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CRISIS PERIODS, CONTAGION AND INTEGRATION EFFECTS IN THE MAJOR AFRICAN EQUITY MARKETS DURING THE 2007-2009 GLOBAL FINANCIAL CRISIS[1]

Summary

A number of studies assert that during critical events cross-market correlations change substantially. The main focus of this paper is to explicitly test two research hypotheses concerning the effect of increasing cross-market correlations in the 2007-2009 Global Financial Crisis (GFC) compared to the pre-crisis period. These hypotheses state that there was no contagion and no integration effects among the U.S., the U.K., and selected African stock markets (South Africa, Namibia, Egypt, Nigeria, Morocco and Kenya) during the GFC. The crisis periods are formally detected using a statistical method of dividing market states into bullish and bearish markets. The sample period begins in January 2003 and ends in December 2013, and it includes the 2007 U.S. subprime crisis. Obtained results indicate that there is no reason to reject both research hypotheses. Moreover, the results confirm a heterogeneity of the African equity markets in the context of the influence of the recent global crisis.

Key words: stock market, crisis, cross-market correlations, contagion, integration

JEL: C10, F36, F65, G01, G15, O55

1. Introduction

The aftermath of the 2007-2009 Global Financial Crisis (GFC) in the context of its influence on both developed and emerging markets in the world is currently one of the

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most active research areas. Most of the researchers stress that the crisis originated in developed countries, largely in the U.S. and the U.K. The crisis transmission through financial and especially banking channels has been very rapid and substantial. It has been amply recognized in the literature that the recent financial crisis timeline, from the U.S. perspective, was marked by the following events: (1) the increase in subprime delinquency rates in the spring of 2007, (2) the liquidity crunch in late 2007, (3) the liquidation of Bear Stearns in March 2008, and (4) the failure of Lehman Brothers in September 2008, e.g. [Brunnermeier, 2009; Bartram, Bodnar, 2009]. Claessens et al. [2010] pointed out that almost all advanced countries and most major emerging markets experienced high levels of financial stress and reduced economic activity. They found that not all economies suffered from the crisis at the same time or to the same extent. The authors recognized five groups of countries in the world based on the date they were affected by the crisis. The U.S. economy entered recession in 2008Q1, while the U.K., France and Germany entered recession in 2008Q2. In Africa, Morocco entered recession in 2008Q3 and South Africa in 2008Q4, as did most of the emerging market economies. Strict exchange control regulations in countries in Africa made direct investment and trade in toxic asset very difficult, if not impossible, and provided a buffer against the initial effects of the GFC.

The GFC sparked interest in the impact of financial contagion caused by the financial crisis. Market integration resulting from the globalization of investments is a further contributing factor to the global impact of the GFC. It is important to distinguish between the concepts of financial contagion and market integration. According to Bekaert et al. [2005] and Brière et al. [2012] both, financial contagion and market integration, have a tendency to increase cross-market correlations among markets, especially during periods of high volatility coupled with down markets. In the research, we select the following countries classified in the literature as African markets: South Africa, Namibia, Egypt, Nigeria, Morocco, and Kenya[2].

The contribution of this paper is twofold. Firstly, a formal statistical identification of crisis periods in the group of the selected African stock markets in the context of the GFC is provided by applying the Pagan and Sossounov [2003] method of dividing market states into up and down markets. The sample period begins in January 2003, and ends in December 2013. We propose October 2007 – February 2009 (17 months) as the period of the recent GFC and May 2006 – September 2007 (17 months) as the pre-crisis period, for the U.S., the U.K., and the selected African countries.

Secondly, two research hypotheses concerning the increasing cross-market correlations during the GFC for the group of markets including the U.S., the U.K. and the six selected African stock markets are explicitly tested. The first research hypothesis states that there was no contagion among the U.S., the U.K., and the six selected African equity markets during the GFC. We examine the effect of increasing cross-market correlations in the crisis period compared to the pre–crisis period in the context of

[2] Although the Tunisian market is one of the major African equity markets, the Tunis Stock Exchange was not taking into consideration. It was closed in the periods: January 17-30, 2011 and February 28 – March 4, 2011, because of the Tunisian Revolution, also known as the Jasmine Revolution. The events in Tunisia began on December 18, 2010.

contagion, applying both a standard contemporaneous cross-market correlations and volatility-adjusted correlation coefficients proposed by Forbes and Rigobon [2002]. The similar approach was employed by Collins and Biekpe [2003b], but they measured contagion among African markets during the 1997 Asian crisis. The second hypothesis says that there was no integration effect between the six African stock markets and the equity markets of the U.S. and U.K., during the GFC. To explore this problem we employ both the Jennrich [1970] and Larntz-Perlman [1985] procedures for testing equality of correlation matrices computed over non-overlapping subsamples: the pre-crisis and crisis periods. The results do not confirm stock markets contagion and integration effects during the GFC.

The remainder of this study is organized as follows. Section 2 presents a literature review concerning the African markets included in the study, also in the context of the influence of the GFC on these markets. Section 3 specifies a methodological background of the statistical method of a formal identification of crisis periods. In Section 4, we propose a brief analysis of the evidence of increasing cross-market correlations in bear markets, in the context of contagion. Section 5 presents the issue of integration. Section 6 reports data description and empirical results in indexes in the investigated stock markets. Section 7 recalls the main findings and presents the conclusions.

2. Short overview of the African equity markets included in the study

It is pertinent to note that in a relatively short time, several African countries have developed equity markets. With only eight active markets in 1980, the number of African stock markets increased to eighteen by the end of 2002, and is currently twenty six [Ntim et al., 2011]. Smith et al. [2002] classified the African stock markets into four groups:

1. South Africa – the largest and the oldest stock market in Africa;
2. A group of medium-size markets, consisting of Egypt, Kenya, Nigeria, Morocco, Tunisia, and Zimbabwe;
3. A group of small, but rapidly growing markets, including Namibia[3] among others;
4. A group of the rest very small stock markets.

As Jefferis and Smith [2005] emphasized, although most African stock markets are relatively small, many have grown rapidly in recent years. The authors appointed a number of factors which have contributed to the expansion and growth of African stock markets. They mentioned e.g. economic reform programmes that have involved a reduction in the role of the state in the economy and a strengthening of the role of the private sector. This process has been accompanied by increased attention from international investors.

The study by Enisan and Olufisayo [2009] was carried out for seven Sub-Sahara African countries. The authors examined the long run and causal relationship between market development and economic growth. They found that stock market development

[3] According to the http://www.african-exchanges.org (access 25.04.2016), the Market Capitalization of the Namibian Stock Exchange in 2012 was quite high, but it included Blue-chips from South Africa [Ntim et al., 2011].

had a significant positive long run impact on economic growth, and they argued that stock markets could help promote growth in Africa.

Kodongo and Ojah [2012] examined the nexus between real foreign exchange rates and international portfolio flows for the African region, represented by Egypt and Morocco (Northern Africa) and Nigeria and South Africa (Sub-Saharan Africa). The results suggested that international portfolio flows to African countries are characterized by high volatility and persistence. Against a background of the other markets, the South African capital market is more likely to command greater awareness of foreign investors as it exhibits the highest level of sophistication.

Asongu [2013] investigated the issue of convergence in financial performance dynamics in the African continent premised on homogenous panels based on regions, income levels, legal origins and religious dominations. The empirical results confirmed that African financial markets have very heterogeneous fundamental, institutional and structural characteristics of development. Moreover, an economic instability and a political unrest have plagued many African countries, and still continue to thwart foreign investments.

The equity market in South Africa is an exception among the African market, as it was becoming increasingly integrated with global markets in the late 1990s. As Collins and Biekpe [2003a] emphasized, most African markets, excluding South Africa, are relatively small compared to other emerging markets, with lower volume and fewer listed companies. The authors pointed out that since 1994, South Africa, upon its inclusion in the IFCI index[4], has carried a very heavy weight in portfolios of emerging market fund managers, who mostly benchmark to the IFCI index. Piesse and Hearn [2005] stressed that, in most cases, African markets are still very small and inactive. The exception to this is South Africa, which has a highly successful financial market and a stock exchange that is linked with world capital markets. Heymans and da Camara [2013] indicated that the U.S. and the U.K. consistently remain by value within the top three rankings of South Africa's main trading partners. Moreover, it is important that 20 percent of the top 40 companies listed on the Johannesburg Securities Exchange are also listed and actively traded on international equity markets. Collins and Abrahamson [2004] investigated global versus regional integration in African equity markets. In order to measure regional integration, they used South African sector indexes as the benchmark foreign series in the regional measure. They emphasized that the South African stock market is the largest market in Africa, and is therefore likely to have the greatest impact on regional markets. Among others, Leung et al. [2014] confirmed that financial and economic crisis of 2008 and 2009 took a heavy toll on the South African economy which officially entered recession during the fourth quarter of 2008. Recession was identified by negative real GDP growth rate after three consecutive negative quarters.

The stock market in Namibia is of a special interest as it has grown significantly since the establishment in 1992. Although a large part of the growth in market capitalization is accounted for by large foreign companies (mainly from South Africa) that are dual listed on the Namibian Stock Exchange (NSX) and the Johannesburg Stock Exchange (JSE),

[4] IFCI – International Finance Corporation Investable index.

a significant development has been observed in the NSX over the last years [Eita, 2012]. Since its independence from South Africa, Namibia has maintained strong and growing economic ties to its 'big neighbor'. Much of Namibia's success is attributed to the fixed exchange rate regime, as the Namibian dollar is fixed at par value to the South African Rand. On the other hand, the fixed exchange regime automatically implies that South African macroeconomic shocks are quickly transmitted to Namibia [Neidhardt, 2009].

The Egyptian Stock Exchange (EGX) is a prime example of a long-established market that has received a lot of investor attention over the last years [Billmeier, Massa, 2008]. Recent changes include revised listing requirements and exchange membership rules, as well as the introduction of new systems for information, dissemination, settlement of transactions and automated trading [Jefferis, Smith, 2005]. Many of the giant Egyptian corporations are listed in foreign markets. During the GFC, the Bourse in Egypt suffered from a flight of capital to safer havens. The tourism sector was also adversely affected and revenue generated from the Suez Canal declined.

The Nigerian Stock Exchange (NSE) was, until the early 1990s, primarily a forum for trading government bonds rather than equities, and trade was highly regulated. An automated trading system was introduced in 1999. Turnover and liquidity have increased significantly, although both remain relatively low [Jefferis, Smith, 2005]. The recapitalization of the Nigerian banking industry in 2004 and the banks' entrance to the stock market have significantly increased the market capitalization in the NSE. During the GFC, the Nigerian financial market was substantially affected and the main NSE index achieved the global minimum on January 2009.

Like Egypt, Morocco has a relatively old stock exchange, established in 1929, although it has been inactive for a long period. The exchange has been transformed by developments during the 1990s, with an extensive series of reforms [Jefferis, Smith, 2005]. The successful reforms of the financial sector focused on the liberalization of interest rates, changes in monetary policy, a decrease in the government access to credit, major regulatory changes of the banking sector, and fundamental changes in the operations of the stock market [Ghysels, Cherkaoui, 2003]. There is a strong link between the Moroccan market and the European markets, and with the French market in particular. Therefore, the Casablanca Stock Exchange (CSE) was substantially affected by the GFC and it dropped by 13 percent in 2008Q3.

The Nairobi Stock Exchange (NSE) was established in 1954. The Kenyan market has denoted an upsurge in activity since 1993 due to economic reforms, privatization, and relaxation of restrictions on foreign investors and of exchange controls. However, implementation of the economic reform programme has been inconsistent and political problems remain [Jefferis, Smith, 2005]. On the other hand, an implementation of live trading on the automated trading system at the NSE in 2006 caused great improvement in market surveillance and liquidity. The Nairobi Stock Exchange was the top ranked equity market in Africa in 2010Q1 [Aduda et al., 2012]. It was believed that the effect on the Kenyan stock market by the GFC would be relatively small as most economies in Africa are marginal recipients of portfolio flows. However, during the crisis period, there was a sharp spike in the inflation rate. Contributing factors to this rise are the 2008 drought and the post 2008 election crisis.

An important strand of the literature explores the GFC influence on stock markets in a worldwide framework. As this research concentrates on the African equity markets, we focus on a brief review of previous studies related mostly to the emerging economies including the selected African countries. Calomiris et al. [2012] considered three 'crisis shocks' related to the key features of the GFC for the emerging and developed economies: the collapse of global trade, the contraction of credit supply, and selling pressure on firm's equity. They investigated two African equity markets in Egypt and South Africa among others emerging economies. Didier et al. [2012] examined the determinants of comovement between the U.S. stock market returns and local stock market returns across 83 countries during the GFC. Their analysis distinguished between the period before and after the collapse of Lehman Brothers on September 15, 2008. They explored the nine African markets (i.e. Nigeria, Kenya, Namibia, Botswana, Egypt, South Africa, Mauritius, Morocco, and Tunisia) in the group of the emerging international equity markets. They found that only countries with high ratios of equity holdings by U.S. investors exhibited greater comovement during the GFC. Lane and Milesi-Ferretti [2011] engaged in the geographical impact of the recent crisis. They prepared rankings of region-based groups of countries among the most and least affected by the crisis, according to various criteria. Several African markets, i.e. Namibia, Togo, Angola, Zimbabwe, Cent. Afr. Rep., Eritrea, Guinea, entered the groups of the "Top 5" crisis countries in the world. Rose and Spiegel [2012] focused on national causes and consequences of the recent global financial crisis in the case of 107 countries, ignoring cross-country relationships and contagion effects. They analysed several selected African markets, but only South Africa and Namibia were shortlisted among others the "Top 40" crisis countries in the world. Lagoarde-Segot and Lucey [2009] investigated a shift-contagion vulnerability in the Middle East and North Africa (MENA) stock markets during major crises including e.g. the 1997-98 Asian crisis, the 1998 Russian and Brazilian financial turmoil periods, the 2001 Turkish crisis, the 2001 WTC terrorist attacks, the 2002 Argentinean crisis, and the GFC. Their results confirmed heterogeneous and increasing levels of financial vulnerability in the MENA stock markets. Neaime (2012) analysed the seven MENA major equity markets indexes in the period January 2007 – December 2010 including the 2007 U.S. subprime crisis. He asserted that in the aftermath of the GFC, the MENA countries (i.e. Egypt, Jordan, Morocco, Tunisia, Kuwait, Saudi Arabia, and the UAE) experienced significant financial and economic slowdowns. Allen and Giovannetti (2011) presented the effects of the GFC on Sub-Saharan Africa (SSA). They investigated the channels through which the economic and financial crisis was transmitted to SSA, with a special focus on counties in situation of fragility. The countries belonging to the operational definition of fragile countries are Kenya and Nigeria, among others. The authors stressed that during the period of growth prior to the GFC, Sub-Saharan Africa had become more integrated with the rest world. This increasing international integration has exposed the SSA economies much more to disruption in trade and to other shocks. Most of the SSA countries have almost consecutively suffered fuel, food and financial shocks.

3. Statistical procedure for formal identification of crisis periods

There exists a vast empirical literature on the interdependences of financial markets during the GFC, but there is no unanimity among researchers about the crisis periods in various countries. In a study such as this one, it is crucial to determine the pre-crisis and crisis periods. In the literature these periods are usually presented arbitrarily. Therefore, the important contribution of this paper is a formal statistical identification of the crisis periods in the group of the selected African stock markets in the context of the GFC.

The literature has shown that a direct identification of crisis periods is possible based on statistical procedures for dividing market states into up and down markets. For example, Lunde and Timmermann [2000] proposed an algorithm for detecting bull and bear states, however, they stressed that there is no generally accepted formal definition of up and down markets in finance literature. Pagan and Sossounov [2003] developed an algorithm that seemed to be useful in locating periods in time that were considered bull and bear markets in the U.S. equity prices. They tested monthly data of the S&P500 index, in the period from January 1835 to May 1997. Lee et al. [2011] proposed a modified version of the Pagan-Sossounov method of dividing market states into bullish, bearish, and range-bound markets. We employ a three-stage procedure of dividing market states into up and down markets, presented in the paper [Olbrys, Majewska, 2014]. The methodology builds on Pagan and Sossounov [2003]. In the first step, we conduct a preliminary identification of turning points, i.e., peaks and troughs, based on the conditions (1)-(2), respectively:

$$\ln P_{t-8},\ldots,\ln P_{t-1} < \ln P_t > \ln P_{t+1},\ldots,\ln P_{t+8}, \tag{1}$$

$$\ln P_{t-8},\ldots,\ln P_{t-1} > \ln P_t < \ln P_{t+1},\ldots,\ln P_{t+8}, \tag{2}$$

where P_t represents the market index of month t, and from successive peaks/troughs we choose the highest/deepest one. Pagan and Sossounov [2003] stressed that in the cycle literature an algorithm for describing turning points in time series was developed by Bry and Boschan [1971], but they modified this algorithm by taking the eight months window (instead of six) in marking the initial location of turning points. In the second step, we rule out the phases (peak-trough or trough-peak) that last for less than four months, and cycles (peak-trough-peak or trough-peak-trough) that last for less than sixteen months. Pagan and Sossounov [2003] pointed out that in cycle dating the minimal cycle length is fifteen months, hence sixteen months were chosen to create a symmetric window of eight periods. Moreover, they advocated four months as the minimal length of a phase. In the last step we calculate the amplitudes A for each phase (amplitude is the difference in the natural logs of the index value in subsequent turning points). During the bull/bear market period there must be a large enough (of at least 20%) rise/fall in the index value. This means that the amplitude of a given phase must fulfill the condition $A \geq 0.18$ or $A \leq -0.22$ for the bull or bear market period, respectively.

4. Testing for contagion effect

There is no unanimity in research regarding the causes of increasing cross-market correlations in crisis periods, but the majority of researchers agree that during critical market events correlations change meaningfully. This effect is often justified by the authors as a consequence of contagion. Edwards [2000] stressed that contagion has been defined in the literature in many different ways, including as any transmission of shocks across countries. He distinguished between three mechanisms through which economic shocks are propagated across countries: (1) global disturbances that affect all (or most) countries in the world; (2) shocks coming from a related country, and (3) all instances not covered by the two previous cases, in which contagion is defined as a residual, and thus as a situation where the extent and magnitude of the international transmission of shocks exceeds what was expected by market participants. For more details see [Edwards, 2000] and the references therein. Pericoli and Sbracia [2003] presented five definitions of contagion adopted by the literature and the corresponding measures used in empirical work. However, they found that early studies did not always distinguish between contagion and interdependence. The authors stressed that definitions and measures of contagion work well in the presence of an unambiguous identification of financial crisis. Bekaert et al. [2005] defined contagion as excess correlation, that is, correlation over and above what one would expect from economic fundamentals.

They engaged contagion from an asset pricing perspective and they expressed it by correlation of the factor model residuals. Dungey et al. [2005] asserted that a range of different methodologies of testing for the existence of contagion make it difficult to assess the evidence for and against contagion. Rigobon [2002] emphasized that "(…) there is no accordance on what contagion means".

In their broadly cited paper, Forbes and Rigobon [2002] defined contagion as a significant increase in cross-market linkages after a shock to one country (or group of countries), but they stated that this definition is not universally accepted. They stressed that heteroskedasticity in market returns biases tests for contagion based on correlation and correlation coefficients are conditional on market volatility. Therefore they proposed the following correction for the volatility bias:

$$\hat{\rho}_{VA} = \frac{\hat{\rho}_C}{\sqrt{1+\delta\left[1-\left(\hat{\rho}_C\right)^2\right]}}, \tag{3}$$

where $\hat{\rho}_{VA}$ is the volatility-adjusted cross-correlation coefficient between markets, $\hat{\rho}_C$ is the estimated conditional cross-correlation coefficient in the crisis period, and δ is the relative increase in the variance of market returns in the crisis period compared to the pre-crisis period:

$$\delta = \frac{\hat{\sigma}_C^2}{\hat{\sigma}_{PC}^2} - 1, \tag{4}$$

where $\hat{\sigma}_C^2$, $\hat{\sigma}_{PC}^2$ are the variances in the high-volatility (crisis) and low-volatility (pre-crisis) periods, respectively. By construction, it is obvious that $\hat{\rho}_{VA} \leq \hat{\rho}_C$, i.e. during the periods

of high volatility the unconditional volatility-adjusted cross-correlation $\hat{\rho}_{VA}$ will be smaller than the estimated conditional cross-correlation $\hat{\rho}_C$ between markets. The evaluation of contagion is carried out by testing the hypotheses:

$$\begin{aligned} H_0 &: \rho_{VA} = \rho_{PC} \\ H_1 &: \rho_{VA} \neq \rho_{PC} \end{aligned}, \tag{5}$$

where ρ_{PC} is the cross-correlation coefficient in the pre-crisis period and the null hypothesis states that there is no contagion. The *Z*-statistic, which is asymptotically a standard normal random variable, tests null of no contagion, that is, the equality of the crisis with pre-crisis cross-market correlation coefficients. The test is performed with the Fisher [1921] z-transformation of sample correlation coefficients. If the absolute value of the *Z*-statistic is greater than the critical value, the null hypothesis of identical correlation coefficients can be rejected.

5. Testing for integration effect

It is well known fact that over the last thirty years, developed and emerging economies have been undergoing a large globalization process. Most countries have become increasingly integrated, both in terms of real and financial transactions. However, Beine et al. [2010] emphasized that globalization reflected by trade and financial integration is likely to have a bright and a dark side for investors, mainly in the context of diversification. The bright side of integration is the opportunity to diversify portfolios worldwide. On the other hand, the globalization can exhibit a dark side for international investors, as it can increase the degree of comovement on the left hand side of the return distribution during periods of financial downturn, exactly when the positive effects of diversification are most needed.

According to the literature, the evidence is that contagion can be confused with market integration since both have a tendency to increase correlations among markets, especially during bear market periods. Growing international integration could lead to a progressive increase in market correlations, and markets could be more correlated in periods of high volatility [Longin, Solnik, 1995]. Some researchers pointed out that integration can be global or regional, e.g. [Collins, Abrahamson, 2004; Bekaert et al., 2005]. As the aim of this paper is to test for integration effects in the selected African equity markets, we employ tests interpreted as integration tests. We use formal procedures for testing the equality of correlation matrices computed over non-overlapping subsamples, e.g. [Jennrich, 1970; Larntz, Perlman, 1985; Longin, Solnik, 1995; Chesnay, Jondeau, 2001; Goetzmann et al., 2005; Brière et al., 2012; Olbrys, Majewska, 2014]. The evaluation of integration is carried out by testing the hypotheses:

$$\begin{aligned} H_0 &: P_C = P_{PC} \\ H_1 &: P_C \neq P_{PC} \end{aligned}, \tag{6}$$

where P_C, P_{PC} are true (population) correlation matrices in the crisis and pre-crisis periods, respectively, and the null hypothesis states that there is no integration effect during crises. Different test statistics have been proposed in the literature to test the problem (6). One of the most popular is the test introduced by Jennrich [1970]. Let $\hat{P}_C = \left(\hat{\rho}_{ij}^{C}\right)$ and $\hat{P}_{PC} = \left(\hat{\rho}_{ij}^{PC}\right)$ be sample correlation matrices in the crisis and pre-crisis periods of sample size n_C and n_{PC}, respectively. The average correlation matrix is equal to $\hat{P} = \dfrac{1}{n_C + n_{PC}}\left(n_C \hat{P}_C + n_{PC} \hat{P}_{PC}\right)$, $\hat{P} = \left(\hat{\rho}_{ij}\right)$, and $\hat{P}^{-1} = \left(\hat{\rho}^{ij}\right)$. As we investigate dependencies in two subsamples of equal size $n_C = n_{PC} = n$, we employ the following version of the Jennrich [1970] test statistic T_J:

$$T_J = \frac{1}{2} tr\left(Z^2\right) - diag(Z)' \cdot S^{-1} \cdot diag(Z), \tag{7}$$

where Z is a square matrix given by the following equation:

$$Z = \sqrt{\frac{n}{2}} \cdot \hat{P}^{-1} \cdot \left(\hat{P}_C - \hat{P}_{PC}\right), \tag{8}$$

and matrix $S = \left(\delta_{ij} + \hat{\rho}_{ij} \cdot \hat{\rho}^{ij}\right)$, where δ_{ij} is the Kronecker delta. In Eq. (7), *diag(Z)* denotes the diagonal of the matrix Z (8) in a column form. The Jennrich test statistic T_J has an asymptotic $\chi^2\left(p(p-1)/2\right)$ distribution if the correlation matrix is computed for p variables. If the value of the T_J statistic (7) is greater than the critical value, the null hypothesis of identical correlation matrices can be rejected.

Although the Jennrich [1970] test statistic (7) is quite popular in the literature, Larntz and Perlman [1985] pointed out that this test is basically a large sample test and can perform poorly for small samples. They proposed a test statistic T_{LP} which determined a test with reasonable small sample properties and with power comparable to that of Jennrich test (7) for large samples. The basic idea is to apply the Fisher [1921] z-transformation to each sample correlation coefficient in the correlation matrices $\hat{P}_C = \left(\hat{\rho}_{ij}^{C}\right)$ and $\hat{P}_{PC} = \left(\hat{\rho}_{ij}^{PC}\right)$, and to consider the $\dfrac{p(p-1)}{2}$-dimensional random column vectors consisting of the off-diagonal z-transformations $(1 \le i < j \le p)$ arranged in lexicographic order. In the case of two subsamples of equal size $n_C = n_{PC} = n$, we use the following version of the Larntz-Perlman test statistic T_{LP}:

$$T_{LP} = \sqrt{\frac{n-3}{2}} \cdot \max_{1 \le i \le j \le p} \left| z_{ij}^{C} - z_{ij}^{PC} \right|, \tag{9}$$

where z_{ij}^{C} and z_{ij}^{PC} are the Fisher z-transformations of sample correlation coefficients $\hat{\rho}_{ij}^{C}$ and $\hat{\rho}_{ij}^{PC}$, respectively. Larntz and Perlman propose the significance level α test under which the null (6) is rejected if $T_{LP} > b_\alpha$, where $b_\alpha > 0$ is chosen such that

$(\Phi(b_\alpha)-\Phi(-b_\alpha))^{p(p-1)/2}=1-\alpha$, and Φ is the cumulative distribution function of the standard normal distribution.

Based on the cases studied, Larntz and Perlman propose the following rule-of-thumb: when the ratio of sample size to dimension does not exceed 4, i.e. when $(n/p)\le 4$, then the T_{LP} test statistic (9) is recommended. As the sample size $n\to\infty$, both the Jennrich and the Larntz-Perlman tests are asymptotically consistent.

6. Data description and empirical results in the U.S., the U.K., and the major African stock markets

The data consists of monthly and weekly logarithmic returns of the major African stock market indexes, the New York market index-S&P500, and the London market index-FTSE100, in the period beginning January 2003 and ending December 2013.

6.1. Preliminary statistics

Table 1. presents a brief information about the equity market indexes analysed in the study, in order of decreasing value of market capitalization at the end of 2012.

TABLE 1.

The stock market indexes used in the study

	Market	Market Cap., USD billion, Dec 2012	Index
1	New York Stock Exchange (United States)	14085.9	S&P500
2	London Stock Exchange (United Kingdom)	3396.5	FTSE100
3	Johannesburg Stock Exchange (South Africa)	998.3	FTSE/JSE ALL SHARE
4	Namibian Stock Exchange (Namibia)	159.9	NSX Overall
5	Egyptian Exchange (Egypt)	60.1	MSCI Egypt
6	Nigerian Stock Exchange (Nigeria)	57.8	NSE ALL SHARE
7	Casablanca Stock Exchange (Morocco)	52.8	MASI
8	Nairobi Securities Exchange (Kenya)	14.8	NSE 20

Source: http://www.african-exchanges.org; http://www.world-exchanges.org (access 25.04.2016)

Table 2. contains summarized statistics for the monthly logarithmic returns for the stock market indexes used in the study, as well as statistics testing for normality.

TABLE 2.

Summarized statistics for weekly logarithmic returns for the equity market indexes used in the study

	Index	Mean	Standard deviation	Skewness	Excess kurtosis	Doornik-Hansen test
U.S.	S&P500	0.001	0.024	-1.045 [0.000]	7.038 [0.000]	196.494 [0.000]
U.K.	FTSE100	0.001	0.024	-0.569 [0.000]	4.348 [0.000]	155.320 [0.000]
Africa	FTSE/JSE ALL SHARE	0.003	0.027	-0.089 [0.387]	1.937 [0.000]	61.151 [0.000]
	NSX Overall	0.002	0.034	-0.277 [0.007]	1.698 [0.000]	45.481 [0.000]
	MSCI Egypt	0.005	0.044	-0.785 [0.000]	3.292 [0.000]	78.355 [0.000]
	NSE ALL SHARE	0.002	0.032	-0.105 [0.304]	3.112 [0.000]	125.978 [0.000]
	MASI	0.002	0.022	-0.454 [0.000]	5.167 [0.000]	223.738 [0.000]
	NSE 20	0.002	0.031	1.149 [0.000]	11.339 [0.000]	402.767 [0.000]

Notes: The table is based on all sample observations during the period January 2003-December 2013. The indexes are in the same order as in Table 1. The test statistic for skewness and excess kurtosis is the conventional *t*-statistic. The Doornik-Hansen test [2008] has a χ^2 distribution if the null hypothesis of normality is true. The numbers in brackets are *p*- values.

Source: Authors' calculations (using *Gretl 1.9.14* software).

The empirical results presented in Table 2 are worth a comment. The measure for skewness shows that the return series are skewed, except for the FTSE/JSE ALL SHARE and NSE ALL SHARE series. The measure for excess kurtosis shows that the series are leptokurtic with respect to the normal distribution. The Doornik-Hansen [2008] test rejects normality for the return series at the 5 per cent level of significance.

6.2. Formal identification of crises for the U.S., the U.K., and the major African stock markets

As was stated in Section 3, we employ the three-stage procedure of dividing market states into bullish and bearish markets to identify crisis periods, based on monthly logarithmic returns of major stock market indexes. Figure 1 presents the crisis periods for the S&P500 and the FTSE100, while Figure 2 demonstrates the crisis periods for the six indexes on the African stock markets, obtained from the procedure. The empirical results are generated in the whole sample period from January 2003 to December 2013. The horizontal axis stands for time (months), and the vertical axis stands for the market index. The vertical lines and light grey areas stand for the crisis periods.

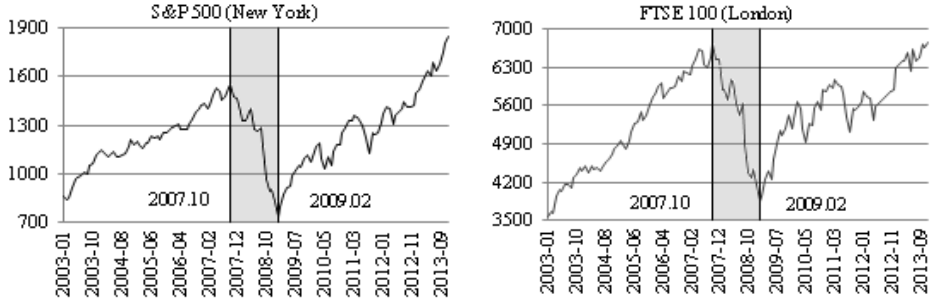
We obtained the following crisis periods for the investigated stock markets:

1. October 2007 – February 2009 (the U.S.),
2. October 2007 – February 2009 (the U.K.),
3. May 2008 – February 2009 (South Africa),
4. October 2007 – February 2009 (Namibia),
5. April 2008 – February 2009 (Egypt),
6. February 2008 – March 2009 (Nigeria),
7. March 2008 – January 2009 (Morocco),
8. January 2007 – February 2009 (Kenya).

As it is necessary to appoint one month as the beggining of the crisis period for all countries, we propose October 2007 (see Fig. 1). In light of the results, it seems that we can treat February 2009 as the end of the crisis. Finally, we advocate October 2007 – February 2009 as the period of the recent global financial crisis. According to the literature, for the African markets (except for Namibia and Kenya) we observe a pronounced delay of the crisis symptoms compared to the developed stock markets. This delay could be a result of the strict exchange control regulations in countries in Africa, which made direct investment and trade in toxic asset very difficult, if not impossible. Only on the Nairobi Securities Exchange, the crisis period was longer and it lasted from January 2007 to February 2009. A contributing factor to the latter could be ascribed to a decline in the inflow of portfolio capital to Africa, which resulted in Kenya (and Ghana) having to postpone sovereign bond issues worth $800 Million. In South Africa, the inflow of investment capital prior to the 2010 FIFA World Cup soccer event probably also contributed to the pronounced delay of the crisis symptoms compared to the developed stock markets. Another contributing factor of the delay is excellent risk management procedures that were in place at the Johannesburg Securities Exchange prior to the default of Lehman Brothers [Kotze, Labuschagne, 2014]. Finally, it is worthwhile to note that in the case of the Namibian stock market the crisis period was exactly the same as for the developed markets.

FIGURE 1.

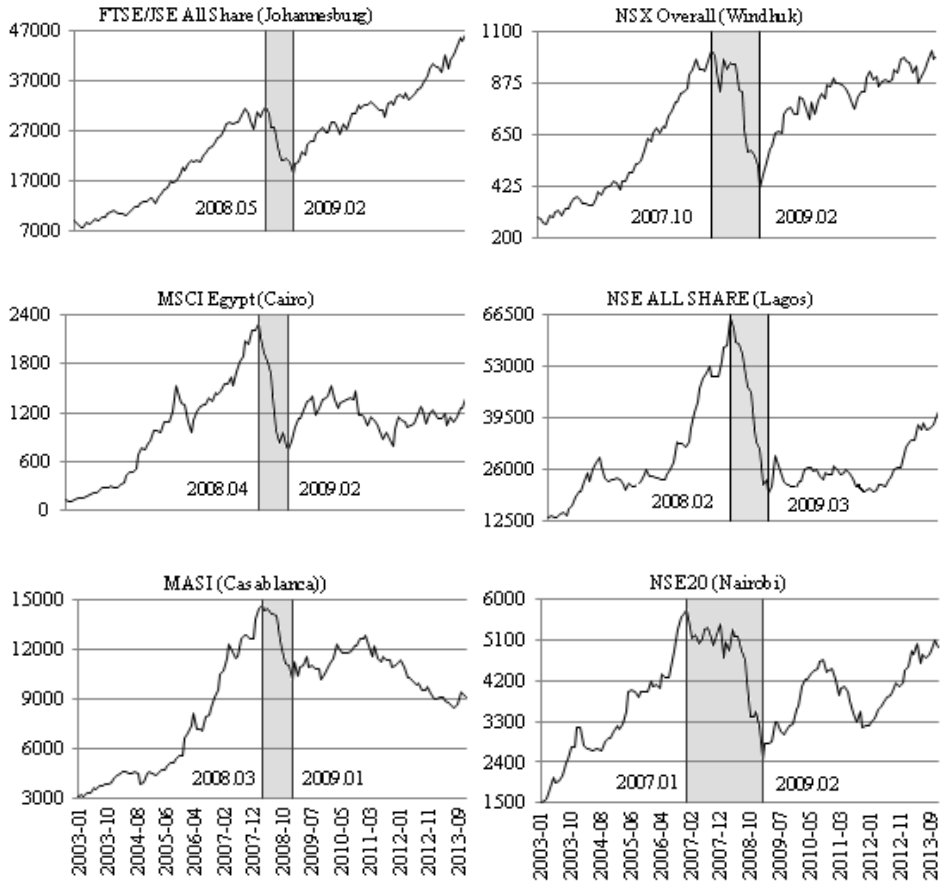
Crisis periods for the U.S., the U.K. stock markets, obtained from the procedure of dividing market states, in the whole sample January 2003 – December 2013



Source: Authors' calculations

FIGURE 2.

Crisis periods for the six African stock markets, obtained from the procedure of dividing market states, in the whole sample January 2003 – December 2013



Source: Authors' calculations.

6.3. Empirical results of contagion tests

This subsection presents the empirical results of the verification procedure of the first research hypothesis of no contagion among the U.S., the U.K., and the major African equity markets during the 2007-2009 financial crisis. Based on the Fig. 1, we observe October 2007 – February 2009 as the crisis period. The crisis period contains only seventeen months and this obliges us to use higher frequency data. Hence we use weekly Wednesday-to-Wednesday logarithmic returns, which are thought to iron out any

possible impact of the day-of-the-week effects of daily data[5]. Moreover, researchers use weekly returns to avoid the nonsynchronous trading effect II, which is felt when we examine various relationships among stock markets located in different time zones, e.g. [Olbrys, 2013] and references therein.

Table 3. contains standard contemporaneous cross-correlations and volatility-adjusted cross-correlation coefficients, given by Eq. (3), of weekly logarithmic returns on pairs of the indexes S&P500/African stock market index. For comparison, we calculate dependencies both in the whole sample (January 2003 – December 2013) and in two adjacent subsamples of equal size: (1) the pre-crisis period May 2006 – September 2007 (74 weekly returns), and (2) the crisis period October 2007 – February 2009 (74 weekly returns).

We investigate the cross-market linkages after a shock to the U.S. financial market. The supporting values are equal to: $\hat{\sigma}_C^2 = 0.00136$ (the variance in the high-volatility period in the U.S. stock market) and (the variance in the low-volatility period in the U.S. stock market), while the relative increase in the variance of the S&P500 returns, given by Eq. (4), is equal to $\delta = 4.272$.

TABLE 3.
Contemporaneous cross-correlations and volatility-adjusted cross-correlations of weekly logarithmic returns on pairs S&P500/African stock market index

Index	Contemporaneous cross-correlations			Volatility-adjusted cross-correlations						
	Whole sample (1)	Pre-crisis (2)	Crisis (3)	Crisis (3)						
	$\hat{\rho}$	$\hat{\rho}_{PC}$	$\hat{\rho}_C$	Change compared to the period (2)	Z-statistic	Contagion	$\hat{\rho}_{VA}$	Change compared to the period (2)	Z-statistic	Contagion
FTSE/JSE ALL SHARE	0.649 [0.000]	0.581 [0.000]	0.695 [0.000]	↑19.6%	1.202	H_0	0.388	↓33.2%	-1.581	H_0
NSX Overall	0.623 [0.000]	0.520 [0.000]	0.633 [0.000]	↑21.7%	1.056	H_0	0.335	↓35.5%	-1.412	H_0
MSCI Egypt	0.274 [0.000]	0.251 [0.031]	0.422 [0.000]	↑68.1%	1.203	H_0	0.199	↓20.8%	-0.342	H_0
NSE ALL Share	0.008 [0.841]	-0.016 [0.893]	-0.307 [0.008]	↑1818.7%	-1.871	H_0	-0.139	↑769.5%	-0.770	H_0
MASI	0.072 [0.084]	0.137 [0.245]	0.019 [0.871]	↓86.1%	-0.738	H_0	0.008	↓94.0%	-0.805	H_0
NSE 20	0.158 [0.000]	-0.035 [0.766]	0.274 [0.018]	↑682.9%	1.964	H_0	0.124	↑251.8%	0.986	H_0

Notes: The table is based on: (1) the whole sample period January 2003 – December 2013; (2) the pre-crisis period May 2006 – September 2007 (74 weekly returns); (3) the crisis period

[5] It is known in the literature that there are day-of-the-week effects reflected in the significantly positive Friday and negative Monday returns.

October 2007 – February 2009 (74 weekly returns). The returns are weekly Wednesday-to-Wednesday logarithmic returns. The indexes are in the same order as in Table 1. *P*-values are in brackets. Fisher *Z*-statistic [1921] tests null of no contagion. The Student's *t* critical value is 2.353 (at the 2% significance level).

Source: Authors' calculations (using *Gretl 1.9.14* software)

Likewise, we investigate the cross-market linkages after a shock to the U.K. financial market. The supporting values are equal to: (the variance in the high-volatility period in the U.K. stock market) and (the variance in the low-volatility period in the U.K. stock market), while the relative increase in the variance of the FTSE100 returns, given by Eq. (4), is equal to $\delta = 3.492$. Table 4 contains standard contemporaneous cross-correlations and volatility-adjusted cross-correlation coefficients, given by Eq. (3), of weekly logarithmic returns on pairs of the indexes FTSE100/African stock market index.

TABLE 4.
Contemporaneous cross-correlations and volatility-adjusted cross-correlations of weekly logarithmic returns on pairs FTSE100/African stock market index

Index	Contemporaneous cross-correlations			Volatility-adjusted cross-correlations						
	Whole sample (1)	Pre-crisis (2)	Crisis (3)	Crisis (3)						
	$\hat{\rho}$	$\hat{\rho}_{PC}$	$\hat{\rho}_{C}$	Change compared to the period (2)	Z-statistic	Contagion	$\hat{\rho}_{VA}$	Change compared to the period (2)	Z-statistic	Contagion
FTSE/JSE ALL SHARE	0.728 [0.000]	0.711 [0.000]	0.755 [0.000]	↑6.2%	0.592	H_0	0.477	↓32.9%	-2.296	H_0
NSX Overall	0.690 [0.000]	0.642 [0.000]	0.703 [0.000]	↑9.5%	0.693	H_0	0.423	↓34.2%	-1.929	H_0
MSCI Egypt	0.309 [0.000]	0.430 [0.000]	0.442 [0.000]	↑2.8%	0.092	H_0	0.226	↓47.3%	-1.425	H_0
NSE ALL Share	-0.008 [0.841]	0.071 [0.550]	-0.272 [0.019]	↑283.1%	-2.174	H_0	-0.132	↑86.2%	-1.267	H_0
MASI	0.070 [0.093]	0.168 [0.153]	0.042 [0.720]	↓75.0%	-0.792	H_0	0.020	↓88.2%	-0.930	H_0
NSE 20	0.120 [0.004]	-0.054 [0.647]	0.305 [0.008]	↑464.8%	2.292	H_0	0.149	↑176.7%	1.270	H_0

Notes: The table is based on: (1) the whole sample period January 2003 – December 2013; (2) the pre-crisis period May 2006 – September 2007 (74 weekly returns); (3) the crisis period October 2007 – February 2009 (74 weekly returns). The returns are weekly Wednesday-to-Wednesday logarithmic returns. The indexes are in the same order as in Table 1. *P*-values are in brackets. Fisher *Z*-statistic [1921] tests null of no contagion. The Student's *t* critical value is 2.353 (at the 2% significance level).

Source: Authors' calculations (using *Gretl 1.9.14* software)

The empirical results presented in Tables 3-4 indicate a heterogeneity of the African equity markets in the scope of changes in both contemporaneous and volatility-adjusted cross-correlations. Firstly, during the crisis period the estimated contemporaneous cross-correlations between the U.S. (the U.K.) and the African markets were greater than the corresponding cross-correlations in the pre-crisis period for five markets, except for Morocco. Secondly, the Forbes-Rigobon [2002] correction seems to be a rather strong tool for adjusting cross-market correlations for the African markets, except for Nigeria and Kenya. To wit, assuming the U.S. (the U.K.) financial market as a source of risk and using the coefficient δ of the relative increase in the variance of the S&P500 (FTSE100) returns in the crisis compared to the pre-crisis period, we get a substantial reduction of the value of correlation. As a result, the volatility-adjusted cross-correlations in the crisis period are lower comparing with the pre-crisis period for four African markets, except for Nigeria and Kenya. Apart from these facts, no reason to reject the null hypothesis (5) was found, both for the U.S. (Table 3.) and the U.K. (Table 4.) stock markets assumed as the sources of crisis.

Regarding the African markets, Ahmadu-Bello and Rodgers [2012] used similar methodology and they compared levels of contagion between the U.S. and developed markets (the high integration group of six markets), against levels of contagion between the U.S. and African markets (the low integration group). They investigated ten African markets in Botswana, Cote D'Ivoire, Egypt, Kenya, Mauritius, Morocco, Nigeria, Tunisia, South Africa, and Zambia. The authors concluded that in African markets rather herding behavior is the best explanation of the contagion effect during the recent crisis.

Moreover, our results are generally consistent with the Morales and Andreosso-O'Callaghan [2014] results. The authors analyzed contagion effects arising from the U.S. sub-prime market in a worldwide framework. They investigated five African markets in Egypt, Kenya, Morocco, Nigeria and South Africa among others and they did not find significant evidence supporting contagion effects derived from the U.S. stock market.

6.4. Empirical results of integration tests

The second research hypothesis states that there was no integration effect between the U.S., the U.K., and the major African equity markets during the GFC. To test the problem (6) we employ both the Jennrich (7) and Larntz-Perlman (9) tests of the equality of the correlation matrices over time. Longin and Solnik [1995] stressed that the covariance/ correlation matrix of international asset returns plays a special role in the finance literature, as knowledge about its behavior is crucial for the computation of trading portfolios. Our calculations are based on weekly Wednesday-to-Wednesday logarithmic returns of stock market indexes. Moreover, we test the equality of the correlation matrices in two subsamples of equal size, see e.g. [Chesnay, Jondeau 2001; Brière et al. 2012]. Likewise in subsection 6.3, we advocate two periods: (1) the pre-crisis period May 2006 – September 2007 (74 weekly returns) and (2) the crisis period October 2007 – February 2009 (74 weekly returns).

Table 5 summarizes the integration tests performed on the whole group containing the S&P500, the FTSE100, and the six African stock market indexes. The results based

on both the Jennrich and the Larntz-Perlman tests show that the differences in correlation between the two sub-periods are not significant. Therefore, we have no reason to reject the null hypothesis (6) which states that the correlation matrix is constant over two adjacent sub-periods: the pre-crisis and the crisis periods.

TABLE 5.

Results of the Jennrich and Larntz-Perlman integration tests

Test periods	Jennrich test					Larntz-Perlman test				
	Test statistic T_J	χ^2 critical value (2%)		χ^2 critical value (5%)		Test statistic T_{LP}	b_α critical value (2%)		b_α critical value (5%)	
May 2006 – Sept 2007 & Oct 2007 – Feb 2009	26.097	45.419	H_0	41.337	H_0	2.202	3.381	H_0	3.116	H_0

Notes: The table is based on: (1) the pre-crisis period May 2006 – September 2007 (74 weekly returns); (2) the crisis period October 2007 – February 2009 (74 weekly returns). The returns are weekly Wednesday-to-Wednesday logarithmic returns. The table contains the Jennrich test statistic, given by Eq. (7), as well as the Larntz-Perlman test statistic, given by Eq. (9). The statistics test the null of no integration. The number of variables $p=8$.

Source: Authors' calculations (using *Gretl 1.9.14* software)

It is pertinent to note, that our study of integration differs from the literature in several aspects. According to the selected research concerning the African markets, Collins and Abrahamson [2004] measured integration for African markets on a sector-by-sector basis. They found that the most integrated markets were in South Africa, Egypt and Morocco, which are also the oldest and largest markets in the continent. However, the autors did not investigate regional and global integration effects during the financial crises. Likewise, Piesse and Hearn [2005] found evidence for potential integration between financial markets in Sub-Saharan Africa, but they employed different methods and did not investigate integration effects in the context of the recent GFC. Therefore, our empirical results of integration tests are not comparable in general with those mentioned above.

7. Conclusion

The purpose of this paper was to test two research hypotheses that there was no contagion and no integration effects among the U.S., the U.K., and the selected African stock markets (in South Africa, Namibia, Egypt, Nigeria, Morocco and Kenya) during the GFC. To address this issue, we formally detected the crisis periods for all investigated markets. We employed the Pagan-Sossounov [2003] procedure of dividing market states into up and down markets based on monthly logarithmic returns of the major indexes. The sample period included the 2007 U.S. subprime crisis. We proposed two periods:

(1) the pre-crisis period May 2006 – September 2007 and (2) the crisis period October 2007 – February 2009.

The empirical results confirmed no reason to reject both hypotheses. Regarding the first hypothesis of no contagion, the results are consistent with the literature and indicate that heteroskedasticity in market returns biases tests for contagion based on correlation, e.g. [Collins, Biekpe, 2003b; Ahmadu-Bello, Rodgers, 2012] for African markets. As for the second hypothesis of no integration effect, the results revealed that the African markets in general, with the exception of South Africa, are rather weakly connected with global capital flows. As Brunnermeier [2009] asserted, the 2007 U.S. subprime crisis has been very close to a classical banking crisis and the crisis transmission through financial and banking channels has been especially crucial.

Due to the importance of the problem, a possible direction for further investigation would be to test the integration effect applying other methods, e.g. the tests based on the international asset pricing models [Bekaert et al. 2005].

The authors' participation in the preparation of the article

Prof. Coennrad Labuschagne - data base for African markets, overview of literature, linguistic preparation – 30%

Elżbieta Majewska, Ph.D. – development of concepts, assumptions and methods, carryting out calculations and econometric analyses – 35 %

Joanna Olbryś, Ph.D., D.Litt. - overview of literature, development of concepts, assumptions and methods, interpretation of econometric research results – 35%

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