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REAL ECONOMY AND FINANCIAL MARKETS. LONG AND SHORT–TERM VOLATILITY DETERMINANTS IN SUB-SAHARAN ECONOMIES

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Abstract. South Africa plays a dominant role in the scope of the Common Monetary Area; Nigeria could assume an equivalent role in the central part of Africa. The aim of the paper is to determine the influence of domestic and international factors on the volatility of the Johannesburg and Nigerian stock exchanges in order to investigate the nexus between financial markets and the real economy as well as the integration of the markets with the global financial market. The long and short-term components of the main stock indices are derived through the spline-GARCH models. The results of the study reveal that the short-term component of JSE volatility is mainly determined by the dynamics of global financial markets, while the long-term volatility component is affected mainly by the changes of domestic macro-factors. However both the short and long-term volatility components of the Nigerian All-Shares Index are driven by the dynamics of the global financial markets, while domestic factors have an insignificant impact on it.

Keywords: spline-GARCH, sub-Saharan Africa, stock exchange volatility, Nigeria, South Africa, long-term volatility.

JEL Classification: D53, H54, B26, F63.

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1. Introduction

The inclusion of the sub-Saharan Africa (SSA) financial markets into the global financial system is in process. As of 2018, there are 29 stock exchanges (SE) in the region including two regional SEs, which cover Western and Central African countries, one in the Ivory Coast and the other in Gabon. Before 1989 there were just five stock markets in sub-Saharan Africa. Most of the

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stock markets are still immature. Yartey and Adjasi [2007] suggest that African SEs face the challenge of integration and need better technical and institutional development to address the problem of low liquidity; also the harmonization of bankruptcy and accounting laws legislations and the liberalization of the trade regime are important to tackle in a regional context.

In the article we determine the influence of domestic and international factors on the volatility of the Johannesburg and Nigerian stock exchanges. The volatility of stock market in the two largest sub-Saharan economies seems a scientific problem worthy of addressing for at least two reasons. First, in the aftermath of the global financial crisis, it is interesting to investigate the nexus between financial markets and the real economy, especially in the case of low and middle-income countries which supposedly require efficient financial markets to support the economic development process, where it is vital to see whether financial markets reflect the conditions of the real economy or are just a "side-show". One way to approach this challenge is by an analysis of the determinants of stock market volatility, which allows to reveal the forces behind the current trends in transactions. Stock markets' volatility carries information on the link between the financial market and its exogenous and endogenous factors. Secondly, it allows to assess the attractiveness of stock markets for investors [Ndikumana 2001]. This in turn is crucial for the countries in the sub-Saharan region that remain affected by poverty issues and the challenges of competition with high income countries. Increasing inflows of foreign capital are expected to boost their economic development [Calderón, Nguyen 2015]. As the aggregate volatility may not be the most accurate measure of financial market volatility, we use the method suggested by Engle and Rangel [2008] and decompose volatility into two components, high-frequency and low-frequency.

For emerging markets and for markets with a small number of listed companies and market capitalization, volatility tends to be higher [Engle, Rangel 2008]. The reasons for this may have an exogenous or endogenous character and we were inclined to analyze, which prevail in the stock market of the largest economies in the region, South Africa and Nigeria.

The rationale to concentrate on South Africa and Nigeria despite of their apparent differences [Auwal, Sanusi 2016] were: the size of their economies, the high amount of foreign direct investments (FDIs), and their potential influence on neighbouring SEs. South Africa already plays a dominant role in the Common Monetary Area, which is a southern African regional grouping

[Frey, Volz 2013], Nigeria could assume an equivalent role in the central part of Africa. Data availability was another important factor.

The methodology is as follows. We first estimate high and low-frequency volatility component based on the spline-GARCH [Engle, Rangel 2008] model. Next, we annualize the spline and verify the interrelationships between macroeconomic variables and annualized long-term volatility as well as global factors and volatility, estimating a set of regression models. As the Johannesburg SE has already a long history, we assumed that the results obtained for this exchange will resemble the results expected in the case of more mature financial markets. We set the following hypotheses:

1. Short-term volatility components should be linked to the volatility of the global markets in the case of the two economies.
2. Johannesburg SE volatility is more tightly linked to the volatility of international financial markets than the Nigerian SE.
3. Changes of the long-term volatility component of the Johannesburg SE are more embedded in the domestic situation of the country than the Nigerian one.

The results of the study through the spline-GARCH model presented in this paper reveal that the short-term component of Johannesburg SE volatility is mainly determined by the dynamics of the global financial markets, while the long-term volatility component is affected mainly by the changes of domestic macro-factors. However, the volatility of the Nigerian All-Shares Index is driven by the dynamics of the global financial markets, while domestic factors have an insignificant impact on it. This may imply that immature financial systems do not reflect the real economy as the mechanisms of information flow between the financial system and the market are not yet established.

2. Literature review

Literature on the financial markets of sub-Saharan Africa is rather scant. It addresses mostly the issues of the financial and economic development and growth nexus [King, Levine 1993; Yartey, Adjasi 2007; Délechat et al. 2010; Brambila-Macias, Massa 2010; Chea 2011; Kagochi et al. 2013; Adeniyi et al. 2015], the stock market development [Yartey, Adjasi 2007], foreign investment relation [Adeniyi et al. 2015], and regional financial integration [Frey, Voltz 2013]. The positive effect of financial markets on economic development is found in most of the studies [Délechat et al. 2010; Brambila-Macias, Massa 2010; Ashford 2011; Kagochi et al. 2013; Adeniyi et al. 2015].

However, some doubts which address the issue of causality of relation also exist [Robinson 1952]. Kagochi et al. [2013] claim that economic growth first stimulates the financial one, but once a certain stage of financial services development is reached, the direction of causality is reversed. Their results are consistent with the prior works of King and Levine: "financial services stimulate economic growth by increasing the rate of capital accumulation and by improving the efficiency with which economies use that capital" [King, Levine 1993].

Competitive stock markets reduce the counterproductive monopoly power of banks and boost innovation projects, improve information dissemination and reduce transaction costs [Naceur, Ghazouani 2007]. According to Délechat et al. [2010], capital market development is closely associated with higher private capital inflows. Strong positive correlations between private capital inflows and real GDP growth in the recipient countries imply the positive impact of capital market development on economic development. The World Bank [2017] suggests also that the development of an economy's financial markets is closely related to its overall development. The implementation of macroeconomic reforms which are conducive for financial markets development, especially through fiscal discipline, promotes a stable business environment [Ndikumana 2001]. Likewise, appropriate institutions that foster low inflation and volatility levels promote consumption and output growth stability [Ahmed, Suardi 2009]. In the context of the recent global financial crisis, researchers are calling for monetary policy reform better suiting SSA to discretionary countercyclical macroeconomic stabilization, with an important role for the discretionary fine tuning of aggregate demand [Kasekende, Brownbridge 2011].

The establishment of stock markets has been found crucial in the domestic financial liberalization programs in most of the African countries [Yartey, Adjasi 2007]. This is important, since financial liberalization increases the efficacy of consumption smoothing and stabilizes income and consumption growth (see: [Ahmed, Suardi 2009]). Financial market depth and institutional quality operate jointly with trade and financial openness to reduce volatility in output and consumption growth. Oyelami et al. [2013], through dynamic panel estimation, established a significant direct relationship between stock price (returns) and consumption growth and the insignificant positive relationship between dividend yield and consumption growth. They suggest that policy makers can leverage on this link to stimulate economic growth.

The two-way causality between stock market development indicators and economic growth was found in the Kagochi et al. [2013] study on seven sub-Saharan states. There is a number of empirical insights from Enisan and Olufisayo [2009] research on the relationship between the stock market and economic growth. For South Africa, they found that the stock market development is cointegrated with economic growth and that stock market development causes economic growth. In other markets (Ivory Coast, Kenya, Morocco and Zimbabwe) a bidirectional relationship has been found. However, for Nigeria the authors established a weak evidence of growth-led financial market development. This implies first, that the stock market can influence economic growth, and that investigating the mechanisms of these markets' volatility may provide important policy implications. However, Ndako [2013] suggests that there is no evidence of cointegration between stock prices and the real exchange rates for five sub-Saharan countries, including Nigeria and South Africa.

The distribution and composition of capital inflows vary substantially across sub-Saharan African countries [Enisan, Olufisayo 2009; Chea 2011]. African stock markets are small and illiquid, with infrastructural bottlenecks and a weak regulatory institution [Yartey, Adjasi 2007]. They are also characterized by high diversity in terms of age, size, and performance [Ndikumana 2001]. Moreover, Yartey and Adjasi [2007] note that in most of SSA SEs, trading occurs for only a few stocks which account for a considerable part of the total market capitalization; for not actively traded stock there are informational and disclosure deficiencies. They also claim that there is too much supervision by regulatory authorities which has a negative impact on these markets. However, they perform remarkably well in terms of returns on investment, which are relatively high.

Stock market stability has the potential to positively impact on economic growth. Increasing inflows of investments of a different nature and increasing the number of foreign firms brings technology to the market. By channeling funds to the most efficient investors and by fostering entrepreneurial innovation, financial intermediaries contribute to finding the right comparative advantage [King, Levine 1993; Ndikumana 2001]. On the other hand, high capital inflow is an impediment to financial market development and increases macroeconomic uncertainty, as market participants interpret it as a signal of loss of control over economic policy by the national authorities. This in turn discourages saving and lending. High capital flight constitutes a drain on national resources and depresses private savings and investment [Ndikumana

2001]. Hence verifying which factors are significant for the stock market volatility on sub-Saharan markets will allow to provide important development policy implications.

3. Methodology and data

In the analyzed stock markets of Nigeria and South Africa we find 183 and 316 listed domestic companies respectively, including foreign companies which are exclusively listed. This is way over the regional average, which according to our own calculations of limited IMF data is 30 (excluding South Africa). There is also a major difference between the studied cases. While the stocks traded, total value as a percentage of GDP in South Africa was on average 66 over the last 10 years, but was barely 3 in Nigeria. Also in absolute terms the total value of stocks traded was 234 billion (current USD) in South Africa and only 4 billion in Nigeria (current USD) in 2015.

Market capitalization of listed domestic companies accounts for over 23% of GDP in South Africa, and for 10% of GDP in Nigeria, below the regional average 25% of GDP (excluding South Africa). However, still there is not enough evidence to determine what causes the volatility of major sub-Saharan African SEs, and are financial markets in fact more prone to shocks from outside than within the economy.

In our study, we model the volatility of the indices using the spline-GARCH model which allows us to decompose the volatility of a financial instrument into two components, low and high-frequency. The low-frequency component represents the long-term volatility which should depend on macro-factors of the economy if the SE is integrated with it. The short-term component describes the high-frequency fluctuations of the daily volatility around its low-frequency pattern. The formal description of the model is presented in Appendix. Based on the data availability, we analyzed the dynamics of the JSE40 over the period 2002-2016 and the dynamics of the NGSEINDX over the period 2002-2016. The volatility models were estimated in OxMetrics7 with G@RCH package, while the linear regressions in R Cran.

When the long-term volatility component is derived from the main stock-exchange indices, we estimate a set of regression models with explanatory variables that are divided into two groups of the local and the global factors. The local factors group consists of macro-factors of yearly frequency such as GDP growth, GDP per capita, inflation and real interest rates, as well as the factors related to the capitalization of the local SEs: the turnover ratio expressed either with relation to GDP or as the local shares turnover ratio (see

also: [Engle, Rangel 2008]). The global factors group consists of the global market indices: S&P500 (America), Hang-Seng (Asia), FTSE250 and CAC40 (Europe), as well as the future prices of oil (Brent) and gold. Based on the quarterly data of the global factors, we compute the realized yearly volatility and include it in the regression model. In the case of the local factors we tested the possible transformation of variables, and the analysis revealed that if any relationships are present they can be found between the level of the explanatory variables and long-term volatility, not between the volatilities of the variables. Through the estimation of the regression models we verify whether the volatility of the main indices of South Africa and Nigeria is related to the fundamentals of the economies, or rather to the global risk factors.

The macro factors were chosen mainly based on the research presented by the authors of the spline-GARCH model [Engle, Rangel 2008]. The authors analyzed the developed and emerging economies in a panel model. Their study reveals that the relationships between the long-term volatility components and macro factors indeed exist, and that volatility of inflation, real interest rates, as well as GDP, tend to positively influence the long-term volatility of stock indices. Moreover, they confirmed the significant influence of the size of the market on the long-term volatility. In the following sections first the volatility factors for Johannesburg, and then for the Nigerian SE are presented.

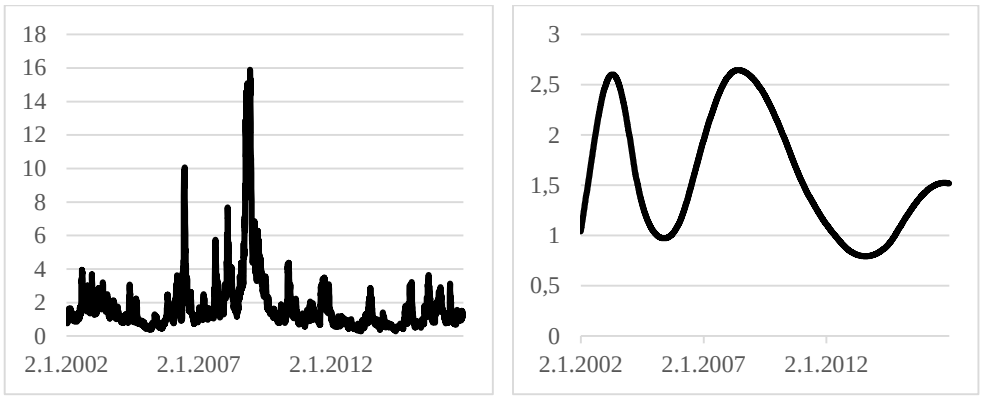
4. Volatility of Johannesburg Stock Exchange

In the first step of the research, the spline-GARCH model for the FTSE/JSE top 40 index over the years 2002-2016 was estimated (descriptive statistics are given in Table A1 in Appendix). The results of the estimation are presented in Table 1. The model was chosen based on the information criteria value, its ability to explain linear and non-linear dependencies in the data, stability and significance of parameters, as well as the results of the Pearson test (we used the skewed-Student distribution – see Table A2 in Appendix for the Jarque-Berra test results)[2].

[2] We performed misspecification tests for all the models presented in the article. The residuals of the models were checked for remaining linear and non-linear relationships (the Box-Pierce test) – see Appendix, Table A3. We also performed the Nyblom test for the parameters' stability and the Pearson test for the goodness of fit. All the results are available upon request. From all the models that passed Box-Pierce for residuals and squared residuals, we chose the best ones based on information criteria and parameters' significance.

In Figure 1 we present the estimates of the volatility. We can notice that the global financial crisis is not reflected in the series. The first peak of volatility is observed in June 2006 and can be interpreted as an echo of the mortgage crisis in the USA. The next peak is dated to the end of the second half of 2008 and can be a consequence of the growth of volatility in the oil market. Next, the situation stabilizes. The peak in 2008 was driven by the good performances of mining and commodity stocks. In the overall struggle for banking in South Africa in 2007-2008 there was the control of inflationary pressures coming from raising oil and food prices [Viegi 2008]. Next the sudden stop of international capital flows produced a collapse of share prices and exchange rate and the SE devalued nearly 20% in three months. In the same time period the Rand depreciated 37% against the US dollar. As reported by Viegi [2008], hard mining and the commodity industry were struck by the collapse of commodity prices. The government finances and international reserves provided a buffer stock against the most extreme effect of the crises, however the credit crunch affected infrastructure investments also in industry and mining.

Estimates of the spline are presented in the right panel of Figure 1. It is interpreted as a low-frequency volatility. If the stock market of South Africa is linked to the macroeconomic situation of the country, we should see the influence of local variables on the long-term component of stock market volatility which may reflect the business cycle of the economy.



* All calculations performed in G@RCH package of OxMetrics7.

Fig. 1. Volatility component of the JSE40 (left panel)
and long-term volatility component (right panel) – spline GARCH model

Source: own computation.

Table 1. Estimates of the spline-GARCH model with no explanatory variables – the case of South Africa

Coefficient	Estimate	Std. error	t-statistics	p-value
μ	0.064	0.016	3.981	0.000
AR(1)	0.001	0.016	0.060	0.952
AR(2)	–0.046	0.017	–2.635	0.009
ω	1.036	0.309	3.353	0.001
Spline_0 (V)	21.356	4.243	5.033	<0.001
Spline_1 (V)	–123.845	18.156	–6.821	<0.001
Spline_2 (V)	208.039	25.311	8.219	<0.001
Spline_3 (V)	–119.452	19.003	–6.286	<0.001
Spline_4 (V)	16.901	35.059	0.482	0.630
Spline_5 (V)	22.094	37.061	0.596	0.551
Spline_6 (V)	32.680	19.621	1.666	0.096
Spline_7 (V)	–59.946	28.004	–2.141	0.032
ARCH(α1)	0.082	0.009	9.496	<0.001
GARCH(β1)	0.895	0.011	84.700	<0.001
Asymmetry	–0.119	0.025	–4.748	<0.001
Tail	16.683	3.835	4.350	<0.001

*****The error distribution was skewed-Student one. Tail denotes the number of the degrees of freedom. All calculations performed in G@RCH package of OxMetrics7.

Source: own computation.

4.1. Domestic and international determinants of long-term volatility

In the opening step we calculated Pearson's, Kendall's and Spearman's correlation between the long-term volatility and the potential explanatory variables (see Table A4 in Appendix A3). It appeared that the significant (at 10%) values of correlations were obtained in the case of real interest rate, inflation and volatility of all the indices: S&P500, FTSE250 and Hang-Seng. We observed the strongest influence of the Asian market – probably due to large engagement of Chinese stakeholders on the market. However, the role of European, and particularly UK investors along with the USA and Switzerland is also considerable. However, as the Chinese economy impacts strongly on the Asian market it may radiate onto South African stock.

Next, we computed a series of linear regression models. In Tables 2-3 we present the results of the estimation. The best models were chosen based on the R^2 value and significance of explanatory variables. When it comes to local (macroeconomic) variables influencing long-term volatility – the model with inflation and real interest rate performed best. Both variables were significant, and R^2 amounted to 0.53. This result can be interpreted as follows: macro-factors explain the movements of long-term stock-market volatility in 53%. The remaining 47% of volatility dynamics is due to other factors not included in the model.

Table 2. Macroeconomic determinants of long-term stock market volatility in South Africa – linear regression model

Variable	Estimate	Standard error	t-statistics	p-value
(Intercept)	0.658	0.175	3.767	0.003
Real interest rate	0.071	0.030	2.369	0.037
Inflation	0.050	0.021	2.418	0.034

* R^2 amounted to 0.53, while adjusted R2 to 0.44. Residuals standard error equaled 0.18. F statistics amounted to 6.18 with p-value of 0.016. The Box-Pierce test revealed no autocorrelation of residuals.

Source: own computation.

Table 3. International determinants of long-term stock market volatility in South Africa – linear regression model

Variable	Estimate	Standard error	t-statistics	p-value
(Intercept)	0.860	0.119	7.236	0.000
vol_Hang_Seng	0.048	0.013	3.549	0.004

* R^2 amounted to 0.62, while adjusted R2 to 0.53. Residuals standard error equaled 0.26. F statistics amounted to 9.04 with p-value of 0.005. The Box-Pierce test revealed no autocorrelation of residuals.

Source: own computation.

In the next step we verified the possible impact of international factors on the long-term volatility of the South-African stock market. The results are presented in Table 3. The best model included only one explanatory variable – the volatility of the Hang-Seng index, representing the volatility of the Asian markets. This model was better than any other model, including both the European and American indices' volatility, as well as models including volatilities of commodity markets (gold and Brent oil). Surprisingly, R^2 of the model was higher than the R^2 of the one including domestic variables.

This can suggest that although the long-term volatility of the South-African SE is indeed linked to macroeconomic variables, it is also strongly linked to the international volatility. The strength of these linkages is higher than the strength of the linkages with domestic variables. As the analysis concerns long-term volatility, we can speculate that the dynamics of the financial market in South Africa is driven mainly by international investors. Since South Africa continues to be one of the most attractive FDIs destination, with an increasing range of sectors, this seems well-founded.

4.2. Robustness check

To check the robustness of the results we estimated yet another model of daily volatility – with Hang-Seng returns and volatility as explanatory variables. We included the returns of the Hang-Seng in the mean equation (coefficient amounted to 0.398) and the absolute values of the returns in the volatility equation (coefficient amounted to 0.095). For the sake of consistency, we do not report the full model here but the results of estimation are available upon request.

In the next step we re-calculated the regression models using the newly obtained series of low-frequency volatility. The results are presented in Table 4. It appears that when Hang-Seng volatility is included in the low-frequency volatility model, then the long-term volatility is again influenced by domestic factors more than by international ones. Despite the daily reactions of the JSE to the Asian stock market performance, in the long run the influence of macroeconomic factors prevails on the volatility of the South African SE.

Table 4. Comparison of models explaining the long-term volatility of the South African stock exchange

Model	Coefficient name	Estimate	Std error	*t*-statistics	*p*-value
Model 1	**(Intercept)**	**0.536**	**0.168**	**3.195**	**0.009**
	real_int.rate	**0.075**	**0.029**	**2.591**	**0.025**
	Inflation	**0.051**	**0.020**	**2.588**	**0.025**
Model 2	(Intercept)	0.823	0.159	5.189	<0.01
	vol_FTSE	0.044	0.02	2.198	0.05
Model 3	(Intercept)	0.777	0.124	6.252	<0.01
	vol_Hang_Seng	0.046	0.0141	3.265	0.01

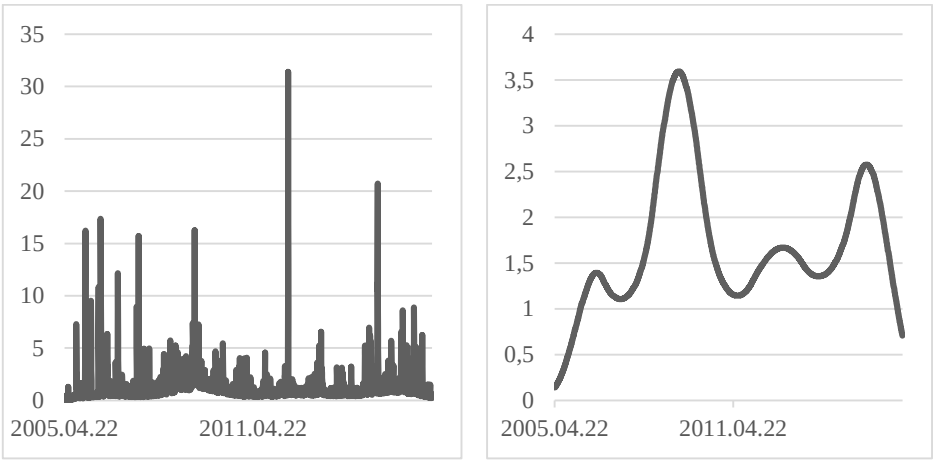
* Model 1: $R^2 = 0.57$; adjusted $R^2 = 0.49$; Model 2: $R^2 = 0.29$; adjusted $R^2 = 0.23$; Model 3: $R^2 = 0.47$; adjusted $R^2 = 0.42$.

Source: own computation.

We can conclude that the daily volatility of the South African SE is strongly influenced by the dynamics of the Asian SE. In the long run, volatility reacts to macro-factors such as real interest rate and inflation: the growth of real interest rate, as well as the inflation results in the growth of stock market volatility (ceteris paribus). Providing the quality of South African macroeconomic policy and the relative stability of the financial sector, we can see some positive effects of that. On the other hand, the role of foreign stock and oil prices indicate that the dependence on foreign investors and oil prices is still important.

5. Volatility of the stock market in Nigeria

The second largest SE in terms of market capitalization of SSA is the Nigerian one. The stock market of Nigeria started functioning already in 1961 as the Lagos Stock Exchange, 16 years later it was re-named the Nigerian Stock Exchange (see: [Agyapong 2014]). As of 1998, there is also the Abuja Securities and Commodities Exchange in the Nigerian financial market. In this research we collected daily data from the CEIC database of NSE All Share Index, from 2005 to 2016. Again, we estimated the Spline-GARCH model. The best model is presented in Table 5. Seven knots were included in the spline equation, similarly to South Africa. Due to the many outliers, we included also binary variables in the mean equation.



* All calculations performed in G@RCH package of OxMetrics7.

Fig. 2. Long-term and short-term volatility of the Nigerian all-stock index; the spline-GARCH model estimates (left panel) and long-term component of volatility (right panel)

Source: own computation.

Table 5. Estimates of spline-GARCH model coefficients – the case of Nigeria

Coefficient	Estimate	Std. error	*t*-statistics	*p*-value
μ	–0.009	0.019	–0.449	0.654
MINUS (M)	–12.393	0.265	–46.710	<0.001
PLUS (M)	11.585	0.599	19.330	<0.001
AR(1)	0.360	0.023	15.390	<0.001
AR(2)	0.041	0.020	2.049	0.041
ω	0.139	0.077	1.800	0.072
Spline_0 (V)	38.019	7.556	5.032	<0.001
Spline_1 (V)	–156.854	27.627	–5.677	<0.001
Spline_2 (V)	229.243	31.968	7.171	<0.001
Spline_3 (V)	–168.599	21.920	–7.691	<0.001
Spline_4 (V)	164.285	22.222	7.393	<0.001
Spline_5 (V)	–103.131	13.420	–7.685	<0.001
Spline_6 (V)	81.846	37.769	2.167	0.030
Spline_7 (V)	–166.566	93.317	–1.785	0.074
ARCH(α)	0.382	0.050	7.645	<0.001
GARCH(β)	0.476	0.056	8.535	<0.001
Student(DF)	3.734	0.266	14.060	<0.001

* Number of degrees of freedom in Student distribution suggest extreme kurtosis. PLUS and MINUS denote binary variable taking 1 in the case of extreme positive (PLUS) and negative (MINUS) return. (M) indicates that the explanatory variable was included in mean equation, while (V)- in variance equation. (DF) denotes number of degrees of freedom. All calculations performed in G@RCH package of OxMetrics7.

Source: own computation.

In the right panel of Figure 2 we can observe the long-term volatility component of the Nigerian stock market. We can see that its peak was reached in July 2009 which can be explained by the recent global financial crisis. However, in the literature, some authors suggest that the financial crisis led to a downturn in the Nigerian markets, while others blame it on the quality of macroeconomic policy [Onuoha, Nwaiwu 2016]. Njiforti [2015] claims that the fact that the price of crude oil slumped to a low level, the money supply decreased and the credit to private sector contracted, reduced the balances which could have been invested in stocks. Also according to Uyaebo et al. [2015], the significant drop in the all-share index recorded in the Nigerian stock market was due to the massive investment withdrawal by foreign portfolio (equity) investors as a general consequence of the 2007/2009 financial crisis.

The reaction of the Nigerian stock exchange to investors' sentiment may be a consequence of the fact that over 80% of the securities in the market are equity stock. The peak in 2012 may reflect the major mergers and acquisitions on the market aimed especially at the oil and telecommunication sector, partly by Chinese investors. Uyaebo et al. [2015] confirmed that the Nigerian stock market is greatly impacted by the Chinese market especially in 2009; events in the Nigerian market follow similar prior events in the Chinese market which occurred five to six months before. The Nigerian market seems to mirror the Chinese market. Apart from that, the situation of the financial market in Nigeria was influenced by the banking sector's condition and its impact on investors. Adepoju [2013] claims that the stock market performance of all the sampled banks has declined especially from about May 2008. He suggested that financially weak or troubled banks showed greater weakness in stock market performance than the healthy ones. Investors might have lost their confidence in the prospect for future growth and could have prompted them to reduce their shareholdings due to the environmental threat to investment return caused by that situation.

5.1. Determinants of the long-term volatility of the Nigerian stock market

In order to analyze the actual factors which affected Nigerian stock, in the next step we annualized the long-term volatility component and estimated a set of regression models to verify which macroeconomic variables influence the long-term volatility component. We took into account the same set of explanatory variables as in the case of South Africa (see: Table A4 in Appendix A3). As in the previous case, we first calculated three kinds of correlations between the long-term volatility component and the potential explanatory variables. In this case no significant correlation between macrofactors and the long-term volatility of the Nigerian SE was found. However, strong and significant correlation has been demonstrated between the volatility of all stock indices (FTSE500, CAC40, S&P and Hang-Seng) and the long-term volatility component of the Nigerian SE.

Next, we estimated a set of regression models, the best of which is presented in Table 6. Due to the error autocorrelation we used the Newey-West estimator. Only global factors proved to significantly influence the volatility. However, R^2 amounted only to 0.46 which suggests that there are other factors that can explain the remaining 56% of volatility dynamics.

Table 6. Determinants of long-term volatility in Nigeria – a linear model

Variable	Estimate	std. Error	t-stat.	p-value
(Intercept)	0.814	0.110	7.396	0.000
vol_Hang-Seng	0.027	0.008	3.328	0.010
vol_S&P500	0.035	0.015	2.385	0.044

* Due to autocorrelation, the Newey-West estimator was used to compute estimation errors and p-value. R^2 amounted to 0.46, while adjusted R^2 to 0.33. Residuals standard error equaled 0.25.

Source: own computation.

5.2. Robustness check

In order to check the robustness of the results, we estimated yet another model with explanatory variables in daily conditional mean and volatility. Since some researchers found relationships between the Nigerian stock market and the oil price, we included first the log-returns of oil prices in the mean and variance equation. The influence of oil prices is strong, if we take into account that petroleum exports revenue represents over 90% of total exports revenue and that the oil and gas sector accounts for about 35% of Nigerian GDP. Other possible explanatory variables were the log-returns of S&P500 and Hang-Seng indices as well as the squares of their log-returns that approximated their volatility. The best model was the one with volatility of Brent oil (coefficient amounted to -0.003) and volatility of S&P (-0.005) in mean equation. The sign of the coefficient can suggest that the growth of volatility of oil or S&P contribute to the decrease of returns in the Nigerian SE. For the sake of consistency we do not report the full model in the text, but the data is available upon request.

Table 7. Determinants of long-term volatility in Nigeria – a linear model

Variable	Estimate	std. Error	t-stat.	p-value
(Intercept)	0.806	0.154	5.246	0.001
Vol_S&P500	0.057	0.022	2.608	0.028

* R^2 amounted only to 0.43, while the adjusted R^2 to 0.37. Residuals standard error was equal 0.25.

Source: own computation

Having obtained the estimates of the long-term volatility, we again computed a series of linear models to find the determinants of it. The best model

is presented in Table 7. Thus we can conclude that there is a strong impact of the Western market on the Nigerian SE. The volatility of the US market (together with the volatility of oil prices) influence both the short-term conditional mean as well as the long-frequency component of the Nigerian index.

6. Conclusions

Stock market data of the two largest SEs in sub-Saharan Africa: Johannesburg and Nigeria were analyzed. Two main stock indices, the JSE40 (South Africa) an the All Share Index (Nigeria) were taken into account. The spline-GARCH model of Engle and Rangel [2008] to derive long and short-term component of the indices volatility was applied. Next, it was verified whether the long-term volatility component of the indices is linked to the macroeconomic situation of the countries. The set of macroeconomic variables were chosen based on the literature review presented in Engle and Rangel [2008]. Variables related to macroeconomic situation (GDP and GDP per capita, real interest rates), predictors of the future state of the economy (inflation), market development (share of domestic companies in overall turnover and size of the stock market related to GDP), were included in the study. Moreover, global factors as potential causes of stock market volatility, i.e. – oil and gold market volatility as well as the volatilities of the financial indices of America, Asia and Europe, were assessed.

The results reveal a major difference between the Nigerian and the more mature South African bourses. We found that the financial market of South Africa is more linked to fundamentals, while the Nigerian one – to the external situation in the global markets, especially oil prices. The low-frequency SE volatility component is higher in Nigeria (which is consistent with the findings of Engle and Rangel who claim that the low-frequency volatility is higher in emerging markets); due to the market size a single investment can drastically increase the stock value. 80% of the instruments traded are stocks, while the share of derivatives is very small. In the case of South Africa, the long-term component of SE volatility is linked to the macro-factors (real interest rate and inflation), while the short-term component to global factors. On the contrary, in Nigeria no dependence between the local factors and long-term volatility component was found. This implies that the stock market is not institutionalized enough. The long and short-term volatility component is driven by the volatility of the global financial and commodity markets (oil, S&P and the Hang-Seng). The economy's dependence on oil, compounded

by the quality of institutions and inefficient financial market regulations, explains its vulnerability to exogenous factors. This implies that immature financial markets do not reflect the real economy conditions. However, they reveal the exposure of the emerging markets to global financial markets. This suggests that such an economy is vulnerable to exogenous markets conjuncture and investors' decisions.

There is evidence in the literature that the development of financial markets may lead to economic development (see e.g. [Manning 2003]). Legal changes and macroeconomic policies enforced in the process of the establishment of financial markets are subsequently creating positive effects for the whole economy, including poverty reduction. Therefore, understanding the mechanisms which drive the volatility of stock markets is important for the development policies and solving the socio-economic problems of populations in low and middle-income countries. As the case of Nigeria has shown, exposure to commodity prices potentially decreases stock market stability and may discourage long-term investors. This calls for institutional development and the creation of an investor- friendly environment. Increasing transparency is one of the crucial policies to increase the credibility of the Nigerian SE. Since capital is scarce in the region, sub-Saharan stock exchanges such as Nigeria's, should be stabilized in order to provide incentives for long-term foreign investments. Rising intra-African investments, regional financial cooperation, and integration policies may contribute to the sophistication of sub-Saharan stock markets. Adopting financial market policies based on more mature but regional stock exchanges experiences, such as South Africa's, can accelerate the process.

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Appendix

A1. Spline-GARCH model

Let us denote by r_t a logarithmic return from the financial instrument price at the moment t, $\mu_t = E(r_t|\Omega_{t-1})$ – conditional mean (Ω_{t-1} is the set of all available information up to time t-1). Let:

$$r_t = \mu_t + y_t,$$

where μ_t can be described as ARMA process with possible additional explanatory variables:

$$\mu_t = a_0 + \sum_{i-1}^{k} \delta_i x_{i,t} + \sum_{i=1}^{p} a_i r_{t-i} - \sum_{i=1}^{q} b_i y_{t-i}.$$

Let $x_{i,t}$ denote a value of some exogeneous i-th variable at moment t. According to the parametrisation used in this study, the model has the following form:

$$(\mu_t - \mu) = \sum_{i-1}^{k} \delta_i x_{i,t} + \sum_{i=1}^{p} a_i (r_{t-i} - \mu) - \sum_{i=1}^{q} b_i y_{t-i},$$

where μ denotes the unconditional mean of process r_t.
When the ARCH effect is present, the residuals y_t can be presented as the product of two processes:

$$y_t = \sigma_t \epsilon_t,$$

where:

$$\sigma_t^2 = var(r_t|\Omega_{t-1}) = \omega + \sum_{i=1}^{q} \alpha_i y_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2,$$

is a GARCH(p,q) process, while $\epsilon_t \sim iid\ N(0,1)$ (or is of another distribution: Student, skewed Student, GED, etc.).

The GARCH model was proposed by Bollerslev in 1986 [Bollerslev 1986]. A special case of it GARCH(1,1), which is stationary when $\alpha + \beta < 1$. A lot of modifications of the base GARCH model have been proposed, one being a splineGARCH one [Engle, Rangel 2008]. In this model σ_t is presented as a product of two components:

$$\sigma_t = \tau_t \cdot s_t,$$

where τ_t is a spline function with k knots, multiplied by the GARCH(p, q) component, while:

$$s_t^2 = 1 - \sum_{j=1}^{\max(p,q)}(\alpha_j + \beta_j) + \sum_{i=1}^{q} \alpha_i \left(\frac{y_{t-i}}{\tau_{t-i}}\right)^2 + \sum_{j=1}^{p} \beta_j s_{t-j}^2.$$

In the case of GARCH(1,1):

$$s_t^2 = 1 - (\alpha + \beta) + \alpha\left(\frac{y_{t-1}}{\tau_{t-1}}\right) + \beta s_{t-1}^2,$$

$$\tau_t^2 = \omega \cdot exp\left(\delta_0 t + \sum_{i=1}^{k} \delta_i [(t - t_{i-1})_+]^2\right).$$

where: $x_+ = x \ for \ x > 0 \ \ or \ \ 0 \ otherwise$, while $E(s_t) = 1$, a $\{t_0 = 0, t_1, \dots, t_{k-1}\}$ – are time indices slicing the time axis for k equal intervals.

The idea of the model is as follows: it allows to model volatility of financial instrument as a combination of macro-factors and own dynamics of the financial instrument. Volatility of daily-quoted instrument (or even more frequently) is modeled as a product of low-changing component – represented as a spline – and GARCH component. The first one is a so called- low-frequency volatility, while the second one determines the short-term fluctuation of the short-term volatility around the long-term one.

A2. Descriptive statistics and preliminary tests

Table A8. Descriptive statistics

Country	Variable	min	mean	max	std.dev
South Africa	Date	2002-01-02	--	2016-12-29	--
	dLog(SA)	-7.959	0.039	7.707	1.324
	Constant	1	1	1	0
	Trend	1	1875.5	3750	1082.5
Nigeria	Date	2005-04-25	--	2016-12-29	--
	dLog(NG)	-34.083	0.007	34.587	1.518
	Constant	1	1	1	0
	Trend	1	1353	2705	780.87

Table A9. Normality test results – Jarque-Bera statistics

Country	Statistics	Estimate	*t*-statistics	*p*-value
South Africa	Skewness	-0.078	1.623	0.105
	Excessurtosis	2.952	30.640	0.000
	Jarque-Bera	939.65	--	<0.001
Nigeria	Skewness	0.074	1.579	0.114
	Excess Kurtosis	196.580	2088.900	<0.001
	Jarque-Bera	4355300.000	--	<0.001

Table A3. Box-Pierce statistics for raw and squared data
– results of the goodness-of fit tests after the estimation of spline-GARCH models

Type of test		Box-Pierce statistics for raw data		Box-Pierce statistics for squared data	
Country	**Lag number**	Statistics	p-value	Statistics	p-value
South Africa	**Q(5)**	24.0243	<0.001	910.131	<0.001
	Q(10)	26.8586	0.003	1840.11	<0.001
	Q(20)	41.3129	0.003	3069.41	<0.001
	Q(50)	109.561	<0.001	5239.6	<0.001
Nigeria	**Q(5)**	27.1437	<0.001	663.997	<0.001
	Q(10)	31.1078	0.001	664.014	<0.001
	Q(20)	50.9425	<0.001	664.696	<0.001
	Q(50)	94.6366	<0.001	665.145	<0.001

A3. Data used in the study

Table A4. Data used in the study

Series name	Source	Frequency	Time span
JSE40 (FTSE/JSE Top 40 index)	Johannesburg Stock Exchange (via CEIC database)	daily	02.01.2002-29.12.2016
Nigerian All Share Index (NGSEINDX)	Nigerian Stock Exchange (via CEIC database)	daily	22.04.2002-29.12.2016
GDP per capita growth (annual %)	World Bank national accounts data, and OECD National Accounts data files	annual	South Africa: 2002-2015 Nigeria: 2005-2015
GDP (current US$)	World Bank national accounts data, and OECD National Accounts data files	annual	South Africa: 2002-2015 Nigeria: 2005-2015
Stocks traded, total value (% of GDP)	World Federation of Exchanges database	annual	South Africa: 2002-2015 Nigeria: 2005-2015
Stocks traded, turnover ratio of domestic shares (%)	World Federation of Exchanges database	annual	South Africa: 2002-2015 Nigeria: 2005-2015
Real interest rate (%)	International Monetary Fund, International Financial Statistics and data files using World Bank data on the GDP deflator	annual	South Africa: 2002-2015 Nigeria: 2005-2015
Brent oil future price	Stooq.pl	Daily/quarterly	2002-2015
Gold future price	Stooq.pl	Daily/quarterly	2002-2015
Hang-Seng	Stooq.pl	Daily/quarterly	2002-2015
S&P500	Stooq.pl	Daily/quarterly	2002-2015
FTSE500	Stooq.pl	Daily/quarterly	2002-2015
CAC40	Stooq.pl	Daily/quarterly	2002-2015