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RESEARCH PAPER

Economic Complexity and Shadow Economy in Africa

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Abstract

In line with the nascent literature on economic complexity, this paper answers whether economic complexity impacts the size of the shadow economy in African economies, a region confronted with a large amount of informal economic operations. We apply four classes of mean group estimators (mean group, augmented mean group, common correlated effects mean group, and dynamic common correlated effects mean group) on African panel data of 27 economies from 1995 to 2017. There is no significant evidence to justify that economic complexity affects the size of the shadow economy in the mean group. However, in the group-specific coefficients, the relationship is significantly negative for the Republic of Congo, Ghana, and Uganda, while the opposite result is confirmed for Botswana, Madagascar, and Tunisia. The study concludes that the impact of economic complexity is heterogeneous in the case of African economies. The policy implications of the results are discussed.

Keywords: Augmented Mean Group Estimators, Economic Complexity, Informality, Product Complexity, Shadow Economy.
JEL Classification: O11, O17, O55.

1. Introduction

The recent shadow economy estimates released by Medina and Schneider (2019) show that the African region has one of the largest sizes of shadow economies after Latin America with 39 percent of the official GDP (Esaku, 2021). The shadow economy which is also known as the informal economy[1] has continually been on the rise in Africa in which countries like Nigeria, the Democratic of Congo, and Zimbabwe have more than 50 percent of the official GDP as the relative size of the shadow economy. This phenomenon presents many concerns to policymakers and government on the best ways to control operations in African shadow economy (Ajide, 2021; Ajide and Dada, 2022). This development is motivated by its tendency to distort macroeconomic policies including other economic and political

[1]. For detail explanation on alternative names of the shadow economy, see Dada and Ajide, (2021); Dada et al. (2021a; 2021b).

relevance. Most importantly, the formulation of economic policies may be difficult and to a larger extent weakened in a country with a large size of informal economic operations which serve as the main inputs for tax evasion estimates and determining the way of controlling them (Medina and Schneider, 2019; Dada et al., 2022).

Neoclassical economists hint that the shadow economy occurs due to the welfare maximization behavior of economic agents and probably due to the failure of the official economy to satisfy their needs (Allingham and Sandmo, 1972; Dell'Anno, 2021). Lewis (1954) provides the link between the shadow economy and macroeconomic factors based on a dualistic ideology of development. The author goes on to observe that developing regions have dual economies in which there is an association between traditional and modern segments of the economic structure. These two segments operate in different modes (Hart, 1973). Accordingly, the shadow economy provides job opportunities, goods, and services for the low-income segments of the urban population. Tokman (1978) analyzes that the shadow economy provides comparative advantages to this group of people in all economic transactions and further enables them to reduce the regulatory bottlenecks that may emerge in the official economy.

Since the theoretical arguments revolve around positive and negative associations between shadow economy-macroeconomic factors nexus, numerous empirical studies have examined these issues ranging from financial inclusion, financial development, and institutional quality to foreign direct investment including economic uncertainties (Njangang et al., 2018; Njangang et al., 2020; Dada et al., 2021; Ajide, 2021; Ajide et al., 2022). Studies suggest that economic agents would prefer to operate in the shadow economy to evade tax and avoid other regulations present in the official economy. These actions distort economic policies and reduce the ability of the government to perform its statutory roles in the economy due to revenue shortfalls that emerge. However, a recent study reveals that economic complexity may have important implications for operations in the shadow economy (Nguyen, 2021). A higher presence of economic complexity may reduce the size of the shadow economy (Dam and Frenken, 2020; Hidalgo, 2021; Nguyen, 2021). Economic complexity may bring new opportunities to the official economy and provide benefits for economic actors (Pintea and Thompson, 2007; Nguyen, 2021).

This paper examines the impact of economic complexity on the shadow economy in Africa. The existing studies neglect the peculiarity of the African region in their sample (Hidalgo, 2021; Nguyen, 2021). A region with one of the highest sizes of shadow economies with a low level of economic complexity. Medina and Schneider (2019) explain that African countries recorded more than the world average (which stands at 31 percent of GDP) of shadow economy with

more than 50 percent of GDP for Africa. On the other hands, African economies operate at the lower space of economic complexity with negative values due to the non-technologically advanced productive structure (Mealy et al., 2019). Ahmad et al. (2021) argue that ECI in developing countries like Africa is low, when compared to developed ones. The need to upgrade the economic complexity is essential for economic prosperity in the continent. However, nothing is known on whether economic complexity in Africa contributes to or reterds the size of shadow economic operations. This study therefore, fills this important gaps in the literature.

The contributions of this paper are as follows. It is the first attempt to discuss the issue of economic complexity and shadow economy in a group of African countries with similar features in respects of economic characteristics, natural and human resource abundance, demographic commonalities including growth trajectories (Ajide, 2021; Dada et al., 2021a). Second, panel data modeling has a lot of issues including spatial dependence, heteroskedasticity, endogeneity, serial correlation and heterogeneity among others. These issues might lead the estimated coefficients to be inefficient and produce biased results as characterized by previous studies (Njangang et al., 2018; Njangang et al., 2020; Ajide, 2021; Nguyen, 2021). To overcome these challenges, the paper implements a number of robust panel data estimators namely; Augmented Mean Group, Common Correlated Mean Group estimator, and Dynamic Common Correlated Mean Group to produce efficient and consistent results. Finally, unlike previous empirical efforts, this study also endeavours to unveil each country specific estimated results that help in policy inferences. Our findings show that economic complexity does not have significant impact on shadow economy in the group estimations. However, in specific country results, we document that economic complexity is effective in reducing shadow economy for the case of Republic of Congo, Ghana and Uganda, while opposite result is confirmed for Botswana, Madagascar and Tunisia. The study concludes that the impact of economic complexity is heterogeneous for the case of African economies.

2. Stylized Facts about Economic Complexity and Shadow Economy in Africa

Shadow economy is defined as all economic activities operating outside the purview of the official economic environment (Ihrig and Moe, 2004; Ajide et al., 2022). Shadow economy is generally regarded as illegal practices because most of the activities in the sector are concealed from the authorities, especially tax authorities. Thus, the shadow economy is difficult to estimate. Shadow economy provides more than 70% of the employment opportunities in Nigeria, Angola, among others (Cervero, 2000; ILO, 2012). Figure 1 shows the average value of the shadow economy as a percentage of GDP between 1995 and 2017. Shadow economy is more than two-thirds of the GDP in most of the African countries.

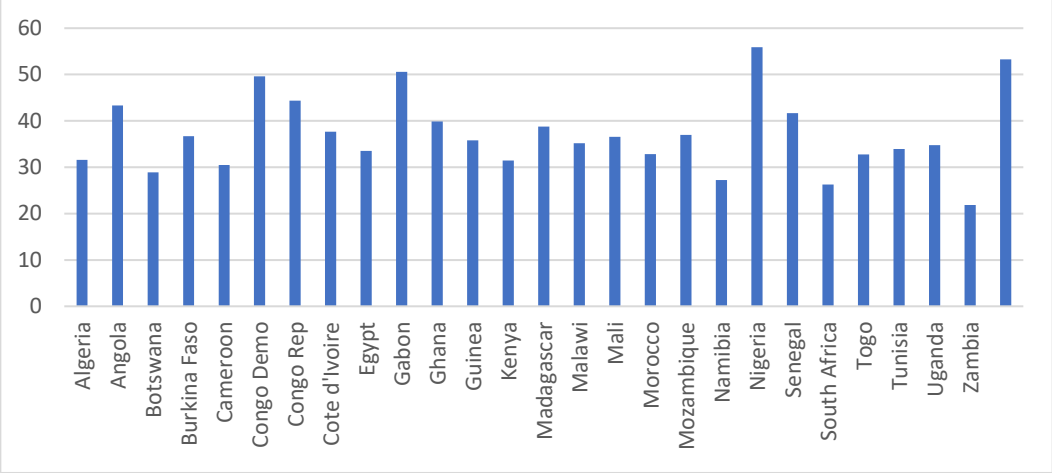

Figure 1. Average Value of Shadow Economy (% of GDP) in Africa (1995-2017)
Source: Melinda and Schneider (2019).

Nigeria, Zimbabwe, Congo Republic, Gabon, and Angola top the ladder of the country with the highest percentage of the shadow economy. However, the region has not fared well on its economic complexity index. Economic complexity measures the state of knowledge used in the production system (Hidalgo and Hausmann, 2009; Hausmann et al., 2014).

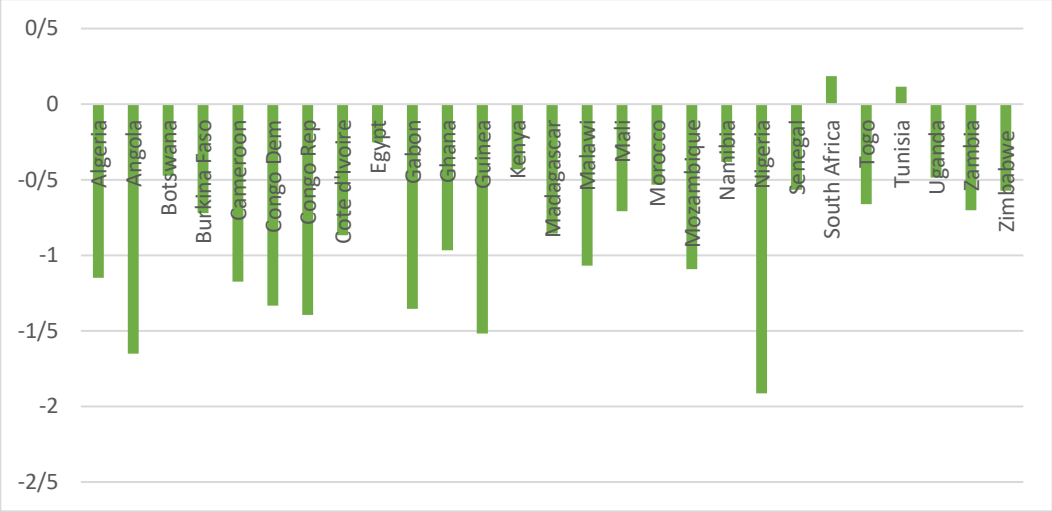

Figure 2. Average Index of Economic Complexity in Africa (1995-2017)
Source: Research finding; data extracted from Atlas of Economic Complexity.

Figure 2 shows the average values of the economic complexity index for 27 African countries between 1995 and 2017. In Figure 2, only South Africa and Tunisia recorded positive values of the economic complexity index, while other countries had negative values.

3. Literature Review

3.1 Shadow Economy and Economic Complexity: The Links

The relationship between macroeconomic factors and shadow economy has been well documented (Dada and Ajide, 2021; Canh et al., 2021; Dada et al., 2021a, 2021b; Awasthi and Engelschalk, 2018; Elgin, 2012; Bajada and Schneider, 2009; Friedman et al., 2000), however, the role of economic complexity in such relationship is still growing. Figure 3 presents the conceptual linkages between the shadow economy, social, and economic factors including economic complexity.

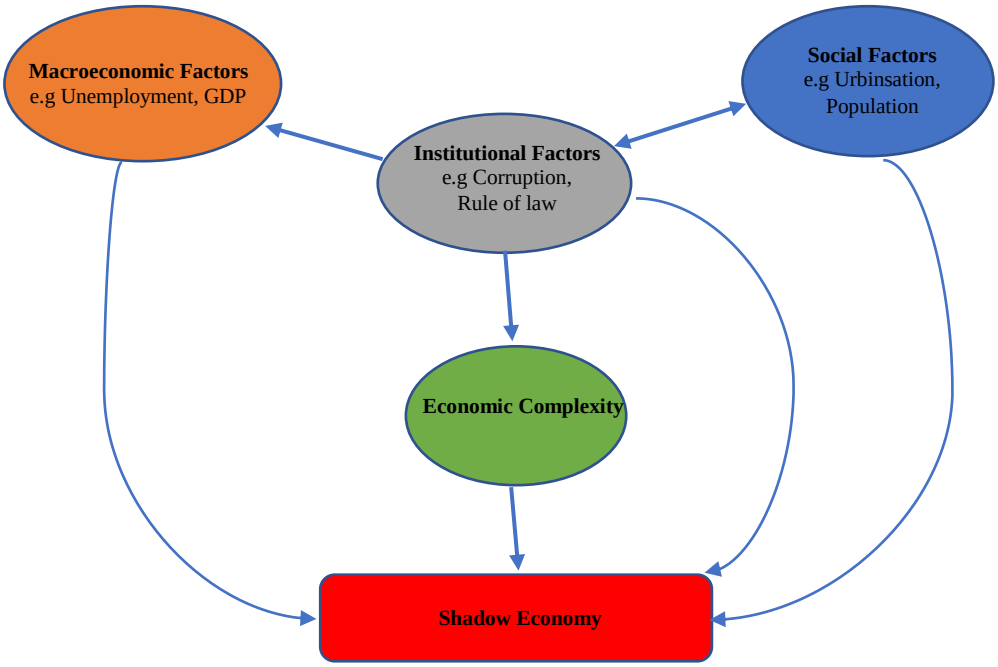

Figure 3. Shadow Economy; Social and Economic Factors
Source: Research finding.

Social factors affects the shadow economy directly, and indirectly through institutional factors and economic complexity. A two-way relationship exists between social and institutional factors. The size of shadow economy be linked to an increase in corruption level since most businesses will want to have their way through bribing the government officials or move to the informal economy to avoid the stiff business regulations. Further, firms could leverage on weak institutional quality such as the enforcement of rule of law and move into the shadow economy to avoid government regulations (Dada et al., 2021b; Singh et al., 2012; Schneider, 2010; Dreher et al., 2009). Macroeconomic factor also influences the shadow economy through the income and substitution effects. The income effect increase (decreases) consumption in both the formal and informal economy during the boom (recession), while the substitution effect allows unemployed laborers to move into the shadow economy during recession, which

boosts activities of the shadow economy. On the other hand, studies have established a connection between the official economy and economic complexity (Pintea and Thompson, 2007; Ferrarini and Scaramozzino, 2016; Lapatinas, 2019). Since the official economy and shadow economy share most features in terms of their determinants (Schneider and Buehn, 2018), economic complexity is also likely to influence shadow economy through the provision of new opportunities, technologies among others (Pintea and Thompson, 2007; Canh et al., 2021; Nguyen, 2021). As noted by Nguyen (2021), entrepreneurs and workers in the shadow economy might not benefit optimally from the new opportunities that the economic complexity has to offer, since they are mostly semi-skilled and unskilled workers that leads to a reduction in shadow activities. However, ICT (especially the internet and mobile phones) as one of the opportunities created by economic complexity could spur activities in the shadow market (Ajide and Dada, 2022; Remeikiene et al., 2018). As shown in Figure 3, strong institutional quality improves economic complexity (Vu, 2019) and affects the size of shadow economic operations, in turn.

3.2 Empirical Literature

The empirical literature on the relationship between economic complexity and shadow economy is still evolving. However, little literature that examines this relationship, in addition to other macroeconomic and institutional factors, is reviewed. Awasthi and Engelschalk (2018) investigate the effect of governance-related and competitiveness factors in the relationship between tax and shadow economy. The outcome from the empirics suggests that out of the six governance indicators considered, only regulatory quality and control of corruption have a measurable impact on the shadow economy and tax level. Similarly, the conclusion from the competitiveness factors indicates that only one factor (technological readiness) out of the twelve factors sampled has a significant impact on the shadow economy and taxation. Finally, the author concludes that a high level of shadow economy has a negative correlation with the level of tax collection. Luong et al. (2020) also examine the relationship between the rule of law, economic growth, and shadow economy in 18 transition economies, spanning from 2002 to 2015. Applying the generalized method of moments, the outcome of the study reveals that economic growth is negatively related to the shadow economy, while the size of the shadow economy is inversely concerning the quality of the rule of law. Nguyen (2021) examines the effect of economic complexity on the shadow economy of 115 countries between 1995 and 2017. The sample size was further divided into three sub-samples: 45 low- and lower-middle-income economies; 32 upper-middle-income economies; and 38 high-income economies. The results show that the economic complexity reduces the relative size of the shadow

economy, while it increases the absolute size of the shadow economy in the short run. In the long run, economic complexity has a negative influence on both the relative and absolute size of the shadow economy. Similarly, Canh et al. (2020) examine the drivers of the shadow economy by focusing on the role of economic integration and institutional quality for a global sample of 112 countries. The outcomes imply that institutional quality and foreign direct investment have a strong negative influence on the shadow economy, while the negative effect of trade openness is weak.

In another but related study, Goel and Nelson (2016) examine the determinants of the shadow economy using three different cross-national measures of the shadow economy. This research lends credence to the fact that bureaucratic complexity is more significant than monetary issues in driving the shadow economy. Furthermore, an increase in tax complexity intensifies the activities in the informal economy, while an increase in business startup cost increases the number of new entrances into the informal economy by more than double. Lastly, the author concludes that the determinant of the shadow economy varies across advanced and developing countries. Abuamria (2019) concludes that the probability of detection and penalty rate reduces shadow economy levels across different economies. Similarly, Ginevicius et al. (2020) show that there is an inverse relationship between national economic development and the shadow economy.

Schneider (2010) assesses the effect of public institutions on the development of the size of the shadow economy in 21 OECD countries. Deductions from the study show that an increase in the burden of tax, and social security payments, labor market regulation, institutional quality, etc. are some of the factors responsible for the increase in the shadow economy in OECD countries. Choi and Thum (2005) examine the relationship between corruption and the underground economy using a theoretical model. The outcome of the study suggests that the ability of an entrepreneur to move to the underground economy depends on the distortions introduced in the economy by a corrupt official.

Canh and Thanh (2020) show a non-linear relationship between export diversification and export quality in the shadow economy for a panel of 116 countries. Bitzenis et al. (2016) examine the determinants of the Greek shadow economy using the multiple-indicators-multiple-causes technique. The authors' conclusion reveals that macroeconomic conditions (unemployment and GDP) and institutional factors (rule of law, tax morale) are the important determinants of the shadow economy. The outcomes also show that corruption and the shadow economy complement each other while the shadow economy and official economy work as substitutes. In another related study, Batrancea et al. (2017) examine the degree of relationship between shadow economy and corruption in 193 countries,

findings show that corruption and shadow economy are complements. Baklouti and Boujelbene (2018) conducted a comparative study about the relationship between economic growth and shadow economy in MENA and OECD countries. The conclusion from the study suggests that economic growth and shadow economy have a unidirectional relationship in MENA, but a bidirectional relationship in OECD. Furthermore, institutional quality plays a moderating role in such a relationship. Looking at the other side of the coin, Estrin and Mickiewicz (2012) investigated the effect of the shadow economy on entrepreneurial startups across the country between 1998 and 2005 using both micro and macro data sets. The authors found a positive relationship between the size of the shadow economy and the likelihood of entrepreneurial entry. Further evidence from the study showed a U-shaped relationship between entrepreneurial entry and the shadow economy.

The above review shows that only a study by Nguyen (2021) has examined the direct relationship between economic complexity and shadow economy in a global sample, with no known study examining the effect in Africa. However, the study pools various countries across different macroeconomic environments together. Thus, this study centers on a region (Africa) that shares the same peculiarities and we propose that: *Hypothesis-Economic complexity significantly affects the shadow economy in Africa.*

4. Materials and Methods

4.1 Empirical Model

This study is based on the empirical model of Nguyen (2021) and the theoretical model proposed by Dell'Anno (2021). The model utilizes the neoclassical approach to analyze issues of the shadow economy as a consequence of the welfare-maximizing behavior of economic agents based on a rational choice (Allingham and Sandmo, 1972). The model explains that social, institutional, and macroeconomic factors influence the shadow economy (Dell'Anno, 2021; Schneider, 2021). This model is augmented with economic complexity which has important links with socio-economic factors. An improvement in economic complexity may affect the size of the shadow economy which has implications for official economic development (Dam and Frenken, 2020; Hidalgo, 2021; Nguyen, 2021). Economic complexity brings new opportunities and may also benefit economic actors in the shadow economy (Pintea and Thompson, 2007; Nguyen, 2021). On the other hand, an improvement in economic complexity increases the knowledge capability materialized in the official production structure which may discourage operations in the shadow economy due to semi-skilled and unskilled laborers (Wu and Schneider, 2019). Economic complexity may also affect the shadow economy because of limited access to financial services and low levels of

technology (Cang et al., 2021). In line with this, this study tests the hypothesis by specifying the following empirical model:

$$SE_{it} = \beta_0 + \beta_1 ECI_{it} + \beta_2 Z_{it} + \varepsilon_{it} \quad (1)$$

where SE_{it} is the dependent variable representing shadow economy; ECI_{it} is the measure of economic complexity, while Z_{it} captures other control variables that have been advanced to play a critical role in the shadow economy literature and ε_{it} is the error term. Thus, Z can be expressed explicitly as stated in Equation (2):

$$SE_{it} = \beta_0 + \beta_1 ECI_{it} + \beta_2 DCPS_{it} + \beta_3 TOP_{it} + \beta_4 POP_{it} + \beta_5 FDI_{it} + \beta_6 INS_{it} + \beta_7 LGDP_{it} + \varepsilon_{it} \quad (2)$$

As discussed in the literature, this study adopts GDP per capita(LGDP), urban population growth (POP), trade openness(TOP), institutional quality(INS), domestic credit to private sector as a percentage of GDP (DCPS), and foreign direct investment as a percentage of GDP (FDI) as the major control variables affecting economic complexity in Africa. The literature suggests that the levels of economic property proxied by GDP per capita may reduce the size of the shadow economy (Ajide, 2021). In addition, better institutions reduce informality (Vu, 2019), and population and/or growth of urbanization affect the size of the shadow economy (Njangang et al., 2020; Vu, 2021; Nguyen, 2021) while Nguyen et al. (2020) documented that the financial development and FDI may affect the shadow economy (also see Ajide, 2021; Ajide et al., 2022).

4.2 Estimation Techniques

The empirical strategies take the following steps. First, we conduct several preliminary tests including panel unit root tests via a cross-sectional dependence version of the augmented Dickey-fuller (PCADF) and the refined Im-Pesaran-Shin W-stat (CIPS). These two unit root tests constitute part of the second-generation panel unit root tests in the literature review. We also assess the spatial dependence using Pesaran's Cross-sectional dependence tests. Furthermore, this study examines the causality of the key variables, the shadow economy, and economic complexity. This is necessary to determine whether there is a reversed causality and to select the appropriate model estimation technique that considers endogeneity issues in panel structure. This is done via the Dumitrescu-Hurlin (2012) Panel Causality Test.

Having done these preliminary tests, the study explores the Augmented Mean Group estimator (AMG) developed by Eberhardt and Bond (2009) to estimate the model built to test the hypothesis of the paper. This estimator relaxes the homogeneity parameter assumption of the conventional panel data estimating techniques by taking the average group-specific parameters of the cross-sectional

units (Eberhardt and Bond, 2009). This empirical strategy robusts to the presence/or absence of co-integration and also takes care of endogeneity in the panel data structure (Aluko and Ibrahim, 2020; Osinubi et al., 2022). It also performs better in the case of nonstationary series whether cointegrated or not with the advantage of robustness analysis in the presence of spatial correlation due to the inclusion of a common dynamic process in the regression (Eberhardt, 2012). We estimate Equation (2) using AMG procedures while we still account for group-specific linear trend as specified in Equation (3):

$$SE_{it} = \beta_0 + \beta_1 ECI_{it} + \beta_2 DCPS_{it} + \beta_3 TOP_{it} + \beta_4 POP_{it} + \beta_5 FDI_{it} + \beta_6 INS_{it} + \beta_7 LGDP_{it} + \tilde{\mu}_t^* + \pi_i t + \varepsilon_{it} \quad (3)$$

In Equation (3), $\pi_i t$ stands for group-specific linear trend while $\tilde{\mu}_t^*$ is the average of the individual unit nonstationary processes used to augment the model as an additional independent variable.

4.3 Data Sources and Variables Measurements

This study utilizes panel data from 27 African countries between 1995 and 2017. The list of the countries can be found in the appendix. The scope of this study and the selection of countries are based on data availability, especially the key variables (i.e. shadow economy and economic complexity). Table 1 explains the structure of the variables, data sources, and the expected signs of each variable.

Table 1. Variables' Measurement and Data Sources

Variable	Acronym	Expected signs	Measurement	Sources
Shadow economy	SE	N/A	Shadow economy is expressed as a percentage of official GDP using Multiple indicators Multiple Causes ' Method	Medina and Schneider (2019)
Economic complexity	ECI	Positive(+) or/ Negative(-)	This is an index ranging around zero. It is a reduced dimensionality representing specialization matrices. An increase in the index signifies an increase in the levels of economic complexity. (Hartmann et al., 2017; Hidalgo, 2021)	Extracted from Atlas of Economic Complexity
Urban Population	POP	Positive (+)	This is used to proxy urbanization. It is measured as the log of the urban population	World Development Indicators
Degree of Openness	TOP	Negative(-)	Trade openness is the summation of export and import expressed as a percentage of GDP	=do=
Financial development	DCPS	Negative(-)	Domestic credit to private sector expressed as percentage of GDP	=do=
Foreign direct investment	FDI	Negative(-)	Foreign direct investment as a percentage of GDP.	=do=
Economic development	LGDP	Negative(-)	Log of GDP per capita (constant 2010 US$)	=do=
Institutions	INS	Negative(-)	The average of three institutional indicators namely: corruption Control, bureaucratic quality, and law and order. We rescaled bureaucratic quality from 0-4 to 0-6 so as to be on the same scale with corruption control and, law and order (0-6) before taking the average of the three indicators (see Dada et al., 2021b; Ajide and Soyemi, 2022)	International Country Risk Guide (2018)

In Table 2, we present the descriptive statistics of the variables. On average, the size of the shadow economy is about 38% of the official GDP. This is above the world average value (30.9%) based on a sample of 157 countries as documented by Medina and Schneider (2019). In addition, there is no strong deviation as revealed by the standard deviation. In Africa, Nigeria and Zimbabwe account for the largest average size of the shadow economy. A similar result is documented by Medina and Schneider (2019).

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
SE	621	38.003	8.571	21.9	61.4
ECI	621	-0.864	0.548	-2.337	0.513
POP	621	2.415	0.700	0.233	3.788
TOP	621	70.403	25.101	20.722	165.645
INS	621	3.655	0.620	1.6	5.583
DCPS	621	25.960	29.733	0.491	180.396
FDI	621	3.451	5.211	-8.589	50.018
LGDP	621	3.141	0.426	2.239	4.076

Source: Research finding.

The ECI indicator reveals that the economic sophistication in Africa is very low with a mean of -0.864. This indicates that African diversity and products' uniqueness is low. The maximum value is 0.513. This indicator also shows that most economies in Africa operate at the bottom of the commodity space in which the export baskets consist of primary and natural resources (i.e. Diamond, Gold, Crude Oil, and agricultural commodities).

Table 3. Pairwise Correlation

Variable	SE	ECI	POP	TOP	INS	DCPS	FDI	LGDP
SE	1.000							
ECI	-0.466*	1.000						
POP	0.197*	-0.492*	1.000					
TOP	-0.060*	-0.045	-0.085*	1.000				
INS	-0.331*	0.338*	-0.302*	-0.115*	1.000			
DCPS	-0.424*	0.622*	-0.575*	0.023	0.276*	1.000		
FDI	-0.014	-0.119*	0.154*	0.385*	-0.061*	-0.068	1.000	
LGDP	-0.171*	0.154*	-0.436*	0.359*	0.185*	0.460*	-0.054	1.000

Source: Research finding.

Note: * denotes significant at 5%.

This implies they are primary product exporters (Pérez and Claveria, 2020; Yellapragada, 2017). In addition, the institutional quality seems to be moderate with a mean of 3.655. The domestic credit to the private sector is 25.96 %. The

foreign direct investment inflow is 3.451%. Table 3 shows that we have a moderate correlation between the variables. This implies that the pairwise correlation between the variables is within the toleration rate and the coefficients of the variables can be estimated in a single model. Furthermore, there is a negative association between economic complexity and the shadow economy. The same applies to other variables except urbanization growth which has a positive association with the shadow economy.

5. Results and Discussion

5.1 Preliminary Tests

To avoid spurious estimated results, this study examines the nature and properties of the variables by conducting several preliminary tests. First, due to the inter-economic connection among African countries, it is necessary to examine the cross-sectional dependence in the panel structure (Tachie et al., 2019; Ajide et al., 2021; Osinubi et al., 2022). Therefore, this study assesses the cross-sectional dependence (CD) via Pesaran's (2015) cross-sectional dependence test. The result is presented in Table 4.

Table 4. Cross-sectional Dependence (CD) Test

Variables	Pesaran (2015)'s CD Test	
	CD-statistics	**P-value**
SE	69.297***	0.000
ECI	1.233	0.218
DCPS	63.905***	0.000
TOP	13.475***	0.000
POP	7.966***	0.000
FDI	10.465***	0.000
INS	32.162***	0.000
LGDP	49.864***	0.000

Source: Research finding.

Note: *, **, *** mean significant at 10%, 5%, and 1%, respectively.

The results show that all the variables have the presence of cross-sectional dependence except ECI which has an absence of cross-sectional dependence. This implies that any shock on the shadow economy, financial development, openness, urbanization, foreign direct investment, institutional structure, or economic development in any economy within the African region may have spillover to other countries in the region.

Table 5. Pesaran's CADF Test

Variables	CADF with trend		CADF without trend	
	Level	**First Diff.**	**Level**	**First Diff.**
SE	-2.109	-3.658***	-1.579	-2.738***
ECI	-2.300	-3.528***	-2.017	-3.522***
DCPS	-2.165	-3.309***	-1.909	-3.104***
TOP	-2.383	-3.348***	-2.034	-3.421***
POP	-5.741***		-3.921***	
FDI	-2.482	-3.825***	-2.578***	
INS	-2.266	-3.703***	-2.271***	
LGDP	-1.651	-2.910***	-1.393	-2.322***

Source: Research finding.

Note: Critical values (without trend) at 10%, 5% and 1% are -2.07, -2.15, and -2.3, respectively. Critical values (with trend) at 10%, 5%, and 1% are -2.58, -2.66, and -2.81, respectively.

Due to the presence of cross-sectional dependence, the conventional panel unit root tests are inappropriate in assessing the stationarity of the variables. This study adopts the second-generation panel unit root consisting of the cross-sectional dependence version of the Im-Pesaran-Shin W-stat (CIPS) and the Augmented Dickey-Fuller (CADF). The results of these two tests are presented in Tables 5 and 6.

Table 6. Pesaran Panel Unit Root Test with Cross-sectional (CIPS)

Variables	CIPS with trend		CIPS without trend	
	Level	**First Diff.**	**Level**	**First Diff.**
SE	-2.497	-4.749***	-2.012	-4.635***
ECI	-2.995***		-2.756***	
DCPS	-2.086	-4.328***	-1.711	-4.123***
TOP	-2.654**		-2.188**	
POP	-4.149***		-2.960***	
FDI	-3.282***		-3.571***	
INS	-2.398***		-2.299**	
LGDP	-1.620	-3.761***	-1.296	-3.431***

Source: Research finding.

Note: Critical values (without trend) at 10%, 5% and 1% are -2.07, -2.15, and -2.3, respectively. Critical values (with trend) at 10%, 5%, and 1% are -2.58, -2.66 and -2.81, respectively.

The results of the CADF and CIPS tests reveal that we have a mixture of I(1) and I(0) variables in which the dependent variable (the shadow economy) is stationary at I(1) in the two tests. Table 7 presents our tests on slope heterogeneity via Pesaran and Yamagata's (2008) slope homogeneity test.

Table 7. Testing for Slope Heterogeneity

Variables	$\tilde{\Delta}$	$\tilde{\Delta}_{adj}$
SE	11.111***	14.241***
	(0.000)	(0.000)
ECI	1.476	1.627
	(0.140)	(0.104)
DCPS	5.200***	5.730***
	(0.000)	(0.000)
TOP	5.992***	6.603***
	(0.000)	(0.000)
POP	3.111***	3.428***
	(0.002)	(0.001)
FDI	2.055**	2.264**
	(0.040)	(0.024)
INS	4.664***	5.139***
	(0.000)	(0.000)
LGDP	8.591***	9.466***
	(0.000)	(0.000)

Source: Research finding.

Note: *, **, *** mean significant at 10%, 5%, and 1%, respectively. H_0: slope coefficients are homogenous. Figures in ( ) are p-values.

As suggested from the results, there is a presence of slope heterogeneity in the panel structure. This implies that our procedures for estimation must take into consideration slope variability among variables. Furthermore, as part of the preliminary tests, we examine whether there is a reversed causality between the key variables of the interest-shadow economy and economic complexity to choose the appropriate estimation technique. Therefore, we employ a pairwise panel causality proposed by Dumitrescu-Hurlin (2012). The results of the test are documented in Table 8.

Table 8. Dumitrescu Hurlin Panel Causality Tests

Hypothesis	W-Stat.	Z-Stat.	Prob.	Any causality
SE →ECI	2.4434	5.3035	0.000	Yes
ECI→SE	2.289	4.7383	0.000	Yes

Source: Research finding.

The results confirm bidirectional causality between shadow economy and economic complexity. This implies that high levels of shadow economy may discourage the production complexity and economic sophistication. In addition, the shadow economy is featured with low-skilled labor in which operating advanced technology is less beneficial (Farzanegan et al., 2020; Nguyen, 2021; Canh et al., 2021). Since, there is a presence of spatial dependence and slope heterogeneity among the variables and, we also confirm a reversed causality

between shadow economy and economic complexity, the most appropriate technique would be the augmented mean group estimator (AMG) that accounts for both cross-sectional dependence and endogeneity issues. This technique is also appropriate for the case of I(1) and I(0) variables mixed in a model. The AMG procedure is flexible in such a way that it can be used whether there is slope homogeneity or heterogeneity (Eberhardt and Bond, 2009; Eberhardt, 2012; Aluko and Ibrahim, 2020; Osinubi et al., 2022).

5.2Empirical Results

Table 9 presents the estimated results on the impact of economic complexity on the shadow economy in Africa via a long-run augmented mean group estimator (AMG). The post-estimation tests confirm the validity of the results. This is based on the fact that the Wald test ch-square is statistically significant at a p-value of 0.000. This implies that the model has a good predictive power of the shadow economy and can give an efficient reliable forecasting results. In addition, the study presents the results of the Mean Group (MG) and Common Correlated Effects Mean Group (CCEMG) for sensitivity analysis. The AMG estimator is more efficient in the presence of heteroscedasticity, endogeneity, cross-sectional dependence, and autocorrelation. Apart from the column that contains variables, columns 2 and 3 show the results of AMG which is our main estimator. It documents that economic complexity (ECI) has no significant impact on the shadow economy throughout the results. In other words, an improvement in economic complexity has no meaningful impact on the size of the shadow economy in Africa. This result is not consistent with Nguyen (2021) who uses global samples and employs a generalized method of moment including panel corrected standard error estimation technique. AMG results imply that improvements in the knowledge capability materialized in the African production structure do not meaningfully discourage operation in the shadow economy of the African region.

Table 9. Heterogeneous Long-Run Parameter Estimated Results, Dependent Variable: SE

Variables	AMG	AMG	MG	CCEMG
ECI	0.262	0.157	-0.242	0.066
	(0.663)	(0.799)	(0.709)	(0.926)
DCPS	0.071**	0.076**	0.120***	0.231**
	(0.014)	(0.013)	(0.003)	(0.001)
TOP	-0.056***	-0.061***	-0.067***	-0.063**
	(0.004)	(0.003)	(0.002)	(0.007)
POP	1.411	1.447	-2.270	2.136
	(0.375)	(0.264)	(0.113)	(0.118)
FDI	0.084	-0.049	-0.056	0.006
	(0.300)	(0.162)	(0.244)	(0.877)
INS	-0.018	0.325	1.038	0.986
	(0.968)	(0.486)	(0.126)	(0.118)
LGDP	-17.496***	-33.400***	-42.369***	-22.143*
	(0.000)	(0.000)	(0.000)	(0.072)
Common dynamic process	0.998***	0.871***		
	(0.000)	(0.000)		
Linear trend		0.161	0.041	-0.258
		(0.114)	(0.746)	(0.500)
Constant	92.760	0.871***	177.120***	116.337
	(0.000)	(0.000)	(0.000)	(0.358)
Wald chi2(7)	32.98***	30.78***	43.31***	24.93***
	(0.000)	(0.000)	(0.000)	(0.000)
RMSE	0.923	0.830	1.045	0.492
Number of groups	27	27	27	27

Source: Research finding.

Note: *, **, *** mean significant at 10%, 5%, and 1%, respectively. Root Mean Squared Error(RMSE). Figures in ( ) are p-values.

This research focuses on three control variables; financial depth, LGDP, and trade openness, since they are significant among control variables. The coefficient of financial development (proxied as domestic credit to the private sector) is positive and significant implying that financial depth increases the size of the shadow economy. This is consistent with the argument of Nguyen and Thanh (2020a). The author explains that financial depth may not necessarily reduce the size of the shadow economy, while financial access and efficiency are the most important components of financial development that reduce the activities in the shadow economy. However, Njangang et al. (2020) reveal that financial development reduces the level of the shadow economy while Ajide (2021) shows that financial inclusion may serve as a policy tool for reducing discouraging operations in the shadow economy.

The GDP per capita (LGDP) and degree of openness with expected signs suggest that a higher level of development is associated with a reduction in the size

of the shadow economy. This confirms the study of Chen (2012) and Ajide (2021). The results suggest that trade openness improves the economic opportunities for firms operating in the official economy and reduces the size of the shadow economy in Africa. Melitz (2003) demonstrates that an economy with trade openness induces productive firms to participate in international trade. Foreign trade improves welfare gain and further mitigates the rise of activities in the shadow economy (Esaku, 2019; Berdiev et al., 2018). Consistent with Esaku (2021), our results suggest that trade openness improves entrepreneurs' ability to participate in foreign trade and serves as an incentive to formalize operations, thereby discouraging operations in the shadow economy in the African region. Furthermore, in columns 4 and 5, we present the results of MG and CCEMG estimators. The former does not consider cross-sectional dependence while the latter does and is more efficient in the case of slope heterogeneity (Le & Bao, 2020; Osinubi et al. 2022). The findings of MG and CCEMG have no difference from what is documented by the AMG estimator, indicating that economic complexity does not have any significant impact on the shadow economy in Africa.

5.3 Robustness Check: Alternative Estimation

In this section, we present the results of an alternative estimation technique, namely; Dynamic Common correlated effects mean group (DCCEMG) with heterogeneous coefficients proposed by Chudik and Pesaran (2015) and supports the CCEMG (Pesaran, 2006; Pesaran and Smith, 1995). The DCCEMG is flexible because it can be explored in the case of either slope heterogeneous or homogeneous and correct for endogeneity. It also corrects for small sample bias. The estimation is carried out in a dynamic environment in which the lagged value of the dependent variable is used as one of the independent variables. The DCCEMG is more powerful and distinct in several ways compared to our earlier estimating techniques one of which is that it accommodates consistent estimates within a dynamic panel. It supports an unbalanced panel structure (Ditzen, 2018). The results of DCCEMG are presented in Table 10.

Table 10. The Dynamic Common Correlated Effects Mean Group (DCCEMG)

Variables	Coefficients	Std. Err.	P-values
SE(Lagged)	-0.272***	0.075	0.000
ECI	-0.306	0.937	0.744
DCPS	0.024	0.127	0.848
TOP	-0.103***	3.622	0.002
POP	2.091	3.622	0.564
FDI	-0.080	0.134	0.552
INS	0.353	1.352	0.794
LGDP	-39.127***	18.751	0.037
R-squared (MG)	0.94		
Number of groups	27		
Root MSE	0.96		

Source: Research finding.

Note: *, **, *** mean significance at 10%, 5%, and 1%, respectively. Figures in ( ) are p-values.

The coefficiency of the lagged dependent variable (SE) is negative and significant, implying that the data fit well in the dynamic environment. The coefficient of economic complexity is negative but not significant. This result is not different from the results that emerged from the AMG and CCEMG reports earlier except that the sign is not negative. However, this does not change our conclusion on the association between the shadow economy and economic complexity in Africa. The signs of the coefficients of the control variables are not different from those reported earlier.

5.4 Robustness Check: Country-Specific Results

As part of robustness checks for this study, it would be interesting to examine the country-specific results via an augmented mean group estimator (AMG). The specific coefficients of the 27 African countries are presented in appendix (Table A2). From the analysis, we discover that the coefficient of economic complexity for the case of Congo-Republic, Ghana, and Uganda is negative and significant at the 1 to 5 percent level. This implies that an improvement in the productive knowledge utilized in the production activities enjoyed in the formal economy may serve as a disincentive factor for operations in the shadow economy of these three countries. This submission is consistent with the study of Nguyen (2021) who suggests that economic complexity may serve as a policy tool for affecting the operation in the informal sector especially where the proportion is higher. However, the coefficient is positive and significant for the case of Botswana, Madagascar, and Tunisia. This suggests that economic complexity in these countries increases the size of the shadow economy. A critical look reveals that both economic complexity and proportion of shadow economy are either moderate

or very low in these three countries. This suggests that there could probably be a turning point for economic complexity to discourage the shadow economy in those countries. This opens opportunities for future studies. Apart from the 6 countries that record a significant coefficient for economic complexity, the remaining 21 countries have their coefficients not significant which supports the results documented in the baseline results. Overall, the results show that economic complexity has heterogeneous impacts on the size of the shadow economy in African economies.

6. Conclusion and Policy Implication

The study provides an answer to the question of whether economic complexity reduces the size of the shadow economy focusing on the case of African nations. To answer these important inquiries, the study explores the panel dataset of 27 African countries from 1995 to 2017. The findings based on AMG, MG, and CCEMG reveal that economic complexity has no significant impact on the shadow economy in Africa. This finding is robust to alternative estimation techniques namely; dynamic CCEMG. Furthermore, the results suggest that trade liberalization proxies by trade openness reduce the size of the shadow economy in Africa. Because it opens new opportunities and allows entrepreneurs to explore new trends in the international markets. Financial depth significantly affects the size of the shadow economy while official economic expansion reduces the activities in the shadow economy in Africa.

This study reveals some interesting findings after estimating the country-specific model. In the Republic of Congo, Ghana, and Uganda, economic complexity significantly reduces the size of the shadow economy while the opposite result is confirmed for Botswana, Madagascar, and Tunisia. Concerning other countries, the economic complexity does not affect the shadow economy. In conclusion, the impact of economic complexity is heterogeneous in the case of African economies. The evidence presented in the paper suggests that the country's level of productive knowledge materialized in the production system may not necessarily determine the size of the shadow economy except each country-specific feature is given consideration probably due to low economic sophistication. Based on these empirical findings, the following policy implications can be drawn.

African nations willing to reduce the size of the shadow economy should formulate economic policies that may improve the level of productive knowledge in the production including trade liberalization to upgrade the export sophistication in Africa. This would assist in facilitating a transition from a shadow economy to an official economy. The specific country results reveal that economic complexity may in some ways be a veritable tool for decreasing the size of the shadow

economy, especially, in countries with a moderate or low size of shadow economies compared to the official economy. Furthermore, since the results suggest that trade openness may reduce the size of the African shadow economy, trade liberalization policy may help control the shadow economy. Economic integration of a country would open new opportunities to firms which may serve as a disincentive to operate in an African shadow economy.

The findings should be viewed in the light of its limitations. This study only considers 27 countries in Africa due to the availability of economic complexity indicators for these countries. Future studies should overcome this shortcoming.

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Appendix

Table A1. List of African Countries Used for the Study

Algeria, Angola, Botswana, Burkina Faso, Cameroon, Congo, DR., Congo, Cote d'Ivoire, Egypt, Gabon, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Togo, Tunisia, Uganda, Zambia, Zimbabwe

Table A2. AMG Results (Group-specific Coefficients)

S/N	Country	ECI	DCPS	TOP	POP	FDI	INS	LGDP	Constant
1	Algeria	-0.348	0.044	-0.145***	2.598	-0.037	0.056	-45.537**	198.706***
		(0.701)	(0.790)	(0.006)	(0.176)	(0.915)	(0.920)	(0.037)	(0.009)
2	Angola	-0.258	0.062	-0.030	4.984	0.039	1.640	-34.739	144.783***
		(0.790)	(0.399)	(0.012)	(0.366)	(0.185)	(0.167)	(0.116)	(0.014)
3	Botswana	**1.508*** **	0.072	0.005	4.389***	-0.152*	-2.021**	11.247	-7.405
		(0.024)	(0.343)	(0.886)	(0.000)	(0.097)	(0.030)	(0.545)	(0.909)
4	Burkina Faso	2.579	0.130	-0.971**	-0.104	-0.380	-2.406	-21.695	115.063
		(0.294)	(0.478)	(0.010)	(0.994)	(0.421)	(0.499)	(0.730)	(0.469)
5	Cameroon	-1.779	0.301	0.055	-4.940	0.038	-0.963	-110.745	378.878
		(0.313)	(0.554)	(0.482)	(0.650)	(0.922)	(0.536)	(0.180)	(0.137)
6	Congo, DR.	**-4.606** **	0.536	0.015	0.752**	-0.025	4.138	-12.853	65.585
		(0.016)	(0.172)	(0.730)	(0.016)	(0.877)	(0.322)	(0.443)	(0.206)
7	Congo	-0.344	0.167**	0.023	1.203	0.025	1.244	13.893	-7.838
		(0.858)	(0.023)	(0.523)	(0.512)	(0.477)	(0.452)	(0.626)	(0.938)
8	Cote d'Ivoire	2.071	0.055	-0.050	-3.431*	1.121	1.191	-29.777	142.417*
		(0.462)	(0.599)	(0.405)	(0.079)	(0.105)	(0.321)	(0.214)	(0.052)
9	Egypt	-3.168	-0.025*	-0.182***	-25.142***	-0.263	0.308	-128.152**	507.348***
		(0.675)	(0.033)	(0.046)	(0.002)	(0.162)	(0.864)	(0.001)	(0.000)
10	Gabon	-0.422	0.275	-0.268***	1.899	-0.062	0.450	-19.661	147.470*
		(0.785)	(0.189)	(0.002)	(0.432)	(0.639)	(0.809)	(0.368)	(0.086)
11	Ghana	**-3.962***	0.204	0.064**	14.743	-0.256	6.667**	19.719	-86.652
		(0.096)	(0.242)	(0.023)	(0.135)	(0.320)	(0.023)	(0.523)	(0.447)
12	Guinea	0.068	0.395**	0.015	-5.160***	-0.164***	2.748***	-75.514***	247.675***
		(0.950)	(0.035)	(0.736)	(0.001)	(0.017)	(0.030)	(0.009)	(0.002)
13	Kenya	-3.218	0.077	-0.071	8.753	0.225	0.592	-78.535***	236.873***
		(0.217)	(0.448)	(0.114)	(0.193)	(0.283)	(0.292)	(0.000)	(0.000)
14	Madagascar	**5.960** **	-0.024	-0.082	17.956	-0.174	-1.688	27.681	-71.870
		(0.023)	(0.895)	(0.019)	(0.284)	(0.150)	(0.296)	(0.252)	(0.361)
15	Malawi	2.987**	0.152	0.063**	0.505	-0.077	-0.856	-2.386	46.343
		(0.017)	(0.230)	(0.018)	(0.635)	(0.846)	(0.380)	(0.846)	(0.137)
16	Mali	1.327	-0.216	-0.236**	-3.214*	-0.236*	1.670	-18.243*	104.165***
		(0.229)	(0.181)	(0.009)	(0.087)	(0.099)	(0.116)	(0.099)	(0.000)
17	Morocco	4.455	-0.035	-0.002	10.378**	-0.101	2.687*	-85.017**	289.895***
		(0.145)	(0.127)	(0.969)	(0.040)	(0.694)	(0.094)	(0.012)	(0.008)
18	Mozambique	-1.122	0.122*	-0.071*	1.303	-0.041	-2.322	-21.033	95.715**
		(0.291)	(0.070)	(0.070)	(0.636)	(0.411)	(0.183)	(0.280)	(0.046)
19	Namibia	0.615	-0.158***	-0.049***	3.965*	-0.061	0.995	11.443	-11.612
		(0.351)	(0.000)	(0.001)	(0.058)	(0.232)	(0.258)	(0.301)	(0.774)
20	Nigeria	-2.398	0.179	-0.101*	34.470	1.264	-2.695	-27.531	63.849
		(0.154)	(0.103)	(0.060)	(0.130)	(0.135)	(0.164)	(0.401)	(0.465)
21	Senegal	-0.512	-0.058	-0.194**	0.642	0.380	-1.993	-99.286**	361.985***
		(0.879)	(0.728)	(0.034)	(0.932)	(0.538)	(0.561)	(0.025)	(0.003)
22	South Africa	2.173	-0.013	0.007	2.507*	0.240	-0.903	-59.280*	251.963**
		(0.571)	(0.561)	(0.903)	(0.087)	(0.117)	(0.408)	(0.056)	(0.030)
23	Togo	-1.881	0.152	-0.013	0.075	-0.048	0.804	-29.903	111.712**
		(0.196)	(0.012)	(0.654)	(0.971)	(0.296)	(0.661)	(0.151)	(0.022)
24	Tunisia	**3.727** **	0.058	-0.112***	-3.302***	0.061	1.013	-110.305***	419.877***
		(0.048)	(0.363)	(0.001)	(0.004)	(0.528)	(0.361)	(0.001)	(0.000)
25	Uganda	**-6.609***	-0.129	0.051	5.698	0.625	5.168**	-60.260	149.758
		(0.063)	(0.559)	(0.753)	(0.346)	(0.140)	(0.008)	(0.346)	(0.376)
26	Zambia	1.630	0.127	-0.199***	-15.482***	0.071	1.048	35.903	-6.179
		(0.520)	(0.401)	(0.004)	(0.001)	(0.755)	(0.403)	(0.283)	(0.946)
27	Zimbabwe	**1.909** **	-0.046***	-0.052	-4.666***	-0.061	-2.974***	2.933	70.463***
		(0.035)	(0.007)	(0.127)	(0.001)	(0.778)	(0.006)	(0.590)	(0.000)

Source: Research finding.

Note: Common dynamic processes and Linear trends are included as additional regressors. Figures in () are p-values.