# *The Dynamic Causal Relationship between Electricity Consumption and Economic Growth in Ghana: A Trivariate Causality Model*

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This paper examines the dynamic causal relationship between electricity consumption and economic growth in Ghana within a trivariate ARDL framework, for the period 1971–2012. The paper obviates the variable omission bias, and the use of cross-sectional techniques that characterise most existing studies. The results show that there is a distinct causal flow from economic growth to electricity consumption: both in the short run and in the long run. This finding supports the growth-led electricity consumption hypothesis, as documented in the literature. The paper urges policymakers in Ghana to resort to alternative sources of electric power generation, in order to reduce any future pressures on the current sources of electricity production. Appropriate monetary policies must also be put in place, in order to accommodate potential inflation hikes stemming from excessive demands for electricity in the near future.

*Key Words:* electricity consumption, economic growth, inflation, co-integration, causality, Ghana
JEL *Classification:* Q43, C32

## Introduction

In recent times, the economic literature has been inundated with the pertinent issue of whether economic growth *Granger-causes* electricity consumption,[1] or whether electricity consumption *Granger-causes* economic growth. Climatic changes, energy crises, hikes in crude oil prices, and excessive carbon emission levels have further added fuel to this debate. Global conferences and academic think tanks are now preoccupied with sustainable energy and similar related issues. The ability to establish the exact causal pattern between electricity consumption and economic growth is of colossal relevance to policy direction, especially for countries that rely heavily on electricity as their sole source of energy.

If the evidence suggests that electricity *Granger-causes* economic growth, then this means that economic policies, which are aimed towards conserving electricity, could be detrimental to economic growth, which inherently enhances poverty, and reduces both job creation and societal welfare (see Ghosh 2002). Furthermore, if economic growth *Granger-causes* electricity consumption, then there might be little to worry about when implementing electricity-conservation policies (see for instance, Asafu-Adjaye 2000; Narayan and Smyth 2005).

The pioneering work of Kraft and Kraft (1978) triggered the interest in the energy consumption-growth debate. Since then, the debate has been extended to specifics, such as the electricity-growth nexus, clean energy-growth, and other related issues. Until this point in time, the energy consumption and economic growth debate had produced conflicting and interesting outcomes. Previous research on this debate was widely conducted for countries in Latin America, the Caribbean and Asia. However, few concentrated on the countries in sub-Saharan Africa (see Odhiambo 2009a) and Ghana's case has been even less researched.

To the best of our knowledge, to date, Lee (2005), Wolde-Rufael (2006), and Akinlo (2008b) are the only available literature on the energy consumption and economic growth debate in Ghana. Furthermore, most of these studies suffer from two main limitations: (a) Omission-of-variable bias, when testing for causality within a bivariate VAR (see Murray and Nan 1994; and Yoo 2005); and (b) and over-reliance on cross-sectional data to explain country-specific issues (see Murray and Nan 1994; and Wolde-Rufael 2006). This study, therefore, attempts to overcome these limitations by employing a trivariate ARDL model to examine the causal relationship between electricity consumption and economic growth. Specifically, the study incorporates inflation as an intervening variable that influences both electricity consumption and economic growth. It has been argued that if such a variable is included in the causality framework, the direction of causality could not only change, but the magnitude might also increase (see Caporale and Pittis 1997; Odhiambo 2009a; and Njindan 2013).

The remaining sections of this paper are organised as follows: Section 2 provides an overview of the trends in electricity consumption, economic growth, and inflation in Ghana; Section 3 discusses the relevant literature on the electricity-growth debate; Section 4 presents the methodological issues, the empirical estimations and the analysis; while Section 5 provides the conclusions.

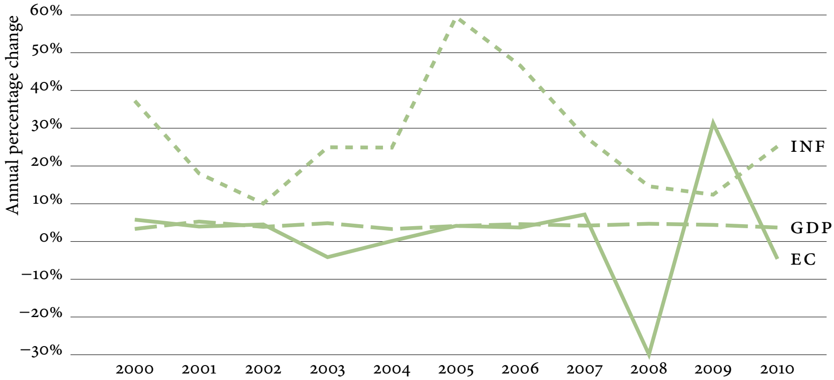


FIGURE 1 The Trends in Economic Growth (GDP), Energy Consumption (EC) and Inflation (INF) (2000–2010; constructed from the World Bank 2014)

## Overview of Trends in Electricity Consumption and Economic Growth in Ghana

The economy of Ghana is highly dependent on electricity, particularly hydro-electricity. As the economy continues to undergo transformation, so has the need for electricity increased. As many as 62 per cent of the urban population have access to electricity, compared with 4 per cent of the rural population (Saghir 2002). The electrification rate, as estimated by IEA (2002), is 45 per cent. Between 1971 and 2010, electricity consumption per capita, per capita real GDP, and inflation rate averaged 277.88kWh, US$ 300.96 and 32.91 per cent, respectively. Figure 1 shows the trends in electricity consumption per capita, per capita real GDP growth, as well as the inflation rate.

From figure 1, real GDP per capita growth increased from 3.3 per cent in 2000 to 5.3 per cent in 2001; electricity consumption per capita, on the other hand, declined from 5.8 per cent to 3.96 per cent over this period. The increase in real GDP per capita growth was associated with a decline in inflation from 37.3 per cent in 2000 to 18.03 per cent in 2001. The graphs appear to indicate that increment in real GDP per capita growth was often associated with declining electricity consumption per capita and vice versa. For example, when real GDP per capita growth increased from 3.9 per cent in 2002 to 4.9 per cent in 2003, electricity consumption per capita declined from 4.5 per cent to −4.2 per cent. Also, when real GDP per capita growth declined from 4.6 per cent in 2006 to 4.2 per cent in 2007, electricity consumption per capita increased from 3.7 per cent to 7.1 per cent. There appear to be no recognisable relationships between inflation and electricity consumption per capita; and, also, inflation and real GDP per capita growth.

The capacity of the Akosombo Dam and the Aboadze Thermal Plant to meet the electricity needs of the Ghanaian populace has been called into question on several occasions. Despite her inability to meet the electricity consumption needs of the people, Ghana has been a net exporter of electricity to Burkina Faso and Togo for more than two decades; and understandably, questions have been asked on whether this is a laudable idea. Political discourses in Ghana have been inundated with promises of constant electricity supply, but to date, no government has been able to fulfil this promise. The Bui Dam, which has been under construction for some time now, demonstrates a renewed commitment on the part of the government to respond to the public clamour. Currently, power rationing is the only viable tool being used to accomplish load shedding in Ghana, in order to avoid a blackout.

## Literature Review

The debate regarding the direction of the causal pattern between energy consumption and economic growth has not yet produced a unanimous conclusion. In the resource and energy economics literature, four main strands are now obvious. The first strand comprises those with the view that energy consumption *causes* economic growth (the energy-led growth thesis); the second strand is made up of those with the conviction that economic growth *causes* energy consumption (the growth-driven energy consumption thesis). The third strand comprises those who believe that energy consumption and economic growth *cause* each other (the feedback thesis); while the fourth strand is made up of those who are of the opinion that energy and economic growth are independent of each other (the neutrality thesis).

Several empirical studies have since corroborated the energy-led economic growth thesis. Among these include: Masih and Masih (1997) for India; Asafu-Adjaye (2000) for India and Indonesia; Wolde-Rufael (2004) for Shanghai; Fatai, Oxley, and Schrimgeour (2004) for Indonesia and India; Lee (2005) for 18 developing countries; Wolde-Rufael (2006) for Benin, Congo DR and Tunisia; Mahadevan and Asafu-Adjaye (2007) for eight net energy importing and exporting countries; Ho and Siu (2007) for Hong Kong; Narayan and Singh (2007) for Fiji Islands; Narayan and Prasad (2008) for nine OECD countries; Akinlo (2008a) for Nigeria; Odhiambo (2009a) for Tanzania; Belloumi (2009) for Tunisia;

Tsani (2010) for Greece; Pao and Tsai (2010) for BRIC countries; Odhiambo (2010) for South Africa and Kenya; Apergis and Payne (2010) for nine South American countries; Al-mulali and Sab (2012) for thirty Sub-Saharan African countries; Ouedraogo (2013) for 15 ECOWAS countries; Shahbhaz, Khan, and Tahir (2013) for China; Muhammad et al. (2013) for Pakistan; Dergiades, Martinopoulos, and Tsoulfidis (2013) for Greece; Aslan, Apergis, and Yildrim (2014) for USA; Odhiambo (2014) for Brazil and Uruguay; and Solarin and Shahbhaz (2013) for Angola. The summary of these selected studies is presented in table 1.

In addition, the growth-driven energy consumption thesis has been confirmed by studies, such as those of Kraft and Kraft (1978) for the USA; Yu and Choi (1985) for the Philippines; Masih and Masih (1997) for India, Indonesia, Pakistan, Malaysia, Singapore and the Philippines; Narayan and Smyth (2005) for Australia; Al-Iriani (2006) for the Gulf Co-operation countries; Wolde-Rufael (2006) for the case of Cameroon, Ghana, Nigeria, Senegal, Zambia and Zimbabwe; Akinlo (2008b) for Sudan and Zimbabwe; Zhang and Cheng (2009) for China; and Odhiambo (2010) for Congo DR. Recent studies have also found evidence in favour of the growth-driven energy consumption thesis. Some of these studies include Ouedraogo (2013) for 15 ECOWAS countries; Stern and Enflo (2013) for Sweden; and Odhiambo (2014) for Ghana and Cote d'Ivoire. Table 2 provides the summary of selected studies in favour of growth-driven energy consumption thesis.

However, there is a group of studies that has confirmed the feedback thesis, in which both energy and economic growth *Granger-cause* each other. These studies include those of Masih and Masih (1997) for Pakistan; Glasure and Lee (1997) for South Korea and Singapore; Asafu-Adjaye (2000) for Thailand and the Philippines; Soytas and Sari (2003) for Argentina; Fatai, Oxley, and Schrimgeour (2004) for Thailand and the Philippines; Oh and Lee (2004) for South Korea; Jumbe (2004) for Malawi; Ghali and El-Sakka (2004) for Canada; Wolde-Rufael (2006) for Gabon, Ghana, Togo and Zimbabwe; Mahadevan and Asafu-Adjaye (2007) for Australia, Japan, Norway, Sweden, UK and USA; Akinlo (2008b) for Ghana, Gambia and Senegal; Wolde-Rufael (2009) for Gabon, Ghana, Togo and Zimbabwe; Belloumi (2009) for Tunisia; and Pao and Tsai (2010) for BRIC countries. Other recent studies which found evidence of feedback causality between energy consumption and economic growth include: Zhang (2011) for Russia; Wesseh and Zoumara (2012) for Liberia; Fuinhas and Marques (2012) for PIGS countries and Turkey;

TABLE 1 Selected Studies on the Energy-Led Growth Thesis

| Author(s) | Countries | Methodology | Conclusion(s) |
|---|---|---|---|
| Odhiambo (2014) | Ghana, Cote d'Ivoire, Brazil, and Uruguay (1972–2006) | ARDL-Bounds Testing Procedure | $EC \rightarrow Y$; Brazil, and Uruguay |
| Aslan et al. (2014) | USA (1973q1–2012q1) | Wavelet Analysis; Granger Causality | $EC \rightarrow Y$ |
| Solarin and Shahbhaz (2013) | Angola (1971–2009) | ARDL-Bounds Testing; VECM Causality Test | $ELC \rightarrow Y$ |
| Shahbhaz et al. (2013) | China (1971–2011) | ARDL-Bounds Test; Granger Causality | $EC \rightarrow Y$ |
| Ouedraogo (2013) | 15 ECOWAS Countries (1980–2008) | Panel Cointegration; Causality Tests | $EC \rightarrow Y$ (Long run) $ELC \rightarrow Y$ (Long run) |
| Muhammad et al. (2013) | Pakistan (1972–2002) | ARDL; Johansen Cointegration; Granger Causality | $EC \rightarrow Y$ |
| Dergiades et al. (2013) | Greece (1960–2008) | Parametric and Non-Parametric Causality Tests | $EC \rightarrow Y$ |
| Al-mulali and Sab (2012) | 30 Sub-Saharan African Countries (1980–2008) | Panel Cointegration; Causality Tests | $EC \rightarrow Y$ |
| Apergis and Payne (2010) | 9 South America Countries (1980–2005) | Panel Cointegration; Causality Tests | $EC \rightarrow Y$ |
| Odhiambo (2010) | Congo DR, Kenya, and South Africa (1972–2006) | ARDL-Bounds Testing Procedure | $EC \rightarrow Y$; South Africa, and Kenya |
| Pao and Tsai (2010) | Brazil, Russia, India, and China (1965–2009) | Granger Causality | $EC \rightarrow Y$ |
| Tsani (2010) | Greece (1960–2006) | Toda-Yamamoto Causality Test | $EC \rightarrow Y$ (Aggregated level) |
| Belloumi (2009) | Tunisia (1971–2004) | VECM | $EC \rightarrow Y$ (Short run) |
| Odhiambo (2009a) | Tanzania (1971–2006) | ARDL-Bounds Testing Procedure | $EC \rightarrow Y$ |
| Wolde-Rufael (2009) | 17 African Countries (1971–2004) | Granger Causality | $EC \rightarrow Y$; Algeria, Benin, and South Africa |
| Akinlo (2008a) | Nigeria (1980–2006) | VECM; Co-Feature Analysis | $ELC \rightarrow Y$ |
| Narayan and Prasad (2008) | 30 OECD Countries (varying samples) | Bootstrapped Causality Tests | $ELC \rightarrow Y$; Australia, Iceland, Italy, Slovakia, Czech Republic, Korea, Portugal, UK |
| Narayan and Singh (2007) | Fiji Islands (1971–2002) | ARDL-Bounds Testing Procedure | $ELC \rightarrow Y$ (Long run) |
| Mahadevan and Asafu-Adjaye (2007) | 20 Net Energy Importing and Exporting Countries (1971–2002) | Panel Error-Correction Model | $EC \rightarrow Y$; Argentina, Indonesia, Kuwait, Malaysia, Nigeria, Saudia Arabia, and Venezuela |
| Ho and Siu (2007) | Hong Kong (1966–2002) | VECM | $ELC \rightarrow Y$ |
| Wolde-Rufael (2006) | 17 African Countries (1971–2001) | ARDL-Bounds Testing Procedure | $EC \rightarrow Y$; Benin, Congo DR, Tunisia |
| Fatai et al. (2004) | Indonesia, India, Thailand, the Philippines (1960–1999) | Bivariate Toda-Yamamoto | $EC \rightarrow Y$; Indonesia, and India |

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TABLE 1 *Continued from the previous page*

| Author(s) | Countries | Methodology | Conclusion(s) |
|---|---|---|---|
| Lee (2005) | 18 Developing Countries (1975–2001) | Panel Cointegration | $EC \rightarrow Y$ |
| Wolde-Rufael (2004) | Shanghai (1952–1999) | Bivariate Toda-Yamamoto | $ELC \rightarrow Y$ |
| Asafu-Adjaye (2000) | India, Indonesia, the Philippines, and Thailand (varying sample periods) | VECM | $EC \rightarrow Y$; India and Indonesia |
| Masih and Masih (1997) | India, Indonesia, Pakistan, Malaysia, Singapore, and the Philippines (varying sample periods) | VECM | $ELC \rightarrow Y$; India |

TABLE 2 Selected Studies on the Growth-driven Energy Consumption Thesis

| Author(s) | Countries | Methodology | Conclusion(s) |
|---|---|---|---|
| Odhiambo (2014) | Ghana, Cote d'Ivoire, Brazil, and Uruguay (1972–2006) | ARDL-Bounds Testing Procedure | $Y \rightarrow EC$; Ghana, and Cote d'Ivoire |
| Stern and Enflo (2013) | Sweden (1850–2000) | Granger Causality | $Y \rightarrow EC$ |
| Ouedraogo (2013) | 15 ECOWAS Countries (1980–2008) | Panel Cointegration; Causality Tests | $Y \rightarrow EC$ (Short run) |
| Odhiambo (2010) | Congo DR, Kenya, and South Africa (1972–2006) | ARDL-Bounds Testing Procedure | $Y \rightarrow EC$; Congo DR |
| Wolde-Rufael (2009) | 17 African Countries (1971–2004) | Multivariate Causality Tests | $Y \rightarrow EC$; Egypt, Cote d'Ivoire, Morocco, Nigeria, Senegal, Sudan, Tunisia, and Zambia |
| Zhang and Cheng (2009) | China (1960–2007) | Toda-Yamamoto Test; Generalised Impulse Response | $Y \rightarrow EC$ |
| Akinlo (2008b) | 11 Sub-Saharan African Countries | ARDL-Bounds Testing Procedure | $Y \rightarrow EC$; Sudan and Zimbabwe |
| Wolde-Rufael (2006) | 17 African Countries | ARDL-Bounds Testing Procedure | $Y \rightarrow ELC$; Cameroon, Ghana, Nigeria, Senegal, Zambia, and Zimbabwe |
| Al-Iriani (2006) | Gulf Co-Operation Countries (1971–2002) | Panel Cointegration and Panel Causality Test | $Y \rightarrow EC$ |
| Narayan and Smyth (2005) | Australia (1966–1999) | ARDL-Bounds Testing; VEC Zivot-Andrews Structural Break Test | $Y \rightarrow EC$ |
| Masih and Masih (1997) | India, Indonesia, Pakistan, Malaysia, Singapore, and the Philippines (varying sample periods) | VECM | $Y \rightarrow ELC$ |
| Yu and Choi (1985) | South Korea, the Philippines (1954–1976) | Standard Granger Test | $Y \rightarrow EC$; South Korea |
| Kraft and Kraft (1978) | USA (1947–1974) | Granger Causality | $Y \rightarrow EC$ |

Fowowe (2012) for fourteen Sub-Saharan African countries; Stern and Enflo (2013) for Sweden; Amusa and Leshoro (2013) for Botswana; and Solarin and Shahbaz (2013) for Angola. Table 3 provides the summary

TABLE 3 Selected Studies on the Feedback Causality between Growth and Energy Consumption Thesis

| Author(s) | Countries | Methodology | Conclusion(s) |
|---|---|---|---|
| Solarin and Shahbaz (2013) | Angola (1971–2009) | ARDL-Bounds Testing; VECM Causality Test | $ELC \leftrightarrow Y$ |
| Amusa and Leshoro (2013) | Botswana (1981–2010) | ARDL-Bounds Testing Procedure | $ELC \leftrightarrow Y$ |
| Stern and Enflo (2013) | Sweden(1850–2000) | Granger Causality; Cointegration Tests | $EC \leftrightarrow Y$ |
| Dagher and Yacoubian (2012) | Lebanon (1980–2009) | Hsiao, Toda-Yamamoto, and ECM-based Causality Tests | $EC \leftrightarrow Y$ |
| Fowowe (2012) | 14 Sub-Saharan African (1971–2004) | Panel Cointegration Tests | $EC \leftrightarrow Y$ |
| Fuinhas and Marques (2012) | Portugal, Italy, Greece, Spain, and Turkey (1965–2009) | ARDL-Bounds Testing Procedure | $EC \leftrightarrow Y$ |
| Wesseh and Zoumara (2012) | Liberia (1980–2008) | Bootstrapped Causality Test | $EC \leftrightarrow Y$ |
| Zhang (2011) | Russia (1970–2008) | Toda-Yamamoto | $EC \leftrightarrow Y$ |
| Pao and Tsai (2010) | Brazil, Russia, India, and China (1965–2009) | Granger Causality | $EC \leftrightarrow Y$ (Long run) |
| Tsani (2010) | Greece (1960–2006) | Toda-Yamamoto Causality Test | $EC \leftrightarrow Y$ (Disaggregated level) |
| Belloumi (2009) | Tunisia (1971–2004) | VECM | $EC \leftrightarrow Y$ (Long run) |
| Odhiambo (2009b) | South Africa (1971 to 2006) | Trivariate Granger Causality Test | $ELC \leftrightarrow Y$ |
| Wolde-Rufael (2009) | 17 African Countries (1971–2004) | Multivariate Granger Causality | $EC \leftrightarrow Y$; Gabon, Ghana, Togo, and Zimbabwe |
| Akinlo (2008b) | 11 Sub-Saharan African Countries | ARDL-Bounds Testing Procedure | $EC \leftrightarrow Y$; Gambia, Ghana, and Senegal |
| Mahadevan and Asafu-Adjaye (2007) | 20 Net Energy Importing and Exporting Countries (1971–2002) | Panel Error-Correction Model | $EC \leftrightarrow Y$; Australia, Japan, Norway, Sweden, UK, and USA |
| Wolde-Rufael (2006) | 17 African Countries (1971–2001) | ARDL-Bounds Testing Procedure | $EC \leftrightarrow Y$; Egypt, Gabon; Morocco |
| Oh and Lee (2004) | South Korea (1981q1–2000q4) | VECM | $EC \leftrightarrow Y$ |
| Ghali and El-Sakka (2004) | Canada (1961–1997) | VECM | $EC \leftrightarrow Y$ |
| Jumbe (2004) | Malawi (1970–1999) | Granger Causality | $ELC \leftrightarrow Y$ |
| Fatai et al. (2004) | Indonesia, India, Thailand, and the Philippines (1960–1999) | Bivariate Toda-Yamamoto | $EC \leftrightarrow Y$; Thailand, and the Philippines |
| Soytas and Sari (2003) | Argentina (1950–1990) | VECM | $EC \leftrightarrow Y$ |

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of selected studies in favour of feedback thesis. Quite interestingly, there are other studies which do not see any *causal* link between energy consumption and economic growth. Such studies include those of Murray and Nan (1994) for France, Germany, India, Israel, Luxembourg, Nor-

TABLE 3 *Continued from the previous page*

| Author(s) | Countries | Methodology | Conclusion(s) |
|---|---|---|---|
| Asafu-Adjaye (2000) | India, Indonesia, the Philippines, and Thailand (varying sample periods) | VECM | $EC \leftrightarrow Y$; the Philippines, and Thailand |
| Yang (2000) | Taiwan (1954–1997) | VAR; Engle-Granger | $EC \leftrightarrow Y$ |
| Glasure and Lee (1997) | South Korea, and Singapore (1961–1990) | Bivariate VECM | $EC \leftrightarrow Y$ |
| Masih and Masih (1997) | India, Indonesia, Pakistan, Malaysia, Singapore, and the Philippines (varying sample periods) | MVECM | $EC \leftrightarrow Y$; Pakistan |

TABLE 4 Selected Studies on the Neutrality Thesis

| Author(s) | Countries | Methodology | Conclusion(s) |
|---|---|---|---|
| Ozturk and Acaravci (2011) | 11 Middle East and North Africa (MENA) Countries (1971–2006) | ARDL-Bounds Testing Procedure | $ELC \sim Y$ |
| Acaravci and Ozturk (2010) | Turkey (1968–2005) | ARDL-Bounds Testing Procedure | $EC \sim Y$ |
| Wolde-Rufael (2009) | 17 African Countries (1971–2004) | Multivariate Granger Causality | $EC \sim Y$; Cameroon, and Kenya |
| Narayan and Prasad (2008) | 30 OECD Countries | Bootstrapped Causality Tests | $ELC \sim Y$; Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Slovakia, Spain, Sweden, Switzerland, Turkey, and USA |
| Akinlo (2008b) | 11 Sub-Saharan African Countries | ARDL-Bounds Testing Procedure | $EC \sim Y$; Cameroon, Cote d'Ivoire, Nigeria, Kenya, and Togo |
| Wolde-Rufael (2006) | 17 African Countries (1971–2001) | ARDL-Bounds Testing Procedure | $EC \sim Y$; Algeria, Congo, Kenya, South Africa, Sudan |
| Soytas and Sari (2003) | | | $EC \sim Y$; Canada, Indonesia, Poland, USA and UK |
| Masih and Masih (1997) | India, Indonesia, Pakistan, Malaysia, Singapore, and the Philippines (varying sample periods) | VECM | $ELC \sim Y$; Malaysia, Singapore, and the Philippines |
| Murray and Nan (1994) | Germany, Israel, Portugal, USA, UK, Zambia, France, and Norway (1970–1990) | Granger Causality; VAR | $ELC \sim Y$ |

NOTES $\rightarrow$ denotes unidirectional causality, $\leftrightarrow$ denotes bidirectional causality, $\sim$ denotes no causality; *EC*, *ELC*, and *Y* represent energy consumption, electricity consumption, and income (GDP), respectively.

way, Portugal, UK, USA and Zambia; Soytas and Sari (2003) for Canada, Indonesia, Poland, USA and UK; Narayan and Prasad (2008) for twenty-four developed countries; Akinlo (2008b) for Cameroon, Cote d'Ivoire, Kenya, Nigeria and Togo; Wolde-Rufael (2009) for Cameroon and Kenya;

Ozturk and Acaravci (2010) for Turkey; and Ozturk and Acaravci (2011) for eleven MENA countries. Table 4 provides the summary of selected studies in favour of neutrality thesis.

## Methodology

### ARDL BOUNDS-TESTING PROCEDURE FOR CO-INTEGRATION

The approach adopted in this study for testing the existence of co-integrating relationships between electricity consumption, inflation and economic growth is the ARDL bounds-testing procedure proposed by Pesaran and Shin (1999), which was subsequently generalised by Pesaran, Shin, and Smith (2001). Following recent studies (see Odhiambo 2014), we formulated our empirical ARDL model as:

$$\Delta \ln Y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta \ln EC_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta \ln INF_{t-i} + \alpha_4 \Delta \ln Y_{t-1} + \alpha_5 \Delta \ln EC_{t-1} + \alpha_6 \Delta \ln INF_{t-1} + \varepsilon_t \quad (1)$$

$$\Delta \ln INF_t = \rho_0 + \sum_{i=1}^{n} \rho_{1i} \Delta \ln INF_{t-i} + \sum_{i=0}^{n} \rho_{2i} \Delta \ln EC_{t-i} + \sum_{i=0}^{n} \rho_{3i} \Delta \ln Y_{t-i} + \rho_4 \Delta \ln Y_{t-1} + \rho_5 \Delta \ln EC_{t-1} + \rho_6 \Delta \ln INF_{t-1} + \varepsilon_t \quad (2)$$

$$\Delta \ln EC_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta \ln EC_{t-1} + \sum_{i=0}^{n} \beta_{2i} \Delta \ln Y_{t-1} + \sum_{i=0}^{n} \beta_{3i} \Delta \ln INF_{t-1} + \beta_4 \Delta \ln Y_{t-1} + \beta_5 \Delta \ln EC_{t-1} + \beta_6 \Delta \ln INF_{t-1} + \varepsilon_t \quad (3)$$

Where $\ln Y_t$, $\ln EC_t$, and $\ln INF_t$ are the logarithms of real GDP per capita, electricity power consumption per capita, and annual rate of inflation, respectively; $\alpha$, $\beta$, and $\rho$ are the parameters of the model; $\Delta$ is the first difference operator; $t$ is the time period; and $\varepsilon_t$ is the error term assumed to be identically and independently distributed (*iid*).

The paper favours the ARDL bounds-testing procedure for co-integration, because it has better finite sample properties, and thus outperforms the Engle Two-Step and the Johansen procedures in small samples (see Pesaran, Shin, and Smith 2001; Narayan and Smyth 2005; Odhiambo 2009a); its estimates are robust even in the presence of endogeniety, whereas the Engle Two-Step and the Johansen procedures are biased under such circumstance; also, the ARDL bounds-testing procedure could be performed, irrespective of whether the variables are $I(0)$, $I(1)$ or mixed, unlike the other tests (see Pesaran and Shin 1999).

The ARDL bounds-testing procedure for co-integrating relationships follows a non-standard asymptotic $F$-distribution under the null hypothesis, which maintains that there exists a minimum of one co-integrating vector. Two sets of critical values were constructed by Pesaran, Shin, and Smith (2001) under this null hypothesis. The first set of critical values is constructed under the assumption that variables in the ARDL model are integrated of order zero, $I(0)$.

The second set of critical values is constructed under the assumption that variables in the model are integrated of order one, $I(1)$. We do not reject the null hypothesis of no co-integrating relationship when the $F$-statistic falls below the lower bound. Similarly, we reject the null hypothesis of no co-integration when the calculated $F$-statistic is greater than the upper bound. However, the test is inconclusive when the $F$-statistic falls between the lower and upper bounds.

### SPECIFICATION FOR THE GRANGER CAUSALITY TEST

In order to examine the short- and long-run causal linkages between electricity consumption, inflation, and economic growth, the study specifies, in line with previous works (see Narayan and Smyth 2005; Odhiambo 2014), the model:

$$\Delta \ln Y_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \gamma_{2i} \Delta \ln EC_{t-i} + \sum_{i=0}^{n} \gamma_{3i} \Delta \ln INF_{t-i} + \gamma_4 ECM_{t-1} + \mu_t \quad (4)$$

$$\Delta \ln INF_t = \theta_0 + \sum_{i=1}^{n} \theta_{1i} \Delta \ln INF_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta \ln EC_{t-i} + \sum_{i=0}^{n} \theta_{3i} \Delta \ln Y_{t-i} + \theta_4 ECM_{t-1} + \mu_t \quad (5)$$

$$\Delta \ln EC_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta \ln EC_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta \ln INF_{t-i} + \delta_4 ECM_{t-1} + \mu_t \quad (6)$$

Where all variables retain the definition provided in the earlier specification. $ECM_{t-1}$ is the error-correction term of the immediate period before $t$; this term was formulated from the long-run equilibrium equation; $\gamma$, $\theta$, and $\delta$ are the parameters of the model; and $\mu_t$ is the *iid* error term for the model.

Evidence suggests that once there exists a long-run relation between the variables, in this case electricity consumption, inflation, and economic growth, then there is a case for causality in one or more directions (see Narayan and Smyth 2005). Nonetheless, we could only establish the direction of the long-run causality between the variables by conducting a test of statistical significance (a $t$-test) on the lagged error-correction term in each equation. The direction of the short-run causal relationships between the variables could also be established by conducting a joint test of statistical significance (an $F$-test) of the explanatory variables in each of the equations (see Oh and Lee 2004; Narayan and Smyth 2005; and Odhiambo, 2009c).

The paper employs the annual time series covering the period 1971–2012. The data were limited, because the records on energy consumption in Ghana were not available before 1971. The data on economic growth, energy consumption, and inflation rate were extracted from the World Development Indicators (World Bank 2014), compiled by the World Bank. Real GDP per capita (constant 2000 US$) was used to proxy the economic growth; electricity power consumption per capita (kWh per capita) was used to proxy the electricity consumption; and consumer prices (annual percentage change) was used to proxy the inflation.

## ANALYSIS OF VARIABLES AND ESTIMATIONS

### *Stationarity Test*

The first step towards investigating the causal relationship between electricity consumption and economic growth in the ARDL framework is to test for the stationary[2] properties of electricity consumption, inflation, and real GDP per capita. Standard inferences can only be made when the variables in the model are not integrated (or are stationary). Besides, the ARDL bounds-testing procedure only works when the variables are integrated of order zero or one (see Pesaran, Shin, and Smith 2001). Unit-root tests were designed to investigate the stationary properties of the time-series observations.

This study used the Phillips-Perron (PP) test, and the Dickey-Fuller Generalised Least Squares (DF-GLS) test to examine the unit root properties of the variables. These two tests were chosen, because they are able to control for serial correlation when testing for unit roots. The test for unit roots of the variables in levels, not provided here, indicated that the

TABLE 5 Test for Unit Roots in First Difference

| Variable | Phillips-Perron | | DF-GLS | |
|---|---|---|---|---|
| $\Delta \ln Y$ | −4.063*** | −5.402*** | −2.888* | −4.753*** |
| $\Delta \ln INF$ | −9.125*** | −9.353*** | −4.384*** | −4.539*** |
| $\Delta \ln EC$ | −4.905*** | −4.837*** | −4.565*** | −4.518*** |

NOTES Truncation lag for DF-GLS is based on the Schwert criterion; truncation lag for Phillips-Perron is based on the Newey-West bandwidth; * and *** denote significance at 10% and 1% levels, respectively.

null hypothesis of unit roots could not be rejected. However, the variables were found to be stationary at first difference (see table 5)

### *Results of ARDL Bounds Test for Co-Integration*

Since the variables were found to be $I(1)$ processes, it was likely that they would move together in the long run when they drift apart in the short run. We employed the ARDL bounds-testing procedure to examine the potential long-run relationships between these variables. To do this, we used the Schwarz-Bayesian Criterion (SBC) to establish the optimal lags of our ARDL specifications above. From the SBC, the optimal lags deemed appropriate (not reported here) were found to be 2, 1, and 2 for equations (1), (2), and (3), respectively. Pesaran et al. (2001) emphasized that an $F$-test on all of the equations (1) to (3) would suffice to examine whether or not there were co-integrating relationships between the variables. Using the optimal lags, we performed an $F$-test on equations (1) to (3), and reported the results in table 6.

The results show that the $F$-statistic, 2.71, calculated for equation (1) was less than the lower bound value at 1 per cent, 5 per cent, and 10 per cent levels of significance. To verify this, we estimated the long-run error-correction model. The results (not reported here) show that the error-correction term was positive and insignificant. So, for equation (1), the conclusion was that $\ln Y$ was not a co-integrating vector. Thus, the null hypothesis of no level effects or co-integration was accepted, in that case.

In equation (2), the inflation equation, the $F$-statistic was clearly greater than the upper bound value at the 10 per cent level of significance. This implies that the null hypothesis of no co-integration was rejected. Therefore, inflation, electricity consumption, and economic growth were said to be co-integrated; and the co-integrating vector was $\ln INF$. Finally, the $F$-statistic estimated for equation (3), the electricity consumption equation, was greater than the upper bound value 10 per cent level of signif-

TABLE 6 ARDL Bounds Test for Co-Integration

| Dependent variable | Function | | | $F$-statistic | | |
|---|---|---|---|---|---|---|
| $\ln Y$ | $\ln Y(\ln INF, \ln EC)$ | | | 2.71 | | |
| $\ln INF$ | $\ln INF(\ln Y, \ln EC)$ | | | 4.18* | | |
| $\ln EC$ | $\ln EC(\ln Y, \ln INF)$ | | | 4.59* | | |
| Asymptotic critical values for unrestricted intercept and no trend reported from table CI (iii) of Pesaran et al. (2001, 300) | 1% | 1% | 5% | 5% | 10% | 10% |
| | $I(0)$ | $I(0)$ | $I(0)$ | $I(0)$ | $I(0)$ | $I(0)$ |
| | 5.15 | 6.36 | 3.79 | 4.85 | 3.17 | 4.14 |

NOTES * Denotes significance at 10% level.

TABLE 7 Granger Causality between Electricity Consumption and Economic Growth

| Variable | W-statistics ($P$-value) | | | Coefficient† |
|---|---|---|---|---|
| | $\ln Y$ | $\ln INF$ | $\ln EC$ | $ECM_{t-1}$ |
| $\ln Y$ | – | 1.142 [.565] | .0216 [.989] | — |
| $\ln INF$ | 2.588 [.274] | — | 9.261 [.001] | –.731 [–5.328]*** |
| $\ln EC$ | 5.168 [.024] | 1.284 [.526] | — | –.247 [–1.846]* |

NOTES † [$t$-statistics]; * and *** imply statistical significance at the 10% and 1% levels, respectively.

icance. There was, therefore, evidence against the null hypothesis of no co-integration. The co-integrating vector was, thus, $\ln EC$.

### *Results of the Granger Causality Test*

After establishing co-integrating relationships between economic growth, inflation, and electricity consumption, the next step was to test the direction of the causal relationships between these variables. This was done in two steps. In the first step, we test how the lagged differenced explanatory variables affect the dependent variable, in order to establish the short-run causality, using the Wald test ($F$-test). In the second step, we test for the significance of the lagged error-correction terms, $ECM_{t-1}$, in order to establish the long-run causality between the explanatory variables and the dependent variable, using the $t$-test. Our results for the causality test are reported in table 7. The results show that there is a unidirectional short- and long-run causal flow from economic growth to electricity consumption in Ghana. The evidence of short-run causal flow from economic growth to electricity consumption could be seen from the $p$-value of 0.024 associated with the joint statistical test of significance of economic growth in equation (6) in table 7.

The long-run causal flow from economic growth to electricity consumption was supported by the negativity and significance of the error-correction term in the electricity consumption equation (equation 6). This results support the growth-led electricity consumption hypothesis found in the literature (see Kraft and Kraft 1978; Narayan and Smyth 2005; among others). Other results show that there was a distinct unidirectional short- and long-run causal flow from electricity consumption to inflation. This finding was supported by the *p*-value associated with the joint statistical test of significance of electricity consumption, and the coefficient of the error-correction term, which was negative and statistically significant.

## Conclusion

The study examined the dynamic causal relationships between electricity consumption and economic growth in Ghana within a trivariate framework. The study was motivated by the fact that the literature on this important debate – the electricity-growth debate – is scant in Ghana. That is, those studies that were specifically done for Ghana are very few in number. Besides, these few available studies on Ghana have two limitations, which render their conclusions questionable: (a) Omission-of-variable bias, when testing for causality within a bivariate model; and (b) over-reliance on cross-sectional data to explain country-specific issues. We resolved these problems by testing for causality in a trivariate ARDL framework. We found electricity consumption, inflation, and economic growth to be co-integrated – with the co-integrating vectors being inflation and electricity consumption – using the ARDL bounds testing for co-integration. The causality test, based on the trivariate ARDL framework, revealed that there was a distinct causal flow from economic growth to electricity consumption in Ghana: both in the short run and in the long run. The results also show that there is a distinct unidirectional causal flow from electricity consumption to inflation in Ghana. This applies both in the short run and in the long run. These results, therefore, support the growth-led electricity consumption hypothesis found in the literature. We urge policy-makers to implement strategies that explore alternative sources of electric power generation in Ghana. This could prevent electric supply shortages – as Ghana could experience rapid economic growth in the future. We also recommend that appropriate monetary policies be put in place to accommodate any potential inflation hikes stemming from excessive demands for electricity in the near future.

## Notes

1 The original debate was whether energy consumption causes economic growth or economic growth causes energy consumption. The over-reliance of certain economies on electricity-a component of energy-has compelled researchers to narrow the debate to specifics. This work follows suit, since Ghana is more electricity dependent; albeit, the use of oil cannot be discounted (see Lee 2005, for a broad debate).

2 A variable is said to be stationary or has no unit root when its moments do not depend on time (see Enders 2004).

## References


Akinlo, A. E. 2008a. 'Electricity Consumption and Economic Growth in Nigeria: Evidence from Co-Integration and Co-Feature Analysis.' *Journal of Policy Modelling* 31 (5): 681–693.

———. 2008b. 'Energy Consumption and Economic Growth: Evidence from 11 African Countries.' *Energy Economics* 30 (5): 2391–2400.

Al-Iriani, M. A. 2006. 'Energy-GDP Relationship Revisited: An Example from GCC Countries Using Panel Causality.' *Energy Policy* 34:3342–3350.

Al-mulali, U., and C. N. B. C. Sab. 2012. The Impact of Energy Consumption and $CO_2$ Emission on the Economic Growth and Financial Development in the Sub Saharan African Countries. *Energy* 39 (1): 180–186.

Amusa, K., and T. L. A. Leshoro. 2013. 'The Relationship between Electricity Consumption and Economic Growth in Botswana.' *Corporate Ownership & Control* 10 (4): 401–406.

Apergis, N., and J. E. Payne. 2010. 'Energy Consumption and Growth in South America: Evidence from a Panel Error Correction Model.' *Energy Economics* 32 (6): 1421–1426.

Asafu-Adjaye, J. 2000. 'The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries.' *Energy Economics* 22 (6): 615–625.

Aslan, A., N. Apergis, and S. Yildrim. 2014. 'Causality between Energy Consumption and GDP in the US: Evidence from Wavelet Analysis.' *Frontiers in Energy* 8 (1): 1–8.

Belloumi, M. 2009. 'Energy Consumption and GDP in Tunisia: Cointegration and Causality Analysis.' *Energy Policy* 37:2745–2753.

Caporale, G., and N. Pittis. 1997. 'Causality and Forecasting in Incomplete System.' *Journal of Forecasting* 16 (6): 425–437.

Dagher, L., and T. Yacoubian. 2012. 'The Causal Relationship between Energy Consumption and Economic Growth in Lebanon.' *Energy Policy* 50:795–801.

Dergiades, T., G. Martinopoulos, and L. Tsoulfidis. 2013. 'Energy Consumption and Economic Growth: Parametric and Non-Parametric Causality Testing for the Case Greece.' *Energy Economics* 36:686–697.

Enders, W. 2004. *Applied Econometric Time Series.* 2nd. ed. New York: Wiley.

Engle, R. F., and C. W. J. Granger. 1987. 'Co-Integration and Error Correction: Representation, Estimation, and Testing.' *Econometrica* 55 (2): 251–276.

Fatai, K., L. Oxley, and F. G. Scrimgeour. 2004. 'Modelling the Causal Relationship between Energy Consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines And Thailand.' *Mathematics and Computers in Simulation* 64 (3–4): 431–445.

Fowowe, B. 2012. 'Energy Consumption and Real GDP: Panel Co-Integration and Causality Tests for Sub-Saharan African Countries.' *Journal of Energy in Southern Africa* 23 (1): 8–12.

Fuinhas, J. A., and A. C. Marques. 2012. 'Energy Consumption and Economic Growth Nexus in Portugal, Italy, Greece, Spain and Turkey: An ARDL Bounds Test Approach (1965–2009).' *Energy Economics* 34 (2): 511–517.

Ghali, K. H., and M. I. T. El-Sakka. 2004. 'Energy Use and Output Growth in Canada: Multivariate Cointegration Analysis.' *Energy Economics* 26 (2): 225–258.

Ghosh, S. 2002. 'Electricity Consumption and Economic Growth in India.' *Energy Policy* 30:125–129.

Glasure, Y. U., and A. R. Lee. 1997. 'Co-Integration, Error-Correction, and the Relationship between GDP and Energy: The Case of South Korea and Singapore.' *Resource and Energy Economics* 20 (1): 17–25.

Ho, C. Y., and K. W. Siu. 2007. 'A Dynamic Equilibrium of Electricity Consumption and GDP in Hong Kong: An Empirical Investigation.' *Energy Policy* 35:2507–2513.

Jumbe, C. B. L. 2004. 'Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi.' *Energy Economics* 26 (1): 61–68.

Kraft, J., and A. Kraft. 1978. 'On the Relationship between Energy and GNP.' *Journal of Energy and Development* 3 (2): 401–403.

Lee, C. C. 2005. 'Energy Consumption and GDP in Developing Countries: A Cointegrated Panel Analysis.' *Energy Economics* 27 (3): 415–427.

Mahadevan, R., and J. Asafu-Adjaye. 2007. 'Energy Consumption, Economic Growth and Prices: A Reassessment Using Panel VECM for Developed and Developing Countries.' *Energy Policy* 35:2481–2490.

Masih, A. M. M., and R. Masih. 1997. 'On Temporal Causal Relationship between Energy Consumption, Real Income and Prices: Some New

Evidence from Asian Energy Dependent NICs Based on a Multivariate Cointegration/Vector Error Correction Approach.' *Journal of Policy Modelling* 19 (4): 417–440.

Muhammad, S. D., M. Usman, M. Muhajid, and G. R. Lakhan. 2013. 'Nexus between Energy Consumption and Economic Growth: A Case Study of Pakistan.' *World Applied Sciences Journal* 24 (6): 739–745.

Murray, D. A., and G. D. Nan. 1994. 'A Definition of the Gross Domestic Product-Electrification Interrelationship.' *Journal of Energy and Development* 19 (2): 275–283.

Narayan, P. K., and A. Prasad. 2008. 'Electricity Consumption-Real GDP Causality Nexus: Evidence from a Bootstrapped Causality Test for 30 OECD Countries.' *Energy Policy* 36:910–918.

Narayan, P. K., and B. Singh. 2007. 'The Electricity Consumption and GDP Nexus for Fiji Islands.' *Energy Economics* 29 (6): 1141–1150.

Narayan, P. K., and R. Smyth. 2005. 'The Residential Demand for Electricity in Australia: An Application of the Bounds Testing Approach to Cointegration.' *Energy Policy* 33:467–474.

Njindan, I. B. 2013. 'Financial Deepening, Trade Openness, and Economic Growth in West Africa.' MPhil Thesis, University of Ghana, Legon.

Odhiambo, N. M. 2009a. 'Energy Consumption and Economic Growth Nexus in Tanzania: An ARDL Bounds Testing Approach.' *Energy Policy* 37:617–622.

———. 2009b. 'Electricity Consumption and Economic Growth in South Africa: A Trivariate Causality Test.' *Energy Economics* 31 (5): 635–640.

———. 2009c. 'Savings and Economic Growth in South Africa: A Multivariate Causality Test.' *Journal of Policy Modelling* 31 (5): 708–718.

———. 2010. 'Energy Consumption, Prices and Economic Growth in Three SSA Countries: A Comparative Study.' *Energy Policy* 38:2463–2469.

———. 2014. 'Energy Dependence in Developing Countries: Does the Level of Income Matter?' *Atlantic Economics Journal* 42 (1): 65–77.

Oh, W., and K. Lee. 2004. 'Energy Consumption and Economic Growth in Korea: Testing the Causality Relation.' *Journal of Policy Modelling* 26 (8–9): 973–981.

Ozturk, I., and A. Acaravci. 2010. '$CO_2$ Emissions, Energy Consumption and Economic Growth in Turkey.' *Renewable and Sustainable Energy Reviews* 14 (9): 3220–3225.

———. 2011. 'Electricity Consumption and Real GDP Causality Nexus: Evidence from ARDL-Bounds Testing Approach for 11 MENA Countries.' *Applied Energy* 88 (8): 2885–2892.

Ouedraogo, N. S. 2013. 'Energy Consumption and Economic Growth: Evidence from the Economic Community of West African States (ECOWAS).' *Energy Economics* 36 (c): 637–647.

Pao, H., and C. Tsai. 2010. 'CO$_2$ Emissions, Energy Consumption and Economic Growth in BRIC Countries.' *Energy Policy* 38 (12): 7850–7860.

Pesaran, M. H., and Y. Shin. 1999. 'An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis.' In *Econometrics and Economic Theory in the 20thCentury,* edited by S. Storm, 371–413. Cambridge: Cambridge University Press.

Pesaran, M. H., Y. C. Shin, and R. Smith. 2001. 'Bound Testing Approaches to the Analysis of Level Relationships.' *Journal of Applied Econometrics* 16 (3): 289–326.

Saghir, J. 2002. 'Energy and Poverty: Talking Points.' Paper Read at the WSSD Summit, Johannesburg, 26 August–4 September.

Shahbaz, M., S. Khan, and M. I. Tahir. 2013. 'The Dynamic Links between Energy Consumption, Economic Growth, Financial Development and Trade in China: Fresh Evidence from Multivariate Framework Analysis.' *Energy Economics* 40:8–21.

Solarin, S. A., and M. Shahbaz. 2013. Trivariate Causality between Economic Growth, Urbanisation and Electricity Consumption in Angola: Cointegration and Causality Analysis. *Energy Policy* 60: 876–884.

Soytas, U., and R. Sari. 2003. 'Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets.' *Energy Economics* 25 (1): 33–37.

Stern, D. I., and K. Enflo. 2013. 'Causality between Energy and Output in the Long-Run.' *Energy Economics* 39:135–146.

Tsani, S. Z. 2010. 'Energy Consumption and Economic Growth: A Causality Analysis for Greece.' *Energy Economics* 32 (3): 582–590.

Wesseh Jr., P. K., and B. Zoumara. 2012. 'Causal Independence between Energy Consumption and Economic Growth in Liberia: Evidence from a Non-Parametric Bootstrapped Causality Test.' *Energy Policy* 50:518–527.

Wolde-Rufael, Y. 2004. 'Disaggregated Energy Consumption and GDP: The Experience of Shanghai, 1952–1999.' *Energy Economics* 26 (1): 69–75.

———. 2006. 'Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries.' *Energy Policy* 34(10): 1106–1114.

———. 2009. 'Energy Consumption and Economic Growth: The Experience of African Countries Revisited.' *Energy Economics* 31 (2): 217–224.

World Bank. 2014. *World Development Indicators.* Washington, DC: The World Bank.

Yang, H. 2000. 'A Note on the Causal Relationship between Energy and GDP in Taiwan.' *Energy Economics* 22 (3): 309–317.

Yoo, S. H. 2005. 'Electricity Consumption and Economic Growth: Evidence from Korea.' *Energy Policy* 33 (12): 1627–1632.

Yu, E. S. H., and J. Y. Choi. 1985. 'The Causal Relationship between Energy and GNP: An International Comparison.' *Journal of Energy and Development* 10 (2): 249–272.

Zhang, Y.-J. 2011. 'Interpreting the Dynamic Nexus between Energy Consumption and Economic Growth: Empirical Evidence from Russia.' *Energy Policy* 39 (5): 2265–2272.

Zhang, X. P., and X. M. Cheng. 2009. 'Energy Consumption, Carbon Emissions, and Economic Growth in China.' *Ecological Economics* 68 (10): 2706–2712.