. The HDI rankings are shown in Figure 7b; 16 high-development countries out of 41 (39%) show evidence of GDP to Petroleum causality, whereas 16 mid-development countries out of 44 (36%) and 6 low-development countries out of 16 (38%) show GDP to Petroleum causality. However, the causal link in low-development countries is a little higher than that of the mid-development countries. This implies that the evidence of GDP Granger causing Petroleum consumption is most prevalent in high-development countries followed by low-development countries and mid-development countries respectively.

![Figure 6a: Causality from Petroleum to GDP for OECD / non-OECD Countries](image1)

![Figure 6b: Causality from Petroleum to GDP for High-, Mid-, Low-Dev. Countries](image2)

![Figure 7a: Causality from Petroleum to GDP for OECD / non-OECD Countries](image3)

![Figure 7b: Causality from Petroleum to GDP for High-, Mid-, Low Dev. Countries](image4)
4. Summary and Conclusion

This study has empirically investigated the causal relationship between ‘Electricity consumption and GDP’ and ‘Petroleum consumption and GDP’ for 26 OECD and 78 non-OECD countries. Causality tests were systematically performed using recently developed techniques. To generate a clearer distinction between developed and developing countries the HDI has been adopted to categorize the countries.

Time series properties of the data were analyzed by way of a unit root test before applying tests for co-integration via the Johansen method. Once the cointegrating relationships were identified, the error-correction terms were extracted and embedded as an additional lagged-level regressor in a bivariate VAR system in first differences. This formulation allowed further channels of causality to emerge and provided the opportunity to examine the causal relationship by preserving the short run dynamics without the loss of long run information. Since the result of causality is very sensitive to lag length, the Hsiao’s Granger technique was adopted which combines the definition of Granger causality and final prediction criteria (FPE) to select the optimum lag for the model.

The results show the evidence of causality to some extent in both OECD/Developed countries and non-OECD/Developing countries. Granger causality between ‘Petroleum and GDP’ is more prevalent in OECD/Developed countries when compared with non-OECD/Developing countries. Causality between ‘Electricity and GDP’ on the other hand is more prevalent in non-OECD/Developing countries compared with OECD/Developed countries.

For the direction of causality, a greater proportion of OECD/Developed countries show evidence of causality from ‘Petroleum to GDP’ than the non-OECD/Developing countries. However in the case of causality from ‘Electricity to GDP’, the proportion in the two groups of countries are little different, particularly in high- and mid development countries. However, a greater proportion of OECD/Developed countries show evidence of causality from ‘GDP to Petroleum consumption’ but surprisingly it is not the case with ‘GDP to Electricity consumption’.

The previous study (Chontanawat, et al. 2004) which focused on testing causality between ‘total energy and GDP’ suggests that causality in OECD/Developed countries is more prevalent than that in non-OECD/Developing countries which yields a different result to initial expectations. This study, which focuses on causality between ‘disaggregate energy and GDP’, yields a clearer picture. There is stronger evidence of causality in non-OECD/Developing countries, particularly in the case of electricity. The causal link from ‘Petroleum to GDP’ in OECD/Developed countries is more prevalent than that in non-OECD/Developing countries whereas the causal link from ‘Electricity to GDP’ in OECD/Developed countries and non-OECD/Developed countries is not that different. This may imply that, in general, petroleum consumption may drive economic growth in OECD/Developed countries rather than in non-OECD/Developing countries whereas electricity consumption seems to drive economic growth in both groups of countries in similar proportions. This also implies that any global policy to reduce energy consumption particularly petroleum consumption, in order to reduce pollutant emissions would, according to these results, have a greater impact on the GDP of the developed world rather than that of the developing world. However, the policy to reduce electricity consumption would have a similar impact in both groups of the countries.

For the causality running from GDP to Petroleum/Electricity, the results show that the link from ‘GDP to Petroleum’ in OECD/Developed countries is more widespread than in non-OECD/Developing countries whereas the causal link from ‘GDP to Electricity’ yields the opposite result. This may imply that, based on this study, GDP may drive Petroleum
consumption better in OECD/developed countries rather than in non-OECD/Developing countries while GDP may drive Electricity consumption better in non-OECD/Developing countries.

References


### Table 1: Summary of Energy-Output* Causality Studies

<table>
<thead>
<tr>
<th>Studies</th>
<th>Countries</th>
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<th>Energy → Output</th>
<th>Output → Energy</th>
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<td>5. Erol &amp; Yu (1987)</td>
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<td>8. Yu &amp; Chow &amp; Choi (1988)</td>
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<td>12. Yu &amp; Jin (1992)</td>
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<td>18.</td>
<td>Masih &amp; Masih (1996)</td>
<td>6 Asian Countries: -Malaysia -Singapore -India -Indonesia -Pakistan</td>
<td>Cointegration &amp; ECM: (E, GDP)</td>
<td>1955-1990</td>
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<td>Year</td>
<td>Author(s)</td>
<td>Country/Region</td>
<td>Method</td>
<td>Sample Period</td>
<td>Variables</td>
<td>Granger Impulse (E→GDP)</td>
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<td>1965-1994</td>
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<td>GDP→E</td>
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<td>34.</td>
<td>Altinay &amp; Karagol (2004)</td>
<td>Turkey</td>
<td>Hsiao’s Granger</td>
<td>1950-2000</td>
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* The definitions of Energy and Output and the abbreviation used are given below:

- $E =$ Total energy consumption
- Gas = Natural gas consumption
- Liquid fuels = Liquid fuel consumption
- Elec. = Electricity consumption
- Oil = Oil Consumption
- Coal = Coal Consumption
- Coke = Coke consumption
- Res.E = Energy consumption in residential sector
- Indus.E = Energy consumption in industrial sector
- Com.E = Energy consumption in commercial sector
- K = Capital
- L = Labour
- T = Time trend (technology)
- P = Price (Consumer price index)
- GDP = Gross domestic product
- GNP = Gross national product
- AGDP = Agricultural-GDP
- NGDP = Non-agricultural-GDP
- Emp. = Employment
- Non-farm Emp. = Non-farm employment
- IP = Industrial production index of manufacturing
- Roil = Real oil price
- rgexp. = Real government expenditure
- $M^s =$ Real money supply

a/ This includes ‘Developing countries’ (India, Philippines, Zambia, Columbia, El Salvador, Indonesia, Kenya and Mexico).
b/ This includes ‘More developed countries’ (Pakistan, Singapore, Canada, Turkey, Hong Kong and Singapore).
Endnotes

1 Tomas and Jemelkova (2003) give a more detailed justification for the effect of energy on development. They argue that the increased availability of energy services acts as a ‘key’ stimulus for economic development at different stages in the development process.

2 In some studies a distinction is made between long-run causality from the EC term and short-run causality from the $\Delta y$ or $\Delta e$ terms. This distinction is not explicitly used in this paper.

3 To test whether $y$ causes $e$, the $e$ and $y$ should be transposed in equations (9) and (11).

4 Again to test whether $y$ causes $e$, the $e$ and $y$ should be transposed in equation (13).

5 Cheng (1999) has adopted a similar technique in a multivariate model.

6 These statistics can be used to confirm the test of $y$ causes $e$ in the same way.

7 Details of how this is undertaken can be found in Harris (1995).

8 Details of how this is undertaken can be found in Harris (1995). The optimal lag structure for the VAR is selected by minimizing Schwarz (SIC) criteria. Verbeek (2001:254) notes that the model with the smallest AIC or SIC is preferred. However, while the two criteria differ in their trade-off between fit and parsimony, the SIC criterion can be preferred. Two structures of the model are specified. The first structure is that there is a linear trend in the data and intercept but no trend in the co-integrating equation. The second structure is that there is linear trend in the data and intercept and a trend in the co-integrating equation.

9 If the coefficient of the EC term yields a positive sign, the causality will be re-estimated on the different term as shown in stage 3a.

10 Technically, the statements about causality refer to the variables in logs (i.e. $e$ and $y$) as used throughout this section on methodology. However, for ease of exposition, references hereafter will be in terms of the levels (i.e. $E$ and $Y$).

11 In this study, four countries; Czech Republic, Mexico, Korea and Slovak are excluded from the total 30 OECD countries as the time series data for electricity and petroleum consumption are not long enough (1982-2000).


13 All estimation was done using EVIEWS4.1.

14 Full tables of results are available from the corresponding author on request.

15 However, the percentage of the causality in the Petroleum case in non-OECD/Developing countries is greater than the case of total energy (see Chontanawat, et al 2004), whereas it shows a smaller percentage in the case of OECD countries.

16 This result is consistent with the case of causality between ‘total energy consumption and GDP’ in the paper Chontanawat, et al. (2004).

17 The initial expectation being that causality in non-OECD/Developing countries is more prevalent than that in OECD/Developed countries.