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Research Article

Consumption of Electricity and Industrial Growth in the Case of Ghana

Eric Abokyi,[1] Paul Appiah-Konadu,[2] Isaiah Sikayena,[3] and Eric F. Oteng-Abayie[4]

[1] *Department of Economics, Università Politecnica Delle Marche, Italy*
[2] *J. S. Addo Business School, Marshalls College, Accra, Ghana*
[3] *Faculty of IT Business, Ghana Technology University College, Accra-North, Ghana*
[4] *Department of Economics, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana*

Correspondence should be addressed to Eric F. Oteng-Abayie; efoteng-abayie.socs@knust.edu.gh

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We examine the causative relationship amongst electricity consumption and industrial growth in Ghana for the period of 1971 to 2014. The results of the ARDL bounds test showed that long-run relationship exists among the variables. The error correction term was also significant and negatively signed providing further evidence of long-run relationship. Contrary to the widespread belief that electricity consumption spurs productivity, the study reveals that electricity consumption has a negative impact on manufacturing sector output in Ghana. This occurrence could be explained by the fact that whiles the average growth in electricity consumption in Ghana is positive, the share of industrial sector's electricity consumption continues to decline on the average. The Toda-Yamamoto test shows a unidirectional causality running from electricity consumption to industrial growth in Ghana, supporting the growth hypothesis in the extant literature.

1. Introduction

Electricity (energy in general) is an important promoter of socioeconomic development [1, 2]. Growth in industrial consumption of electricity is recognized as an instantaneous indicator of a country's economic progress [3]. According to Lin and Liu [4], the consumption of electricity is a direct reflection of the economic development situation in an economy. This vital role of industrial electricity (energy) consumption in economic growth and development is seen in the amount of empirical research and policy interest it has generated over the past two decades [3, 5]. For policy makers to find ways of improving electricity use, efficiency, and power saving policies for sustainable development, it is of both academic and empirical significance to analyse and fully appreciate the link between electricity consumption and industrial growth in Ghana.

At independence in 1957, Ghana's industrial sector was underdeveloped and the inherited economic system was heavily dependent on manufactured products from Britain. In the quest to exploit the country's domestic resources, to satisfy the basic needs of the population, the Nkrumah-led government adopted an Import Substitution Industrialization (ISI) strategy in the early 1960s [6]. The government of Ghana invested heavily in the provision of infrastructure and manufacturing activities by setting up State-Owned Enterprises (SOEs). These SOEs were resourced to produce consumer goods which were previously imported and to process primary products for exports (agricultural and mining). Government also invested in the expansion and development of building materials as well as electrical, electronic, and machinery industries. The development of the electrical, electronic, and machinery industry was necessary to provide the energy needed to expand the industrial sector [7].

The ISI strategy resulted in the rapid growth of the manufacturing sector from a 2 percent share of real GDP to 9 percent in 1957 and 1969, respectively. During the 1960s, the manufacturing sector's output was growing at a rate of 13 percent per annum, whiles the share of the manufacturing output in total industrial output increased from 10 percent in 1960 to 14 percent in 1970. The manufacturing sector also experienced growth in employment, about 90 percent in total

between 1962 and 1970 [6]. As a result of external shocks (hikes in oil prices) and inappropriate domestic policies during the mid-1970s to 1983, the industrial sector and the Ghanaian economy as a whole suffered severe deteriorations in economic and financial performance. Ghana's industrial recovery occurred in the period 1984-1988; the first five years after the Economic Recovery Program (ERP) was launched. The industrial sector expanded at an annual average of 11.2 percent [8]. Despite the improved performance of Ghana's industrial sector in the post ERP era, it continues to face challenges and these are expected to continue to endanger its growth prospects. The high cost of credit, which reflects high lending rates, rising fuel prices, and more importantly unreliable electrical power supply compelled many firms, especially those operating in import-dependent manufacturing, to cut production [6].

The key to unlocking other resources is energy and it also increases the fortune of man by furnishing the modern world with fuel. According to Youngquist [10], the material standard of living of man is determined directly and indirectly by the availability of energy per capita. This implies that energy provides fundamental support to all industrial productions in Ghana and the world at large. To this end, the Ghana Poverty Reduction Strategy (GPRS 2006-2009) outlined wide-ranging policy interventions in the energy subsector to ensure dependable supply of high quality energy services to back the growing agro-industrial and services sector and residential use [11]. The Centre for Policy Analysis (2007) and Ministry of Finance and Economic Planning [12] report that the power rationing exercise experienced in Ghana from 2007 to 2008 accounted for the drop in the manufacturing sector's contribution to GDP from 9.5 percent in 2006 to 7.4 percent in 2008. For the 13 problems affecting the manufacturing sector in Ghana, unreliable electricity supply is ranked first (Owusu, 2010). According to Gand [13] electricity demand in Ghana keeps rising at an average rate of 12 percent per annum from 1999 to 2009. The domestic electricity consumption in 2004 was 6,004 GWh and was projected to rise by 58.9 percent to 9,300 GWh in 2010. What is not empirically clear is whether the persistent increasing demand for power has any bearing on industrial development. Aboh [14] has projected that total electricity use in Ghana will rise from 3,721.7GWh in 2008 to 65,239.6KWh by 2030 with industry's demand for power estimated to rise from 3,433.1KWh to 50,145.6KWh within the period. The high projected increase in electrical energy demand requires a significant step-up in both private and public investments towards expanding the operational power generation capacity.

Although a policy framework has been designed for Ghana to attract private investment in power production, very little has been achieved in this area. The private sector has invested in only two operational power plants as of 2014, namely, the Takoradi International Company (TICO) and the Sunon Asogli Power Plant [15]. Whiles TICO produced 220 MW of power as of 2014, plans are put in place to expand the plant's production capacity to 330 MW. The Sunon Asogli Power Plant is currently producing 200 MW; the production capacity is expected to be expanded in future to produce 560 MW of power. In addition to these two plants, there are a few numbers of other power plants under construction by the private sector. These plants include the Tema Osono Power Limited, which is expected to generate 126 MW of power upon completion, and the CenPower Limited, which is also expected to generate 330 MW of power [15].

The public sector has also made a lot of efforts towards providing and expanding the electricity generation in Ghana. The evolution of electricity supply in Ghana has gone through three stages according to ISSER [16]. The first is the "Before Akosombo" stage, followed by "the Hydro-years", and then the "Thermal Complementation" stage. The "Before Akosombo" stage is the time period, which preceded the construction of Akosombo Dam in 1966 to produce power. The country relied on diesel generators to supply electricity for use in industrial and health sectors as well as for private consumption [16]. The amount of electricity power supplied during this period was insufficient relative to the demand. The industrial sector suffered during the "Before Akosombo" stage due to the insufficient and unreliable power supplied for industrial use. This brought about "the Hydro-years" which is also known as the Volta Development era [16] spanning from 1966 to the mid-eighties. This period saw the construction of the Akosombo Dam and the Kpong Hydroelectric Plant. The commissioning of the Akosombo Dam took place in 1966, whiles the Kpong Hydroelectric Plant was completed in 1982. The Akosombo Dam alone could produce 912 MW of power as of 1972 [17]. The total installed power generation capacity from Akosombo and Kpong Plant had increased to 1,072 MW by the end of 1975. By the mid-eighties, the demand for electricity power had gone up above the total electricity supply in Ghana [16]. The "Thermal Complementation" covers the period from the mid-eighties to date. Efforts have been made in this era to expand the generation of power via the Takoradi Thermal Power and the developing of the West African Gas Pipeline to make available affordable source of fuel for the generation of power [16].

Currently, there has been huge investment to increase the power generation capacity of the above-mentioned plants. More power plants have also been constructed to increase the supply of power in the country. These include Takoradi Thermal Power Plant, Takoradi T3 Plant, Tema T1 Power Plant, Mines Reserve Plant, Tema T2 Plant, and the Kpone Thermal Plant [18]. Notwithstanding the efforts made by successive governments to expand power generation capacity, the country is still far from becoming power sufficient.

The government of Ghana is still pursuing policies to improve the shortcomings in the power sector. The Millennium Challenge Corporation (MCA) plans to invest a maximum of $498 million in total to help transform the power sector of Ghana and also stimulate private investment over the next five years. The objective is to create a power sector which is financially viable and be able to meet the current needs as well as the future needs for both businesses and households [15]. In showing commitment, the government of Ghana has promised to invest into the power sector a sum of money not less than $37.4 million. It is anticipated that the compact will catalyse not less than $4 billion in private investment and activity in the energy sector of Ghana in the coming years [15]. Owing to the competing demands on limited government

revenues in a developing country like Ghana, there is the need to assess the viability of increasing public (and private) investments in the power sector to meet the projected demand to propel industrial growth. Therefore, the present study is intended to inform public policy and even private investment decisions in the power sector.

Despite the above positive developments in the electricity power generation in Ghana, little empirical research efforts have been devoted to studying the causal links between electricity consumption and industrial growth in the specific case of Ghana. Two earlier studies by Adom [19] and Enu [20] can be identified in the extant literature. Adom [19] focused on the impact of electricity consumption on overall economic growth. Though Enu [20], which is directly related to this study, reports that electricity promotes manufacturing in Ghana, it has serious time series econometrics deficiencies. This current study therefore seeks to provide new estimates for the relationship between electricity consumption and industrial growth in Ghana. From the empirical results, we find a long-run relationship between electricity consumption and industrial growth. The results further reveal that electricity consumption has a negative impact on manufacturing sector output in Ghana. A result explained by the mismatch between the positive average growth in electricity consumption and the decline in the share of industrial sector's electricity consumption in Ghana.

In the next section we present a review of related studies on the electricity consumption and industrial growth. Section 3 is a presentation of the data used and the econometric methodology employed. A discussion of the empirical results is done in Section 4 and Section 5 concludes with policy implications.

2. Review of Related Literature

Studies on the causal link between energy (electricity specifically) consumption and economic growth abound in the extant literature [1, 21–26]. From the results of the existing studies, four main types of causal relationships (hypotheses) emerge and have been summarized by Mawejje and Mawejje [1] as follows. First is the growth hypothesis where causality is one-way from electricity consumption to output growth (see [1, 22, 24, 27]). Second is the conservation hypothesis in which causality rather runs from output growth to electricity consumption (see [24, 28, 29]). Third, the feedback hypothesis proposes a two-way causality between electricity consumption and output growth (see [26, 30, 31]). Fourth, the neutrality hypothesis is related to no causality between electricity consumption and output growth (see [25, 32, 33]).

In an empirical examination of energy consumption-growth nexus, Odhiambo [24] employed the ARDL method for the Democratic Republic of Congo (DRC). His result suggested that growth drives energy consumption. Thus, the study lends support to energy conservation hypothesis. Adom [19] applies the Toda and Yomamoto Granger Causality test and time series data spanning the period 1971-2008 to investigate the causal link between electricity consumption and economic growth in Ghana. This study brought to light that there is a unidirectional causality running from economic growth to the consumption of electricity. This study gives credence to the growth-led-energy hypothesis in the case of Ghana. Adom [19] concludes that electricity conservation measures are required to manage electricity demand and consumption as the economy of Ghana expands. Other studies, which found similar results, include Hu and Lin [29], Halicioglu [34], and Mozumder and Marathe [28] for Taiwan, Turkey, and Bangladesh, respectively. Contrary to these findings, Odhiambo's [24] results offer support to the growth hypothesis. The study found a unidirectional causality from electricity consumption to economic growth for Kenya and South Africa using ARDL trivariate framework for three countries, namely, Kenya, South Africa, and DRC. Moreover, Narayan et al. (2008) found similar result for G7 countries. Aslan [35] also found positive and unidirectional relationship where electricity consumption causes economic growth for Turkey. Bayar and Özel [23] investigated the causative relationship between electricity consumption and growth for emerging economies. They employed Pedroni, Kao, and Johansen cointegration tests as well as Granger causality test in the study and the results of the tests showed that electricity consumption spur growth, with causation from electricity consumption to economic growth and vice versa, thus, lending support to the feedback hypothesis. Similarly, Chontanawat et al. [36] examined the causal relationship between energy and GDP for 30 OECD and 78 non-OECD countries. Their finding revealed a bidirectional causal relationship running from aggregate energy consumption to GDP and vice versa. This causal relationship was common in the developed OECD countries than for the developing non-OECD countries. Bidirectional causality was also discovered by Belloumi [26] for Tunisia, Odhiambo [30] for South Africa, and Jumbe [31] for Malawi. Interestingly, Halicioglu [25] applied Granger causality test and ARDL bound testing for Turkey and found no causal relationship between electricity consumption and growth. Other studies, which also support the neutrality hypothesis, include Ozturk and Acaravci [32] for eleven MENA countries and Payne [33] for USA. Faisal et al. (2016) employ time series data from 1990-2011 and the Toda and Yamamoto approach to analyze the causal link between electricity consumption, energy consumption, and GDP growth in Russia. The authors reported that there is a bidirectional causality running from electricity consumption to GDP growth. This finding validates the feedback hypothesis. They however found no causality running from GDP to energy consumption, which gives credence to the neutrality hypothesis. The findings of Faisal et al. (2016) point to the fact that there exist a mutual and complementary relationship between electricity consumption and economic growth in Russia for the period 1990-2011.

In line with our specific objectives, we focus on studies that concentrated on the relationship between electricity consumption and disaggregated sectoral growth. For instance, Mawejje and Mawejje [1] analysed the link between electricity consumption and agriculture, industrial, and service sector growths independently. Mawejje and Mawejje [1] employed the Johansen cointegration test and Granger causality and their results support the growth hypothesis in the industrial sector. Their result showed that electricity consumption and economic growth are positively related and causality runs

from electricity consumption to industrial sector growth in the long-run for Uganda. Within the context of a trivariate vector autoregressive framework that includes entrepreneurship, Sun and Anwar [37] examined the link between electricity consumption and industrial production in Singapore's manufacturing sector and find that electricity consumption causes industrial output. The growth hypothesis concerning energy consumption and economic growth is present in the manufacturing sector of Singapore. Shahbaz et al. [22] examined the relationship between industrialization and electricity consumption for Bangladesh using the ARDL bound testing and Innovative Accounting Approach (IAA). The result showed a unidirectional causality with electricity consumption Granger causing industrial growth. Furthermore, Soytas and Sari [38] examined the causative connection between industrial electricity consumption and manufacturing value-added for Turkey using cointegration and vector error correction framework and found a one-way direction causal relationship where industrial electricity consumption drives growth in manufacturing value-added. In the case of Abid and Mraihi [39], a long-run one-way causality from electricity consumption to industry GDP was found but the short-run result indicated no causal relationship in support of the neutrality hypothesis for Tunisia. However, Kermani et al. [21] who also employed the Johansen cointegration test, VECM and Granger causality analysis for Iran showed that there was no short-run and long-run causal relationship between industry value-added and electricity consumption, thus lending support to the neutrality hypothesis in the manufacturing sector for Iran. Similarly, Jobert and Karanfil [40] also found no causal relationship between energy consumption and economic growth at the sectoral level as well as the aggregate level for Turkey. Danmaraya Hassan [41] finds a bidirectional relationship between manufacturing industry efficiency and electricity consumption in Nigeria for the period of 1980-2013. Moreover, Husaini and Lean [42] analysed the relationship between output and price in electricity consumption and manufacturing sector in Malaysia but finds that in the long run a unidirectional relationship from the manufacturing industry output to electricity consumption exists.

In conclusion, the available studies have not reached a consensus on the causal connection between electricity consumption and industrial output growth. In the following sections, we conduct an analysis of the relationship between electricity consumption and industrial output growth in the case of Ghana where there is paucity of empirical evidence. We deviate from the earlier work by Adom [19] and analyse only the industrial sector growth link to electricity consumption. Mawejje and Mawejje [1] show that the causal linkage between electricity consumption and industrial growth could produce different results from using overall economic growth variable.

3. Materials and Methods

3.1. Data Description and Empirical Model. The data used in this study are annual time series covering the period 1971 to 2014 since data on electricity consumption is only available for the period under study. The source of the data used in this study is the World Bank Development Indicators (2015) with the manufacturing value-added (MNF) computed as a ratio of GDP since the data available on the ratio of these variables for Ghana is not continuous. The functional relationship between electricity consumption and industrial growth is stated as follows:

$$\ln MNF_t = \alpha_0 + \alpha_1 \ln EC_t + \vartheta X_t + \varepsilon_t \tag{1}$$

where $\ln MNF$ is the natural logarithm of manufacturing value-added as a ratio of GDP which is a proxy for industrial growth in the study. This is guided by the fact that growth in manufacturing output is interpreted as increase in industrialization [43]. α_0 is a constant, $\ln EC$ represents the natural logarithm of electricity consumption per capita, ε denotes the white noise error correction term, and X refers to the other factors which influence industrial growth apart from electricity consumption. Since other factors such as trade openness, labour, and capital formation also influence industrial growth, therefore omission of these variables could bias the cointegration and causality tests conducted in the study leading to simultaneity bias [44]. It is expected that these variables will have positive influence on manufacturing output and hence industrial growth. Thus, increase in trade openness, labour, and capital formation should lead to increase in industrial growth. X_t is therefore defined as

$$X_t = f\left(\ln TRD_t, \ln LAB_t, \ln CPF_t\right) \tag{2}$$

where $\ln TRD$ represents the natural logarithm of trade openness. Trade openness is defined in the study as the sum of exports and imports as a ratio of GDP. $\ln LAB$ is the natural logarithm of labour force in Ghana and $\ln CPF$ denotes the natural logarithm of gross fixed capital formation as a ratio of GDP.

Putting (2) into (1) gives (3) as specified below

$$\begin{aligned}\ln MNF_t = {} & \alpha_0 + \alpha_1 \ln EC_t + \alpha_2 \ln TRD_t + \alpha_3 \ln LAB_t \\ & + \alpha_4 \ln CPF_t + \varepsilon_t\end{aligned} \tag{3}$$

$\alpha_1, \alpha_2, \alpha_3$, and α_4 are the coefficients of elasticity. All other variables in the model are as previously defined.

3.1.1. ARDL Bound Test and Cointegration Analysis. Due to the short data span, this study employed the ARDL bounds testing approach to cointegration developed by Pesaran et al. [9]. This is because, in finite sample data, the ARDL approach has proven to be more efficient than the other traditional cointegration approaches such as the Johansen and Juselius [45] and Engle and Granger [46]. Moreover, this approach is suitable for models with a mixture of variables which are $I(0)$ and $I(1)$. The general error correction model (ECM) is stated as

$$\begin{aligned}\Delta \ln MNF_t = {} & \theta_0 + \eta \ln MNF_{t-1} + \lambda_1 \ln EC_{t-1} \\ & + \lambda_2 \ln TRD_{t-1} + \lambda_3 \ln LAB_{t-1} \\ & + \lambda_4 \ln CPF_{t-1} + \sum_{i=1}^{n} \delta_{1i} \Delta \ln MNF_{t-i}\end{aligned}$$

$$+\sum_{i=0}^{n}\delta_{2i}\Delta\ln EC_{t-i}+\sum_{i=0}^{n}\delta_{3i}\Delta\ln TRD_{t-i}$$
$$+\sum_{i=0}^{n}\delta_{4i}\Delta\ln LAB_{t-i}$$
$$+\sum_{i=0}^{n}\delta_{5i}\Delta\ln CPF_{t-i}+v_t \tag{4}$$

where θ_0 is a constant, Δ is the change operator, η and λ_i are the long-run elasticities, δ_i are the short-run elasticities, and the white noise error term is v_t.

Equation (4) is estimated using OLS and the F-statistic is compared with the Pesaran et al. [9] critical bound values to check for long-run cointegration relationship among the variables. The null hypothesis $\eta = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$ suggests no cointegration, whiles the alternative hypothesis of cointegration among the variables is stated as $\eta \neq \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq 0$. If the independent variables are integrated of the order $I(d)$, where $0 \leq d \leq 1$, then the two critical bound values provided by Pesaran et al. [9] provide a test for cointegration. The computed F-statistic is compared with the lower and upper critical bounds. If the F-statistic is more than the upper bound, there exists cointegration among the variables. However, if the F-statistic is lower than the lower bound, there is no cointegration. The test outcome is inconclusive if the computed F-statistic is between the lower and upper critical bounds.

The coefficients of the long-run ARDL (m, p, q, r, s) are then estimated after evidence of cointegration has been found to exist among the variables. The long-run model is specified as follows.

$$\ln MNF_t = \theta_1 + \sum_{i=1}^{m}\eta_{1i}\ln MNF_{t-i}+\sum_{i=0}^{p}\lambda_{5i}\ln EC_{t-i}$$
$$+\sum_{i=0}^{q}\lambda_{6i}\ln TRD_{t-i}+\sum_{i=0}^{r}\lambda_{7i}\ln LAB_{t-i} \tag{5}$$
$$+\sum_{i=0}^{s}\lambda_{8i}\ln CPF_{t-i}+\varepsilon_{1t}$$

where θ_1 is a constant, while the white noise error term is ε_{1t} in (5). The other variables and parameters are as previously defined.

The error correction model specified in (6) below is estimated to obtain the short-run parameters.

$$\Delta\ln MNF_t = \theta_2 + \sum_{i=1}^{m}\delta_{6i}\Delta\ln MNF_{t-i}$$
$$+\sum_{i=0}^{p}\delta_{7i}\Delta\ln EC_{t-i}+\sum_{i=0}^{q}\delta_{8i}\Delta\ln TRD_{t-i}$$
$$+\sum_{i=0}^{r}\delta_{9i}\Delta\ln LAB_{t-i}+\sum_{i=0}^{s}\delta_{10i}\Delta\ln CPF_{t-i}$$
$$+\sigma ECT_{t-1}+\varepsilon_{2t} \tag{6}$$

where θ_2 is the constant, the coefficient of the error term is σ, and the white noise error term is ε_{2t}.

In order to ascertain the causality between the variables, the Toda and Yamamoto [47] causality approach, which uses a modified Wald test, was employed. Similar to the ARDL bounds test, the Toda-Yamamoto [47] causality method requires no pretesting of the variables to determine the order of integration and can still be employed in the absence of cointegration [48]. The method employs a VAR framework in levels. Here, the appropriate VAR order k is augmented by the maximum integration order (d) of the variables in the model. Then VAR $(k + d)$is estimated variously as follows:

$$\ln MNF_t = \varphi_1 + \sum_{i=1}^{k}c_{1i}\ln MNF_{t-i}$$
$$+\sum_{j=k+1}^{d}c_{2j}\ln MNF_{t-j}+\sum_{i=1}^{k}c_{3i}\ln EC_{t-i}$$
$$+\sum_{j=k+1}^{d}c_{4j}\ln EC_{t-j}+\sum_{i=1}^{k}c_{5i}\ln TRD_{t-i}$$
$$+\sum_{j=k+1}^{d}c_{6j}\ln TRD_{t-j}+\sum_{i=1}^{k}c_{7i}\ln LAB_{t-i} \tag{7}$$
$$+\sum_{j=k+1}^{d}c_{8j}\ln LAB_{t-j}+\sum_{i=1}^{k}c_{9i}\ln CPF_{t-i}$$
$$+\sum_{j=k+1}^{d}c_{10j}\ln CPF_{t-j}+\xi_{1t}$$

$$\ln EC_t = \varphi_2 + \sum_{i=1}^{k}d_{1i}\ln EC_{t-i}+\sum_{j=k+1}^{d}d_{2j}\ln EC_{t-j}$$
$$+\sum_{i=1}^{k}d_{3i}\ln MNF_{t-i}$$
$$+\sum_{j=k+1}^{d}d_{4j}\ln MNF_{t-j}$$
$$+\sum_{i=1}^{k}d_{5i}\ln TRD_{t-i}$$
$$+\sum_{j=k+1}^{d}d_{6j}\ln TRD_{t-j}$$
$$+\sum_{i=1}^{k}d_{7i}\ln LAB_{t-i}$$

$$+\sum_{j=k+1}^{d} d_{8j}\ln LAB_{t-j}$$
$$+\sum_{i=1}^{k} d_{9i}\ln CPF_{t-i}$$
$$+\sum_{j=k+1}^{d} d_{10j}\ln CPF_{t-j}+\xi_{2t} \tag{8}$$

$$\ln TRD_t=\varphi_3+\sum_{i=1}^{k} f_{1i}\ln TRD_{t-i}$$
$$+\sum_{j=k+1}^{d} f_{2j}\ln TRD_{t-j}+\sum_{i=1}^{k} f_{3i}\ln EC_{t-i}$$
$$+\sum_{j=k+1}^{d} f_{4j}\ln EC_{t-j}$$
$$+\sum_{i=1}^{k} f_{5i}\ln MNF_{t-i}$$
$$+\sum_{j=k+1}^{d} f_{6j}\ln MNF_{t-j}+\sum_{i=1}^{k} f_{7i}LAB_{t-i} \tag{9}$$
$$+\sum_{j=k+1}^{d} f_{8j}\ln LAB_{t-j}$$
$$+\sum_{i=1}^{k} f_{9i}\ln CPF_{t-i}$$
$$+\sum_{j=k+1}^{d} f_{10j}\ln CPF_{t-j}+\xi_{3t}$$

$$\ln LAB_t=\varphi_4+\sum_{i=1}^{k} g_{1i}\ln LAB_{t-i}$$
$$+\sum_{j=k+1}^{d} g_{2j}\ln LAB_{t-j}$$
$$+\sum_{i=1}^{k} g_{3i}\ln TRD_{t-i}$$
$$+\sum_{j=k+1}^{d} g_{4j}\ln TRD_{t-j}+\sum_{i=1}^{k} g_{5i}\ln EC_{t-i}$$
$$+\sum_{j=k+1}^{d} g_{6j}\ln EC_{t-j}$$
$$+\sum_{i=1}^{k} g_{7i}\ln MNF_{t-i}$$
$$+\sum_{j=k+1}^{d} g_{8j}\ln MNF_{t-j}$$
$$+\sum_{i=1}^{k} g_{9i}\ln CPF_{t-i}$$
$$+\sum_{j=k+1}^{d} g_{10j}\ln CPF_{t-j}+\xi_{4t} \tag{10}$$

$$\ln CPF_t=\varphi_5+\sum_{i=1}^{k} h_{1i}\ln CPF_{t-i}+\sum_{j=k+1}^{d} h_{2j}\ln CPF_{t-j}$$
$$+\sum_{i=1}^{k} h_{3i}\ln LAB_{t-i}$$
$$+\sum_{j=k+1}^{d} h_{4j}\ln LAB_{t-j}$$
$$+\sum_{i=1}^{k} h_{5i}\ln TRD_{t-i}$$
$$+\sum_{j=k+1}^{d} h_{6j}\ln TRD_{t-j}+\sum_{i=1}^{k} h_{7i}\ln EC_{t-i} \tag{11}$$
$$+\sum_{j=k+1}^{d} h_{8j}\ln EC_{t-j}$$
$$+\sum_{i=1}^{k} h_{9i}\ln MNF_{t-i}$$
$$+\sum_{j=k+1}^{d} h_{10j}\ln MNF_{t-j}+\xi_{5t}$$

where ϕ_i are the constants, k is the optimal order of VAR model which was determined by Schwarz information criterion, d is the maximum integration order, and ξ_{it} are the error terms in the VAR system. This approach ensures that there is no loss of information since it only uses VAR in levels and therefore differencing which has the potential to cause loss of information is avoided. The procedure is therefore used as long-run test [49].

4. Results and Discussion

4.1. Descriptive Statistics and Tests for Unit Root. Table 1 displays the summary statistics for the variables used at their levels before natural logarithm transformation to deal with the deal with the huge differences in magnitudes due to units of measurement.

Pretesting to establish the stationarity status of the variables used in both the Toda-Yamamoto causality test and the ARDL approach to cointegration test is not required. However, the Pesaran et al. [9] cointegration bound test assumes

Table 1: Descriptive statistics of the variables.

Variables	Mean	Median	Maximum	Minimum	Std. Dev.
MNF	0.0876	0.0902	0.1395	0.0360	0.0223
EC	318.8182	334.8928	425.9385	93.4924	72.0023
TRD	0.5636	0.5133	1.1605	0.0632	0.3006
LAB	8939749	8434678	15534587	4558257	3323490
CPF	0.1650	0.1730	0.3093	0.0353	0.0801

Table 2: Tests for unit root in variables.

	ADF test (with intercept)			KPSS test (with intercept)		
Variables	Levels	1st Difference	$I(d)$	Levels	1st Difference	$I(d)$
ln *MNF*	-1.9771	-4.1749∗∗∗	$I(1)$	0.3490∗	0.2035	$I(1)$
ln *EC*	-2.6811∗	-5.2134∗∗∗	$I(0)$	0.2300	0.1931	$I(0)$
ln *TRD*	-0.9308	-4.3702∗∗∗	$I(1)$	0.3212	0.1571	$I(0)$
ln *LAB*	0.3243	-3.0658∗∗	$I(1)$	0.4214∗	0.1695	$I(1)$
ln *CPF*	-1.1275	-6.9149∗∗∗	$I(1)$	0.3437	0.1741	$I(0)$

∗∗∗Significance at 1%, ∗∗significance at 5%, and ∗significance at 10%.

that the variables are integrated at $I(0)$ or $I(1)$. To ensure that there are no $I(2)$ variables or higher orders of integration in the model, unit root tests were done using the Augmented Dickey-Fuller (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin tests (KPSS) with intercepts. Conducting ARDL bounds test for long-run relationship with $I(2)$ variables is senseless [50]. The results of the unit root tests are displayed in Table 2. The ADF and KPSS tests, respectively, show that the variables are a combination of $I(0)$ and $I(1)$.

4.2. Cointegration Test Results. In conducting the bounds test to check for cointegration among the variables, (4) was estimated. The study employed a general-to-specific modelling approach to arrive at a parsimonious model for the bounds test with the lag order of 2 chosen based on information criteria. Normalizing manufacturing value-added, the result for the bounds test is reported in Table 3. The computed F-statistic of $F_{MNF} = 13.7070$ is greater than the upper bound at 1 percent significance level. This implies that there exist long-run relationships among the variables since there is evidence of cointegration.

4.3. Long-Run Estimates. Having established that the variables are cointegrated in the log-run, (5) is estimated to obtain the long-run coefficients of the cointegrating variables. The study selected the lag orders of the ARDL model (m, p, q, r, s) using Schwarz information criterion. The results of the long-run coefficients are reported in Table 4.

Table 4 shows that electricity consumption has negative effect on industrial growth. The coefficient of -0.84 suggests that a 1 percent increase in electricity consumption per capita will cause 0.84 percent decline in industrial growth. This finding contradicts the widespread findings that increase in electricity consumption results in positive output growth [1, 23, 35]. Enu [20] also finds insignificant impact of electricity consumption on manufacturing output. A lot of factors could have accounted for this result.

First, whiles the average growth in electricity supply in Ghana is positive, the portion allotted to industrial sector continues to decline on the average. From 2000 to 2010, the portion of electricity allotted to the industrial sector declined from 68 percent to 46.6 percent; meanwhile, both the residential and the nonresidential sectors (schools, offices, etc.) experienced growth in the share of electricity supply from 20 percent to 40 percent and from 8.5 to 14.3 percent, respectively [51]. Moreover, in 2013, electricity consumption in the industrial sector declined from 48 percent in 2012 to 45 percent in 2013, whiles the residential sector's electricity consumption remained the same at 35 percent and the nonresidential sector experienced an increase in electricity consumption from 13 percent in 2012 to 16 percent in 2013 [52]. According to the Energy Commission [53], there has been upward adjustment of tariffs in the industrial sector and these rates are unsustainable in some cases. The high cost of electricity in the sector due to the upward adjustment of tariffs could possibly explain the fall in electricity consumption in the industrial sector. Another possible cause of decline in the industrial sector's electricity consumption can be attributed to the frequent load shedding. Indeed, the industrial sector was more affected than the other sectors during the load shedding in 2003-2004 and 2007 [51]. In addition, the sector is also characterized by the use of obsolete and inefficient energy consuming equipment [53]. It is therefore not surprising that whiles the average electricity consumption in Ghana increased, the industrial sector's contribution to GDP diminished from 27.9 percent to 19.1 percent from 2000 to 2010.

Table 3: ARDL bound test.

Dependent Variable	F-statistic	K=4	
$F_{MNF}(MNF\|EC, TRD, LAB, CPF)$	13.7070		
Critical Value		Lower Bound	Upper Bound
1%		3.74	5.06
5%		2.86	4.01

Lower and upper-bound critical values were obtained from Pesaran et al. [9], Table CI(iii) Case III.

Table 4: Long-run coefficients.

Dependent variable is ln MNF : ARDL(1,1,0,0,1) selected based on SBC				
Regressors	Coefficient	Standard Error	T-Ratio	Probability
ln EC	-0.8412	0.1897	-4.4342	0.000
ln TRD	0.3182	0. 1253	2.5402	0.016
ln LAB	-1.7130	0. 1934	-8.8577	0.000
ln CPF	0. 5918	0. 1901	3.1138	0.004
C	31.0567	4.1634	7.4595	0.000

Trade openness and capital formation were found to impact industrial growth positively at 5 percent and 1 percent significance levels, respectively. On the other hand, labour was found to impact industrial growth negatively.

4.4. Short-Run Relationship. The short-run coefficients or elasticities associated with the long-run were estimated and the results are reported in Table 5. The error correction coefficient is expectedly negative and significant. The value of the error correction term (-0.5180) suggests that the rate of correction of short-run disequilibrium in the long-run equilibrium is 51.80 percent. This implies that the speed of convergence to long-run equilibrium after a shock is moderate. Table 5 also shows a negative and statistically insignificant relationship between electricity consumption and industrial growth. Capital formation was also not significant but has positive impact on industrial growth. The signs of the rest of the short-run parameters are consistent with the long-run coefficients and the significance levels are also maintained.

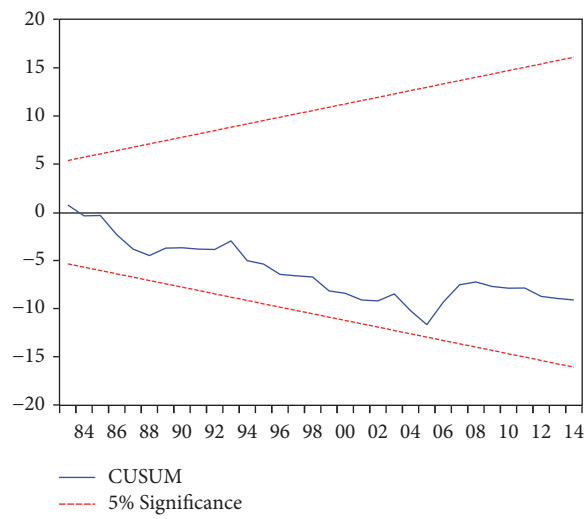

Figure 1: Cumulative sum of recursive residual.

4.5. Model Diagnostic Tests. The ARDL regression model has good fit and passed all diagnostic tests (Table 6). The model also passed parameter stability test as indicated by the recursive residuals graphs (Figures 1 and 2).

4.6. Toda-Yamamoto Causality Analysis. Since the bounds test result showed evidence of cointegration, the long-run causal relationships between consumption of electricity and industrial growth was determined using Toda-Yamamoto [47]. The test results presented in Table 7 indicate a unidirectional causality between electricity consumption and industrial growth where electricity consumption drives industrial growth in Ghana. This finding is consistent with Shahbaz et al. [22] and Mawejje and Mawejje [1] who found unidirectional causality running from electricity consumption to industry for Bangladesh and Uganda, respectively. Unidirectional causality between labour and industrial growth was also detected with industrial growth driving labour. No causality was found between capital formation and industrial growth. The study found a unidirectional causality between trade openness and industrial growth in Ghana with causality running from trade openness to industrial growth. The result also showed that trade openness has a very strong influence on capital formation and not vice versa. Unidirectional causality was also found running from labour to capital formation, labour to trade openness, and labour to electricity consumption.

5. Conclusions

The paper investigated for the first time the causal relationship between electricity consumption and industrial growth in Ghana using annual time series data from 1971 to 2014. The ARDL approach to contegration was employed to test for the existence of long-run relationship between electricity consumption and manufacturing value-added, a proxy for

Table 5: Short-run estimates.

Dependent variable is $\Delta \ln MNF$: ARDL(1,1,0,0,1)				
	Coefficient	Standard Error	T-Ratio	Probability
$ECT(-1)$	-0.5180	0.0855	-6.0553	0.000
$\Delta \ln EC$	-0.1191	0.0769	-1.5498	0.130
$\Delta \ln TRD$	0.1648	0.0663	2.4877	0.018
$\Delta \ln LAB$	-0.8872	0. 1153	-7.6984	0.000
$\Delta \ln CPF$	0.1263	0.0866	1.4579	0.154
C	16.0858	1.9430	8.2790	0.000
R-Sq. = 0.8214			F-stat. F(5, 36) 31.2775[0.000]	
Adj. R-Sq. = 0.7847			DW-statistic = 1.9914	

Table 6: Model diagnostic tests.

Test Statistics	F-statistic	Probability
Breusch-Godfrey Serial Correlation LM Test	1.7955	0.1834
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.7325	0.6622
Jarque-Bera	0.1765	0.9155
Ramsey RESET Test	0.5634	0.4585
Chow Breakpoint Test	1.8622	0.1104
Chow Forecast Test	1.0443	0.4703

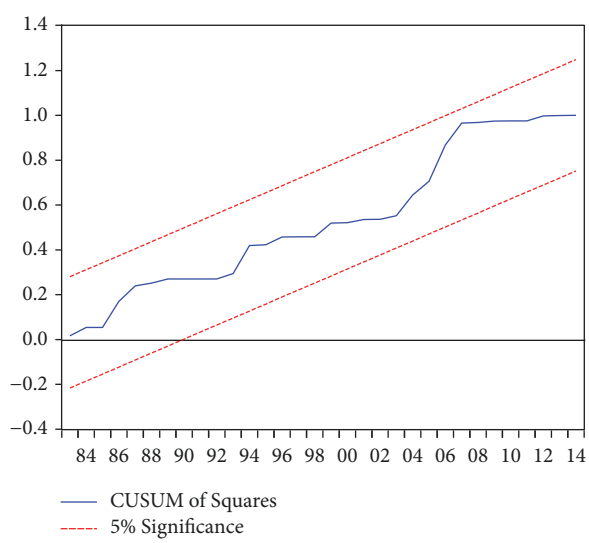

Figure 2: Cumulative sum of square recursive residual.

industrial growth. The results show evidence of cointegration or long-run relationship between consumption of electricity and industrial growth in Ghana. The findings of the study showed that electricity consumption negatively impact industrial growth both in the long-run and the short-run in Ghana even though the short-run impact of electricity consumption was not significant. The result from the Toda-Yamamoto modified Granger causality test showed the existence of a one-way causal relationship running from consumption of electricity to industrial growth, supporting the growth hypothesis in Ghana.

The study recommends that, with industrialization of the economy, investment in electricity power generation be increased to make more power available to the industrial sector at affordable prices to boost the output in the sector. Government should also strengthen its energy efficiency measures, which will ensure that firms in the industrial sector avoid the use of obsolete and inefficient equipment and machinery or ban their imports into the country. The energy conservation policy which was started in 2007 was therefore in the right direction. However, this policy should be intensified in the country and also extended to cover other areas where little or no effort has been made to conserve power.

We also recommend that government should step up public investment on capital goods since evidence from the study shows that capital formation positively impacts industrial growth in Ghana. International trade, which was also found to promote industrial growth, should be increased through a progressive reduction of trade barriers. The study also recommends reformation of the labour sector in Ghana with emphasis on human resource development in order to make labour more productive.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Table 7: Toda-Yamamoto causality analysis.

Dependent variable	ln *MNF*	ln *EC*	ln *TRD*	ln *LAB*	ln *CPF*	Direction of causality
ln *MNF*	-	16.9814∗∗∗	9.6052∗∗∗	2.7087	1.6018	*EC* → *MNF* *TRD* → *MNF*
ln *EC*	2.7799	-	0.1338	7.8682∗∗	1.0885	*LAB* → *EC*
ln *TRD*	0.8412	4.2650	-	8.5139∗∗	2.9077	*LAB* → *TRD*
ln *LAB*	6.9188∗∗	0.1371	2.0606	-	3.9641	*MNF* → *LAB*
ln *CPF*	0.6789	0.1721	21.3834∗∗∗	8.5975∗∗	-	*TRD* → *CPF* *LAB* → *CPF*
Autocorrelation test						
LM-Stat	27.8038	Prob	0.3170			

Significance at ∗∗∗ 1%, ∗∗ 5%, and ∗ 10%.

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