FOREIGN DIRECT INVESTMENT AND ELECTRICITY CONSUMPTION ON ECONOMIC GROWTH: EVIDENCE FROM SOUTH AFRICA*

1. Introduction

In emerging markets, the shortage of domestic capital (savings) makes international capital inflows a critical component of the available capital pool. Other than portfolio flows ('hot money') and loans, the much sought after component of international capital flows is foreign direct investment (FDI). Economic literature is full of a plethora of both theoretical and empirical studies on the impact of FDI on economies of the host countries. For the most part, FDI inflows are not just restricted to supplementing savings in the host country. The assertion is that FDI represents a medium for acquiring skills, technology, organizational and managerial practices, and access to markets. Thus, FDI flows are expected to generate a positive impact on economic growth in the host country. However, various studies point to the conditional nature of the effect of FDI on economic growth. The proposition being that positive benefits from FDI are *conditional* on the host country's absorptive capacity as reflected mainly in its stock of human capital and/or electricity consumption[1].

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[1] More often than not, we have no prior knowledge of the threshold/cut-off level of human capital that is critical to the impact of FDI on economic growth. The usual approach is to estimate the threshold level of human capital that is critical in determining whether FDI has a positive or negative impact on economic growth. Econometric models often include additional variables that affect economic growth such as the degree of openness (the ratio of exports plus imports to GDP), the relative interest rate (US and host country), measures of financial depth, and political instability (crudely measured by inflation rates). Since the data on human capital is not available for South Africa for all the years, we do not pursue this approach in this paper.

The purpose of this paper is to examine the interrelationships between economic growth, electricity consumption and foreign direct investment (FDI) using South African time series. The debate whether such an interrelationship exists in South Africa today is a subject of a growing interest in policy formulation. On January 31, 2008, one of the leading politicians, Mr. Mangosuthu Buthelezi, seemed to appreciate such interrelationships. He challenged the assertion made by the Minister responsible for state-owned industries (for example, ESKOM) that the economy would continue to grow at 4% to 5% until 2010 even if demand for electricity could be reduced. Buthelezi rejected that assertion by noting:

> "economic growth and investment are intimately tied up with market sentiments in the global economy. If perception takes hold that South Africa cannot meet its energy needs, foreign investors, already scarce, may stay away[2]".

STATSA, the national statistical body that publishes all statistics, recently reported that electricity rationing and unplanned outages have reduced the quarterly economic growth rate from 4.53% (2007Q4) to 2.1% (2008Q1) – the slowest growth rate in six years[3]. We contribute to the debate by employing the bounds testing approach to cointegration and the methodology of Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996) to investigate linear causality interrelationships in electricity consumption, foreign direct investment, and economic growth.

There is extensive literature on the nexus between economic growth and electricity consumption. Similarly, the literature on economic growth and foreign direct investment is also extensive. For the most part, these studies focus on estimating bivariate models only. The purpose and contribution of our study is threefold. First, we extend the analysis of relationship between electricity consumption and economic growth to the *only* emerging economy in Africa, South Africa[4]. Second, we investigate cointegration and causality via the bounds test and the Toda and Yamamoto approaches respectively. These techniques are more suitable for small samples, such as the

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[2] See "Mangosuthu Buthelezi's Weekly Newsletter to the Nation" at http://ifp.org.za/Newletters/080131wn.htm.

[3] See de Lange (The STAR, May 29, 2008), "Electricity crisis is still serious", at http://www.int.iol.co.za/Index.php.

[4] South Africa is part of CIBS (China, India, Brazil, and South Africa) – large emerging economies.

48 observations in this paper. Third, we merge the growth-electricity consumption and growth-foreign direct investment literature by examining the interrelationships between economic growth, electricity consumption and foreign direct investment. We employ a bounds test cointegration methodology and Granger non-causality procedure developed by Toda and Yamamoto. By going beyond the traditional two-variable VAR model to a three-variable model, we avoid the possible misspecification bias inherent in the former.

According to Nayaran and Singh (2007), the relationship between energy and economic growth has seen extensive debate in the literature, but the direction of causality remains unresolved. The critical issue in the debate is whether energy consumption (usually represented by electricity consumption) causes economic growth or economic growth causes electricity consumption. Ghosh (2002), Asafu-Adjaye (2000), Nayaran and Smyth (2005a) and Nayaran and Singh (2007) among others suggest the resolution of the causality issue is important for formulating policy. On the other hand, a positive unidirectional causality from economic growth to electricity consumption can be used as a basis for energy conservation policies such as rationing (load shedding in South Africa) since such causality indicates that a country is not dependent on electricity for economic growth[5].

On the hand, if causality runs from electricity consumption to GDP or foreign direct investment, rationing of electricity consumption (load shedding) might lead to reductions in both GDP and foreign direct investment. Under this scenario, a country is deemed energy dependent and negative energy shocks such as high prices, shortages, incidents on the transmission system, and exports under SAPP negatively affect both GDP growth and foreign direct investment. In fact, energy conservation policies, if implemented, would be costly in terms of economic growth[6].

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[5] In South Africa, the rationing of electricity reflects disequilibrium between demand and supply capacity. Rationing is termed 'load shedding' to reflect the ability of ESKOM to limit demand to consumers when there is insufficient power to be distributed. ESKOM is majority-owned by the government. It accounts for about 95% of generation and distribution of electricity consumed in the country, with the balance produced by private generators and municipal generators.

[6] Under the Southern African Power Pool (SAPP), power is imported and exported using the ESKOM Transmission system. A model that allows for structural breaks might be more suitable to capture the effects of reduced foreign direct investment. This paper does not allow for such breaks.

TABLE 1 - *Growth of Real GDP, Electricity Consumption, Foreign Direct Investment and Population, 1960-2007*

Year	Electricity Consumption growth rate (%)	Foreign Direct Investment growth rate (%)	Population growth rate (%)	Real GDP growth rate (%)	Electricity Consumption growth rate to GDP growth ratio	Foreign Direct Investment to GDP growth ratio
1960-1970	7.66	10.1	2.61	5.6	1.37	1.80
1971-1980	6.96	8.71	2.58	3.50	1.99	2.49
1981-1990	8.71	**-133.7**	2.31	0.90	5.36	**-148.56****
1991-2000	2.58	**-0.42**	2.07	2.22	1.18	**-0.19**
2001-2007	3.50	26.9	0.73	4.56	0.79	5.90

Source: Author's calculations from data obtained from South African Reserve Bank (SARB), UN Database sources.

Table 1 shows the growth rates of electricity consumption, foreign direct investment, and population for South Africa. For all 10-year intervals, the growth rate of electricity consumption has been greater than real GDP growth. With the exception of the 1991-2000 and 2001-2007 periods, electricity consumption increased for all periods while real GDP growth hit an all-time low in period 1981-1990. The electricity consumption growth rate-to-GDP growth rate steadily increased from the 1960s before falling in periods 1991-2000 and 2001-2007. The period 2001-2007 masks many problems in the South African economy such as increasing consumption of electricity partly reflects rapid urbanization (mainly Africans) unimpeded by apartheid laws as before, increasing rural electrification, and generally low prices for electricity throughout South Africa. Under normal circumstances, a growth rate of 4.56% in real GDP and a 3.50% growth rate in electricity consumption would be enough to support economic growth. However, for more than ten years since 1994, South Africa did not invest in expanding supply capacity of ESKOM due to bureaucratic ineptitude. Thus, the current load shedding is likely to constrain both economic growth and foreign direct investment if causality runs from electricity consumption to these two variables.

Foreign direct investment flows to South Africa over the past fifty years partly reflect the sensitivity of foreign capital to the practice of *apartheid* that ended in 1994. The 10-year interval, 1981-1990 saw

foreign direct investment fall by 134%[7]. In 1985, overseas private banks withdrew trade credit flows to South Africa firms in response to disinvestment pressures in their home countries. The drying-up of foreign direct investment continued until 1991 when financial ties were restored once it was clear that *apartheid* would end with the 1994 democratic elections. While electricity consumption remained high at 8.75%, real GDP growth fell from an average of 3.50% (1971-1980) to 0.90% in 1981-1990. For the 2001 to 2007 period, foreign direct investment and economic growth rebounded to 26.9% and 4.56%, respectively. The ratio of foreign direct investment growth-to-GDP growth also rebounded from -149 (1981-1990) to 5.90 in 2001-2007.

With steady population growth, the relationship between foreign direct investment and economic growth is clearly a positive one. However, the relationship of electricity consumption to economic growth and foreign direct investment is not obvious in Table 1. The current electricity shortages in South Africa are due to increased demand caused by years of economic growth, and the provision of electricity to townships (where a majority of Africans live) that were not connected to the power grid during the *apartheid* years. A major reason for the current electricity rationing is failure to heed seriously the warning from ESKOM in 1997 that without funding ESKOM's capital expansion to build more power plants, the parastatal would not be able to meet demand by 2007[8].

Earlier this year, Alec Erwin, the Minister of Public Enterprises (ESKOM is a public enterprise) suggested that the economy would continue to grow at the rate of 4%-5% until 2010 if only demand for electricity could be reduced. As correctly pointed by Mangosuthu Buthelezi (leader of the Inkatha Freedom Party, IFP, the main opposition party), Alec Erwin failed to recognize that

"in a global economy, economic growth and investment are closely related to investor's (domestic and foreign) perceptions[9]. If foreign investors conclude that South Africa cannot meet its energy demand, foreign investment inflows may dry up[10]".

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[7] Some studies report even larger drops in foreign direct investment during this period.

[8] A parastatal is a public enterprise or state-owned enterprise.

[9] See "Mangosuthu Buthelezi's Weekly Newsletter to the Nation" at http://ifp.org.za/Newletters/080131_wn.htm

[10] See "Mangosuthu Buthelezi's Weekly Newsletter to the Nation" at http://ifp.org.za/Newletters/080131_wn.htm

Similarly, domestic investors, particularly in the mining and manufacturing industry may reduce investment. The statement by the Minister implicitly placed a ceiling of 5% on economic growth when South Africa needs to grow its economy at a much higher rate to reduce growing unemployment, particularly that of the youth. This paper seeks to examine the interrelationships between electricity consumption, foreign direct investment and economic growth within a time series framework.

The paper is organized as follows. Section 2 provides a brief overview of the literature on electricity-economic growth nexus and foreign direct investment-economic growth nexus. Section 3 presents the econometric methodologies, the bounds test and the Toda and Yamamoto Granger non-causality procedure. In Section 4, we discuss the results followed by Section 5 that provides concluding remarks.

2. Literature on electricity consumption-economic growth and foreign direct investment-economic growth

2.1 Electricity Consumption and Economic Growth

As expected, studies on the nature of relationship between economic growth and electricity consumption are mixed: some studies point to causality running from economic growth to electricity consumption, while others find causality running from electricity consumption to economic growth. The purpose of this review is to provide an overview of the relationship and place this paper on South Africa in the context of these studies[11].

The studies on electricity consumption and economic growth can be arranged into four categories[12]. First are studies that find unidirectional causality from economic growth to electricity consumption. Under this category, this is the case of Hatemi-J and Irandoust (2005) for Sweden in 1965-2000, Ghosh (2002) for India in 1950-1997, and Fatai *et al*. (2004) for New Zealand and Australia in 1960-1999. Second are studies that find unidirectional causality from electricity consumption to economic growth. Under this category are

[11] Nayaran and Singh (2007), Nayaran and Smyth (2005b), Wolde-Rufael (2004, 2006), Dunkerley (1982), Ebohon (1996), and Ciarreta and Zarraga (2007) provide an excellent review of the literature.

[12] Section 2 relies heavily on Nayaran and Singh (2007), Wolde-Rufael (2004, 2006) and Ciarreta and Zarraga (2007).

studies by Lee and Chang (2005) for Taiwan in 1954-2003, Shiu and Lam (2004) for China in 1971-2000, Soytas and Sari (2003) for Turkey, France, Germany and Japan in 1950-1992, and Altnay and Karagol (2005) for Turkey in 1950-2000. Third are studies that find bi-directional causality between electricity consumption and economic growth. Under this category are studies by Oh *et al*. (2004) for South Korea in 1970-1999, Yoo (2006) for South Korea in 1970-2002, Soytas and Sari (2003) for Argentina in 1950-1990, and Ho and Siu (2007) for Hong Kong in 1966-2002. Finally, there are studies that find no relationship at all as in Cheng (1995) and Stern (1993) for the US in 1947-1990, Wolde-Rufael (2006) who finds a mixture of results for various African countries, and Squalli and Wilson (2006) find a mixture of all categories for the Cooperation Council for Arab States of the Gulf (GCC) countries.

In the case of African countries (South Africa in particular), Wolde-Rufael (2005) fail to find any relationship between electricity consumption and real GDP for South Africa. Wolde-Rufael (2006) established that cointegration exists between real GDP *per capita* and electricity consumption *per capita* with the former as the dependent variable. However, he failed to find any causality between electricity consumption and real GDP. Thus, South Africa falls under the fourth category as explained above[13]. Whether causality exists between real GDP and electricity consumption in South Africa remains subject to empirical debate.

2.1.1 Foreign Direct Investment and Economic Growth

The adoption of a more liberal policy towards foreign direct investment (FDI) by many developing countries in the mid-1980s spurred many studies on the interaction of FDI and economic growth. Relevant literature can be divided into three categories. The first focuses on the role of factors that explain the existence of transnational firms. The hypothesis associated with this view suggests causality running from economic growth to FDI (*growth-driven FDI*). The literature suggests that FDI is attracted to host

[13] *"However, even for South Africa, the largest consumer of electricity in both absolute and in per capita terms, there is no causality in any direction between electricity consumption per capita and per capita GDP"*. See Footnote 7 in Wolde-Rufael (2006:1113).

countries because of relatively expected higher returns. FDI inflows tend to increase with domestic demand for capital that is generated by high economic growth in the destination economy. Tanna and Topaiboul (2005) suggest that additional factors such as the existence of economies of scale, infrastructure, political stability, improvements in human capital, and a stable macroeconomic environment associated with economic growth further increases the marginal rate to capital. Zang and Markusen (1995) present evidence that better economic performance in host countries is attractive to foreign investors interested in increasing their profits.

The second category is founded on growth theory in which FDI is included as one of the proximate factors (in addition to labor and capital) in explaining real GDP growth via spillovers or technology transfer[14]. In this category, causality runs from FDI to economic growth (*FDI-led economic growth*).

Despite the inclusion of FDI in models of economic growth, traditional growth theories confine the impact of FDI to the *short-run* level of income because of diminishing returns to capital in the long run. However, recent studies point to an endogenous long-run role of FDI in economic growth determination[15]. The rise of endogenous growth models has made it possible to model FDI as promoting economic growth even in the long run through the permanent transfer of knowledge that accompanies FDI.

Other externalities, such knowledge transfer, remove the onset of diminishing returns such that FDI contributes to economic growth. In other words, technology spillovers from advanced to emerging countries are in the form of FDI flows. According to De Mello (1997), Bengoa and Sanchez-Robles (2003), Buckley *et al*. (2002), and Borenszstein *et al*. (1998), the extent to which FDI positively contributes to economic growth depends on the degree of complementarity and substitution between domestic capital and FDI, other country-specific characteristics, savings, the existence of an open trade regime, ability of local firms to absorb FDI and other factors[16]. In other words, the positive effect of FDI on

[14] Tanna and Topaiboul (2005), Das (1987), Rodriguez-Clare (1996), Balasubramanyam *et al*. (1996).

[15] De Mello (1997) provides a thorough survey of these studies. In addition, see Nayaran and Smyth (2005a).

[16] Recent work by Ford *et al*. (2008) suggest that the lack of finding positive spillovers from FDI in many studies of the FDI-economic growth nexus is due to the failure of these studies to account for local firms' ability

economic growth is *conditional* on human capital, skills, and adequate infrastructure (proxied by electricity consumption in this paper). However, some studies show that FDI may have a negative effect on economic growth if capital inflows result in substantial reverse outflows in the form of remittances of profits, interest income, and dividends and/or if foreign investors are able to extract substantial concessions from the host country[17].

The third category points to bi-directional causality where FDI and economic growth are interdependent. In this case, it is possible for a host economy to enjoy the benefits of a virtuous cycle – more FDI leads to higher economic growth that in turn, increases FDI inflows and so forth. Since the causality relationship (if it exists) between FDI and economic growth may run in either directions, one must empirically test for the direction of causality in bivariate form before the inclusion of a third variable, electricity consumption.

Nayaran and Singh (2007) report that the use of the bounds testing approach to cointegration and the Granger causality test to examine the relationship between economic growth and electricity consumption usually includes an additional variable. Chang *et al*. (2001), Fatai *et al*. (2004), and Nayaran and Smyth (2005a) include the employment variable. Girma (2003) and Borenszstein *et al*. (1998) use some measure of human capital while Masih and Masih (1997) include energy prices. Nayaran and Singh (2007) include the labor force variable[18]. For the most part, the choice of a variable to be included seems to be dictated by the influence it has on economic growth and FDI and by the availability of data for that variable. Tsikata *et al*. (2000) study on determinants of foreign direct investment (FDI) in Ghana notes that a feature of FDI is a three-way interrelationship of political stability, investment and economic growth. Thus, studies in this area increasingly augment the bivariate

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to adopt foreign technology. In a study that uses data from 48 US states, they provide evidence that FDI (measured by foreign control of the US economy in non-bank employment) contributes more to economic growth than domestic investment when a minimum human capital threshold is realized.

[17] Seabra and Flach (2005).

[18] They found unidirectional causality from GDP to electricity running and from economic growth to electricity consumption. The inclusion of additional variables serves many purposes. It often accounts for some omitted variables. Furthermore, these are often variables of interest to the study. For example, including employment serves to examine the relationship of economic growth, electricity consumption and employment effects.

relationship between FDI and economic growth by adding a third variable[19]. In the paper, electricity consumption has an impact on both FDI and economic growth and data is widely available[20].

3. The empirical methodology

3.1 The Bounds Test Approach to Cointegration

Since most time series data have unit roots, the usual approach is to test for unit roots prior to establishing long-run cointegration (see Table 2). For the most part, the widely used procedures require that all series be integrated of order one or I(*I*) if meaningful inferences are to be drawn from such analysis. If the series are not I(*I*) or are integrated of different orders, no test for a long-run relationship can be performed. However, widely used unit root tests such as the ADF and PP tend to have low power against alternative hypothesis of stationarity; the results from these tests suffer from pre-testing bias.

Table 2 - *Results of the ADF and PP Unit Roots Tests*

Variable	Augmented Dickey-Fuller (ADF) test		Phillips-Perron (PP) test	
	Level Form	First Differences	Level Form	First Differences
GDP	-1.60 (3)	-3.68(1)*	-1.86(3)	-6.11(1)*
Kwh	-1.89(2)	-6.67(1)*	-1.76(3)	-3.73(1)*
FDI	-1.56 (2)	-2.95(1)*	-1.99(2)	-5.96(3)*

Notes: The number in parentheses are the optimum number of lags determined using the SBC information criteria. * denotes the rejection of the null hypothesis at the 5% significance level. For the ADF and PP, the significance levels are 1% (3.96), 5% (-3.51), 10% (-3.13).

All test statistics are less (in absolute value) than the critical value of 3.51. Thus, it is not possible to reject the null of a unit root

[19] See Tshikata *et al*. (2000).

[20] Human capital is also a critical variable for South Africa, given the skill shortages. However, this data is missing for many years, particularly the period 1960-1994 – *apartheid* years. Electricity consumption data (not supply) is available.

for all variables in level form. Similarly, all test statistics (absolute value) are greater than the critical value of 3.51 for variables in first difference form. Since the bounds test can be implemented without regard to the order of integration, we test whether there exists a linear combination of individual non-stationary which is stationary itself using models (1)-(3) below.

Pesaran *et al*. (2001) cointegration test, the autoregressive distributed lag (ARDL) procedure or bounds test do not require stationary pre-testing and can be used whether the variables are I(0), I(*I*), or mutually cointegrated. If the series are integrated of the same order, then Engle and Granger (1987), Johansen (1988) or Johansen and Juselius (1990) tests for integration are valid. However, tests for cointegrating ranks (in a model with more than two variables) are sensitive to the nuisance parameters in case of small samples. The bounds test is more appropriate for finite or small samples in which the order of integration is unknown or not the same for all variables. The test consists of estimating the following unrestricted error correction models (UECM):

$$\Delta \ln gdp_t = \alpha_{0gdp} + \sum_{i=1}^{k} \beta_{igdp} \Delta \ln gdp_{t-i} + \sum_{i=1}^{k} \theta_{igdp} \Delta \ln kwh_{t-i} + \sum_{i=1}^{k} \phi_{igdp} \Delta fdi_{t-i} + \lambda_{1gdp} \ln gdp_{t-1} + \lambda_{2gdp} \ln kwh_{t-1} + \lambda_{3gdp} fdi_{t-1} + \varepsilon_{1t} \quad (1)$$

$$\Delta \ln kwh_t = \alpha_{0kwh} + \sum_{i=1}^{k} \beta_{ikwh} \Delta \ln kwh_{t-i} + \sum_{i=1}^{k} \theta_{ikwh} \Delta \ln gdp_{t-i} + \sum_{i=1}^{k} \phi_{ikwh} \Delta fdi_{t-i} + \omega_{1kwh} \ln gdp_{t-1} + \omega_{2kwh} \ln kwh_{t-1} + \omega_{3kwh} fdi_{t-1} + \varepsilon_{2t} \quad (2)$$

$$\Delta \ln fdi_t = \alpha_{0fdi} + \sum_{i=1}^{k} \beta_{ifdi} \Delta fdi_{t-i} + \sum_{i=1}^{k} \theta_{ifdi} \Delta \ln gdp_{t-i} + \sum_{i=1}^{k} \phi_{ifdi} \Delta \ln kwh_{t-i} + \psi_{1fdi} \ln gdp_{t-1} + \psi_{2fdi} \ln kwh_{t-1} + \psi_{3fdi} fdi_{t-1} + \varepsilon_{3t} \quad (3)$$

Model	Null Hypothesis	Alternative Hypothesis
Model (1)	$\lambda_{1gdp} = \lambda_{2gdp} = \lambda_{3gdp} = 0$	$\lambda_{1gdp} \neq \lambda_{2gdp} \neq \lambda_{3gdp} \neq 0$
Model (2)	$\omega_{1kwh} = \omega_{2kwh} = \omega_{3kwh} = 0$	$\omega_{1kwh} \neq \omega_{2kwh} \neq \omega_{3kwh} \neq 0$
Model (3)	$\Psi_{1fdi} = \Psi_{2fdi} = \Psi_{3fdi} = 0$	$\Psi_{1fdi} \neq \Psi_{2fdi} \neq \Psi_{3fdi} \neq 0$

Here, ln *gdp*, ln *kwh*, *fdi* represent the log of real GDP, electricity consumption and foreign direct investment, respectively. Since some of the data points for foreign direct investment have negative values, we use the growth rate instead of takings logs. The bounds test

is completed by estimating each of the three equations, then re-estimating each after excluding long-run terms. For example, in (1) re-estimation excludes the terms lm gdp_{t-1}, ln kwh_{t-1}, fdi_{t-1}.

An F-statistic is then computed and compared to the non-standard critical bounds values reported in Pesaran *et al*. (2001) [Nayaran and Smyth (2005b) adjust these values for sample size 30 to 80[21]]. If the computed F-statistic exceeds the critical upper bound value, the null hypothesis of no cointegration is rejected. However, if the computed F-statistic lies below the critical lower bound value, the null hypothesis of no cointegration cannot be rejected. If the computed F-statistic falls between the critical upper bound and the critical lower bound value, no conclusion can be reached about cointegration without additional information on the order of integration of the variables. The appropriate lag structure is determined by Akaike Information Criterion (AIC), Schwartz Bayesian Criterion (SBC), and the Hannan-Quinn Criteria (HQC). Since the SBC criterion tends to choose a more parsimonious model, we use this criterion in the paper. The F-tests determine the appropriate model from (1) to (3) with evidences of a long-run relationship. The added advantage of the ARDL procedure is that an error correction term (ECM) is included as an explanation variable so that one obtains an assessment of how fast the relationships between electricity consumption, FDI and economic growth revert to a long-run equilibrium path.

3.2 The Toda-Yamamoto and Dolado-Lutkepohl Approach to Granger Causality Test

The standard Granger causality test in VAR or autoregressive model uses a simple F-test to jointly test whether the parameters of specified equations are zero. However, the use of this method requires that the series (in our case ln *gdp*, ln *kwh*, and *fdi*) be stationary, since using non-stationary data can yield spurious results (Toda and Phillips, 1983).

When the series are non-stationary, they may be also cointegrated even if individual series are non-stationary if there is a stable relationship among the series. In this case, cointegration guarantees

[21] The critical value bounds reported in Pesaran and Pesaran (1997) in Tables F and W are from simulations for T=500 and 20,000 replications. Our sample size, being so small, necessitates such an adjustment.

the existence of Granger causality between the series in at least one direction. On the other hand, if the series are integrated but not cointegrated, causality tests can still be implemented by estimating a VAR in first differences of the series to achieve stationarity, and the standard asymptotic theory is valid for hypothesis testing (Ciarreta and Zarraga, 2007.) If the series are integrated of the same order, then Engle and Granger (1987), Johansen (1988) or Johansen and Juselius (1990) tests for integration are valid. However, tests for cointegrating ranks (in a model with more than two variables) are sensitive to the nuisance parameters in the case of small samples.

Dolado and Lutkepohl (1996) and Toda and Yamamoto (1995) have suggested a possible solution in the form of estimating a VAR for the series in *levels* and testing general restrictions on the parameter matrices even if the series are integrated or cointegrated. They suggest a modified version of the Granger causality test that involves a modified Wald (MWald) test in an intentionally augmented VAR model. The procedure involves first establishing the optimal order of the VAR process k, using AIC, SBC and HQC information criteria. Once the optimal lag or order is established, Toda and Yamamoto (1995) suggest estimating a $VAR(k+d_{max})$ model where $d_{\max}$ is the maximal order of integration that captures the data generation process. Once the estimation is carried out, linear or non-linear restrictions on, the k coefficients of the model can be tested using standard Wald tests ignoring the last $d_{\max}$ lagged variables. Dolado and Lutkepohl (1996) also propose an augmented VAR with the difference that they add only one lag to the true model. Thus, they suggest the estimation of a $VAR(k+1)$. Once the model is estimated, one performs the standard Wald tests ignoring the last lag of the vector or lagged variables [these are indexed by $j=k+1$ in (4)-(6)]. The model is estimated using seemingly unrelated regression (SUR)[22]. To estimate the Toda and Yamamoto version of the Granger non-causality test, we represent the economic growth-electricity consumption-FDI model in the following VAR system:

$$\ln gdp_t = \beta_0 + \sum_{i=1}^{k} \beta_i \ln gdp_{t-i} + \sum_{j=k+1}^{d} \beta_i \ln gdp_{t-j} + \sum_{i=1}^{k} \theta_i \ln kwh_{t-i} + \sum_{j=k+1}^{d} \theta_i \ln kwh_{t-j} + \sum_{i=1}^{k} \phi_i fdi_{t-i} + \sum_{j=k+1}^{d} \phi_i fdi_{t-j} + \varepsilon_{1t} \quad (4)$$

[22] For details on implementing the SUR and the calculation of the MWALD statistic using established packages, see Rambaldi and Doran (1996).

$$\ln kwh_t = \theta_0 + \sum_{i=1}^{k} \theta_i \ln kwh_{t-i} + \sum_{j=k+1}^{d} \theta_i \ln kwh_{t-j} + \sum_{i=1}^{k} \phi_i fdi_{t-i} + \sum_{j=k+1}^{d} \phi_i fdi_{t-j} + \sum_{i=1}^{k} \beta_i \ln gdp_{t-i} + \sum_{j=k+1}^{d} \beta_i \ln gdp_{t-j} + \varepsilon_{2t} \quad (5)$$

$$fdi_t = \phi_0 + \sum_{i=1}^{k} \phi_i fdi_{t-i} + \sum_{j=k+1}^{d} \phi_i fdi_{t-j} + \sum_{i=1}^{k} \theta_i \ln kwh_{t-i} + \sum_{j=k+1}^{d} \theta_i \ln kwh_{t-j} + \sum_{i=1}^{k} \beta_i \ln gdp_{t-i} + \sum_{j=k+1}^{d} \beta_i \ln gdp_{t-j} + \varepsilon_{3t} \quad (6)$$

Define $V_1=\{\theta_1=\ldots=\theta_p\}$, $V_2=\{\beta_1=\ldots=\beta_p\}$, V3= $\{\phi_1=\ldots=\phi_p\}$ where $\varepsilon_{1t},\varepsilon_{2t},\varepsilon_{3t}$ are serially independent random error terms with mean zero and a finite covariance matrix. Causality tests are carried out by generating χ^2 statistics to establish whether the null hypotheses can be accepted or not. The hypotheses are stated as below. The null hypotheses for (4), (5), and (6) are $V_1=0$ and $V_3=0$; $V_2=0$ and $V_3=0$, and $V_1=0$ and $V_2=0$ respectively. The advantages of these tests is that they are easy to calculate and do not require pre-testing for integration or cointegration of data series just as the bounds test[23].

4. Discussion of results

The data used in this study represent annual observations for the period 1960 to 2007. Most of the data used in this paper are from the United Nations Statistics Division (UNSD)[24]. All data are in South African Rands (ZAR) and include *per capita* electricity consumption, *per capita* real GDP, and *per capita* FDI. The series are extracted from the relevant databases by code number (UN data) and series kbp**** number (SARB). Electricity consumption in kWh (millions) (code 17520), GDP at market prices, current prices (code 19460), GDP deflator, base 2000 (code 30201) or GDP deflator, World Bank estimates (code 29920), and total population, estimates and projections (code 13660). An alternative source for GDP *per*

[23] Rambaldi and Doran (1996) illustrate this method in detailed examples.

[24] United Nations Statistics Division Common Database: http://unstats.un.org/unsd/cdb/cdb_series.

capita, constant 2000 prices (series kbp7270y) comes from the South African Reserve Bank database. FDI data come from two sources; the South African Reserve Bank (SARB) derived from two alternatives sources[25]. The first takes the differences between total liabilities (FDI) (series kbp 5640j) and total assets (FDI) (series kbp5656j) and the second alternative source is net FDI (series kbp5683j). These series are very close but there are differences reflecting the unsatisfactory manner in methods of recording FDI in the world.

We experimented with different data series for GDP, electricity consumption and FDI from these sources. Other than FDI data, all other data are expressed in logs. FDI has negative entries that prevent the taking of logs. Thus, FDI series used in the paper are expressed as growth rates of FDI *per capita* to real GDP *per capita*. The bounds test results are reported in Table 3.

TABLE 3 - *Tests for Cointegration*

F-Statistics	Exact 5% Critical Value Bounds*		Exact 1% critical Value Bounds*	
	I(0)	I(*I*)	I(0)	I(*I*)
	3.990	4.538	4.943	6.128
Calculated F Statistic $F_{gdp}(gdp \mid kwh, fdi) = F(3,22) = 7.0014[0.000]$ $F_{fdi}(fdi \mid gdp, kwh) = F(3,22) = 4.0200[0.0502]$ $F_{kwh}(kwh \mid gdp, fdi) = F(3,22) = 3.7185[0.456]$				

Note: * The critical values are from Nayaran and Smyth (2005b: 1113) for sample sizes between 30 and 80.

Table 3 shows that when electricity consumption is treated as a dependent variable, there is no long-run relationship among variables. When FDI is the dependent variable, the bounds test shows an F-statistic of 4.020 which falls between the lower and upper critical bounds. Thus, no conclusion can be reached with regard to cointegration. However, when GDP is the dependent variable, the bounds test shows an F-statistic of 7.0014 that is larger than the critical upper bound value of 4.538. This means that there is a single long-run relationship. The existence of one cointegrating

[25] The South African Reserve Bank: http://www.reservebank.co.za/.

relationship among electricity consumption, FDI, and economic growth implies that there must be Granger causality in at least one direction (Nayaran and Smyth, 2005b; Wolde-Rufael, 2005). However, cointegration does not indicate the direction of causality. Having found a long-run cointegration relationship among FDI, electricity consumption, and economic growth, we estimate model (1) using the ARDL (k=3) specification.

To begin with, we estimate (1) excluding the ECM term which is subsequently incorporated into the ARDL model. Since we have 48 observations, we experimented with various lags and ultimately chose three as the maximum lag using the SBC criteria. Pesaran and Smith (1998) argue that the SBC should be used in preference to other model specification criteria because it has a tendency to choose a more parsimonious specification. Since we have a small sample, the SBC chose three lags. The long-run results from ARDL (2, 0, 1) are reported in Table 4.

TABLE 4 - *Estimated Long Run Coefficients Using ARDL (2, 0, 1), Based on SBC Criterion: GDP is the Dependent Variable*

Regressor	Coefficient	Standard Error	*P*-value
kWh	0.531	0.023	0.000*
FDI	0.054	0.022	0.072**
INPT	7.223	0.286	0.000*
d=dummy	-0.041	0.033	0.232

Note: * and ** represent the level of significance at 5% and 1% respectively.

The long-run results show electricity consumption to be positively related to GDP since the coefficient of electricity consumption (0.531) is statistically significant at the 5% level. A one percent increase in electricity consumption leads to 0.53 percent growth in GDP. Similarly, FDI is positively related to GDP although the impact of the term is barely significant at 1% level of significance. The dummy (d) captures the restrictions of capital flows to South Africa imposed by overseas private banks and public entities over the practice of *apartheid*. The dummy variable was imposed from 1985 until 1991 when sanctions against South Africa were removed once it became clear that democratic elections would be held in 1994. Although the coefficient on the dummy variable has the correct sign, the term is

insignificant. A one percent reduction in FDI during these years reduced economic growth by 0.04 percent[26].

The short-run results are reported in Table 5. The one-period growth rate of GDP has a positive and significant impact on current growth (0.389). The importance of electricity consumption is shown by the significance of the current growth rate on economic growth. The elasticity of electricity consumption with respect to GDP is 0.276, which points to the dependence of South Africa's growth rate on energy. The dummy variable in the short run as in the long run carries the correct sign and remains insignificant. The growth rate of FDI negatively affects economic growth. The explanation may be that foreign investors react negatively to electricity rationing by reducing investment flows that in turn undermine economic growth. There is evidence that foreign investment in the first quarter of 2008 has declined. The projected growth rate has been revised downwards as GDP has not increased as expected largely due to disruptions in the service and mining sectors due to limited supply of electricity[27].

The lagged correction term, $ECM(-1)$ (-0.520) is statistically significant indicating the percentage of adjustment towards a long-run equilibrium in economic growth when electricity consumption and FDI are 'forcing variables'. Deviations from the long-run equilibrium are corrected by 0.52 percent over the following year. Banerjee *et al*. (1998) show that a highly significant error correction term is further evidence of a stable long-term relationship among variables. Figure 1 indicates that the model tracks economic growth reasonably except for the forecast period (see the Appendix.) When analyzing the stability of long-run coefficients together with short-run dynamics in these relationships, the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUM Square) show the in-sample stability of the model (see Figures 1 and 2 in the Appendix.) Specifically, the CUSUM test detects systematic changes in the regression coefficients while the CUSUM Square test is particularly useful for detecting sudden departures from the constancy of regression coefficients.

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[26] We experimented with an interactive variable, kWh*FDI. For the error correction model, the value is -0.011 [0.501] and for the long run, the coefficient is -0.023 [0.535]. Although the term is not significant in both short and long run, it does point to the negative effects of FDI and electricity consumption on economic growth.

[27] See de Lange (The STAR, May 29, 2008) "Electricity crisis is still serious" at http://www.int.iol.co.za/Index.php.

Table 5 - *Error Correction ARDL (2, 0, 1) Chosen by SBC: Dependent Variable is* Δ ln *gdp*

Regressor	Coefficient	Standard Error	T-Ratio [Prob]
Δ ln *gdp*(–1)	0.389	0.121	3.2[0.003]
Δ ln *kWh*	0.276	0.059	4.7[0.000]
Δ *fdi*	-0.003	0.171	-0.201[0.842]
Δ *Inpt*	3.759	0.762	5.594[0.000]
Δ *d=dummy*	-0.021	0.016	-1.321[0.195]
ECM(–1)	-0.520	0.100	-5.120[0.000]
$\bar{R}^2$=0.59425; F (5, 34)=12.624[0.000]			

ECM(–1) = ln gdo -0.531 ln *kWh* -0-054 *fdi* -7.22INPT + 0.041D

The underlying ARDL equation passes all the diagnostic tests (serial correlation, functional form, and heteroscedasticity) computed except the normality test that is not critical in these types of studies.

Causality among electricity, FDI and economic growth is tested using a modified Wald test (MWALD) suggested by Toda and Yamamoto (1995). The test is similar to the bounds test in that it does not require prior knowledge of the order of integration of the variables. Zapata and Rambaldi (1997) even suggest that it can be applied when cointegration does not exist. Although the bounds/ ARDL test failed to find cointegration when electricity consumption and FDI were dependent variables, it is legitimate to implement Granger non-causality tests as we do below. Zapata and Rambaldi (1997) and Toda and Yamamoto (1995) report that unlike the standard Granger causality test and the Johansen-Juselius tests, the Toda and Yamamoto test is less sensitive to problems associated with the residuals in finite samples. Since we found evidence of cointegration, we can estimate a VAR in *levels*, not *first differences*. The VAR system is estimated using a seemingly unrelated regression procedure[28]. The lag structure of the VAR (3+1 = 4) was determined using the SBC criteria and a standard Wald statistic as $\chi^2(7)$ – the modified Wald test (MWALD). The results are reported in Table 6.

[28] For similar approaches, see Wolde-Rufael (2005, 2006) and Rambaldi and Doran (1996).

TABLE 6 - *Toda/Yamamoto Causality Test*

Null Hypothesis	MWald-statistic	χ^2 (7) Critical Value	Decision
KWH and FDI does not Granger cause GDP	19.34	14.067	Reject Null
GDP and FDI does not Granger cause KWH	12.308	14.067	Do Not Reject Null
GDP and KWH does not Granger cause FDI	31.45	14.067	Reject Null

Both electricity consumption and FDI are significant at the 5% level. That is, the null hypothesis that electricity consumption (kWh) and foreign direct investment (FDI) do not 'Granger cause' GDP is rejected since the MWALD statistic (19.34) is greater that the $\chi^2(7)$ critical value (14.067). In addition, the null hypothesis that GDP and electricity consumption do not 'Granger cause' FDI is rejected at the same level of significance. However, the null hypothesis that GDP and foreign direct investment (FDI) do not 'Granger cause' electricity consumption is accepted. Hence, the idea that electricity consumption and foreign direct investment 'Granger cause' output growth is critically important for South Africa.

This result supports the statement by Mangosuthu Buthelezi in January 2008 that

"if foreign investors conclude that South Africa cannot meet its energy demand, foreign investment inflows may dry up. Similarly, domestic investors, particularly in the mining and manufacturing industry may reduce investment[29]".

Current rationing of electricity undermines FDI inflows that are crucial for South Africa's growth prospects as it deals with rising unemployment. The result that economic growth and electricity consumption Granger cause foreign direct investment is equally important in other ways. Electricity rationing in critical sectors such as mining, services, and manufacturing undermines their contribution to gross value added directly and indirectly through reductions in foreign direct investment.

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[29] See "Mangosuthu Buthelezi's Weekly Newsletter to the Nation", at http://ifp.org.za/Newletters/080131_wn.htm.

When taken together these causality results have important policy implications. They confirm that South Africa is an energy dependent economy. Thus, energy conservation policies that rely on rationing of electricity consumption negatively impact economic growth since high consumption induces economic growth and foreign direct investment. At the same time, high FDI supplements inadequate savings and stimulates investment and hence economic growth. Furthermore, higher economic growth and electricity consumption stimulates more foreign direct investment.

5. Concluding remarks

The paper used annual time series data from 1960 to 2007 to determine the interrelationship of electricity consumption, foreign direct investment and economic growth in South Africa. Given a small sample size, we employed the bounds test/ARDL methodology to establish if there exists a long-run relationship among the variables. This method is applicable to time series data irrespective of the order of integration. We established a long-run relationship (cointegration) only if GDP is the dependent variable with electricity consumption and foreign direct investment as 'forcing variables'.

We applied the ECM version of the ARDL model to estimate both long- and short-run coefficients of FDI and electricity consumption, allowing for a dummy variable (d) for years 1985 to 1991 when FDI was restricted by overseas private banks and other public entities. In addition, we obtained an expected and highly significant negative error correction coefficient that determines the speed of adjustment. The electricity consumption coefficient term is positive and highly significant in the short and long run. The FDI coefficient is positive and barely significant in the long run and negative and insignificant in the short run. We suspect that in the short run, foreign investors react negatively to electricity rationing and reduce FDI, resulting in reductions in economic growth.

With respect to causality, the null hypothesis that electricity consumption (kWh) and foreign direct investment (FDI) do not 'Granger cause' GDP is rejected. Similarly, the null hypothesis that GDP and electricity consumption do not 'Granger cause' FDI is rejected at the same level of significance. When taken together these causality results have important policy implications. They confirm that South Africa is an energy dependent economy. Thus, energy conservation policies that rely on rationing of electricity consumption

negatively impact economic growth, since high consumption induces economic growth and foreign direct investment. At the same time, high FDI supplements inadequate savings and stimulates investment and hence economic growth. Furthermore, higher economic growth and electricity consumption stimulates more foreign direct investment.

Our result differs from Wold-Rufael (2005) who failed to find any relationship between electricity consumption and real GDP for South Africa. However, Wolde-Rufael (2006) found cointegration but failed to find any causality between these two variables[30]. We find both cointegration and causality. The differences might be due to the data series used. His data are mainly from the World Development Indicators CD-Rom version 2004 while our data are mainly from the United Nations Statistical Database (UNSDB) and the South African Reserve Bank (SARB). The differences in data collection methods by these bodies might account for different results.

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[30] Wolde-Rufael (2005) points to the fact that "*South Africa had below average level of energy efficiency, in part due to the absence of energy conservation in the industrial sector*".

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ABSTRACT

This paper specifies a model in which we investigate the interrelationship of economic growth, electricity consumption and foreign direct investment. We find that foreign direct investment and electricity consumption are only cointegrated when GDP is the dependent variable. With respect to causality, the null hypothesis that electricity consumption (kWh) and foreign direct investment (FDI) do not 'Granger cause' GDP is rejected. Similarly, the null hypothesis that GDP and electricity consumption do not 'Granger cause' FDI is rejected at the same 5% level of significance. We find that electricity consumption and foreign direct investment Granger cause economic growth.

Keywords: ARDL, Toda and Yamamoto Granger Non-causality, South Africa, Augmented VAR

JEL Classification: F21, F32, F43, Q43

RIASSUNTO

Effetto degli investimenti diretti esteri e del consumo di elettricità sulla crescita economica: evidenze dal Sud Africa

Questo studio presenta un modello nel quale viene esaminata la relazione tra crescita economica, consumo di elettricità e investimenti diretti esteri. Si riscontra che gli investimenti diretti esteri e il consumo di elettricità sono cointegrati solo quando il PIL è la variabile dipendente. Quanto alla causalità, l'ipotesi nulla che il consumo di elettricità (kWh) e gli investimenti diretti esteri non "Granger causano" il PIL è respinta. Analogamente, l'ipotesi nulla che il PIL e il consumo di elettricità non "Granger causano" il PIL è respinta allo stesso livello di significatività del 5%. Si evince che il consumo di elettricità e gli investimenti diretti esteri "Granger causano" la crescita economica.

APPENDIX

FIGURE 1 - *Plot of Cumulative Sum of Recursive Residuals*

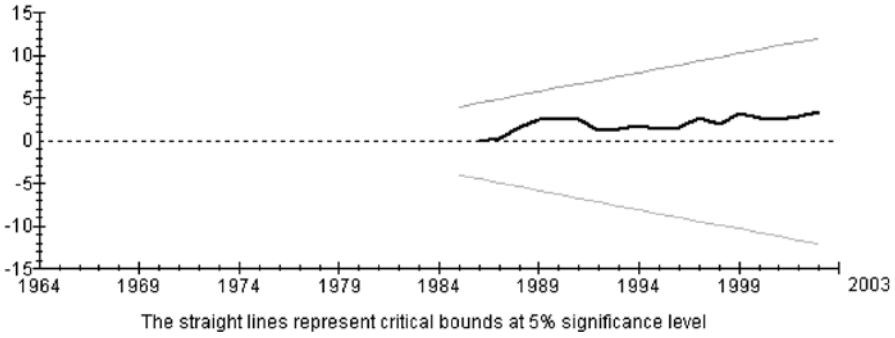


FIGURE 2 - *Plot of Cumulative Sum of Squares of Recursive Residuals*

