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FACTORS OF INDUSTRIAL PRODUCTION WITH EXCHANGE RATE AS CONTROL VARIABLE

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ABSTRACT

In Africa, industrialization has no robust linkages to domestic economies due mainly to the non-diversification of these economies. So, we evaluated the impact of energy supply, aggregate capital stock and labour as factors of industrial production in 18 SSA countries. We utilized both MG and PMG estimators to provide empirical solutions to heterogeneity bias that characterized our dynamic panel equation specification. The calculated Hausman test statistic of 29.679 with zero probability value provided us with the rejection of homogenous long-run coefficients with the implication that we based analysis on mean group results. The results show both first and second lags of megawatts of electric power supplied had contributed ineffectively to industrial production in SSA. Estimates reveal that lately, capital flows had been significantly impactful to industrial output of SSA countries unlike what it was in the past. The current stock of capital flows to SSA could positively and meaningfully contribute to the growth of industrial output in the coming years. This study found support for the need to enhance the electricity supply to SSA nations while advocating for more foreign capital and domestic capital formation in SSA to boost industrial production among these nations.

Keywords: Capital, industrial production, megawatts, ARDL model, Hausman test statistic.

JEL classification*:* G20, M30, A24

1. Introduction

The growth of industrial output is an acute ingredient for persistent and inclusive economic growth in Sub-Saharan African (SSA) countries. This is because industry can heighten productivity, by spawning employment via the efficiency of the workforce, given the ease of stock of capital. Unfortunately, in SSA, industrialization has no robust linkages to domestic economies due mainly to the non-diversification of these economies (Erzi 2022, Huang & Chen 2020, Joseph et al. 2019). These put together may have resulted in poor growth and development with amplified defencelessness to external shocks measured in terms of global oil price shocks, global liquidity crisis, Ukraine-Russia war crisis etc. No wonder, in 1989, the General Assembly of the United Nations, proclaimed November 20 of every calendar year as "Africa Industrialization Day".

The rationale had been to raise awareness about industrial defies faced by Africa and/or SSA and how to provide the solutions to the problem. For example, manufacturing output in SSA for 2020 compared to 2019 output shows a stable decline of 3.03% from $194 billion in 2019 to $188 in 2020 billion. Table 1 shows that SSA has the least output amongst other regions of the world.

Table 1. Manufacturing Output of World Regions

Region	Output (Billions of USD)
Euro Area	1,858.02
European Union	2,202.5
East Asia & Pacific	6,210.8
South Asian	437.4
Sub-Saharan Africa	188.2
Latin America & Caribbean	644.6

Source: World Manufacturing Production, UNIDO, 2021.

This could be attributed to the covid-19 pandemic which pushed different regions to execute restraint measures. This demonstrates the fact that Africa's manufacturing share in the world stays at 1.9 per cent. SSA countries cannot do without the importation of capital goods and other raw supplies. Available statistics show that; 62 per cent of Africa's aggregate imports were manufactured goods between 2011 to 2013 (United Nations Report, 2016). This constitutes a capital flight from the region. Ironically, the status quo is precarious and severe in Africa where structural limits, together with violence, insecurity, pipeline exterminations, and kidnappings endanger efforts for private sector-led economic expansion and diversification of the production base. "According to the former President of the Manufacturers Association of Nigeria (NAN), Alhaji Bashir Borodo, the basic infrastructure needed for production in Nigeria is non-existent and this had resulted in the absence of a favourable manufacturing setting in the country" (Umoru, 2022). Consequently, most SSA could not create jobs leading to a huge unemployment problem whereby thousands have been compelled to take to migration overseas.

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African sub-region is endowed with power including solar, wind, hydro and biomass energy, which can be harnessed to meet local energy needs and promote growth. Notwithstanding this energy potential in the sub-region, energy consumption, more precisely, electricity consumption is very low (Economic Commission for Africa, 2004) with more than two-thirds of its population not having access to a contemporary power supply (International Energy Agency, 2014). For example, most ECOWAS nations have been confronted with challenges in power generation, transmission and distribution for over twenty years. According to Ekpo (2009), there occur adverse effects on the cost of production owing to the high level of generator usage in Nigeria. Unstable and insufficient electric power supply has been a recurring decimal in African nations (Adenikinju, 2003). This issue exacerbated shut down of most industries leading to relocation from one African country to a neighbouring one. This aligns with the submission that inconsistent electricity supply in Africa has affected nearly all key segments of the economy and has mainly affected the industrial zone (Adenikinju, 2003). The Nigerian Renewable Energy Council of Nigeria reports that power outage costs $ 984.38 million yearly.

Orazulike (2012) opines that due to the inability to meet the electricity needs of individuals and businesses, obviously turn to self-help through the use of diesel, and facilities to produce much-needed power. Therefore, diesel is in high request in sectors such as banking, industrial production, shipping, transport, tourism, etc. Regrettably, important as diesel is for economic growth, accessibility and cost remain the problem in developing countries. Similarly, Premium Motor Spirit (PMS), usually identified as petroleum, the furthermost debatable of all the energy sources obtainable in the nation, faces insufficient domestic supply and ever-increasing price problems. This lies the drive for this study. Hence, we set out in this study to comprehensively evaluate the various classes of energy supply to the industrial sector and how these have impacted the productivity of the industrial sector in developing countries. This study shall disaggregate the various energy supply to the industrial sector, contrary to the aggregation done by previous studies, it shall also provide a more recent examination of the energy supply problem in Nigeria.

Our aim is to study the influence of electricity supply, aggregate capital stock, and labour as factors of industrial production in SSA. A conspicuous contribution of the present study derives from its use of the ARDL method of estimation. The modeling and estimation are based on ARDL technqiue. With this method of estimation, our present research provides valuable empirical findings as regards the significant factors of industrial production in developing countries than similar studies in the past. Having modified the conventional production function to include energy supply, the study provides additional support for existing theories and interpretations. To suitably situate the debate, we combined both the MG and PMG estimation techniques. Data estimation shows that over the past 20 years, megawatts of electric power supplied in those countries have been insignificant for pursuing a deep industrial transformation in SSA. Despite labour availability, industries are deficient in electricity supply. This indeed necessitates the need for a committed course to making energy adequately available in addition to a stock of aggregated capital for purpose of mitigating low industrial output in SSA. The originality of our study is entrenched in the fact that it is a contribution to the empirical argument on the role of energy supply as a factor of production and as an engine for industrial development geared towards meeting basic household needs for economic growth in eighteen countries. The study established that the quantum of megawatts of electric power supplied in SSA does not grow industrial output and that lately, capital flows are significantly impactful to the industrial development of the SSA region unlike what it was in the past. Indeed, the current stock of capital inflows to SSA would positively and significantly contribute to the growth of industrial output in the coming years. The finding that both the first and second lag of megawatts of electric power supplied had an insignificant effect on industrial production in SSA provided effective information to the knowledge of government authorities, and policymakers. The study is divided into five sections, namely, Section 2 is a review of previous studies on this subject, Section 3 provides the research methods, empirical model development, theories and materials, Section 4 analyses the results from the estimation exercise, and Section 5 is the conclusion.

2. Literature review

Energy is largely measured to be a motivating strength that drives economic activity and, certainly behind trade production. Thus, high-quality energy assets will enhance the influence of technology and generate greater economic strength (Onakoya et al., 2013). The rank of energy lies in another feature of growth: the rise in external profits when power goods are exported, the relocation of technology in the search, manufacturing and trading processes; increased employment in energy productions; improving employees' welfare through increases in wages and salaries, socio-economic and infrastructure actions in the growth of power resource exploitation (Onakoya et al., 2013). Theoretically, there is the relaxed electricity market theory, the traditional theory of cost and the Schumpeterian concept of capitalist growth, the growth theory, the conservative theory, the feedback theory and the neutrality theory that explains the relation between power and productivity of the manufacturing sector. According to Osobase & Bakare (2014), energy market theory explains the right of companies to invest in power plants that allow electricity production at varying marginal costs. The growth theory sees electricity consumption as a direct control of economic growth in the existence of capital and labour control. The theory argued for unidirectional hazards from power usage to economic growth. Here, an energy strategy aimed at decreasing energy consumption for conservative purposes has a negative bearing on economic progress. The conservative theory posits that economic growth attracts energy consumption (one-way link). Here, energy-saving measures would not harm the economy in terms of energy consumption. The feedback theory posits a two-sided hazard concerning power use and economic growth. In this condition, energy-saving policies to reduce power consumption have an unfavourable effect on the growth of the economy, and these changes are also reflected in energy consumption. The neutrality theory posited that energy use does not upset economic development. She asserts that there exists no causal connection between energy utilization and economic development. In this instance, energy-saving measures to reduce energy utilization do not influence economic growth.

Empirically, issues regarding energy, capital stock, and the output of industries have gained the attention of many economists across the world. According to Tang (2022), an inverse relation existed between energy consumption and GDP in China. Erzi (2022) reported that gasoline saving contributed significantly to the product development of the Chinese industrial sector. Chauliah & Sahbana (2021) identified nine productivity factors and these included technology. The following studies, namely, Li et al. (2022), Sun et al. (2022), Cang et al., (2021), Qiu et al., (2021), Rehman et al. (2021a), Ma et al., 2021), Kosemania & Bamgboye (2021), Manigandan et al. (2021), Huang & Chen (2020), Wang et al. (2019), Kong et al. (2019), Zhang et al. (2019), and (Chen et al., 2019) have all forecasted and also established a significant positive link between productivity and energy consumption. Kowsar & Farajnia (2022) established a significant and positive substitution effect of capital stock for labour in industrial production whereas, a weaker substitution effect of labour for capital was estimated. Deniz et al. (2022), and Salisu & Bukola (2021) found significant manufacturing output effects of labour, capital and electricity consumption based on ARDL evidence in Nigeria. Adekunle et al. (2020) reported significant positive effects of foreign capital inflows as measured by FDI, capital formation, and labour participation on industrial performance in Nigeria. Kassim & Abdurrahman (2020) obtained an insignificant negative association between manufacturing output and voltage usage. Ogundipe & Olarewaju (2020) obtained significant manufacturing output effects of the labour force based on a static panel regression analysis after controlling for technology in ECOWAS nations. According to Joseph et al. (2019), there is no optimal point of capital inflows for manufacturing exports. Vo, Vo & Le (2019), Bercu et al. (2019) and Arminen & Menegaki (2019) established a two-way causal link between energy consumption and economic growth.

Akinlo and Lawal (2015) executed a vector error correction model to investigate the effects of exchange rate changes on industrial production in Nigeria in order to ascertain the existence of a long-term relationship between the manufacture indexes, which act as a proxy for manufacturing production, the exchange rate, money supply, and inflation, and certain macroeconomic indicators. The analysis concluded that over the analyzed period (1986–2010), currency rate depreciation in Nigeria had a very significant short-term impact. Furthermore, currency rate depreciation is advantageous for long-term industrial productivity. However, the research did not take into consideration changes in the currency rate or the impact of the shock on industrial production. The VECM does not adequately capture the impact of exchange rates on output. Onakoya (2018) looked at the dynamics of macroeconomic determinants as well as the output in Nigeria's industrial sector. The study analyzed data from 1981 to 2015 using descriptive statistics and stationary assessment. Understanding that there is no short-term correlation between production, exchange rate, and unemployment, among other variables, is necessary to comprehend how changes in macroeconomic factors affect the industrial segment's production. The report recommended combining monetary and fiscal policy to advance economic stability. However, the study did not say if these elements had a long-term impact on industrial production. Furthermore, the proposed solution is insufficient since the study concentrated on industry production behavior rather than macroeconomic stability.

Lee (2018) argues that income levels and trade openness have a significant role in anticipating shocks to industrial output, particularly in terms of agriculture productivity, in his research on differences in industrial production in emerging economies. Lee asserts that a decline in agricultural output is anticipated to increase food prices and labor expenses, allowing money to flow from the industrial sector into agriculture in order to meet the need for food at a subsistence level. The results of the study show that changes in agricultural productivity are responsible for around 44% of changes in industrial yield in developing countries. Thus, a decline in yield has an impact on employment and, ultimately, industrial production. Onyeizugbe and Umeagugesi (2014) examined how the currency rate, in particular the naira's depreciation, affects the survival of the manufacturing sub-segment in Nigeria between 1990 and 2013. They used the Ordinary Least Square (OLS) regression technique. The results showed a positive relationship between export and the use of industrial capacity. Thus, the research recommended that manufacturing firms begin producing high-quality goods and that the government promotes the expansion of the regional industrial subsector. Musa and Sanusi (2013) used a vector error correction model to analyze how Nigeria's total industrial production responded to relative pricing and exchange rate fluctuations between 1970 and 2011. Since their empirical study revealed a strong correlation between exchange rate and industrial output, they suggested that inflation and exchange rate may considerably impact industrial production in Nigeria. This research thus suggested that stronger governmental focus be given to controlling inflation and the exchange rate. Opaluwa, Umeh, and Abu (2010) used a linear regression method to examine how changes in the exchange rate affected the Nigerian industrial sector during a twenty-year period (1986–2005). The findings demonstrated that industrial production was negatively yet statistically significantly impacted by the exchange rate.

Wolde-Rufael (2005) obtained long-term association between energy utilization and development for Gabon, Ivory Coast, Nigeria, Sudan, Algeria, DRC, Egypt and Ghana among the 19 nations and short-term causality for 10 countries, namely Cameroon, Algeria, Egypt Congo DR, Ghana, Ivory Coast, Gabon, Morocco, Nigeria and Zimbabwe. Wolde-Rufael (2009) revisited their study using 17 African nations (Ivory Coast, Egypt, Morocco, Senegal, Nigeria, Sudan, Tunisia, Algeria, Zambia, Benin, Cameroon, South Africa, Gabon, Kenya, Ghana, Zimbabwe and Togo). The outcomes of their multivariate improved test discarded neutrality theory aimed at the energy-revenue association in African nations. Also, Akinlo (2008) performed a multivariate causality test and discovered contradictory outcomes for eleven African nations including Cameroon, Ivory Coast, Kenya, Gambia, Ghana, Senegal, Zimbabwe and Sudan. Wolde-Rufael (2006) initiate indication of unidirectional relation consecutively from economic growth to energy utilization in five African nations (Benin, DR Congo, Morroco, Namibia, and Tunisia), whereas bidirectional causality was found for two nations, namely, Egypt and Gabon and no indication of causal relationship was reported for the other five African nations (Congo Rep, Algeria, Kenya, Sudan and South Africa). Odhiambo (2009) found a one-way relation consecutively from energy consumption to monetary growth in Tanzania. Odhiambo (2010) again reported same unidirectional causal results for Kenya and South Africa while for Congo it is growth in the economy that energies power utilization. In like manner, Ouedraegoo (2010) discovered signs of an encouraging causal feedback interconnectedness between electricity usage and actual GDP for Burkina Faso.

Ozturk et al. (2010) examined the causal link between energy utilization and economic growth for 51 nations between 1971 and 2005, including Benin, Bangladesh, Congo, Haiti, Ghana, India, Nepal, Kenya, Nigeria, Pakistan, Sudan, Zambia, Togo, Zimbabwe, Bolivia, Algeria, Cameroon, Colombia, China, DRCongo, Ecuador, Dominican Republic, Egypt, Guatemala, El Salvador, Honduras, Iran, Indonesia, Jamaica, Nicaragua, Morocco, Paraguay, Philippines, Peru, Syrian, Sri Lanka, Thailand, Argentina, Tunisia, Chile, Gabon, Costa Rica, Hungary, Mexico, Malaysia, Oman, South Africa, Panama, Uruguay, Turkey and Venezuela. These countries were shared into a group of three and long-term causality consecutively to energy consumption for nations with incomes below GDP was found while two-way relation was established for middle-income nations. Engaging a panel of 82 nations of varied revenue levels, Agbede & Favour (2016) considered electricity utilization and industrial production in Nigeria using figures from 1981 to 2017 identifying some salient energy consumption levels and their impacts on outputs of the manufacturing segment in Nigeria.

The study by Yahaya et al. (2015) identifies electricity supply as a key driver of manufacturing growth in Nigeria. Nwankwo & Njogo (2013) found in their studies that power generation and manufacturing stimulate economic growth as both variables disclosed positive influence influences commercial output, while also power variable influenced the industrial sector through appropriate flow. Ogunjobi (2015) examined the impact of electricity consumption on industrial growth in Nigeria and reported a long-run positive association between manufacturing growth, and exchange rate while having a negative association with capital deployment. Enang (2010, 2011) and Apochi (2015) found positive effect of energy supply on manufacturing efficiency improvement, but the coefficient is very low due to insufficient and erratic electricity supply, especially for the manufacturing sub-sector of the economy, reflecting governments' unnecessary spending for non-economic and unproductive sectors.

3. Methodology and empirical development of models

For purpose estimation, we utilized both the Mean Group (MG) estimator and Pooled Mean Group (PMG) estimator to provide empirical solutions to heterogeneity bias that characterised our dynamic panel equation specification considering the very mathematical fact that ARDL exhibits dynamic specification whereby the ECM becomes an adjustment representation of both short and long-run periods of analysis. The theoretical foundation of this study is the theory of industrial production which is the theory of the production function of firms and the theory of energy cost. Energy cost theory goes to establish the fact that the cost of using energy in industrial production is recompensed by the total positive economic impact of business operations based on the demand multiplier effect (Vosooghzadeh, 2020). Meanwhile, the firm's objective is to maximise output in the short-term era which is equivalent to production cost minimization in the short-term era.

Theoretically, the industrial output decision is a function of production cost especially when it is the case that industrial supplies depend on production cost. But the firm's production cost is a function of the production function which relates industrial output to factor inputs namely, wages (labour costs), and interest rate (cost of capital). The study employs the Solow (1956) and Swan (1956) Cobb Douglas form of output while introducing the variable of energy supply that describes how production factors drive growth industrial output. This is specified in equation (1):

$$Q_t = AK^{\varphi}(AL)^{\phi}E^{\delta} \tag{1}$$

where Q is industrial output, K is capital stock, L is labour services, E is energy supply (in megawatts) and A is efficiency. The level of efficiency A is explained by the equation;

$$A_t = A_0 eKe^{g_t + p_t^{\delta}} \tag{2}$$

where g is the rate of technological progress assumed to be constant (Solow, 1956); ρ is the vector signifying all the additional features such as electricity utilization that might impact the level of skill and production in the economy; θ is the trajectory of coefficients related to these variables; A_0 is a constant, and the subscript t denotes time. Given that firm's objective is to maximize output which theoretically translates to minimizing the cost of industrial production, the cost function becomes the dual equation to the technical equation of industrial production. Using Solow's (1956) output model taking a lift from Amar's (2013), the industrial output equation with capital and energy as explanatory variables is thus specified as:

$$\ln(Q\_)_t = \ln(A\_{-1}) + \theta[(mwats)] + \phi/(1-\varphi)\ln(L) + \ln(K) - \phi/(1-\varphi)\ln(n+g+\delta) \tag{3}$$

Where Q is industrial output per labour for every SSA country and hereafter denoted as indo, mwats epitomizes megawatts of energy supplied, and K denotes capital aggregation. It tends to capture the direct influence of electricity supply, capital and labour on the general production of an economy. It is however adopted because the industrial output is a component of economic output measured as *q*. Unlike Agbede (2018), the energy variable is aggregated while the capital stock (ktsc) variable is also an aggregation of two market variables which are gross capital formation and foreign direct investment flows into SSA. The variable of labour services (lbse) is also included in the model specification in line with the neoclassical PF. In sum, the equation using natural log notation given data size becomes:

$$\ln indo_t = \beta_1 + \beta_2 \ln mwats_t + \beta_3 \ln ktsc_t + \beta_4 \ln lbse_t + e_t \tag{4}$$

Restrictions $\beta_i > 0$ are estimable parameters. The general representation of the ARDL model notably ARDL (p,q) model as specified with lagged value(s) of the industrial output, and predetermined variables where predetermined variables consist of the current and lagged values of capital aggregation, labour services, and energy supply is here given by:

$$\Delta \ln indo_t = \delta_1 + \delta_2 \ln indo_{t-1} + \delta_3 \ln mwats_{t-i} + \delta_4 \ln ktsc_{t-i} + \delta_4 \ln lbse_{t-i} + \sum_{i=1}^{p}\gamma_1 \Delta \ln indo_{t-i} + \sum_{i=1}^{q}\gamma_2 \Delta \ln mwats_{t-i} + \sum_{i=1}^{q}\gamma_3 \Delta \ln ktsc_{t-i} + \sum_{i=1}^{q}\gamma_4 \Delta \ln lbse_{t-i} + e_t \tag{5}$$

The corresponding empirical model becomes the ARDL (1,1,1) model as specified with lagged value(s) of industrial output, and predetermined variables.

$$\Delta \ln indo_t = \delta_1 + \delta_2 \ln indo_{t-1} + \delta_3 \ln mwats_t + \delta_4 \ln mwats_{t-1} + \delta_5 \ln ktsc_t + \delta_6 \ln ktsc_{t-1} + \delta_7 \ln lbse_t + \delta_8 \ln lbse_{t-1} + e_t \tag{6}$$

The ECM representation of our ARDL equation was accordingly derived as follows:

$$\Delta \ln indo_t + \ln indo_{t-1} = \delta_1 + \delta_2 \ln indo_{t-1} + \delta_3(\Delta \ln mwats_t + \ln mwats_{t-1}) + \delta_4 \ln mwats_{t-1} + \delta_5(\Delta \ln ktsc_t + \ln ktsc_{t-1}) + \delta_6 \ln ktsc_{t-1} + \delta_7(\Delta \ln lbse_t + \ln lbse_{t-1}) + \delta_8 \ln lbse_{t-1} + e_t \tag{7}$$

$$\Delta \ln indo_t = \delta_1 - \ln indo_{t-1} + \delta_2 \ln indo_{t-1} + \delta_3 \Delta \ln mwats_t + \delta_3 \ln mwats_{t-1} + \delta_4 \ln mwats_{t-1} + \delta_5 \Delta \ln ktsc_t + \delta_5 \ln ktsc_{t-1} + \delta_6 \ln ktsc_{t-1} + \delta_7 \Delta \ln lbse_t + \delta_7 \ln lbse_{t-1} + \delta_8 \ln lbse_{t-1} + e_t \tag{8}$$

$$\Delta \ln indo_t = \delta_1 - (1-\delta_2)\ln indo_{t-1} + + (\delta_3 + \delta_4)\ln mwats_{t-1} + \delta_5 \Delta \ln ktsc_t + (\delta_5 + \delta_6)\ln ktsc_{t-1} + \delta_6 \ln ktsc_{t-1} + \delta_7 \Delta \ln lbse_t + (\delta_7 + \delta_8)\ln lbse_{t-1} + \delta_3 \Delta \ln mwats_t + \delta_5 \Delta \ln ktsc_t + \delta_7 \Delta \ln lbse_t + e_t \tag{9}$$

$$\Delta \ln indo_t = \delta_1 - (1-\delta_2)\begin{bmatrix} \ln indo_{t-1} - \frac{(\delta_3+\delta_4)}{(1-\delta_2)}\ln mwats_{t-1} \\ -\frac{(\delta_5+\delta_6)}{(1-\delta_2)}\ln ktsc_{t-1} - \frac{(\delta_7+\delta_8)}{(1-\delta_2)}\ln lbse_{t-1} \end{bmatrix} + \delta_3 \Delta \ln mwats_t + \delta_5 \Delta \ln ktsc_t + \delta_7 \Delta \ln lbse_t + e_t \tag{10}$$

$$\Delta \ln indo_t = \delta_1 - \phi ECT_{t-1} + \delta_3 \Delta \ln mwats_t + \delta_5 \Delta \ln ktsc_t + \delta_7 \Delta \ln lbse_t + e_t \tag{11}$$

where

$$\phi = (1-\delta_2), \quad ECT_{t-1} = \begin{bmatrix} \ln indo_{t-1} - \frac{(\delta_3+\delta_4)}{(1-\delta_2)}\ln mwats_{t-1} \\ -\frac{(\delta_5+\delta_6)}{(1-\delta_2)}\ln ktsc_{t-1} - \frac{(\delta_7+\delta_8)}{(1-\delta_2)}\ln lbse_{t-1} \end{bmatrix}$$

The long-run coefficients were thus estimated from our ARDL (1,1,1). Recall the ARDL equation (6) as:

$$\Delta \ln indo_t = \delta_1 + \delta_2 \ln indo_{t-1} + \delta_3 \ln mwats_t + \delta_4 \ln mwats_{t-1} + \delta_5 \ln ktsc_t + \delta_6 \ln ktsc_{t-1} + \delta_7 \ln lbse_t + \delta_8 \ln lbse_{t-1} + e_{1t}$$

□ $Long-run\ equilibirum,\ Z_t = Z_{t-1} = Z$

□ □ □ $$\Delta \ln indo_t = \delta_1 + (\delta_3 + \delta_4)\ln mwats_t + (\delta_5 + \delta_6)\ln ktsc_t + (\delta_7 + \delta_8)\ln lbse_t + e_t \tag{12}$$

where

$$\mu_2 = \frac{(\delta_3+\delta_4)}{(1-\delta_2)}$$

$$\mu_3 = \frac{(\delta_5+\delta_6)}{(1-\delta_2)}$$

$$\mu_4 = \frac{(\delta_7+\delta_8)}{(1-\delta_2)}$$

The MG estimator has separate regressions for each country as a cross-section. Accordingly, given our autoregressive distributed lag model as:

$$\ln indo_{it} = \delta_i + \phi_i \ln indo_{it-1} + \gamma_i \ln mwats_{it} + \alpha_i \ln ktsc_{it} + \rho_i \ln lbse_{it} + u_{it} \quad (13)$$

The LR coefficient for country i denoted by ω_i ϖ_i & ρ_i was estimated as:

$$\omega_i = \frac{\gamma_i}{1-\phi_i}$$

$$\varpi_i = \frac{\alpha_i}{1-\phi_i}$$

$$\rho_i = \frac{\varphi_i}{1-\phi_i}$$

The MG estimators for the whole panel of ECOWAS countries were then estimated as:

$$\omega = \frac{1}{N}\sum_{i=1}^{N}\omega_i,$$

$$\varpi = \frac{1}{N}\sum_{i=1}^{N}\varpi_i,\ \rho = \frac{1}{N}\sum_{i=1}^{N}\rho_i,\ \delta = \frac{1}{N}\sum_{i=1}^{N}\delta_i$$

The PMG estimator on the other hand is a reparameterization of the unrestricted autoregressive distributed lag (ADL). Consequently, for a sample of SSA countries, i = 1... N countries together with a time series data that spans from t = 1, 2, ... T, periods, we have as follows:

$$\ln indo_{it} = \delta_i + \sum_{j=1}^{p}\phi_{ij}\ln indo_{i,t-j}\sum_{j=1}^{q}\gamma_{ij}\ln mwats_{i,t-j} + \sum_{j=1}^{q}\alpha_{ij}\ln ktsc_{i,t-j} + \sum_{j=1}^{q}\rho_{ij}\ln lbse_{i,t-j} + \upsilon_i + u_{it}$$

(14)

$$\Delta\ln indo_{it} = \Theta_i(\ln indo_{i,t-1} - \gamma_1\ln mwats_{i,t-1} - \alpha_1\ln ktsc_{i,t-1} - \rho_1\ln lbse_{i,t-1}) + \sum_{j=1}^{p-1}\phi_{ij}\Delta\ln indo_{i,t-i} + \sum_{j=1}^{q-1}\gamma_{ij}\Delta\ln mwats_{i,t-j} + \sum_{j=1}^{q-1}\alpha_{ij}\Delta\ln ktsc_{i,t-j} + \sum_{j=1}^{q-1}\rho_{ij}\Delta\ln lbse_{i,t-j} + \upsilon_i + u_{it} \quad (15)$$

Equation (14) is the unrestricted ADL model while equation (15) is the re-parameterized model. The **p** lags are lags of industrial output, that is, the dependent variable, q lag are lags of exogenous variables, namely, capital, labour, and energy supply, γ_1, α_1 & ρ_1 are LR parameters, $\phi_{ij}, \gamma_{ij}, \alpha_{ij}$, & ρ_{ij} are SR coefficients, and Θ_i are EC parameters, and these are the adjustment parameters of the panel model. The suitable lag length for the equation of individual SSA nations was chosen based on the criterion with the lowest value between SBC and AIC. The Hausman test was conducted to ascertain the effect of heterogeneity. The Hausman hypothesis is given by $H_0: \gamma_1 = \alpha_1 = \rho_1$ *vs.* $H_1: \gamma_1 \neq \alpha_1 \neq \rho_1$. The acceptance of the null hypothesis of the homogenous long-run coefficient indicates PMG as the most efficient estimator while acceptance of the alternative provides pieces of evidence in favour of MG as the most efficient estimator.

The following are other alternative estimation methods of a production function. Input-output approach, method of quantile regression, Markov chain regression, and VECM estimation technique. However, we are desirous of an ARDL specification for industrial production. This is because the panel ARDL/PMG method provides impartial estimates when endogenous covariates are present. And it is also active level if the variables have diverse optimum delay dimensions. The foremost characteristic of coordinated variables is that their period trails are affected by deviations from long-term equilibrium (Mallick et al., 2016). This provides the necessity for re-parameterization from the ARDL ideal panel as described by equation (15). This paper employs a panel dataset for 18 SSA nations covering from 2008 to 2022. We collected data on total electricity consumption and foreign capital for ten (17) SSA nations from the World Bank's Growth Indicators (2020) record. We collected data on industrial production, total electricity consumption, petroleum consumption and foreign capital from World Manufacturing Production. The 18 countries are Benin, Angola, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Gabon, Ghana, Guinea, Kenya, Malawi, Mauritius, South Africa, Sudan, Tanzania, Zimbabwe, and Nigeria

4. Results and discussions

The data set was abridged and the outcome is shown in Table 1. The obtained mean values are worthy methods of central tendency, as they are all halfway between the maximum and minimum values. In the SSA countries, the worth of industrial output (production) averages about US$6.16 billion per annual, whereas the uppermost and lowest values are US$55.9 billion and US$49 billion, respectively. For total energy supply, the average value obtained for the region is 0.22 *quadrillion Btu, w*ith the maximum and minimum values being 1.69 *quadrillions Btu* and 0.01 *quadrillion Btu* respectively. For Electricity supply, SSA countries consume an average of 4.82 billion kilowatts with maximum and minimum being 29.59 billion KWTs and 0.23 billion KWTS. Aggregated capital stock attracted to these SSA countries averaged USD150b with maximum and minimum being USD8.840b and USD0.73b, respectively.

Table 1: Summary statistics

Variables	Obs	Mean	Std Dev	Maximum	Minimum
lnindo	280	6,160	12,100	55,900	4900
lnmwats	280	4.82	7.07	29.59	0.23
lnktsc	280	64.91	109.13	461.37	3.55
lnlbse	280	1.25	5.00	42,900	124

Source: Authors

There are two generations of panel unit root test methods. The first generation (FG) of tests include, the IPS test by Im et al. (2003), the LLC test by Levin et al. (2002), Choi (2001), Breitung (2000), Maddala & Wu (1999), and Hadri (2000) posits independence of individual units (cross sections) whereas the second generation (SG) tests which comprises Pesaran (2003), Moon & Perron (2004a), Bai & Ng (2004), Chang (2004), and Choi (2002), permits dependence of cross-sectional units. Amongst the FG that concede homogeneous panels which convey common unit root are the Hadri test, Breitung test, and Levin et al. test methods while the Im et al. (2003), Choi (2001), and the Maddala et al. (1999) tests assume heterogeneity in cross-sectional units.

According to Banerjee et al. (2000), and Strauss & Yigit (2003), the application of FG test methods to data pigeonholed by cross-sectional dependence results in distortions and low power efficiency. Therefore, we conducted the cross-section dependence in the residuals and the results shown in Table 2. Table 2 demonstrated that for the three testing methods, the probability values, namely, 0.1268, 0.5279, and 0.2268 exceeded 5%. Since we are confronted with the null hypothesis of no cross-section correlation in residuals, we reject the alternative with the conclusion that there is an absence of cross-sectional dependence

Table 2: Results of cross-section dependence test

test method	Statistic	Probability
Pesaran CD	-1.3479	0.1268
Pesaran scaled LM	0.5237	0.5279
Breusch-Pagan LM	1.7824	0.2268

Source. Authors

Table 3 results of the panel unit root tests show that the data are stationary in the first difference. The variables are stationary because the estimated statistics are significant and exceeded the critical values. Given the presence of heterogenous units in our cross-country analysis, the heterogeneity that characterized the test methods presents asymmetry since the same null hypothesis was executed across individual units while the alternative hypothesis was permitted to vary with individuals. Our dynamic estimates in essence are devoid of spurious results. Therefore, taking asymmetry into cognizance, a statistically significant p-value, $p<0.05$ denote stationary series.

In particular, with a homogeneity testing procedure, the LLC and Breitung t-statistic rejected the presence of a unit root. The same results are obtained for the heterogeneity testing procedure, namely, the ADF, PP Fisher Chi-Square as well as the IPS W-statistic respectively. The first differences of the variables accept the alternative hypothesis of stationary series.

To ascertain the long-run association among variables, we conducted the Kao and the Pedroni residual co-integration tests. The results are reported in Table 4. The results demonstrate co-integration among all the variables. This follows from the significance of the panel and group test methods as reported by the probability values. For the within-dimension Pedroni test, 0.0000 probability was obtained except for the v-statistic which had 0.1456. Similarly, for the between-dimension results, all the group test methods reported a 0.0000 probability value. Therefore, our estimators are efficient because the variables in our study are stationary and co-integrated.

Table 4: Co-integration results

Pedroni test results based on within-dimension		
Panel test methods	Statistic	Probability
v-Statistic	0.02156	0.1456
rho-Statistic	-11.5730	0.0000
PP-Statistic	-20.3047	0.0000
ADF-Statistic	-17.3491	0.0000
Pedroni test results based on between-dimension		
Group test method	Statistic	Probability
rho-Statistic	-4.0691	0.0001
PP-Statistic	-13.4562	0.0000
ADF-Statistic	-18.7328	0.0000
Kao co-integration results		
	t-statistic	Probability
ADF	-24.9800	0.0000

Source: Authors

Table 5 shows the results of ARDL bound test for co-integration. The ARDL bound tests results indicate evidence of co-integration between industrial output, energy supply, capital stock and labour. This is made evident by significant F-statistic of 23.5 as it exceeds both the lower and upper bound critical values at both levels of significance.

Table 5: ARDL Bound test results

Table 3: Unit root/stationary test results

Variable	LLC t-Statistics		Breitung t-statistic		Hadri Statistics	
	Level	1st difference	Level	1st difference	Level	1st difference
lnindo	2.0578	-6.3789***	1.2896	-4.0238***	2.0374	-6.7638***
lnmwats	-1.2964	-8.9230***	1.1120	-6.1643***	-0.1358	-10.216***
lnktsc	0.7834	-7.5827***	0.3794	-5.3621***	-1.3904	-5.2467***
lnlbse	-5.4895**	-9.6843***	1.0932	3.5689**	-3.7835	-19.7835***
Variable	ADF – Fisher Chi-Square		ADF – Fisher Chi-Square		IPS W-Statistics	
	Level	1st difference	Level	1st difference	Level	1st difference
lnindo	1.3082	-234.795***	10.8246	124.559***	2.0374	-6.7638***
lnmwats	0.2375	-190.79**	40.3485**	109.485***	-0.1358	-10.216***
lnktsc	0.5763	-345.128***	17.3794	82.4891***	-1.3904	-5.2467***
lnlbse	0.2308	-101.386***	39.5831	48.5720**	-3.7835	-19.7835***

Source. Authors

Note: ∗∗ and ∗∗∗ implies stationary series at the 5% and 1% significance levels.

F-statistic	1% CV		5% CV	
	Lower bound I(0)	Upper bound I (1)	Lower bound I(0)	Upper bound I(1)
23.4579***	3.967	5.298	3.176	4.269

Note: *** denotes significance at levels.
Source: Authors

Having computed probabilities under the assumption of asymptotic normality, our variables used in this analysis are integrated into an order I(1). Nevertheless, the ARDL models a combination of I(1) and I(0) variables but certainly not I(2). Hence, our variables of interest are well behaved as our estimation of the ARDL model does not include a variable that is integrated of order 2. This order of integration allows us to use the ARDL estimation procedure (Pesaran et al. 2001). Combining all of these variables in the first order, I(1), suggests the LR relationship. The main results of ARDL and short-run coefficients of variables are contained in Tables 5 and 6 below. In particular, the short-run (SR) and long-run (LR) estimates of panel MG and PMG are shown in Tables 5 and 6 respectively with the logarithm of industrial output serving as a dependent variable. The best model selected based on the smallest AIC value for the MG estimations is ARDL (1, 2, 2, 1) equation and this forms the basis of empirical interpretations. Comparable, the suitable model chosen for the PMG estimations is ARDL (1, 1, 2, 1) equation. Speed adjustment is -0.43952. This shows a moderate speed of adjustment to the restoration of equilibrium by the mean group equation. In effect, there is a guarantee of system convergence and the relationship is stable. That the ECT is significantly different from zero points to some validation of stable long-run association that is significant to the growth of industrial output in SSA. The calculated Hausman test statistic is 29.679 with a zero probability value. This provides the basis for the rejection of homogenous long-run coefficients with the implication that empirical analysis is based on mean group estimations. Basing analysis of estimates of ARDL (1, 2, 2, 1) equation where the lag of industrial output is 1, the lag order of megawatts is 2, the lag order of aggregated capital stock is 2, and the lag order of labour services is 2.

The results show clearly both the first and second lag of megawatts of electric power supplied have an insignificant effect on industrial output in SSA in the short run. The same result was obtained for the long-run coefficient of megawatts even at a 10% level of statistical significance. What this means is that in SSA countries, energy supplied does not grow industrial output. This could be responsible for the 23% contribution of the manufacturing sector to GDP as against, 42%, and 35% contributions by services and agrarian sectors (Hollinger & Staatz, 2015). The coefficient of first lag of capital aggregation is 0.05042 with 0.0000 p-value at the 1% level, while the second lag order coefficient of 0.00397 had an insignificant p-value of 0.8726 respectively. The same significant estimate was obtained for the long-run coefficient of capital aggregation. This is an indication that in recent times, capital flows are significantly impactful to the industrial development of SSA countries unlike what it has been (in the past). By implication, the current stock of capital inflows to SSA would positively and significantly contribute to the growth of industrial output in the coming years. Both SR and LR (first lag order and current period) coefficients of labour services are statistically significant at a 1% significant level. This explains that labour services do have some sort of significant relationship with industrial output among SSA nations.

Table 5. Panel mean group estimation results

Short Run Equation for log of industrial output, ARDL (1, 2, 2,1)			
Variable	Coefficient	t-Statistic	Prob.*
ecm(-1)	-0.43952	-3.18152	0.0004
d(lnindo(-1))	0.30417	7.6209	0.0000
d(lnmwats(-1))	0.16152	0.7130	0.2958
d(lnmwats(-2))	0.03859	1.36239	0.1765
d(lnktsc(-1))	0.05042	20.64201	0.0000
d(lnktsc(-2))	0.00398	0.14578	0.8726
d(lnlbse(-1))	0.79132	10.5021	0.0000
Cointegrating and long-run equation for log of industrial output			
Variable	Coefficient	t-Statistic	Prob.*
lnmwats	0.31026	1.100449	0.5389
lnktsc	0.39510	2.897067	0.0053
lnlbse	0.78204	6.897067	0.0000
Con	1.6293	5.10283	0.0000
Diagnostics			
Mean (INDO)	0.055479	B-G Serial Correlation LM	5.7862 (0.1397)
S.E. of regression	0.00024	Akaike info criterion	1.4536
Sum squared resid	10.0345	Schwarz criterion	2.9862
Log-likelihood	-2923.68	Hannan-Quinn	2.0784

Source: Authors

Table 6. Panel pooled mean group estimation results

Short-run equation for log of industrial output, ARDL (1, 1, 2,1)			
Variable	Coefficient	t-Statistic	Prob.*
ecm(-1)	-0.39420	-16.79850	0.0000
d(lnindo(-1))	0.25570	2.7635	0.0271
d(lnmwats(-1))	0.11859	1.00439	0.1035
d(lnktsc(-1))	0.4972	4.95642	0.0000
d(lnktsc(-2))	0.67910	2.00813	0.00156
d(lnlbse(-1))	1.09327	3.35681	0.0001
Cointegrating and long-run equation for log of industrial output			
Variable	Coefficient	t-Statistic	Prob.*
lnmwats	1.00826	0.34265	086540
lnktsc	0.53819	1.57920	0.0057
lnlbse	1.07352	9.34100	0.0000
Con	1.08711	2.36580	0.0046
Diagnostics			
Mean (indo)	0.06798	B-G Serial Correlation LM	6.0579 (0.1562)
S.E. of regression	0.01293	Akaike info criterion	1.0862
Sum squared resid	13.0867	Schwarz criterion	2.0579
Log-likelihood	-2457.09	Hannan-Quinn	2.0978

Source: Authors

Table 7. Hausman test results

Group	Chi-sq	p-value
SSA	29.679	0.0000

Source: Authors

Figures 1 and 2 are the stability graphs based on cumulative sum and the cumulative sum of squares. Given that the fitted line which represents CUSUM and CUSUNSQ lies within the lower and upper critical bounds, the estimated parameters are indeed dynamically stable at 5% level.

Figure 1: Plot of stability

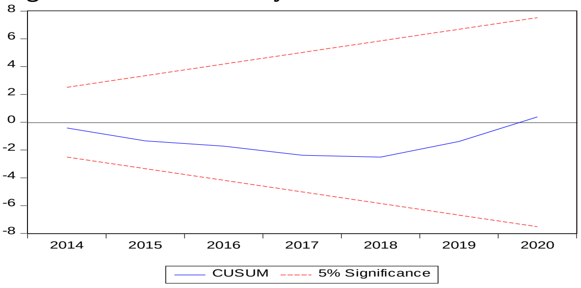
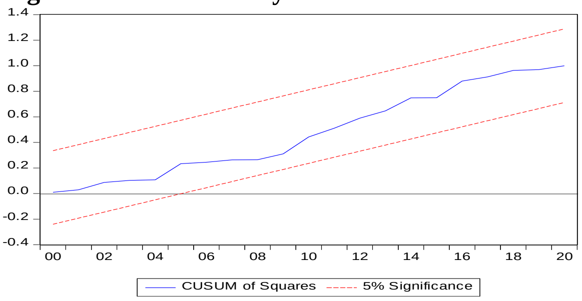


Figure 2. Plot of stability



5. Conclusion

In this study, we examined the impact of energy supply and capital aggregation on industrial output aimed at eighteen selected SSA member nations over a sample period of 2008 to 2022. Such variables as industrial output, megawatts of electric power supply, and aggregation of domestic capital and foreign capital inflows were utilized as relevant variables of interest. We used the Pedroni co-adjustment test to find the validity of this long-term relationship and we found a co-integrating association between the variables used. The MG and PMG estimation methods were deployed for analysis. The ARDL/PMG panel has been shown to have certain appeals above extra estimation techniques. Analysis was based on the MG estimator and the selected ARDL (1,2,2,1) model with a -0.43952 speed adjustment. The results show evidently that in SSA countries, energy supplied does not grow industrial output. This corroborates the submission of Evbogba (2021) that in Nigeria with about 213 million population (UN, 2020), only 3000 megawatts of power are generated for consumption. Such megawatts of electric power supply cannot withstand industrial productivity and basic household needs. The empirical findings established significant contributions of capital stock and labour factors as production inputs to industrial growth in SSA. In sum, SSA nations should intensify efforts aimed at generating electricity as a source of energy for industrial sectors to stimulate growth in industrial outputs. Also, the paper established that the quantum of megawatts of electric power supplied in SSA countries does not grow industrial output and that lately, capital flows are significantly impactful to the industrial development of SSA countries unlike what it was in the past. Indeed, the current stock of capital inflows to SSA would positively and significantly contribute to the growth of industrial output in the coming years. Furthermore, we found that despite labour availability, industries are deficient in electricity supply. This indeed necessitates the need for a committed course to making energy adequately available in addition to a stock of aggregated capital for the resolve of mitigating low industrial output in SSA. The present paper reports findings that are limited to eighteen selected SSA nations. For purpose of reporting wide-ranging findings, the dynamic stochastic general equilibrium (DSGE) model could be implemented by future researchers to model a general production function of a larger sample of African nations based on production theory that explains and estimates co-movements of factors over the production sequence and also executes findings-based policies.

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