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INDUSTRIAL DEVELOPMENT IN AFRICA: THE ROLE OF ENERGY PRICE VOLATILITY

Forthcoming: Energy Sources, Part B: Economics, Planning, and Policy

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Abstract

This study examines the impact of energy price volatility on industrialization in 39 sub-Saharan African economies between 2001 and 2023. Two measures of energy price volatility are analyzed: the standard deviation of energy price inflation and the standard deviation of the residuals of energy price inflation from an autoregressive process. Using the ordinary least squares, the Fixed Effects regression, the quantile regression, and the system generalized method of moment as estimation strategies, the result revealed that irrespective of the measure of energy price volatility, the increase in energy price volatility reduces both manufacturing and industry growth. Countries with lower initial manufacturing growth are more adversely affected, while those with high industry growth experience greater volatility impacts. Interestingly, where manufacturing growth is high, volatility may increase growth rates. Results hold robustly against cross-sectional dependence, unobservable heterogeneity, and endogeneity. Insights and policy recommendations are provided based on these findings.

Keywords: Energy Price; Volatility; Manufacturing; Industry; Africa.

1. Introduction

Globally, sub-Saharan Africa's (SSA's) industrial development lags behind other regions. Despite numerous policies and programs aimed at advancing the sector, industrial efforts across the continent have remained underdeveloped. According to the World Bank (2024a, 2024b), both manufacturing and industry-wide productivity in the region has remained low. The COVID-19 pandemic further exacerbated the poor industrial productivity numbers. In 2023, SSA manufacturing output stood at approximately $193.42 billion, which was 3.1 times lower than that of South Asia, 4.9 times lower than Latin America and the Caribbean, and 17.69 times lower than Europe and Central Asia. Additionally, total industrial output in the region remains far below that of other parts of the world, reflecting SSA's ongoing struggle to build a competitive industrial base (see Figures A1 & A2).

Past literature such as Narayan and Smyth (2008) have identified the importance of the availability and access to energy on the performance of an economy. While there are several factors that have affected industrialization in SSA, the volatility in energy prices can also contribute to the slow pace of economic activities and industrialization in the region. According to Mohammad et al. (2023), energy price volatility has become a concerning issue for industrial development in the region. Volatility in energy prices not only leads to unpredictable costs for businesses but can also deter long-term investment commitment (Frimpong, Antwi & Brey, 2018; Takentsi, Sibanda, & Hosu, 2022). According to Andre et al. (2023), pessimism arising from energy price volatility can also have short-run consequences for industrial output. This also creates a negative spillover issue for the broader economy by reducing manufacturing and industry employment and dampening aggregate supply, which creates supply-side inflation. Energy price volatility also acts as a deterrent as potential investors seek stable environments to minimize risks (Bartekova & Ziesemer, 2019; Saussay & Sato, 2024). According to Guan et al. (2023), higher energy prices impose an additional cost burden on the economy, affecting both consumers and producers. Geo-political events such as the Russia-Ukraine war and the rising post-pandemic global economic recovery have fed into the volatility of energy prices (IEA, 2022).

Notwithstanding the intuitive implications of energy price volatility on industrialization, empirical studies on the nexus between energy price volatility and industrialization in SSA are surprisingly sparse. In this study, we use novel data on energy price inflation developed by Ha, Kose, and Ohnsorge (2023) and compute a volatility series using two methods: (i) a 3-year non-overlapping interval to compute the standard deviation to obtain a volatility series for energy prices, and (ii) the standard deviation of residuals after a first-order autoregressive process of energy prices. These volatility computation methods will be further discussed in the methodology section. The study also employs two measures of industrialization. They include manufacturing growth rate and industry growth rate. The study employed these two proxies for industrialization for robustness purposes. However, it is important to note that for Africa, manufacturing growth rate is a more crucial indicator due to its uniqueness in capturing economic diversification and job creation for the African economy and mirrors the structural transformation needed for sustainable economic development in the region.

Several reasons justify the need to study the impact of energy price volatility on industrialization in SSA. Firstly, understanding the impact of energy price volatility on industrialization is important for industrial policy formulation because it enables policymakers to formulate targeted interventions for the manufacturing and industrial sectors. Secondly, as a result of the effect of energy prices on investment decisions, understanding the effect of energy price volatility on industrialization will contribute to building frameworks that help to stabilize the economy and promote sustainable growth. Thirdly, this study will provide empirics on the need for businesses and African governments to build resilience through the need to diversify energy sources and improve energy efficiency to withstand the volatility in energy prices. Additionally, the findings from this study will also feed into long-term strategic planning and policy adjustments for sustainable industrial growth in SSA.

As revealed earlier, the literature on the nexus between energy price volatility and industrialization in SSA is sparse. African studies have largely focused on the nexus between energy prices and economic growth (Khobi, Mugano, & Le Roux, 2017; Longe et al., 2021; Takentsi, Sibanda, & Hosu, 2022) and energy consumption and economic growth (Arouri et al., 2014; Gozgor, Lau, & Lu, 2018; Qi et al., 2022; Odhiambo, 2023). Studies on the nexus between energy prices and industrialization do not explicitly consider African countries (Taiebnia & Shakeri, 2012; Al-Risheq, 2016). Moreover, these studies employed crude oil prices as a proxy for energy prices. Our study employs a novel dataset on energy price inflation that incorporates a broader range of energy sources and prices. This study employs data from 39 SSA countries spanning 2001 to 2023 and uses several estimation methods to ensure robustness. These methods include Ordinary Least Squares (OLS), Fixed Effects (FE) estimation to control for unobservable heterogeneity, and System Generalized Method of Moments (GMM) to address endogeneity bias. Additionally, Quantile Regression (QR) is used to enhance both estimation and policy relevance of the study. QR is particularly valuable as it examines the impact of energy price volatility on industrialization across different quantiles of the industrialization distribution, offering insights into how volatility in energy prices affects industrialization at various levels of industrial growth. It is important to know whether energy price volatility can affect industrialization differently across SSA countries based on the existing level of industrialization. This approach fills an additional gap in the literature and also offers important insights for policy. The remainder of this study is the literature review which is covered in Section 2, the method and data section is disclosed in Section 3, the presentation and analysis of results are provided in Section 4, and the conclusions with relevant policy recommendations are covered in Section 5.

2. Theoretical and Empirical Literature Review

2.1 Theoretical Literature

This study takes into consideration two theories that loosely explain how energy price volatility influences industrial growth in Africa. From an investment standpoint, Jorgenson's (1963) user cost of capital model highlights the role of cost in investment decisions. Accordingly, because energy influences the efficiency and utilization of capital and feeds directly into operational expenses, especially for manufacturing, a rise in energy prices will affect the profitability of capital investment and raise the user cost of capital, discouraging firms from investing in new industrial capacity, thereby slowing down the industrialization process. This, with a further issue of uncertainty as a result of energy price volatility, can significantly slow down the industrial process in Africa. The seminal works of McDonald and Siegel (1986) and Dixit and Pindyck (1994) on real option theory further highlight the impact of uncertainty on firms' investment decisions. As noted by Reside (2022), the theory suggests that firms often exercise the option to delay new investments when faced with uncertainty. Within the context of a firm's investment decision, the real option theory provides insights into how energy price volatility influences the pace of industrialization in Africa. The volatility in energy prices introduces uncertainties into the cost of production, which delays investment in new capital, feeding into a slower growth rate in industry.

2.2 Empirical Literature

Empirically, Rahman et al. (2021) examined the impact of energy consumption on industrialization in Bangladesh between 1975 and 2018. The result showed that electricity consumption and industrialization have bidirectional causality, indicative of the need for energy in enhancing industrialization. Moreover, Takentsi, Sibanda, and Hosu (2022) using data between 1994 and 2019 and using the autoregressive distributed lag (ARDL) estimator for the South African economy revealed that the increase in electricity prices significantly dampened economic growth. The result further revealed that there is no causality running from electricity prices to economic growth in South Africa. Guan et al. (2023), using data for 116 countries to examine the impact of energy prices on 201 expenditure groups, revealed that energy costs reduce household expenditure. This can have demand-side implications for industry growth. Furthermore, He et al. (2016), in a study of the Chinese economy using data from 1988 to 2012 and employing the ridge regression and state-space model, revealed that energy prices significantly reduce both total energy consumption and intensity. Chen et al. (2023) have also highlighted that surging energy prices have adversely affected firms’ productivity and have lowered potential output in Germany.

Wang (2022) utilized data from 30 provinces in China for the period 2005 to 2020 and employed the fully modified ordinary least squares (FMOLS) as the estimation strategy in examining the effect of energy prices on regional economic growth. The result revealed that rising energy prices have a negative impact on GDP at the national level. The results further revealed that energy price fluctuations have a similar negative impact on GDP across the regions of China. However, energy prices have the least impact on the eastern region and the most severe impact on the west, revealing heterogeneity on the nexus across regions. In the study of Andre et al. (2023) on the nexus between energy prices and firm productivity in 21 countries between 1995 and 2020, it is revealed using the FE estimator, the GMM estimator, and the impulse response function that a 5% increase in energy prices reduces firm productivity by 0.4% after one year. The study further revealed that a shock corresponding to a 10% increase in energy prices will increase productivity growth by 0.9 percentage points after four years of the shock. The study attributes this positive nexus to less energy-intensive sectors of the economy. Additionally, Chiacchio et al. (2023) have further revealed that higher energy prices significantly affect domestic industrial production in the euro area. Saussay and Sato (2024), using data from 41 nations and a gravity model framework, discovered that a 10% increase in the energy price disparity between two countries causes a 3.2% increase in cross-border acquisitions. This demonstrates the impact of relative energy prices on the global geographic distribution of industrial investments.

The reviewed literature highlights several gaps that this study aims to address regarding the relationship between energy price volatility and industrialization in SSA. These gaps include: (i) much of the existing research focuses on regions outside Africa; (ii) studies within Africa tend to be country-specific and examine the impact on GDP rather than industrialization; (iii) this study utilizes a comprehensive dataset for the SSA region; and (iv) unlike previous research, this study specifically examines energy price volatility rather than energy prices.

3. Method and Data

3.1 Method

Four econometric methods are used in this study. They include the OLS, the FE regression, the QR, and the system GMM estimator. Accordingly, the OLS and FE regressions employ the Driscoll and Kraay (1998) standard errors in order to provide heteroskedastic and autocorrelation consistent (HAC) standard errors. The Driscol and Kraay standard errors also correct for cross-sectional dependence in the modeling exercise. FE regression accounts for unobservable heterogeneity in the modeling exercise, which can lead to estimation bias if not accounted for. The OLS and FE equations are presented in equations (1) and (2), respectively.

$$i_{i,t} = \tau_0 + \tau_1 energyvol_{i,t} + \tau_j \sum_{2}^{7} X_{i,t} + u_{i,t} \quad (1)$$

$$i_{i,t} = \tau_1 energyvol_{i,t} + \tau_j \sum_{2}^{7} X_{i,t} + e_i + u_{i,t} \quad (2)$$

Where, i is a representation of industrialization, composed of two proxies. (i) Manufacturing, value-added growth, and (ii) industry value-added growth. $energyvol$ is energy price volatility and X is a set of control variables that includes bank credit to bank deposit, per capita GDP, total population, remittances, natural resources, and foreign direct investment (FDI). e_i captures the unobserved country-specific fixed effect, and $u_{i,t}$ is the error term in country i at time t.

To account for existing levels of industrialization in SSA, the QR is employed. According to Boateng et al. (2018), the QR has the advantage of assessing nexuses across the distribution of the dependent variable. Iheonu and Oladipupo (2023), and Iheonu, Obumneke, and Agbutun (2023) revealed that QR improves policy relevance as parameters are derived at multiple points of the conditional distribution of the dependent variable (see Okada & Samreth, 2012). This study's QR analyzes the impact of energy price volatility on industrialization in the 10th, 25th, 50th, 75th, and 90th quantiles. Obtaining the θ^{th} quantile estimate of industrialization involves solving the optimization problem:

$$\min_{\beta \epsilon R^k} \left[\frac{\Sigma\theta|y_i - x_i\beta|}{i\epsilon\{i: y_i \geq x_i\beta\}} + \frac{\Sigma(1-\theta)|y_i - x_i\beta|}{i\epsilon\{i: y_i < x_i\beta\}} \right] \quad (3)$$

where, $\theta \,\epsilon\, (0,1)$. At each quantile, QR minimizes the weighted sum of absolute deviations by weighing the residuals approximately. Hence, the conditional quantile of industrialization given energy price volatility is $Q_y\left(\frac{\theta}{x_{i,t}}\right) = x_i'\beta\theta$. The distinct slope parameters are thus modeled for each

θ^{th} quantile. To address unobservable heterogeneity in the QR, year and country fixed effects are included in the modeling exercises.

Endogeneity bias is explicitly addressed in this study using the system GMM estimator via the procedure of Roodman (2009a, 2009b). This procedure is an extension of Arellano and Bover (1995) and Blundell and Bond (1998). Simultaneity and reverse causality are addressed using internal instruments, and unobservable heterogeneity is accounted for employing year effects. Additionally, the system GMM is employed as an estimation strategy because the number of countries is greater than the number of time periods. Equations (4) and (5) represent the standard GMM equations in levels and first difference, respectively.

$$i_{i,t} = \tau_0 + \tau_1 i_{i,t-1} + \tau_2 energyvol_{i,t} + \sum_{h=3}^{7} \lambda_h X_{h,i,t-\rho} + \delta_i + \vartheta_t + \mu_{i,t} \qquad (4)$$

$$i_{i,t} = \tau_1 (i_{i,t-\rho} - i_{i,t-2\rho}) + \tau_2 (energyvol_{i,t} - energyvol_{i,t-\rho}) + \sum_{h=3}^{7} \lambda_h (X_{h,i,t-\rho} - X_{h,i,t-2\rho}) + (\vartheta_t - \vartheta_{t-\rho}) + (\mu_{i,t} - \mu_{i,t-\rho}) \qquad (5)$$

The variables in Equations (4) and (5) are as defined in Equation (1) and (2). δ_i is the country-specific effect, ϑ_t is the time-specific constant, $\mu_{i,t}$ is the residual. According to Asongu and Odhiambo (2020), the GMM estimator uses a two-step method to account for heteroskedasticity. The presence of serial correlation in the model is examined using the Arellano and Bond second-order tests. Furthermore, the validity of the instruments employed in the model is examined using the robust Hansen test.

In line with GMM-focused literature (Asongu, Nnanna, & Acha-Anyi, 2020), the explanatory variables in the models are treated as endogenous, while the time-invariant variable is considered exogenous, following Roodman (2009b). The Difference in Hansen Test (DHT) is applied to verify the assumption that the exogenous time-invariant variables affect the dependent variable solely through the exogenous part of the endogenous variables. For the exclusion restriction hypothesis to hold, the DHT null hypothesis must not be rejected. Additionally, forward orthogonal deviations are employed in the GMM procedure to further ensure that the expected value of the lagged dependent variable and the error term is zero.

3.2 Data

Energy price inflation data is employed as a proxy for energy prices and is derived from Ha, Kose, and Ohnsorge (2023). Accordingly, the energy price inflation measures a broad-based increase in the prices of energy. Industrialization is proxied with two indicators, including manufacturing value added, percentage growth, and industry value added, percentage growth. Both measures of industrialization have their merits. Manufacturing is largely labor intensive in SSA, thus giving us a closer focus on value-added production and employment generation, both of which are crucial for the medium- to long-term progress of the economy. Moreover, even though industry growth provides an overall perspective of how energy price volatility affects industrialization, it tends to dilute the focus on manufacturing, which is the core driver of sustained industrialization and employment in Africa.

Following Asongu, Uduji, and Okolo-Obasi (2020), two measures of energy price volatility are utilized in this study. First, standard deviations of the energy price series are calculated using a three-year non-overlapping interval. Secondly, a first-order autoregressive process of energy price inflation is utilized. The corresponding procedure is summarized in Equation (6).

$$energy_{i,t} = \sigma_0 + \sigma_1 energy_{t-1} + kT + u_{i,t} \qquad (6)$$

Where: $energy_{i,t}$ is energy prices in country i at time t; $energy_{i,t-1}$ is energy prices in country i at time $t-1$. T represents a time trend and $u_{i,t}$ is the error term. Estimating Equation (6) using OLS, the standard deviation of the saved residual for two-year averages after a loss of one degree of freedom from the initial autoregressive processes is computed to obtain the second measure of energy price volatility. This computational procedure using annual frequency data has been employed by Kangoye (2013), Tchamyou and Asongu (2017), Tchamyou, Asongu, and Nwachukwu (2018), Asongu and Nnanna (2019), and Asongu, Uduji, and Okolo-Obasi (2020).

To avoid omitted variable bias, control variables are included in the modeling exercise, as highlighted in the method section. They include bank credit to bank deposit, which is a proxy for financial development, GDP per capita, total population, personal remittances, natural resources, and FDI. Naude and Tregenna (2023) have revealed the importance of these socioeconomic fundamentals to industrialization in Africa. Additionally, Yan and Chen (2023), Bokosi (2022), Zhou (2009), Efobi et al. (2019), Nkemgha et al. (2022), and Chen, Isah & Gummi (2024) have all highlighted the essentiality of these control variables in industrial development. These variables are explicitly expressed in Table 1.

Table 1: Data Description and Sources

Variables	Descriptions	Sources
m.growth	Manufacturing, value added growth (%)	WDI (2024)
i.growth	Industry, value added growth (%)	WDI (2024)
energyvol1	Standard deviation of energy price inflation.	Authors' computation using standard deviation of energy prices from Ha, Kose, and Ohnsorge (2023).
energyvol2	Standard deviation of residual from first-order autoregressive process of energy price inflation.	Authors' computation from the standard deviation of first-order autoregressive process of energy prices from Ha, Kose, and Ohnsorge (2023).
bc	Bank credit to bank deposits (%)	World Bank GFDD (2024)
gdp	Gross domestic product, constant 2015 $US	WDI (2024)
pop	Total population	WDI (2024)
rem	Personal remittances, received (% of GDP)	WDI (2024)
nr	Total natural resources rents (% of GDP)	WDI (2024)
fdi	Foreign direct investment, net inflow (% of GDP)	WDI (2024)

Source: Authors' compilation and computation. Note: WDI is World Development Indicators. GFDD is Global Financial Development Database.

The study scope covers 39 SSA economies between 2001 and 2023. Moreover, a three-year non-overlapping interval is used in this study for data consistency, which also has the advantage of accounting for measurement error bias and business cycle fluctuations. The study converts GDP per capita and population to their natural logarithms for ease of interpretation.

4. Presentation and Analysis of Results

The presentation of the results begins with a description of the variables used in the models. The dependent variables, manufacturing growth and industry growth, have average growth rates of 3.86% and 4.32%, respectively. Manufacturing growth exhibits a maximum rate of 126.51%, while industry growth reaches a maximum of 79.52%. Both manufacturing and industry growth show negative minimum values, indicating instances of deindustrialization in the region. The wide range between the minimum and maximum values supports the use of QR, which examines how energy price volatility impacts manufacturing and industry across different levels of manufacturing and industry growth distributions. Energy price inflation averages 7.39%, with significant variations across countries and time, as highlighted by the observed minimum and maximum values.

On average, about 74.01% of bank deposits are allocated as credit, with a minimum of 18.02% and a maximum of 151.42%. GDP per capita in SSA averages $2,055, and the average population stands at approximately 21.1 million. Other control variables also show significant variations across countries and time as revealed by their minimum and maximum values. Personal remittances contribute up to 50.8% of GDP at the maximum, though they reach a minimum of 0%. Remittances also have an average contribution to GDP of 3.37%. Natural resources rents range from 0.0024% to 51.47% of GDP, with an average value of 10.31%, while FDI net inflows average 4.14%, with a minimum of -2.16% and a maximum of 33.5%.

Table 2: Summary Statistics of Variables

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
m.growth	287	3.8600	9.1852	-16.8106	126.5161
i.growth	301	4.3273	7.0519	-18.4276	79.5284
energy	279	7.3973	11.8551	-13.7773	132.7447
bc	290	74.0182	25.0512	18.0252	151.4268
gdp	312	2055.284	2712.814	263.2748	16060.01
pop	312	2.11e+07	3.24e+07	82018.66	2.16e+08
rem	304	3.3719	5.7863	0	50.8413
nr	311	10.3191	9.4103	0.0024	51.4757
fdi	312	4.1451	4.8894	-2.1670	33.5048

Source: Authors' computation.

In Table 3, the correlation matrix is presented. Consistent with empirical literature, the correlation matrix is used to examine the correlation among the right-hand side variables of the model. High correlation values reflect the presence of multicollinearity, and low correlation values denote the absence of multicollinearity. Consistent with this intuition, the correlation between the explanatory variables is not large enough to cause multicollinearity. Moreover, manufacturing growth and industry growth have a negative correlation with both indicators of energy price volatility. Manufacturing growth also has a negative correlation with GDP and FDI but has a positive correlation with bank credit, population, remittances, and natural resources rents. Additionally, industry growth has a negative correlation with bank credit, GDP, remittances, and natural resources rents but has a positive correlation with population and FDI. In essence, only the energy price volatility proxies exceed the threshold of 0.600 which has been documented in the extant literature as the critical level above which, multicollinearity is apparent (Asongu et al., 2021). Hence, these two energy price volatility variables exhibiting a correlation of 0.9269 are employed in distinct specifications.

Table 3: Correlation Matrix

	m.growth	*i.growth*	*energyvol1*	*energyvol2*	*bc*	*gdp*	*pop*	*rem*	*nr*	*fdi*
m.growth	1.0000									
i.growth	0.2923	1.0000								
energyvol1	-0.1345	-0.0826	1.0000							
energyvol2	-0.1584	-0.0916	0.9269	1.0000						
bc	0.0344	-0.1051	-0.1717	-0.1147	1.0000					
gdp	-0.1102	-0.2014	0.0366	0.0175	0.1070	1.0000				
pop	0.1678	0.1179	-0.0129	0.0028	0.1819	-0.4802	1.0000			
rem	0.0005	-0.0019	0.0633	0.0740	-0.2988	-0.1403	-0.1836	1.0000		

nr	0.1526	-0.0467	-0.0411	-0.0706	-0.1473	-0.2027	0.0678	-0.1293	1.0000	
fdi	-0.1040	0.0888	-0.0330	-0.0295	-0.2878	0.0775	-0.2471	-0.0459	0.1519	1.0000

Source: Authors' computation.

Table 4 presents the empirical results based on the OLS and the FE regressions within the Driscoll and Kraay framework. The findings reveal that an increase in the volatility of energy prices significantly reduces both manufacturing growth and industry growth in SSA. This result is robust irrespective of the measure of energy price volatility adopted. However, after controlling for unobservable heterogeneity, the impact of energy price volatility on manufacturing growth becomes less pronounced while it intensifies in the industry growth model. The negative and significant effect of energy price volatility on industrialization in SSA supports the results of Guan et al. (2023), Chen et al. (2023), and Andre et al. (2023). It is further revealed that energy price volatility does not only influence manufacturing growth but industry-wide growth in the region.

Table 4: OLS and FE Regressions

	Manufacturing Growth (%)				Industry Growth (%)			
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
energyvol1	-0.0693***	-0.0586***			-0.0555***	-0.0688***		
	(0.001)	(0.000)			(0.000)	(0.001)		
energyvol2			-0.0724***	-0.0693***			-0.0656***	-0.0672***
			(0.000)	(0.000)			(0.000)	(0.000)
bc	-0.0087	0.0331***	0.0003	0.0375	-0.0265	0.0316**	-0.0250	0.0339**
	(0.662)	(0.008)	(0.981)	(0.177)	(0.137)	(0.036)	(0.208)	(0.021)
gdp	1.0584	10.5607**	0.0663	0.4245	-1.4134***	-4.0540	-1.4479***	-2.9294
	(0.179)	(0.020)	(0.611)	(0.824)	(0.000)	(0.347)	(0.000)	(0.520)

pop	0.2040 (0.323)	-16.9366*** (0.000)	0.5420*** (0.000)	-5.4862*** (0.000)	0.2827 (0.184)	-2.4736 (0.430)	0.3694 (0.101)	-2.6419 (0.421)
rem	0.0184 (0.840)	0.5333*** (0.000)	0.0483 (0.611)	0.3744** (0.027)	-0.0574 (0.258)	0.1951*** (0.000)	-0.0452 (0.392)	0.1883*** (0.000)
nr	0.2316*** (0.001)	0.1245 (0.370)	0.0901*** (0.008)	0.0987 (0.122)	-0.0934*** (0.000)	0.0298 (0.562)	-0.1051*** (0.000)	0.0082 (0.860)
fdi	-0.2286*** (0.003)	-0.2935*** (0.002)	-0.1070*** (0.027)	-0.2221** (0.042)	0.1759** (0.040)	0.1499*** (0.000)	0.1803** (0.047)	0.1497*** (0.009)
constant	-7.0476*** (0.000)	193.6084*** (0.000)	-5.7773 (0.117)	84.4775*** (0.000)	12.7588** (0.033)	69.4215*** (0.002)	11.5197* (0.059)	64.1556*** (0.005)
Fisher	117.37*** (0.0000)	66.93*** (0.0000)	654.02*** (0.000)	47.95*** (0.0000)	46.65*** (0.0000)	42.64*** (0.0000)	64.91*** (0.0000)	42.77*** (0.0000)
Observations	230	230	216	216	241	241	227	227

Source: Authors' computation. Note: ***, ** and * represent statistical significance at 1%, 5%, and 10%, respectively. Probability values are in parentheses.

Pertaining to the control variables, the results have further revealed the importance of financial development as proxied by bank credit to bank deposits, after unobservable heterogeneity has been accounted for in improving both manufacturing and industry growth. This result supports other empirical study on finance and industrialization nexus such as Svilokos, Vojinic, and Tolic (2019) and Yan and Chen (2023). The study further finds GDP to increase manufacturing growth significantly only in the model where energy price volatility is captured using the standard deviation of energy prices. Additionally, the FE model reveals that the increase in population decrease the growth rate of manufacturing but has no significant impact on industry growth. This finding is intuitive as fast pace rise in population can strain infrastructure and resources, potentially hampering the growth rate of manufacturing (Zhou, 2009). The study finds that after controlling for unobservable heterogeneity, personal remittance is revealed to push up industrialization in SSA supporting the findings of Efobi et al. (2019). The positive influence of remittances on industrialization can be explained through their role in improving household consumption, providing capital for small businesses and smoothing productive investment, feeding into improved industrial performance.

Moreover, while natural resources enhance manufacturing in the OLS regression, supporting the result of Nkemgha et al. (2022), no significant relationship exists in the FE model. On the other hand, it is revealed that when the share of natural resources to GDP increases, industry growth significantly declines in the OLS regression, but no significant relationship is revealed in the FE regression. Additionally, the study finds robustness irrespective of method used on the nexus between FDI and manufacturing growth and FDI on industry growth. The negative nexus between the share of FDI in GDP and manufacturing growth supports the results of Moussa et al. (2019). This result is intuitive, as FDI into SSA is often associated with primary and service industries (Chen, Geiger & Fu, 2015), leading to a crowding-out effect in manufacturing as resources are diverted to FDI-associated industries. This further explains why the nexus between FDI and industry growth is positive and significant.

Table 5: Quantile Regression estimates, Manufacturing Growth

	Manufacturing Growth (%)									
	Q.10	Q.25	Q.50	Q.75	Q.90	Q.10	Q.25	Q.50	Q.75	Q.90
energyvol1	-0.0434***	-0.0391	-0.0442	-0.0239	0.0002					
	(0.009)	(0.339)	(0.166)	(0.762)	(0.992)					
energyvol2						-0.0439***	-0.0437	-0.0510	0.0055	0.0587**
						(0.001)	(0.270)	(0.107)	(0.897)	(0.035)
bc	-0.0093	0.0091	0.0175	0.0176	0.0145	-0.0114	0.0087	0.0177	0.0229	0.0395
	(0.563)				(0.601)	(0.382)				(0.162)

		(0.820)	(0.577)	(0.821)			(0.829)	(0.582)	(0.597)	
gdp	-0.4634	0.5341	8.6059**	10.1032	10.2974***	0.7732	3.1698	8.4445*	6.0024	6.7168*
	(0.833)	(0.922)	(0.043)	(0.338)	(0.000)	(0.666)	(0.566)	(0.056)	(0.314)	(0.083)
pop	16.2920***	13.0784	5.4944	1.7698	-1.2028	16.8537***	13.0951	7.0816	0.7673	-12.1214**
	(0.000)	(0.117)	(0.396)	(0.912)	(0.833)	(0.000)	(0.130)	(0.302)	(0.934)	(0.045)
rem	0.3158***	0.2727	-0.0278	0.5358	0.4084***	0.2819***	0.0942	-0.1445	0.6326***	0.5830***
	(0.000)	(0.142)	(0.847)	(0.136)	(0.002)	(0.000)	(0.608)	(0.324)	(0.002)	(0.000)
nr	0.1881***	0.1249	0.1447*	0.0849	0.0716	0.1889***	0.0807	0.0802	0.0677	0.1483**
	(0.000)	(0.236)	(0.079)	(0.677)	(0.323)	(0.000)	(0.437)	(0.332)	(0.544)	(0.042)
fdi	-0.1223**	-0.2214	-0.1350	-0.3044	-0.2915***	-0.1523***	-0.2344	-0.1390	-0.2894*	-0.3031***
	(0.029)	(0.110)	(0.211)	(0.256)	(0.002)	(0.001)	(0.100)	(0.220)	(0.059)	(0.003)
constant	-258.4537***	-206.8026	-139.4391	-86.9703	-36.6573	-275.4516***	-224.3002	-163.404	-45.7641	154.9679
	(0.000)	(0.146)	(0.208)	(0.751)	(0.707)	(0.000)	(0.128)	(0.164)	(0.772)	(0.132)
Pseudo R^2	0.4355	0.2498	0.2003	0.2178	0.4387	0.4741	0.2841	0.2449	0.2695	0.4428
Observation	230	230	230	230	230	216	216	216	216	216

Source: Authors' computation. Note: ***, ** and * represent statistical significance at 1%, 5%, and 10%, respectively. Probability values are in parentheses. Year FE and Country FE are included in the analysis.

In Table 5, QR results are represented on the nexus between energy price volatility and manufacturing growth. Accordingly, the results show that when the standard deviation of energy prices is used to capture energy price volatility, energy price volatility reduces manufacturing growth only in the 10th quantile orin countries where existing levels of manufacturing growth are lowest. This suggests that manufacturing firms in the 10th quantile, who are smaller and likely less diversified, are more vulnerable to the volatility in energy prices. However, our second measure of energy price volatility via the autoregressive process of energy prices reveals that while energy price volatility reduces manufacturing growth in the 10th quantile, it increases manufacturing growth in the 90th quantile, orin countries where the existing levels of manufacturing growth are highest. This finding seems counterintuitive but is feasible for at least two reasons. (i) Countries in the 90th quantile will likely have a more developed and resilient manufacturing sector due to better access to technology and energy-efficient technologies and can better shift towards alternative sources of energy. (ii) Energy price volatility can stimulate investment in energy-efficient technologies that potentially raises manufacturing growth in the presence of the volatility in energy prices.

However, in Table 6, industry growth is used to capture industrialization with the findings revealing that higher energy price volatility reduces industry growth in the 90th quantile, irrespective of the measure of energy prices. This result contradicts the manufacturing growth equation, where energy price volatility reduces industry-wide growth. Additionally, it is revealed that the increase in energy price volatility decreases industrialization in the 10th quantile, using the autoregressive process that captures energy price volatility.

Table 6: Quantile Regression estimates, Industry Growth

	Industry Growth (%)									
	Q.10	Q.25	Q.50	Q.75	Q.90	Q.10	Q.25	Q.50	Q.75	Q.90
energyvol1	-0.0047 (0.740)	-0.0112 (0.801)	-0.0224 (0.470)	-0.0429 (0.442)	-0.0782*** (0.002)					
energyvol2						-0.0482*** (0.000)	-0.0123 (0.782)	-0.0218 (0.464)	-0.0473 (0.417)	-0.1180*** (0.000)

bc	0.0583***	0.0670	0.0822***	0.0177	0.0893***	0.0702***	0.0499	0.0783***	0.0120	0.0326
	(0.000)	(0.114)	(0.006)	(0.738)	(0.000)	(0.000)	(0.256)	(0.008)	(0.834)	(0.264)
gdp	-6.3573***	-6.1200	-7.8390**	-5.1958	-11.5141***	-4.8228***	-2.4732	-7.5417*	-4.9430	-17.6475***
	(0.001)	(0.278)	(0.047)	(0.463)	(0.000)	(0.001)	(0.674)	(0.056)	(0.521)	(0.000)
pop	1.4976	8.7385	5.8104	4.5737	11.7766**	-2.8317	11.9319	6.0425	5.5369	18.5735***
	(0.596)	(0.324)	(0.347)	(0.681)	(0.018)	(0.232)	(0.205)	(0.337)	(0.653)	(0.003)
rem	0.2906***	0.2356	0.1559	0.1228	0.2567**	0.3467***	0.2170	0.1628	0.1217	0.0072
	(0.000)	(0.241)	(0.265)	(0.739)	(0.022)	(0.000)	(0.290)	(0.236)	(0.650)	(0.958)
nr	-0.0794**	-0.0660	0.0085	0.0465	0.2726***	-0.0747***	-0.0860	0.0007	0.0545	0.0756
	(0.026)	(0.554)	(0.913)	(0.739)	(0.000)	(0.009)	(0.447)	(0.992)	(0.713)	(0.316)
fdi	-0.2064***	0.1052	0.0995	0.0040	-0.0728	-0.2081***	0.0628	0.0766	0.0133	0.0138
	(0.000)	(0.470)	(0.327)	(0.982)	(0.369)	(0.000)	(0.681)	(0.454)	(0.947)	(0.892)
Constant	12.7512	-99.7557	-40.8142	-29.7527	-104.7083	70.2538*	-174.6157	-46.6916	-46.8332	-167.4667
	(0.792)	(0.509)	(0.698)		(0.214)	(0.082)	(0.276)	(0.663)	(0.823)	(0.117)
Pseudo R^2	0.3998	0.2573	0.2370	0.2398	0.4417	0.4032	0.2655	0.2555	0.2574	0.4515
Observation	241	241	241	241	241	227	227	227	227	227

Source: Authors' computation. Note: ***, ** and * represent statistical significance at 1%, 5%, and 10%, respectively. Probability values are in parentheses. Year FE and Country FE are included in the analysis.

Results from Table 5 also find a significant nexus between bank credit and manufacturing growth in the QR results. We find evidence that GDP, remittances, and natural resource rents spur manufacturing growth in the QR results. Population growth has a positive and significant impact on manufacturing output in the 10th quantile but reduces manufacturing growth in the 90th quantile when energy price volatility is captured using the autoregressive process of energy prices. Furthermore, the nexus between FDI and industrialization is revealed to be significant in countries where the existing levels of manufacturing are at the lowest and highest levels. Moreover, in Table 6, the study also finds evidence that bank credit increases industrial growth in some quantiles but not in some, revealing that existing levels of industrial growth affect the nexus between bank credit and industrial growth. In addition, GDP largely reduces industrial growth, while population increases industrial growth. Furthermore, population increases growth in countries where industrial growth is at the highest levels orin the 90th quantile. The study also finds evidence of remittances, natural resource rents, and FDI influencing industrial growth in some quantiles.

Table 7: System GMM estimates

	Manufacturing Growth (%)		Industry Growth (%)	
energyvol1	-0.0343***		-0.1851***	
	(0.003)		(0.000)	
energyvol2		-0.0784***		-0.0621***
		(0.000)		(0.000)
bc	-0.0404	-0.0272	-0.0026	-0.0206
	(0.160)	(0.105)	(0.926)	(0.199)
gdp	1.6345*	1.5872*	2.1830	3.8438**
	(0.093)	(0.069)	(0.252)	(0.026)
pop	0.1030	1.8709***	3.4488**	4.3436***
	(0.900)	(0.008)	(0.018)	(0.004)
rem	-0.4782***	-0.1747***	0.4695***	0.2763***
	(0.000)	(0.003)	(0.001)	(0.005)
nr	0.2385***	-0.0305	-0.1296*	-0.1361**
	(0.000)	(0.420)	(0.050)	(0.015)
fdi	-0.3926***	-0.1117***	0.2691***	0.2349***

	(0.000)	(0.004)	(0.000)	(0.000)
constant	519.4408***	372.5723***	617.4293***	670.3675***
	(0.000)	(0.000)	(0.000)	(0.000)
AR(1) p-value	0.001	0.001	0.213	0.216
AR(2) p-value	0.471	0.773	0.228	0.240
Hansen p-value	0.215	0.430	0.236	0.211
DHT for exogeneity of instruments:	0.202	0.445	0.210	0.202
IV (years, eq (diff))				
H excluding group				
Diff (null, H=exogenous)	0.372	0.257	0.493	0.345
Fisher	392.05***	156.51***	228.28***	133.83***
	(0.000)	(0.000)	(0.000)	(0.000)
Instruments	32	32	32	32
N	39	37	39	38
Observations	204	191	215	202

Source: Authors' computations. Note: ***,**, * indicates statistical significance at 1%, 5%, and 10%, respectively. Probability values are in parentheses. DHT is Difference in Hansen Test for Exogeneity of Instruments'. P-values of the DHT tests are presented, signifying the validity of the exclusion restriction. Diff is Difference. *N* is number of countries. The AR(2) p-value indicates the models are free from serial correlation. The Hansen p-value indicates the validity of the instruments in the models. Lag of the dependent variables are included in the models.

Table 7 presents the result of the system GMM regression. The results showed that the relationship between energy price volatility and manufacturing growth and energy price volatility and industry growth is significantly negative, supporting the results of the OLS and FE regressions. These results support the conclusion that energy price volatility dampens industrialization in SSA. The study further finds the coefficient of GDP and population to be smaller after endogeneity has been accounted for. Remittance and FDI have a negative and significant influence on manufacturing growth but a positive and significant impact on industry growth. Evidence is also found that natural resource rents increase manufacturing growth but reduce industry growth. The GMM estimates establish no significant relationship between bank credit and industrialization in SSA.

5. Conclusions

The essentiality of industrialization to economic development cannot be overemphasized. Industrialization remains a pillar to structural transformation in Africa and a prerequisite for long-run economic growth and development. In this study, we have examined how industrial development in SSA is influenced by the volatility in energy prices. The study adopted data from 39 countries in the region between 2001 and 2023 and applied several robust estimation procedures. The results revealed the negative implications energy price volatility has on industrialization in SSA. Moreover, the study finds evidence that the impact of energy price volatility on manufacturing growth in Africa is influenced by existing manufacturing growth levels, and the impact of energy price volatility on industry growth is influenced by existing industry growth levels.

Accordingly, the study revealed that countries where manufacturing growth is low have a more pronounced negative effect of energy price volatility on manufacturing growth. However, the study finds evidence, though not robust to both measures of energy price volatility used in this study, that energy price volatility can have a positive impact on manufacturing growth in countries with robust manufacturing growth. This finding can be explained from the standpoint of the ability of firms to withstand energy price fluctuations through the increase in the use of efficiency-efficient technology and improving the flexibility of resource allocation. In a volatile energy price environment, more robust firms are more likely to innovate and adopt new energy-efficient technologies that allow them to maintain or improve productivity even in periods of volatile energy prices. Nonetheless, the study revealed that energy price volatility has a significantly negative impact on industry-wide growth, particularly in countries where existing levels of industry growth in Africa are at their highest levels.

Based on these results, the study recommends that the SSA region should prioritize regional energy cooperation to help build energy infrastructure in order to enhance regional energy security and lower the associated cost of energy imports. Additionally, the need to encourage investment in energy-efficient technologies by governments in Africa is also important to ameliorate the effect of energy price volatility on industrialization in the region. Moreover, targeted support for firms in countries with low manufacturing growth is essential. This support could be tax holidays and low-interest loans aimed at improving resilience.

Conclusively, further studies can examine the role financial institutions and financial access can play in mitigating the negative effect of energy prices on industrialization in Africa. Moreover, assessing how energy price volatility affects inclusive development outcomes such as poverty, income inequality and gender inclusion in the sampled countries will provide more insights into how the underlying dynamics influence some United Nations' sustainable development goals (SDGs).

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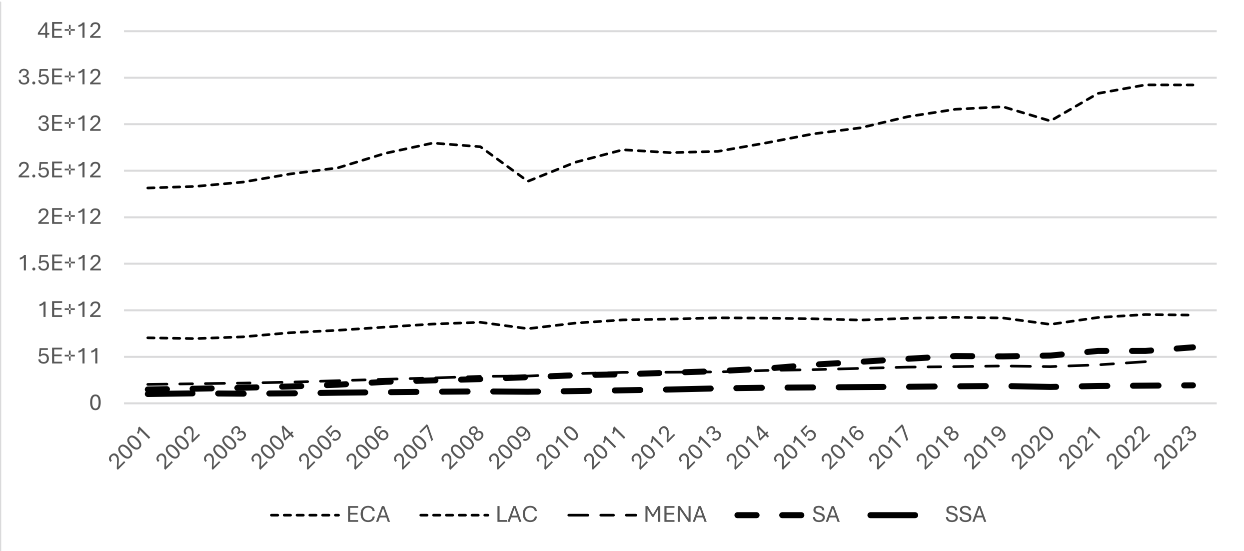
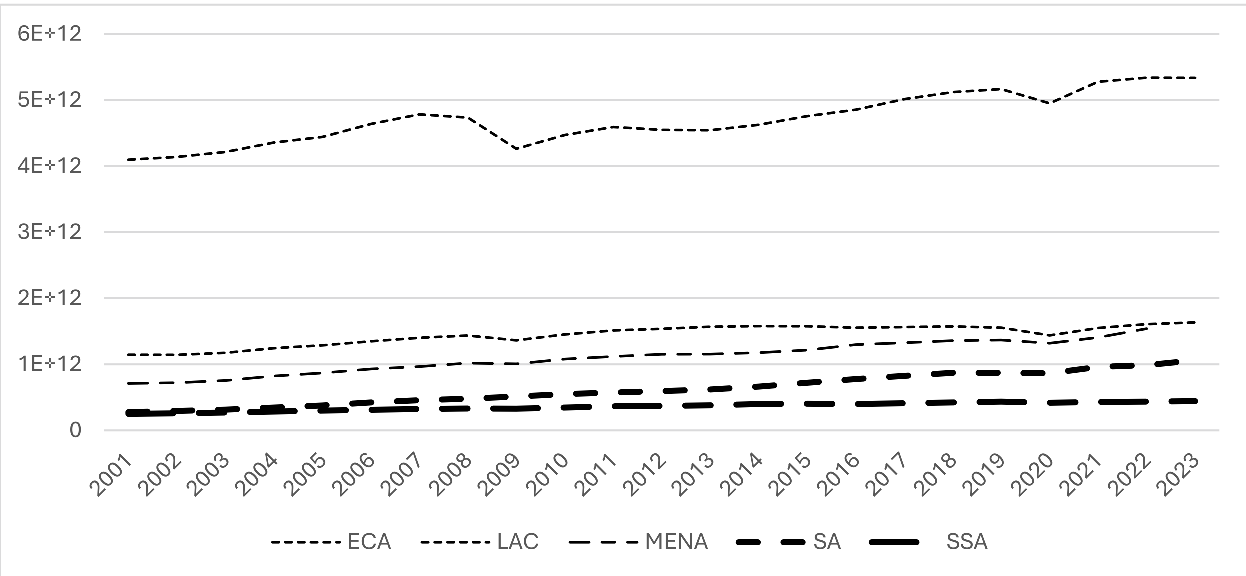
Appendix

Figure A1: Manufacturing, value added (constant 2015 US$)



Source: WDI (2024). Note: ECA is Europe & Central Asia, LAC is Latin America & the Caribbean, MENA is Middle East & North Africa, SA is South Asia, SSA is Sub-Saharan Africa.

Figure A2: Industry, value added (constant 2015 US$)



Source: WDI (2024). Note: ECA is Europe & Central Asia, LAC is Latin America & the Caribbean, MENA is Middle East & North Africa, SA is South Asia, SSA is Sub-Saharan Africa.

Table A1: List of Countries

The countries used in this study include Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo Democratic Republic, Congo Republic, Cote d'Ivoire, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.