Return and volatility spillovers to African equity markets and their determinants

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Abstract

The main goal of this study is to examine how international and regional shocks are transmitted to African equity markets using a network methodology introduced and developed by Diebold and Yilmaz (Econ J 119:158–171, 2009; Int J Forecast 23:57–66, 2012; J Econom 182:119–134, 2014) with daily data ranging from January 03, 2007 till September 19, 2019. The main finding is that international and regional market shocks have heterogeneous and time-varying effects on African equity markets, the magnitude of which is explained by the degree of financial exposure and share to the world trade. Bidirectional spillovers reveal that African markets are net receivers for both return and volatility spillovers. Moreover, volatility shocks on these markets spread more vigorously than return shocks to Africa. Episodes of high spillovers emerged during the 2008 global financial and the 2012 European debt crisis. Peaks also appear when structural economic reforms or measures increasing market efficiency intervene on African markets. New to previous works on financial market spillover, we assess spillover channels in Africa employing linear panel regressions. Empirical estimates show that trade and financial exposure do not significantly explain return and volatility spillovers in African equity market. Global factors such as oil and metal prices are the main channels through which foreign shocks spread to African stock markets.

Keywords Equity market · Forecast error variance · Spillover index · Linear panel · Trade exposure · Financial exposure

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1 Introduction

Many empirical studies have shown that financial activity is a significant determinant of economic growth [see for instance, Hassan et al. (2011), and Kar et al. (2011)]. The deepness, accessibility, and liquidity of capital markets are crucial factors for a sustainable development since they mobilize funds for public and private investments. However, economies often face intense competition for attracting funds. In making decisions, investors carefully consider the business environment including the macroeconomic and legal framework, and the political stability of the host country. Within this context, Africa appears to be the least attractive region in the world. Corruption, armed conflicts, and persistent economic imbalances are significant constraints. Moreover, the atrophy of their domestic markets makes them vulnerable to developments in international markets and the risk appetite of foreign investors. Nonetheless, there is evidence of growing interest among American and European investors in African capital markets because of the high returns that these markets offer.[1]

The international integration of African markets has become especially relevant over the last two decades. The arrival of new information and communication technologies has enhanced their liberalization, allowing more flexible investment decisions through automated trading systems. Previous researchers (e.g., Jeon and Chiang 1991; Blackman et al. 1994) have documented that those innovations increase market efficiency and reduce transaction costs. More specifically, improvements in communication technology have enhanced the connectedness between African markets and world markets. As a result, individual and institutional investors, portfolio managers, and market regulators in Africa cannot remain oblivious to international developments.

The empirical finance literature is replete with studies that show how foreign shocks propagate to domestic markets. Most of them, however, focus on major markets and emerging markets. The seminal work of Eun and Shim (1989) found that innovations in the US stock market move quickly to other markets while no single foreign market could significantly explain the US market dynamics. In the same vein, Hamao et al. (1990) reported inward volatility spillovers from New York and London to Tokyo and from New York to London. They did not, however, find significance in other directions. On the other hand, Lin et al. (1994) found a bidirectional relationship between unexpected daytime returns and overnight returns between Tokyo and New York.

One common strand of the above-cited studies is that they do not examine whether and the extent to which spillovers change over time. A number of empirical studies [see for instance, Forbes and Rigobon (2002), Ehrmann et al. (2005) and Corsetti et al. (2005)] have attempted to address this shortcoming by demonstrating that the transmission is more rapid and sizeable during crisis periods. In the BRICS markets,

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[1] As an example, the Ghana Stock Exchange (GSE) was one of the best performing markets in the world in 2014. The GSE Composite Index (GSE-CI) recorded a year to date gain of 78.81% while the GSE Financial Stock Index (GSE-FSI) posted a return of 71.81% (African Securities Exchanges Association Yearbook 2014).

Bekiros (2014), Jin and An (2016), and Syriopoulos et al. (2015) have all shown that spillovers greatly accelerated during the 2008 financial crisis. For the emerging markets of East Asia and Latin America, empirical estimates suggest that spillover effects and interdependencies increased significantly during financial crises [see for instance, Baig and Goldfajn (1998), Caporale et al. (2005), Liu et al. (2013), Cardona et al. (2017) and Gamba-Santamaria et al. 2017)].

The empirical literature on financial markets spillovers is not abundant in the African context. Moreover, no consensus currently exists in the literature on the exact nature of spillovers in Africa. Neaime (2005) has shown that Egypt and Morocco are integrated with the world stock markets. Giovannetti and Velucchi (2013) showed that South Africa and US shocks significantly affect other African stock markets. El Ghini and Saidi (2017) and Belcaid and El Ghini (2019) have documented significant inward spillover effects of foreign shocks in Morocco. More specifically, they found evidence of varying degrees of inward spillovers from four major markets (US, UK, France and Germany) to Morocco before and during the global financial crisis. By contrast, Graham (2013) have reported a modest degree of co-movement of stock returns between the S&P 500 and the Egyptian stock market. Employing the Diebold and Yilmaz's (2012) index, Sugimoto et al. (2014) have found that African markets were insulated from the 2008 global financial turmoil and the European debt crisis.

At the regional level, Darrat et al. (2000) showed that shocks emanating from Egypt significantly impact the Moroccan market. Giovannetti and Velucchi (2013) found that South Africa produced significant outward spillovers in African financial markets. Kuttu (2014) reported significant bidirectional spillovers between the Ghanaian and the Kenyan markets on the one hand, and between the Nigerian and the South African markets on the other hand. Moreover, Kuttu (2014) showed that the Nigerian market transmits volatility shocks to Ghana, Kenya, and South Africa. In contrast, Humavindu and Floros (2006) found that there is no evidence of spillover effects between Namibia and South Africa. Finally, Sugimoto et al. (2014), found that regional spillovers within Africa are smaller than international spillovers.

This paper fills an important gap in the literature by examining inward spillovers in African markets. To that end, we assess the contribution of foreign shocks in explaining return and volatility forecast error variance (FEV) of their equity markets. The methodology follows the static and dynamic spillover index approach proposed by Diebold and Yilmaz (2009, 2012, 2014) using daily data of stock indices from January 04, 2007 to September 19, 2019.

Although Sugimoto et al. (2014) have conducted a similar analysis for African markets, they focus mainly on the period covering the US financial crisis and the European sovereign debt crisis. This study extends and improves Sugimoto et al. (2014)'s work by examining more recent events which are germane to African markets. More specifically, we examine the impact of the collapse of oil prices, the 2015 Chinese crisis, BREXIT, and the trade war between the United States and China on spillover in African markets. Our study also contributes to the debate on financial markets' spillover in three additional significant ways. First, we investigate dynamic spillovers to West African markets (Nigeria and the *Bourse Régionale des Valeurs Mobilières*

(BRVM)[2]), Eastern African markets (Tanzania), and Botswana. It is worth noting that none of these markets was included in Sugimoto et al. (2014)'s sample. Second, we examine both return and volatility spillover effects to African markets using a spillover index. This is a novelty compared to Sugimoto et al. (2014) who only examined return spillovers. Finally, we examine the role of trade linkages, financial exposure, and global factors in driving inward spillovers in Africa using linear panel regressions (fixed effect and random effect model).

The remainder of the paper is organized as follows. Section 2 presents an overview of African stock markets by describing institutional settings and their liberalization processes. Section 3 describes the methodology, while Sect. 4 presents the data and some preliminary analyses. Empirical results are discussed in Sects. 5 and 6 presents a summary and some concluding remarks and implications for market practitioners.

2 Overview of African stock markets: institutional settings, liberalization and liquidity

African capital markets have registered an impressive development since the early 1990s. Prior to 1989, there were just five stock markets in sub-Saharan Africa and three in North Africa. As of April 2020, there were 29 exchanges in the continent representing 38 nations' capital markets, and most of them have transited from manual trading systems to automated trading.

The Egyptian and Moroccan stock exchanges are the largest in North Africa. However, in spite of their geographic proximity to Europe and the common language and culture with the oil rich Gulf economies, they have attracted relatively little private capital and have been viewed as rather marginal by foreign investors. All the North African stock markets are state-owned although the boards of directors are mainly composed of brokerage firms and regulatory authorities. There are no restrictions on foreign capital inflows, but in practice these are partially limited. Foreign investors, including those from Arab countries have little participation in North Africa markets (Liste et al. 2012). The taxation of capital gains depends on the residence of investors in Tunisia while non-domestic corporate investors are exempt from capital gains tax on listed securities in Egypt and Morocco. As a result, Tunisia is the North African market with the lowest participation of foreign investors (Table 1).

The West African stock exchanges are less controlled than North African markets. The Nigeria Stock exchange (NSE) is the most important stock market in the region. The government has abolished legislation preventing inflows of external capital to boost foreign investments. Nigerian companies can also take advantage to cross-border listings. Furthermore, the taxation of dividends, interest and capital gain is the same for foreign and local investors. As a result, 81% of the total value traded in the NSE was due to foreign investors in 2011 (Table 1), a far greater percentage compared to North African stock exchanges. The BRVM is a fully integrated regional stock exchange. Any company quoted on the BRVM is available for trading in the eight

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[2] BRVM is the regional stock market for all the eight member states in the West African Economic and Monetary Union (WAEMU), namely Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo.

Table 1 Investors in African stock markets. *Source*: African Securities Exchanges Association Yearbook 2014

Exchanges	% of the total value traded US $							
	Foreign investors				Local investors			
	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)
North Africa								
Bourse de Tunis	10	11.3	6.3	12.10	90	88.70	93.7	87.90
Casablanca stock exchange	–	11	11	35	–	89	89	64
Egyptian exchange	22	29	26.9	20.5	78	71	73.1	79.5
West Africa								
Ghana stock exchange	–	–	–	49.69	–	–	–	50.31
Nigeria stock exchange	49	81	56	51	51	19	44	49
Eastern Africa								
Dar es Salaam stock exchange	43	46	30	23	57	54	70	77
Nairobi securities exchange	–	52	49	47	–	48	51	53
Southern Africa								
Botswana stock exchange	–	–	–	33	–	–	–	67
Johannesburg stock exchange	15.63	14.35	15.35	16.22	84.37	85.65	84.65	83.78
Stock exchange of Mauritius ltd	21.16	38.87	26.64	29.36	78.24	61.13	73.36	70.64
Lusaka stock exchange	–	19	21	36	–	81	79	64
Zimbabwe stock exchange	23	36	41	50	77	64	59	50

member states in the WAEMU and can raise capital in any of the member countries since these countries have the same legal tender, business law, central bank, and are highly integrated. The Ghana stock exchange (GSE) is also an important market in the sub-region. It was incorporated in July 1989 with trading commencing in 1990.

With the exception of the Johannesburg stock exchange (JSE), most of the national exchanges in Southern and Eastern Africa are relatively new, operating since the late 1980s and 1990s. An informal share market emerged in Botswana in 1989, followed by the establishment of the Botswana Stock Exchange (BSE) in 1995. The Dar-es-Salaam stock exchange (DSE) and the Lusaka stock exchange (LSE) began trading in 1998 and 1994, respectively. The recent proliferation of stock exchanges tended to coincide with a new policy emphasis on privatization of large stakes in state-owned enterprises. These exchanges support capital market development through the introduction of financial instruments such as mutual funds and other collective investment vehicles. Since the early 1990s, exchange controls on inward portfolio investment were liberalized in several Eastern and Southern African countries. This development has stimulated cross-border listings and facilitated closer regional links among capital markets.

There is significant progress toward integration and cooperation among African countries. For instance, all Southern African Development Community (SADC)[3] exchanges have harmonized their listing requirements based on the principles of the Johannesburg stock exchange's listing requirements. However, national listing rules are not identical across the board since there exist some slight differences that account for domestic constraints. The installation of the JSE's electronic trading system[4] on the Namibia exchange in 1998 also marked a major step toward harmonized trading in the sub-region. The Namibia Stock Exchange also joined the JSE in adopting the London Stock Exchange's trading system technology, SETS (Stock Exchange Electronic Trading System), in May 2002. The Common Market for Eastern and Southern Africa (COMESA) also encourages cooperation among member states. For example, COMESA member states are urged to harmonize listing requirements in the hopes that this will lead to eventual full integration of COMESA capital markets. In the East African Community, the capital market regulatory authorities of Kenya, Tanzania, and Uganda signed a memorandum of understanding (MoU) in 1997. This MoU sets out cooperation goals for the three countries' securities markets and set up the East African Member States Securities Regulatory Authorities (EASRA) as the coordinating regulatory body for capital markets integration and cooperation.

Despite a series of institutional reforms that have gradually amplified their liberalization, most African equity markets are relatively illiquid (Table 2) with domestic shares trading less frequently relative to foreign shares. In fact, their market capitalization does not often exceed US $100 million. However, there are some notable exceptions such as Egypt, Morocco, Nigeria, and South Africa where market capitalization is relatively significant.[5] Furthermore, stock market capitalization as a share of

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[3] The 16 member states of SADC are Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia, and Zimbabwe.

[4] The Johannesburg Equities Trading (JET) system.

[5] As of 2018, market capitalization was US$42 billion in Egypt, US$61 billion in Morocco, US$31.5 billion in Nigeria, and US$865.3 billion in South Africa.

Table 2 Stock markets: market capitalization, direct liquidity, turnover and listing. *Source*: World Development Indicators, The World Bank

Countries	Market capitalization				Market liquidity		Turnover ratio		Listed domestic companies	
	$ millions		% of GDP		Value traded		Value traded		Number	
					% of GDP		% of market capitalization			
	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017
North Africa										
Egypt, Arab Rep.	84,277	46,546	38.5	19.8	17.0	6.1	44.2	30.7	227	252
Morocco	69,152	67,048	74.2	61.4	6.5	3.9	8.8	6.3	73	73
Tunisia	10,652	8923	24.2	22.2	4.2	–	17.2	–	56	81
Southern Africa										
South Africa	925,007	1,230,977	246.5	352.3	73.9	117.3	30.0	25.7	352	294
Mauritius	7753	9743	77.5	73.0	3.6	3.4	4.7	4.6	62	74
Zambia	3184	–	13.6	–	0.1	–	0.6	–	20	–
West Africa										
Nigeria	50,546	37,218	13.7	9.9	1.4	0.6	10.1	5.9	215	166
Major markets										
France	1,911,515	2,749,315	72.3	106.5	51.1	–	70.6	–	617	465
Germany	1,429,719	2,262,223	41.8	61.5	43.7	42.4	104.5	63.6	690	450
Japan	3,827,774	6,222,825	67.2	127.7	74.9	118.6	111.6	92.8	2281	3598
United Kingdom	1,868,153	–	64.6	–	131.6	–	146.4	–	2105	–

Table 2 continued

Countries	Market capitalization				Market liquidity		Turnover ratio		Listed domestic companies	
	$ millions		% of GDP		Value traded		Value traded		Number	
					% of GDP		% of market capitalization			
	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017
United States	17,283,452	32,120,703	115.5	165.7	240.7	205.2	208.4	116.1	4279	4336
Emerging markets										
Brazil	1,545,566	954,715	70.0	46.4	41.1	31.3	58.8	67.0	373	335
China	4,027,840	8,711,267	66.0	71.2	135.4	140.3	205.0	197.1	2063	3485
India	1,631,830	2,331,567	98.5	89.8	65.3	45.7	66.2	50.9	5034	5615
Mexico	454,345	417,021	43.0	36.3	10.5	9.5	24.5	26.0	130	141
Russian Federation	951,296	623,425	62.4	39.5	33.2	9.2	53.3	23.1	556	230

GDP remains under 50% in most of these countries.[6] Here too, there are a few exceptions such as Morocco, Mauritius, and South Africa where stock market capitalization as a proportion of nominal GDP was 52.6%, 55.2%, and 260.2% in December 2017, respectively.

3 Methodology

In this section, we present the asymmetric power ARCH (APARCH) model used to estimate the time-varying volatility series. We also present the methodological framework used to compute spillover indices and the panel model used to examine their determinants.

3.1 APARCH modeling for time-varying volatility

The APARCH model introduced by Ding et al. (1993) is well suited to capture the fat tails and excess kurtosis in return series. Additionally, this econometric methodology captures leverage or asymmetric effects. The structure of the model is as follows:

$$r_t = \mu + \varepsilon_t \tag{1}$$

$$\sigma_t^\upsilon = \omega + \sum_{i=1}^p \alpha_i (|\xi_{t-i}| - \gamma_i \xi_{t-i})^\upsilon + \sum_{j=1}^q \beta_j (\sigma_{t-j})^\upsilon$$

$$\xi_t = \sigma_t z_t, \quad z_t \sim N(0, 1) \tag{2}$$

where r_t represents return series. μ, ω, α, γ_i, β_j and υ are estimated parameters. γ_i, reflects the asymmetry. A positive γ_i means negative information has stronger impact than positive information on volatility.

3.2 Model-based analysis for measuring spillovers

The measurement of return and volatility spillovers is based on the variance decomposition approach introduced by Diebold and Yilmaz (2009). Their method is based on the decomposition of the H-step-ahead forecast error variance for each of the N variables of an N-dimensional Vector Autoregression (VAR) model. This enables us to examine the portion of the forecast error variance of variable i, with $i = 1, 2, \ldots, N$ which can be attributed to shocks from variable j, with $j = 1, 2, \ldots, N, i \neq j i \neq j$ and aggregate these measures in order to construct spillover indices.

Diebold and Yilmaz (2012, 2014) have refined this method by employing the generalized VAR framework of Pesaran and Shin (1998). The new framework allows the calculation of the variance decomposition results in a dynamic way. This is not considered in the Cholesky factorization used in Diebold and Yilmaz (2009).

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[6] This is consistent with the relatively low number of listed firms on these stock markets.

Assume a VAR model for x_t,

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t, \quad \text{with} \quad \varepsilon_t \sim \text{i.i.d}(0, \Sigma_\varepsilon) \tag{3}$$

where Φ_i are the $N \times N$ coefficient matrices, ε_t is an $N \times 1$ vector of identically and independently distributed errors. In our subsequent empirical analysis, x_t will be either a vector of equity returns or a vector of stock return volatilities. The moving average representation of the VAR model is given by:

$$x_t = \sum_{i=0}^{\infty} \theta_i \varepsilon_{t-i} \tag{4}$$

with θ_i being the $N \times N$ moving average coefficients matrix which can be estimated using the following recursion: $\theta_i = \Phi_1 \theta_{i-1} + \Phi_2 \theta_{i-1} + \cdots + \Phi_p \theta_{i-p}$ with θ_0 being an $N \times N$ identity matrix and $\theta_i = 0, \forall i < 0$. Given this VAR framework, the H-step-ahead forecast error variance decomposition $\left(\Delta_{ij}^g(H)\right)$ is defined as:

$$\Delta_{ij}^g(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} \left(e_i' \theta_h \Sigma_\varepsilon e_j\right)}{\sum_{h=0}^{H-1} \left(e_i' \theta_h \Sigma_\varepsilon \theta_h' e_i\right)} \tag{5}$$

where σ_{ii} is the standard deviation of the error term for the i-th equation and e_i is the selection vector with one as the i-th element and zeros otherwise. By construction, the sum of the elements of each row of the variance decomposition table is not 1, $\sum_{i=1}^{N} \Delta_{ij}^g(H) \neq 1$. Therefore, we normalize each entry of the variance decomposition matrix by the row sum as:

$$\tilde{\Delta}_{ij}^g(H) = \frac{\Delta_{i \to j}^g(H)}{\sum_{j=1}^{N} \Delta_{i \to j}^g(H)} \tag{6}$$

Note that, by construction, $\sum_{j=1}^{N} \tilde{\Delta}_{ij}^g(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\Delta}_{ij}^g(H) = N$.

Using the normalized elements of the decomposition matrix of Eq. (6), we construct the total spillover index $(\vartheta^g(H))$, which captures the proportion of H-step-ahead forecast error variance explained by shocks across all variables. The total spillover index, computed on H-step ahead forecasts, is given by:

$$\vartheta^g(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\Delta}_{ij}^g(H)}{\sum_{i,j=1}^{N} \tilde{\Delta}_{ij}^g(H)} \times 100 = \frac{1}{N} \sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\Delta}_{ij}^g(H) \times 100 \tag{7}$$

We are now able to assess the direction of spillover effects from and toward a specific equity market. The generalized VAR framework enables us to compute directional

spillover indices ($\psi^g(H)$) measuring the spillovers received by market i from all other markets j for $i \neq j$:

$$\psi^g_{i \leftarrow j}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\Delta}^g_{ij}(H)}{\sum_{j=1}^{N} \tilde{\Delta}^g_{ij}(H)} \times 100 \tag{8}$$

The corresponding index which measures the spillover effects transmitted by market i to all other equity markets j is:

$$\psi^g_{i \rightarrow j}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\Delta}^g_{ji}(H)}{\sum_{j=1}^{N} \tilde{\Delta}^g_{ji}(H)} \times 100 \tag{9}$$

From (8) and (9) it is possible to calculate the net spillover $\left(\bar{\psi}^g(H)\right)$ index for market i, which allows us to determine the role played by i on the global system: a leader or a follower. $\bar{\psi}^g(H)$ is defined as:

$$\bar{\psi}^g_i(H) = \psi^g_{i \rightarrow j}(H) - \psi^g_{i \leftarrow j}(H) \tag{10}$$

The net return/volatility spillover presented in (10) provides summary information about how much in net terms each equity market contributes to return/volatility variance in other equity markets. It is also of interest to examine net pairwise volatility spillovers as:

$$\bar{\psi}^g_{ij}(H) = \left[\frac{\tilde{\Delta}^g_{ij}(H)}{\sum_{k=1}^{N} \tilde{\Delta}^g_{ik}(H)} - \frac{\tilde{\Delta}^g_{ji}(H)}{\sum_{k=1}^{N} \tilde{\Delta}^g_{jk}(H)} \right] \times 100 \tag{11}$$

The net pairwise spillover between markets i and j is simply the difference between gross shocks transmitted from market i to j and gross volatility shocks transmitted from j to i.

3.3 Econometric approach for the determinants of inward spillovers

To assess the determinants of inward spillovers in Africa, we employ linear panel models (random effect and fixed effect model) featuring return and volatility spillovers as a function of three potential channels, namely trade, financial, and global factors (commodity prices and exchange rate). Since the paper's focus is on the determinants of inward spillovers in Africa, the estimation is applied to panel data including only the ten selected African equity markets.

The econometric specification is as follows:

$$\hat{\bar{\psi}}^g_{i \rightarrow j}(H) = \varphi_0 + \varphi_1 Trade_{ij,t} + \varphi_2 Finance_{ij,t} + \varphi_3 \Delta_t + \varphi_4 Dummy_t + \eta_i + \xi_{i,t} \tag{12}$$

where, $\hat{\bar{\psi}}_{i \to j}^{g}(H)$ is the annualized[7] bidirectional spillovers between African and foreign equity markets. The trade exposure, $Trade_{ij,t} = \left[\psi_{ij,t} \ \varpi_{ij,t} \right]$, enters the model's specification through: (i) the degree of openness, $\psi_{i \to j,t} = \frac{X_{i \to j,t} + M_{i \leftarrow j,t}}{GDP_{i,t}}$, i.e., the sum of bilateral exports $X_{i \to j,t}$ (exports from i to j) and bilateral imports $M_{i \to j,t}$ (imports from j to i) between market i and market j as a share of the GDP in market i; (ii) and the bilateral export share, $\varpi_{ij,t} = \frac{X_{i \to j,t}}{X_t^W}$. More specifically, $\varpi_{ij,t}$ represents the exports from market i to market j, $X_{i \to j,t}$ as a share of total exports from market i, X_t^W. The variable $Finance_{i,t}$ is a measure of bilateral portfolio exposure calculated as $\psi_{ij,t} = \frac{Portfolio_{ij,t}}{Portfolio_{i,t}}$ where $Portfolio_{ij,t}$ denotes the total of bilateral inward and outward portfolio investment between i and j, and $Portfolio_{i,t}$ represents total portfolio investment in country i. In contrast to Shinagawa (2015), the trade exposure and financial exposure are defined bilaterally.

$\Delta_t = \left[\Omega_t \ \Xi_t \ \Psi_t \right]$ represents global factors given by oil prices (Ω), metal prices (Ξ), and US dollar exchange rate expressed in euro (Ψ). To deal with past recent observed financial disturbances, we introduce a matrix of time dummies given by $Dummy_t$. The matrix includes the 2008 global financial crisis (GFC) and the 2015 collapse of commodities' markets (CCM).

To check the robustness of our empirical estimates, we conduct two linear econometric regressions: fixed effect and random effect models. The random effect model is estimated using the Generalized Least Squares (GLS) estimator. The standard errors are derived from the asymptotic theory, using the conventionally derived variance estimator for GLS regression.

4 Data and preliminary analysis

The data set is composed of daily price indices denominated in local currencies for eleven African markets, five developed markets, and seven emerging markets. The sample period is from January 04, 2007 till September 19, 2019. All the price indices were retrieved from the Bloomberg terminal.

Nonsynchronous trading hour sessions are also considered in our dataset. The traditional procedure consists of choosing weekly series to avoid time-matching problems. However, as noted by Schotman and Zalewska (2006) among others, this approach often results in a significant loss of information. Since the non-synchronicity is caused by timing effects, we use opening prices for the US, Mexican, and Brazilian stock exchanges and closing prices for African markets and other world markets. Trading on North and South American markets and the rest of the markets that we study occurs in different time zones (see "Appendix"), with North and South American markets lagging behind. This implies that investors in other parts of the world are able to observe opening prices in the US, Mexican, and Brazilian markets. Therefore, news embedded in opening prices in North and South America markets are more likely to be transmitted to other markets than closing prices.

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[7] Annual directional spillovers are measured by computing averages of daily directional spillovers.
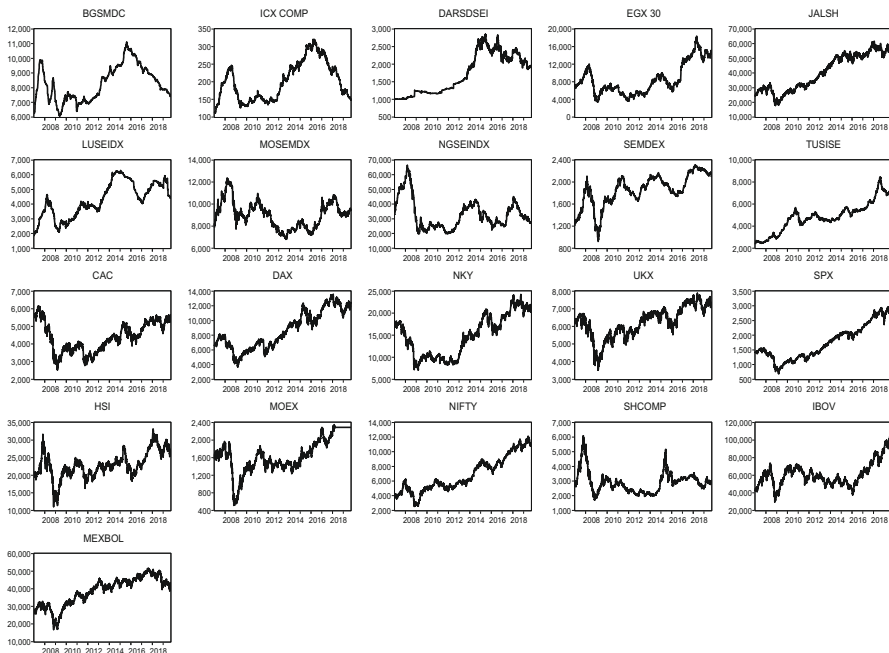
Fig. 1 Time-variations in equity price indices. January 04, 2007–September 19, 2019. Depicts equity price indices under the period covering January 03, 2007 and September 19, 2019. During the 2008 global financial crisis, many African stock markets collapsed following the downtrend of major and emerging markets. *Notes*: The abbreviations are consistent with the Bloomberg nomenclature: WAEMU (ICX COMP), Botswana (BGSMDC), Egypt (EGX 30), Mauritius (SEMDEX), Morocco (MOSEMDX), Nigeria (NGSEINDX), South Africa (JALSH), Tanzania (DARSDSEI), Tunisia (TUSISE), Zambia (LUSEIDX), France (CAC), Germany (DAX), UK (UKX), Japan (NKY), US (SPX), Brazil (IBOV), Hong Kong (HSI), Mexico (MEXBOL), Russia (MOEX), India (NIFTY), and China (SHCOMP). *Source*: Bloomberg terminal

As noted earlier in the paper, three key potential spillover channels are examined in the present study, namely international trade linkages, portfolio exposure, and global factors. Data on exports, imports, portfolio investments and commodity prices are extracted from the International Monetary Fund (IMF).

Figure 1 depicts time-variations of equity price indices during the period under investigation. Although there are some heterogeneities in their time profiles, all African stock indices were on an upswing prior to the 2008 financial turmoil.

One year after the revolution in Tunisia the stock index regained its upward trend perhaps as a result of investors' confidence in the newly democratically elected government. In Egypt, by contrast, the recovery of the stock market was less robust due in part to the establishment of a military regime and the unelected technocratic government appointed after Mubarak. Moreover, Anti Sisi protests appeared to have hurt the performance of the Egyptian stock exchange in 2016 after the president introduced harsh austerity measures and cut subsidies to fuel and some foodstuffs.

In 2011, the capital market in Nigeria was gripped by rising interest rates, banking sector reforms, and decreased investors' appetite for shares. Furthermore, the uncertainty related to the presidential elections' outcome and lower oil prices also

Table 3 Summary statistics of stock market returns. *Source*: Authors' calculations

	Max	Min	SD	Skewness	Kurtosis	Jarque–Bera
African markets						
BGSMDC	2.30	− 2.07	0.15	− 0.03	52.96	344,805.50
ICX COMP	3.05	− 2.59	0.35	0.42	10.70	8285.59
DARSDSEI	5.71	− 5.50	0.43	0.80	44.30	235,971.30
EGX 30	4.86	− 7.81	0.69	− 0.91	14.43	18,523.30
JALSH	2.97	− 3.29	0.50	− 0.13	7.05	2275.68
LUSEIDX	4.00	− 4.00	0.38	− 0.13	19.25	36,510.60
MOSEMDX	1.98	− 2.14	0.32	− 0.22	9.15	5259.05
NGSEINDX	5.11	− 4.12	0.47	0.31	13.96	16,652.83
SEMDEX	3.48	− 2.77	0.29	0.34	30.81	106,908.20
TUSISE	1.78	− 2.17	0.24	− 0.55	15.72	22,515.99
Major markets						
CAC 40	4.60	− 4.11	0.60	− 0.03	9.77	6338.08
DAX	4.69	− 3.23	0.59	− 0.02	9.45	5746.75
NKY	5.75	− 5.26	0.65	− 0.54	11.90	11,097.70
SPX	4.40	− 3.96	0.50	− 0.45	14.71	19,049.70
UKX	4.08	− 4.02	0.50	− 0.14	11.40	9765.18
Emerging markets						
HIS	5.82	− 5.90	0.65	0.01	12.60	12,721.74
IBOV	5.95	− 5.25	0.73	− 0.03	9.54	5913.65
MEXBOL	4.50	− 3.08	0.50	0.08	11.36	9669.85
MOEX	10.96	− 8.97	0.80	− 0.11	33.94	132,302.50
NIFTY	7.09	− 5.65	0.58	0.06	15.95	23,188.28
SHCOMP	3.92	− 4.02	0.70	− 0.64	7.93	3586.02

contributed to downtrend movements of the Nigerian equity market in 2014. In Ivory Coast, the 2011 post-electoral disturbances contributed significantly to the sluggish performance of the BRVM composite index after the global financial crisis.

After the global financial crisis, the Johannesburg stock exchange all share index resumed its upward trajectory starting in January 2009 after experiencing its worst performance between the last quarter of 2018 and the early beginning of 2019.

Table 3 reports summary statistics for the daily returns. These statistics show that African equity markets have provided higher returns to investors compared to developed markets between January 04, 2007 and September 19, 2019.

The Egyptian equity market recorded the poorest daily return (− 7.81%) in Africa on October 7, 2008 while Tanzania and Nigeria posted the highest daily return (5.1 and 5.7%, respectively) during the sample period.

The standard variation ranges from 0.15 (Botswana) to 0.69% (Egypt) for African markets, from 0.50 (US and UK) to 0.65% (Japan) for developed markets and from 0.50 (Mexico) to 0.80% (Russia) for emerging markets. The low volatility of African

stock markets compared to previous findings (see for instance Giovannetti and Velucchi 2013) can be explained by the low number of important financial events in our sample.

Table 3 also reports the shape and overall patterns of the distribution of returns by looking at the measures of Jarque–Bera, skewness and kurtosis. The characteristics of log-returns series used in our data set suggest the existence of non-normality and fat tails. The Jarque–Bera statistics reject the null hypothesis that log-returns are identically and independently distributed since the p values for all equity returns are above zero. The skewness measures are statistically different from 0 in all the markets under consideration, suggesting asymmetric errors in the distribution of equity returns. Overall, equity market returns are negatively skewed with values ranging from -0.9 (Egypt) to -0.02 (UK). This result suggests that return series have a distribution skewed to the left. Only equity markets in WAEMU, Tanzania, Nigeria, Mauritius, Hong Kong, Mexico, and India display positive skewness. The reported kurtosis values for the equity market returns are relatively high and statistically significant, implying that there is a high peak at the center of the returns. This also suggests that the distribution of returns has fatter tails than a normal distribution.

Table 4 summarizes information on the unconditional correlations of daily returns. Overall, the correlation coefficients between equity markets are positive and there is no evidence of significant correlation between world markets and African markets. However, South Africa's equity market, with its correlation coefficients ranging from 0.23 (China) to 0.67 (UK) is the most integrated African market. Egypt's market also exhibits relatively high correlations to world markets with the highest being with the US (0.28) and Hong Kong (0.26). Intra-regional correlations among African equity markets are relatively weak and there appears to be no frontier effects. Egypt and South Africa also display a relatively high correlation (0.17) during the period under investigation. Finally, the Mauritian stock market is relatively connected to the Moroccan, South African, and Egyptian markets with correlations that hover around 11%.

5 Empirical results and discussion

5.1 Static (full-sample, unconditional) analysis of spillovers

The empirical estimates of spillover indices are reported in Tables 5 and 6. Some interesting findings emerge. First, the total spillover index is 47.8% and 44.4% for the return and volatility series, respectively. This suggests a relative low level of interconnectedness among the equity markets under consideration.

The directional spillover results in Table 5 show that the highest share of return variance in African equity markets is explained by own-market shocks which account for more than 80% of the FEV in most African markets with Egypt, Mauritius, and South Africa being the exceptions. Table 6 reveals that volatility often spreads more forcefully than return to African markets. This contrasts sharply with the finding of Yarovaya et al. (2016) who report that the size of return spillover is greater than volatility spillover.

Table 4 Unconditional correlation of equity returns, January 04, 2007 to September 19, 2019. *Source:* Authors' calculations

	ICX COMP	BGSMDC	EGX 30	SEMDEX	MOSEMDX	NGSEINDX	JALSH	DARSDSEI	TUSISE	LUSEIDX
ICX COMP	1.00									
BGSMDC	0.04	1.00								
EGX 30	0.00	0.01	1.00							
SEMDEX	0.02	0.00	0.11	1.00						
MOSEMDX	0.00	− 0.01	0.11	0.11	1.00					
NGSEINDX	0.02	0.03	0.08	0.05	0.06	1.00				
JALSH	− 0.02	− 0.01	0.17	0.11	0.06	0.04	1.00			
DARSDSEI	0.00	0.00	0.03	0.02	0.01	0.00	− 0.01	1.00		
TUSISE	− 0.02	− 0.01	0.04	0.10	0.03	0.01	0.07	0.00	1.00	
LUSEIDX	0.01	0.06	− 0.01	0.03	0.01	0.06	− 0.02	0.00	0.00	1.00
CAC 40	− 0.02	0.01	0.14	0.09	0.06	0.04	0.65	− 0.01	0.06	0.02
DAX	− 0.01	0.02	0.14	0.07	0.06	0.05	0.62	− 0.01	0.06	0.02
UKX	0.00	0.01	0.15	0.09	0.07	0.04	0.67	− 0.01	0.06	0.00
NKY	0.02	0.00	0.24	0.17	0.10	0.04	0.37	− 0.02	0.08	− 0.02
SPX	− 0.01	0.00	0.28	0.20	0.10	0.05	0.38	0.01	0.10	0.00
IBOV	− 0.01	0.00	0.20	0.16	0.08	0.07	0.24	0.00	0.08	− 0.02
HIS	0.00	0.02	0.26	0.17	0.13	0.03	0.48	− 0.02	0.09	− 0.02
MEXBOL	0.00	− 0.02	0.22	0.14	0.08	0.07	0.28	− 0.01	0.10	− 0.03
MOEX	− 0.02	0.01	0.16	0.10	0.10	0.04	0.56	− 0.01	0.10	− 0.01
NIFTY	− 0.02	0.01	0.23	0.09	0.07	0.02	0.43	0.00	0.10	0.00
SHCOM	0.00	0.00	0.12	0.10	0.08	0.03	0.23	− 0.02	0.01	0.02

Table 4 continued

	CAC 40	DAX	UKX	NKY	SPX	IBOV	HSI	MEXBOL	MOEX	NIFTY	SHCOM
ICX COMP											
BGSMDC											
EGX 30											
SEMDEX											
MOSEMDX											
NGSEINDX											
JALSH											
DARSDSEI											
TUSISE											
LUSEIDX											
CAC 40	1.00										
DAX	0.93	1.00									
UKX	0.90	0.85	1.00								
NKY	0.32	0.30	0.32	1.00							
SPX	0.32	0.29	0.35	0.56	1.00						
IBOV	0.12	0.09	0.15	0.36	0.58	1.00					
HIS	0.39	0.39	0.41	0.57	0.47	0.35	1.00				
MEXBOL	0.17	0.14	0.19	0.40	0.64	0.62	0.39	1.00			
MOEX	0.55	0.53	0.57	0.31	0.27	0.19	0.39	0.21	1.00		
NIFTY	0.40	0.41	0.42	0.34	0.29	0.18	0.55	0.25	0.35	1.00	
SHCOM	0.17	0.16	0.18	0.28	0.20	0.14	0.49	0.14	0.16	0.25	1.00

Table 5 Spillover (connectedness) table, equity markets returns, January 04, 2007 to September 19, 2019. *Source:* Authors' calculations

	ICX COMP	BGSMDC	EGX 30	SEMDEX	MOSEMDX	NGSEINDX	JALSH	DARSDSEI	TUSISE	LUSEIDX	CAC 40
ICX COMP	98.2	0.3	0	0.1	0.1	0.2	0	0.1	0.1	0.1	0
BGSMDC	0.4	96.2	0.1	0.1	0.3	0.3	0	0	0.1	0.3	0.2
EGX 30	0	0	64.4	0.5	0.5	0.2	3.8	0.1	0.3	0.1	4.1
SEMDEX	0	0.1	1	75.4	0.8	0.1	2.7	0	0.6	0.1	2.5
MOSEMDX	0.2	0.1	1.1	0.9	90.3	0.2	0.4	0.1	0.2	0	0.5
NGSEINDX	0	0.1	1.1	0.4	0.7	89.7	1	0	0.1	0.4	1.3
JALSH	0	0	0.8	0.4	0.1	0.2	27.9	0	0.2	0	12.1
DARSDSEI	0	0	0.1	0.1	0	0.1	0.1	98.8	0	0	0.1
TUSISE	0.2	0	0.3	1	0.1	0	0.7	0	90.8	0.2	0.5
LUSEIDX	0.2	0.5	0	0.6	0.2	0.6	0.1	0	0	96.8	0.1
CAC 40	0	0	0.5	0.3	0.1	0.2	10.2	0	0.1	0	23.9
DAX	0	0	0.5	0.2	0.1	0.1	10	0	0.1	0	21.6
UKX	0	0	0.6	0.3	0.2	0.2	10.9	0	0.1	0	19
NKY	0	0	0.9	0.6	0.2	0	6.5	0	0.2	0	11.3
SPX	0	0	1	0.5	0.2	0.1	7.7	0	0.3	0	13.8
IBOV	0	0	0.7	0.7	0.1	0.2	8.5	0	0.2	0	10.4
HIS	0	0	1.2	0.5	0.4	0.1	8	0	0.3	0	8.1
MEXBOL	0	0	0.8	0.2	0.1	0.1	9	0	0.3	0	11
MOEX	0	0	0.7	0.4	0.4	0.2	10.8	0	0.3	0	10.5
NIFTY	0	0	1.5	0.3	0.2	0.1	7.4	0	0.1	0.1	7.5
SHCOM	0	0	0.5	0.4	0.3	0.1	3.3	0	0	0	3
TO	1	2	13	9	5	3	101	1	4	2	137
INCLUDING OWN	100	98	78	84	96	93	129	99	94	98	161

Table 5 continued

	DAX	UKX	NKY	SPX	IBOV	HSI	MEXBOL	MOEX	NIFTY	SHCOM	FROM
ICX COMP	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	2
BGSMDC	0.2	0.3	0.2	0.1	0.3	0.3	0	0.3	0.1	0.1	4
EGX 30	4.2	4.2	1.4	2.6	0.6	3	1.2	3.8	4.4	0.6	36
SEMDEX	2.6	2.8	1.2	1.6	0.5	2.2	0.7	2.8	1.4	0.6	25
MOSEMDX	0.6	0.7	0.4	0.4	0.1	1.1	0.2	1.1	1	0.4	10
NGSEINDX	1.1	1.1	0.2	0.2	0.3	0.6	0.3	0.5	0.5	0.4	10
JALSH	11.4	13.2	3.6	4.5	1.4	6.6	2.2	8.6	5.2	1.4	72
DARSDSEI	0.1	0.1	0.2	0	0.1	0.1	0.1	0	0.1	0.1	1
TUSISE	0.6	0.6	0.5	1	0.5	0.8	0.7	0.9	0.4	0	9
LUSEIDX	0.2	0.1	0.1	0	0.1	0	0	0.2	0	0.1	3
CAC 40	20.5	19.1	3.2	3.8	0.5	4.5	1	7.2	4.2	0.8	76
DAX	25.1	18.1	2.9	3.3	0.3	4.5	0.7	7.2	4.4	0.7	75
UKX	17	23.7	3.3	4.6	0.7	5	1.3	7.7	4.5	0.8	76
NKY	10.9	10.8	31	5.8	1	7.8	1.7	5	4.5	1.8	69
SPX	13.7	13.6	4.5	21.1	3.4	5	5	5.2	4.2	0.7	79
IBOV	9.4	10.9	2.1	4.8	28.1	6.1	5.7	6.7	4.4	1.1	72
HIS	7.9	8.9	6.7	4.5	1.7	28.3	2.6	5.5	8.6	6.7	72
MEXBOL	10.8	11.2	2.7	6.5	4.9	6.2	24.1	6.3	4.7	0.9	76
MOEX	10	11.4	3.2	3.1	1.3	5.5	1.6	34.7	4.8	0.9	65
NIFTY	7.5	8	3.8	3.4	0.8	11.1	2.2	5.5	38.3	2.2	62
SHCOM	2.8	3.4	3.4	1.6	0.4	13.9	0.4	2.2	3.5	60.6	39
TO	132	138	44	52	19	85	28	77	61	20	933
INCLUDING OWN	157	162	75	73	47	113	52	111	99	81	44.40%

Each entry (i, j) of the spillover tables is an estimate for the contribution to i market's forecast error variance created by shocks to market j. The diagonal elements of the tables are the own variance shares estimates. They show the part of the forecast error variance of market that is due to its own shocks

Table 6 Spillover (connectedness) table, equity markets volatilities, January 04, 2007 to September 19, 2019. *Source*: Authors' calculations

	ICX COMP	BGSMDC	EGX 30	SEMDEX	MOSEMDX	NGSEINDX	JALSH	DARSDSEI	TUSISE	LUSEIDX	CAC 40
ICX COMP	95	0.4	0.3	0.1	0	0.9	0.2	0.4	0.1	0.7	0.2
BGSMDC	0.1	90	0.3	0.2	0.4	0	0.9	0	1	2.6	0.6
EGX 30	0.4	0.4	49.7	0.1	0.4	0	11.3	0.3	5	0.1	6.6
SEMDEX	0.4	0.2	1.8	56.7	0.6	0.2	4.2	0	3.9	0.3	4.8
MOSEMDX	0.1	0.7	0.4	0.3	81.1	0.2	3	0	0.2	1.6	0.8
NGSEINDX	0.2	0	0.6	0.3	0	97.2	0.2	0.2	0.1	0	0
JALSH	0	0	0.5	0.2	0	0.1	34.8	0	0.4	0	13.3
DARSDSEI	0.1	0.1	0	0	0	0	0.1	98.1	0.2	0.4	0.2
TUSISE	0	0.2	0.3	1.3	0.1	0	1.6	0.2	86.8	0.9	0.8
LUSEIDX	0.2	1.5	0.4	0.8	0.7	0	0	0.5	1.6	90.5	0
CAC 40	0.1	0	1.2	0.5	0	0.3	13	0.1	1.2	0	23.9
DAX	0.2	0	1.7	0.2	0.1	0.4	12.3	0.1	1.1	0	21.8
UKX	0.2	0	1.5	1	0	0.4	13.7	0.1	1.9	0	19.2
NKY	0.1	0	1.2	0.2	0.3	0.1	13.3	0	1.8	0	11.2
SPX	0.2	0	1.6	0.4	0.1	0.4	15.4	0.1	2.3	0	15.4
IBOV	0	0	0.5	0.6	0.2	0.4	14.6	0.1	0.9	0.1	10.9
HIS	0	0	0.8	0	0.1	0.3	12.5	0.1	0.9	0.1	9.2
MEXBOL	0	0	0.5	0.1	0	0.2	17.3	0.2	1	0.2	8.7
MOEX	0	0.5	1.9	1.8	0.4	0.1	13.3	0.1	2.6	0	9.3
NIFTY	0.1	0.1	1	0.1	0	0.2	12.3	0.1	0.5	0.3	8.7
SHCOM	0.4	0.1	0.5	0.2	0.6	0	1.2	0.2	0	0	1.5
TO	3	4	17	8	4	4	160	3	27	8	143
INCLUDING OWN	98	95	67	65	86	102	195	101	114	98	167

Table 6 continued

	DAX	UKX	NKY	SPX	IBOV	HSI	MEXBOL	MOEX	NIFTY	SHCOM	FROM
ICX COMP	0.2	0.2	0.1	0.3	0.1	0	0.3	0.1	0.2	0.2	5
BGSMDC	0.6	0.1	0.1	0.1	0.5	0.2	1.1	0.8	0.3	0	10
EGX 30	6.8	6.6	0	1.1	2	0.1	2.4	4.6	1.8	0.4	50
SEMDEX	4.5	6.7	0.8	10.4	0.3	0.3	0.9	2.7	0.2	0.1	43
MOSEMDX	0.9	1.9	1.1	0.3	0.5	1.3	0.3	2.8	2.6	0	19
NGSEINDX	0.1	0.1	0.2	0	0.1	0.2	0.3	0	0.1	0.1	3
JALSH	14.6	16.8	1.1	2.1	2	1.3	3.4	3.9	5.2	0.2	65
DARSDSEI	0.1	0.1	0	0	0.1	0.2	0	0.1	0.1	0.1	2
TUSISE	0.4	1	0.3	1.8	1.8	0.3	1.1	0.8	0.2	0.1	13
LUSEIDX	0	0	0.4	1.2	0.1	0.4	0.8	0	0.7	0.1	9
CAC 40	23.4	20	1.8	3	1.6	1.9	1.3	3	3.3	0.4	76
DAX	28.6	19.2	1.3	2.3	1.7	1.2	1.4	2.9	3	0.5	71
UKX	19.5	23.8	1.7	4.2	1.8	1.5	1.6	4.1	3.4	0.4	76
NKY	13.1	15.1	17.1	3.3	3.8	4	4.4	4	6.6	0.3	83
SPX	16.2	17.1	2.1	14.9	3.5	1.1	4.6	2.9	1.4	0.1	85
IBOV	10.9	15.8	1.5	4.3	19.5	2.7	6.1	6.3	4.4	0.1	80
HIS	11.1	13.5	5.3	0.9	3	16.5	4.6	5.2	14.5	1.3	84
MEXBOL	11.2	13.7	1.3	2.6	8.1	2.2	21.8	4.4	6.4	0.1	78
MOEX	9.8	13.1	0.3	3.1	4.3	0.6	1.4	35.5	1.9	0.1	64
NIFTY	11.6	14.4	3.1	0.9	2	4.1	4	3.3	32.8	0.5	67
SHCOM	2.2	1.7	0.5	0.1	0.1	5	0.1	1.6	2.9	81.2	19
TO	157	177	23	42	37	28	40	53	59	5	1004
INCLUDING OWN	186	201	40	57	57	45	62	89	92	86	47.80%

Each entry (i, j) of the spillover tables is an estimate for the contribution to i market's forecast error variance created by shocks to market j. The diagonal elements of the tables are the own variance shares estimates. They show the part of the forecast error variance of market that is due to its own shocks

Table 5 shows that, overall, African equity markets are net return receivers,[8] that is, inward return spillovers ("FROM") exceed outward return spillovers ("TO"). This suggests that they are sensitive to changes on world equity markets. Only the South African equity market is a net return transmitter. This is consistent with its high integration with the global financial system and its influence on the other SADC markets. By contrast, equity markets such as Tunisia, Nigeria, and South Africa are net volatility transmitters.

As seen in the correlation analysis, South Africa and Egypt are highly exposed to external shocks. The South African equity market is specifically exposed to shocks from the UK equity market because of dual quotations of many South African firms in Johannesburg and London. Moreover, South Africa is Africa's largest beneficiary of foreign direct investment (FDI) from the UK. The international connectedness of the Egyptian equity market is also significant as foreign shocks account for 36% of return FEV and 50% of volatility FEV. Volatility spillovers from the US to Mauritius are relatively pronounced, accounting for 10.4% of the volatility FEV. The Moroccan equity market is also exposed to foreign shocks since there are tight trade and financial linkages with the Eurozone, especially with France and Spain. WAEMU and Tanzania are the least exposed to shocks from foreign markets. Spillovers account for less than 5% of both return and volatility FEV in these two markets.

### 5.2 Rolling sample analysis of spillover plots

From Fig. 2, we notice that return spillovers are more stable and less pronounced than volatility spillovers which react more to economic and financial events.

As in Sugimoto et al. (2014), we also find that peaks of spillovers occurred during the 2008 global financial crisis in African equity markets even though volatility spillovers later increased during the second and the third quarters of 2015 as investors were progressively anxious by Africa's commodity-based economies that were reacting to the economic slowdown in China. Pronounced spillovers also appeared in 2016 as a result of the BREXIT. The trade war between the US and China has also enhanced spillovers to Africa at the beginning of 2019. Although there are similar spillover traits among African markets, some country-specific patterns exist across these markets. For example, In Nigeria, the 2009 banking crisis considerably reduced inward spillovers. A peak reappeared at the beginning of 2010 when the regulatory authorities initiated a battery of measures[9] to re-establish investors' confidence. However, the largest amplitude of volatility spillover was registered in 2012 because of high oil prices and strategic initiatives adopted by market authorities.

Southern African markets are highly interwoven with the international environment. In Botswana, for instance, spillover indices reached a crest during the last semester of 2008 due in part to the negative impact on domestic firms of falling metal prices

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[8] Net transmitter means that total outward spillovers ("TO") are greater than total inward spillovers ("FROM"), whereas net receiver means that total inward spillovers ("FROM") are greater than total outward spillovers ("TO").

[9] The regulatory authorities have established the Asset Management Company of Nigeria (AMCON) and have instituted zero tolerance for market infractions and compliance with post-listing requirements.
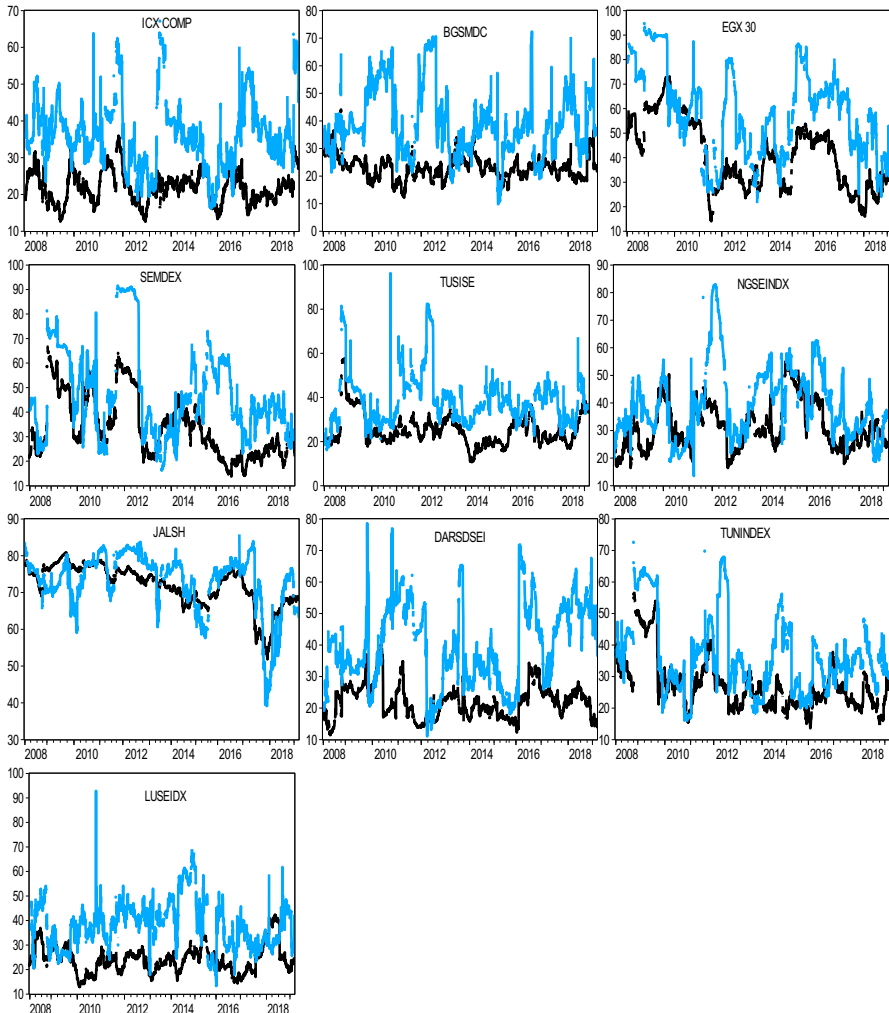
Fig. 2 Directional return and volatility spillovers to equity market in Africa. Depicts total directional return and volatility spillovers received by each selected African market from other equity markets. Directional volatility spillover from other equity markets appears to be most pronounced than return spillover, except in South Africa. This result suggests that uncertainty on world equity markets spread more forcefully to Africa than news of these markets. A peak of spillovers received from other markets appear both for volatility and returns across African markets. *Note*: The black line depicts return spillovers while the blue depicts volatility spillovers. Vertical lines represent structural breaks. Red for return spillovers and green for volatility. *Source*: Author's calculations. (Color figure online)

in world markets. Volatility spillover rose sharply again in the third quarter of 2012 and at the end of 2016. Similarly, strong inward spillovers emerged during the global financial crisis in Mauritius. Inward spillovers also peaked in Mauritius during the Eurozone sovereign debt crisis because the fear that European tourists would curtail visits to the island nation almost led to the collapse of the local leisure industry. Inward

spillovers in the South African equity market have remained relatively strong over time. The dynamics of return spillovers present some commonalities with those of volatility spillovers. Another important result is that inward spillovers significantly decreased in November 2017. Problems in the mining industry and the depreciation of the Rand can explain this insulation of the South African stock market. Inward volatility spillovers in Zambia are tightly linked to movements in copper mining which happens to be the main economic activity. Three episodes of high inward volatility spillovers occurred in Zambia: in 2011, 2012 and 2014.[10] The China–US trade dispute has also put pressures on copper prices, increasing inward spillovers in 2018.

Turning to the BRVM, we see that a pick of volatility spillovers appeared in 2013 as a result of the BRVM transiting from a call market system to continuous trading. This led to an increase in market liquidity (see Ouattara 2016) and boosted visibility and recognition from international investors. Market regulators in Tanzania have also adopted awareness initiatives to enhance market efficiency in 2013. This can explain the smooth peak of volatility spillover in July 2013 in its stock market.

In North Africa, the political instability caused by the persistent military regime appeared to have reduced the effects of foreign innovations in the Egyptian market in 2011. Moreover, uncertainty brought about by attacks in the Sinai border province has reduced the size of inward spillovers in November 2012. In the same way, protests caused by the Tunisian revolution in 2011 resulted in reduced connectedness of its equity market with the global financial system. In Morocco, the global financial crisis substantially increased inward spillovers from its main investment partners (France and Spain). Moreover, its foreign reserves from the country's crucial tourism industry almost entirely collapsed.

Figures 3 and 4 present net return and volatility spillovers. As seen in Sect. 5.1, African equity market are net return receivers, meaning that they follow changes on world equity markets. News from these markets are not relevant to foreign investors operating in major or emerging markets. The South African equity market is the only net return transmitter. This is consistent with its deep integration into the international financial system compared to other African equity markets and its influence on SADC economies and markets. By contrast to net return spillovers, many African equity markets are net volatility transmitters. This suggests that only uncertainty from these markets can spread in foreign markets.

5.3 Spillover channels in African equity markets

Our study also deals with an interesting and under researched topic, namely the determinants of African stock market returns and volatilities and the integration of these markets with global markets. More specifically, we examine the role of bidirectional portfolio exposure, bidirectional trade exposure and export share, commodity (oil and metal) prices, and US$/Euro exchange rate in driving inward spillovers in African

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[10] Copper prices experienced a record high in January 2011 due to a recovery in the global economy and low stockpiles after the 2008 financial crisis. The second peak observed in 2012 was the result of copper prices uncertainty on international markets during the first half of the year. Another episode of increase occurred in January 2014 when a strike in all ports in Chile pushed prices up again.
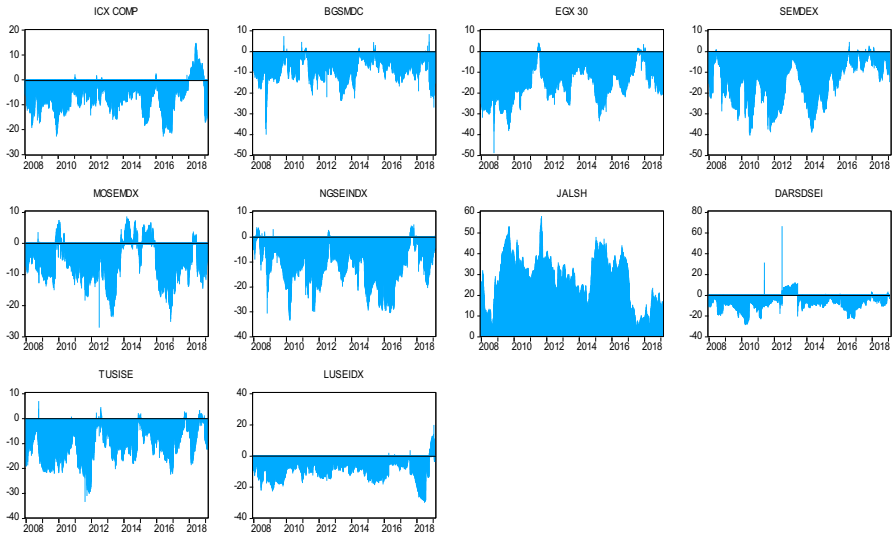
Fig. 3 Net return spillovers. Depicts net return spillovers for each selected African equity market. It clearly appears that they net receivers of return shocks from other markets, except the South African market which is the leading and the biggest market in the region. *Note*: The figure plots the net volatility spillover using a rolling window length of $w = 250$ trading days with the forecast horizon set to $h = 10$ trading days. *Source*: Author's calculations
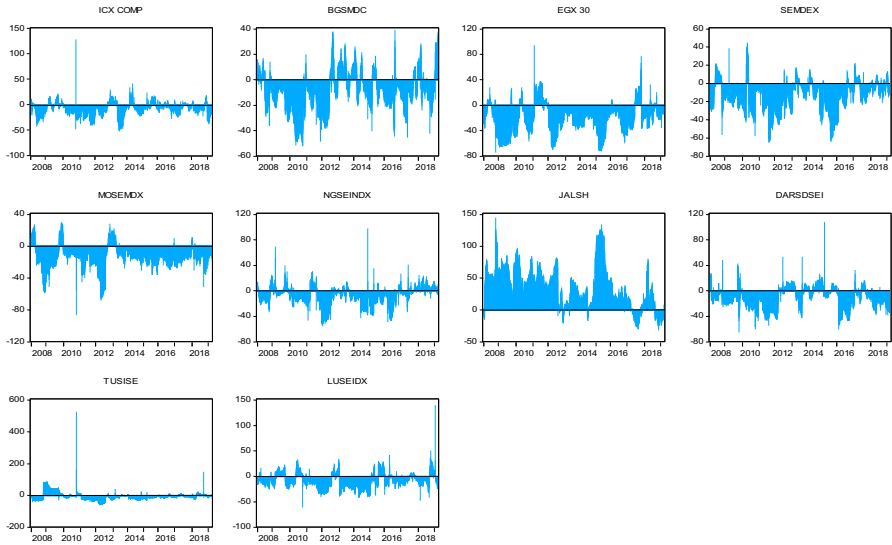
Fig. 4 Net volatility spillovers. Depicts net volatility spillovers for each selected African equity market. By contrast to return spillovers, African equity markets are sometimes net receivers and sometimes net transmitters. Note: The Figure plots the net volatility spillover using a rolling window length of $w = 250$ trading days with the forecast horizon set to $h = 10$ trading days. *Source*: Author's calculations

equity markets. Fixed and random effect regressions are conducted. The estimates are reported in Tables 7. The Hausman test shows that the random effect model is adequate to model individual-level effects for both return and volatility spillovers in all the African markets under consideration.

The significance and the sign of the coefficients for trade openness are mixed African markets. They are not significant in many cases, suggesting that the trade exposure is not a robust channel through which foreign shocks spread in African equity markets. Therefore, trade channel is not enough to explain inward return and volatility spillovers. This is in line with the results of Shinagawa (2015) who has documented that there is no relationship between the degree of openness and financial market spillovers. However, the trade openness is a relevant spillover channel in Mauritius and Egypt. The export channel also has different effects on inward spillovers in African markets. More specifically, the export share is a significant channel that increases inward return spillovers in Tunisia, whereas it reduces inward return spillovers in Mauritius. Moreover, the export share significantly increases volatility spillovers in South Africa while decreasing volatility spillovers in Botswana.

Our empirical results show that the effects of bilateral portfolio are small and non-significant in most African markets. This contrasts with the findings of Shinagawa (2015) who suggests that portfolio asset holding explains equity market spillovers in major and emerging markets. However, the low level of portfolio investment in Africa can explain our results. Portfolio investment is a significant determinant of inward return spillovers in South Africa. This is not surprising since the country attracts an important amount of portfolio investments from the United Kingdom and the United States in the mining activity and the financial sector. In contrast, portfolio investment tends to reduce the connectedness of small countries such as Zambia and Mauritius.

Overall, metal prices have negative effects on inward return and volatility spillovers in Africa. This suggests that metal price movements exert asynchronous effects on producers and foreign firms producing manufactured goods from this raw material. A decrease in nonferrous metal prices depresses share prices of listed companies in African countries and likely boosts business activity in China, the US, and the UK which are among the main exports' destinations from Zambia, South Africa, and Morocco. By contrast, metal price movements tend to reduce return spillovers in WAEMU and Egypt which are net importers of base metals.

Oil prices tend to significantly reduce inward return spillovers in African equity markets, except in Mauritius and Zambia. The high oil dependency of many economies in the continent makes their markets sensitive to developments of oil prices. However, developments on oil markets have an asynchronous impact on African stock markets and world markets. Even oil-importing countries like Tunisia and Morocco are susceptible to be hit by external shocks through the channel of oil prices. More specifically, an increase in world oil production can lead to a reduction in the fuel bill paid by locally-quoted companies. Surprisingly, directional spillovers to the Nigerian market are not significantly explained by oil prices.

The US$/Euro exchange rate is also a significant determinant of bidirectional financial spillovers in Africa although the sign of its effects varies across markets. Overall though, the effects are positive. The US$/Euro exchange rate has a pronounced positive effect on bidirectional volatility spillovers in Mauritius and Morocco. The high

Table 7 Equity market spillover channels in Africa. *Source*: Authors' calculations

	Return spillovers		Volatility spillovers	
	Fixed effect	Random effect	Fixed effect	Random effect
Panel (a) Botswana				
Oil prices	− 0.664	− 0.566	2.532	2.464
	(0.827)	(0.834)	(1.741)	(1.739)
Metal prices	0.246	0.156	− 0.213	− 0.285
	(0.911)	(0.921)	(1.918)	(1.919)
Exchange rate	− 1.477	− 1.832	24.11***	23.14***
	(3.028)	(3.046)	(6.374)	(6.350)
Portfolio share	− 0.0152*	− 0.00563	− 0.0237	− 0.00677
	(0.00874)	(0.00594)	(0.0184)	(0.0132)
Export share	− 0.808	− 0.746	− 3.701*	− 0.741
	(1.062)	(0.740)	(2.236)	(1.626)
Trade openness	0.0240	0.0129	0.0149	0.00452
	(0.0162)	(0.0144)	(0.0340)	(0.0310)
GFC	0.377*	0.308	0.182	0.138
	(0.216)	(0.217)	(0.455)	(0.453)
CCM	− 0.108	− 0.0591	− 1.723***	− 1.650***
	(0.267)	(0.269)	(0.561)	(0.560)
Constant	1.156***	1.156***	2.090***	1.953***
	(0.0682)	(0.0563)	(0.144)	(0.135)
Chi2	8.66		3.75	
Panel (b) WAEMU				
Oil prices	− 1.671**	− 1.660**	− 0.904	− 0.969
	(0.658)	(0.654)	(2.105)	(2.116)
Metal prices	2.011***	1.978***	2.912	2.924
	(0.730)	(0.724)	(2.335)	(2.342)
Exchange rate	− 1.081	− 1.254	− 12.84*	− 13.77*
	(2.385)	(2.369)	(7.625)	(7.670)
Portfolio share	− 0.000295	0.00147	− 0.0306**	− 0.0138
	(0.00413)	(0.00353)	(0.0132)	(0.0111)
Export share	0.0367	0.0306	0.00453	− 0.0414
	(0.0341)	(0.0314)	(0.109)	(0.1000)
Trade openness	− 0.0642	− 0.0897	0.00329	0.0619
	(0.115)	(0.0976)	(0.368)	(0.310)
GFC	0.113	0.0960	− 0.461	− 0.520
	(0.169)	(0.167)	(0.539)	(0.540)
CCM	− 0.386*	− 0.368*	0.260	0.337
	(0.210)	(0.209)	(0.673)	(0.676)
Constant	1.113***	1.148***	2.183***	2.200***
	(0.0748)	(0.0624)	(0.239)	(0.184)

Table 7 continued

	Return spillovers		Volatility spillovers	
	Fixed effect	Random effect	Fixed effect	Random effect
Chi2	1.25		6.90	
Panel (c) Tanzania				
Oil prices	− 1.568*	− 1.690**	2.252	2.488
	(0.857)	(0.788)	(1.944)	(1.768)
Metal prices	0.403	0.472	− 2.860	− 3.086
	(0.917)	(0.870)	(2.082)	(1.952)
Exchange rate	− 1.432	− 1.604	11.77*	11.70*
	(2.877)	(2.848)	(6.529)	(6.388)
Portfolio share	0.00665	− 0.00476	0.00238	− 0.00120
	(0.0135)	(0.00901)	(0.0306)	(0.0200)
Export share	3.103	0.297	− 10.48	− 6.409
	(9.249)	(5.014)	(20.99)	(11.09)
Trade openness	− 0.0927	0.0129	0.257	0.118
	(0.236)	(0.0926)	(0.537)	(0.205)
GFC	0.409**	0.420**	− 0.312	− 0.340
	(0.204)	(0.200)	(0.463)	(0.449)
CCM	− 0.612**	− 0.615**	− 0.791	− 0.756
	(0.256)	(0.252)	(0.581)	(0.564)
Constant	1.329***	1.288***	1.642***	1.744***
	(0.250)	(0.0571)	(0.569)	(0.126)
Chi2	0.99		1.00	
Panel (d) Egypt				
Oil prices	− 8.125***	− 8.417***	− 6.995**	− 7.344***
	(1.618)	(1.638)	(2.760)	(2.758)
Metal prices	7.570***	7.609***	4.566	4.639
	(1.763)	(1.787)	(3.007)	(3.011)
Exchange rate	10.88*	10.38*	15.74	15.26
	(5.875)	(5.946)	(10.02)	(10.02)
Portfolio share	0.000891	0.0108	0.0232	0.0300
	(0.0197)	(0.0175)	(0.0337)	(0.0285)
Export share	− 0.0319	− 0.104	− 0.156	− 0.294
	(0.155)	(0.131)	(0.264)	(0.215)
Trade openness	0.333	0.653*	0.626	1.020*
	(0.376)	(0.362)	(0.641)	(0.603)
GFC	2.444***	2.333***	2.664***	2.535***
	(0.424)	(0.428)	(0.723)	(0.721)
CCM	− 1.433***	− 1.400***	− 1.405	− 1.364
	(0.515)	(0.522)	(0.879)	(0.879)
Constant	1.804***	1.677***	2.482***	2.446***
	(0.266)	(0.258)	(0.454)	(0.387)

Table 7 continued

	Return spillovers		Volatility spillovers	
	Fixed effect	Random effect	Fixed effect	Random effect
Chi2	12.00		3.85	
Panel (e) South Africa				
Oil prices	− 0.774	− 1.124	0.699	0.787
	(1.466)	(1.467)	(2.087)	(2.067)
Metal prices	0.834	0.978	− 1.222	− 1.364
	(1.643)	(1.652)	(2.339)	(2.329)
Exchange rate	5.619	5.539	7.025	6.922
	(5.312)	(5.354)	(7.560)	(7.550)
Portfolio share	0.478**	0.134*	− 0.00715	0.0379
	(0.186)	(0.0771)	(0.265)	(0.0781)
Export share	− 0.00621	0.0848	0.352	0.392**
	(0.150)	(0.141)	(0.214)	(0.186)
Trade openness	0.0987	0.0804	− 0.00392	− 0.0267
	(0.0921)	(0.0922)	(0.131)	(0.129)
GFC	0.347	0.469	0.191	0.166
	(0.379)	(0.377)	(0.539)	(0.530)
CCM	− 0.784*	− 0.883*	− 0.927	− 0.937
	(0.474)	(0.476)	(0.675)	(0.670)
Constant	1.829***	2.827***	2.936***	2.741***
	(0.656)	(0.954)	(0.933)	(0.945)
Chi2	3.53		2.16	
Panel (f) Zambia				
Oil prices	0.674	0.644	2.202	2.151
	(0.778)	(0.782)	(1.958)	(1.936)
Metal prices	− 1.644*	− 1.631*	− 2.707	− 2.630
	(0.859)	(0.864)	(2.163)	(2.140)
Exchange rate	− 0.810	− 0.613	1.530	1.794
	(2.839)	(2.864)	(7.149)	(7.094)
Portfolio share	− 0.00384	− 0.0108**	0.0183	− 0.00133
	(0.00984)	(0.00533)	(0.0248)	(0.0145)
Export share	0.00365	− 0.00885	− 0.0276	0.00918
	(0.0515)	(0.00724)	(0.130)	(0.0204)
Trade openness	0.0107	0.00868	− 0.0191	− 0.0309
	(0.0599)	(0.0189)	(0.151)	(0.0526)
GFC	0.0144	0.0319	− 0.325	− 0.294
	(0.202)	(0.201)	(0.509)	(0.499)
CCM	0.243	0.225	− 0.0409	− 0.0793
	(0.251)	(0.252)	(0.631)	(0.625)
Constant	1.157***	1.221***	1.995***	1.941***
	(0.154)	(0.0554)	(0.389)	(0.153)

Table 7 continued

	Return spillovers		Volatility spillovers	
	Fixed effect	Random effect	Fixed effect	Random effect
Chi2	0.37		1.04	
Panel (g) Morocco				
Oil prices	− 1.568*	− 1.690**	2.252	2.488
	(0.857)	(0.788)	(1.944)	(1.768)
Metal prices	0.403	0.472	− 2.860	− 3.086
	(0.917)	(0.870)	(2.082)	(1.952)
Exchange rate	− 1.432	− 1.604	11.77*	11.70*
	(2.877)	(2.848)	(6.529)	(6.388)
Portfolio share	0.00665	− 0.00476	0.00238	− 0.00120
	(0.0135)	(0.00901)	(0.0306)	(0.0200)
Export share	3.103	0.297	− 10.48	− 6.409
	(9.249)	(5.014)	(20.99)	(11.09)
Trade openness	− 0.0927	0.0129	0.257	0.118
	(0.236)	(0.0926)	(0.537)	(0.205)
GFC	0.409**	0.420**	− 0.312	− 0.340
	(0.204)	(0.200)	(0.463)	(0.449)
CCM	− 0.612**	− 0.615**	− 0.791	− 0.756
	(0.256)	(0.252)	(0.581)	(0.564)
Constant	1.329***	1.288***	1.642***	1.744***
	(0.250)	(0.0571)	(0.569)	(0.126)
Chi2	0.99		1.00	
Panel (h) Mauritius				
Oil prices	0.106	0.0931	1.502	0.897
	(1.147)	(1.135)	(2.194)	(2.203)
Metal prices	− 0.168	− 0.120	− 3.401	− 2.345
	(1.279)	(1.258)	(2.446)	(2.440)
Exchange rate	11.16***	11.47***	18.23**	19.46**
	(4.221)	(4.176)	(8.073)	(8.098)
Portfolio share	− 0.0458*	− 0.0322**	− 0.120**	− 0.00261
	(0.0276)	(0.0155)	(0.0528)	(0.0209)
Export share	− 0.202***	− 0.191***	− 0.111	− 0.170***
	(0.0659)	(0.0439)	(0.126)	(0.0642)
Trade openness	0.522***	0.496***	0.178	0.411***
	(0.117)	(0.0903)	(0.225)	(0.136)
GFC	0.220	0.250	− 0.249	− 0.0830
	(0.298)	(0.293)	(0.570)	(0.568)
CCM	− 1.102***	− 1.120***	− 1.177*	− 1.347*
	(0.369)	(0.366)	(0.706)	(0.710)
Constant	1.492***	1.469***	2.681***	2.132***
	(0.177)	(0.143)	(0.338)	(0.179)

Table 7 continued

	Return spillovers		Volatility spillovers	
	Fixed effect	Random effect	Fixed effect	Random effect
Chi2	0.55		7.50	
Panel (i) Tunisia				
Oil prices	− 2.758***	− 2.520***	− 0.512	− 0.341
	(0.955)	(0.933)	(1.801)	(1.741)
Metal prices	1.449	1.371	− 2.438	− 2.581
	(1.029)	(1.025)	(1.942)	(1.913)
Exchange rate	− 1.326	− 0.913	5.207	5.703
	(3.384)	(3.383)	(6.385)	(6.311)
Portfolio share	− 0.0171	0.00367	− 0.0208	0.000795
	(0.0164)	(0.00697)	(0.0309)	(0.0136)
Export share	24.77**	11.46*	− 20.36	− 14.12
	(10.24)	(6.721)	(19.31)	(12.89)
Trade openness	0.00142	− 0.0948	0.179	0.141
	(0.134)	(0.0670)	(0.253)	(0.128)
GFC	0.917***	0.902***	0.402	0.402
	(0.236)	(0.237)	(0.446)	(0.442)
CCM	− 0.785***	− 0.779***	− 1.267**	− 1.289**
	(0.297)	(0.298)	(0.561)	(0.555)
Constant	0.864***	1.299***	2.005***	1.864***
	(0.299)	(0.0722)	(0.564)	(0.141)
Prob > Chi2(7)	5.17		0.87	
Panel (j) Nigeria				
Oil prices	− 0.388	− 0.415	1.100	1.085
	(1.029)	(1.023)	(1.769)	(1.755)
Metal prices	0.248	0.247	− 4.392**	− 4.380**
	(1.135)	(1.128)	(1.950)	(1.937)
Exchange rate	− 2.501	− 2.622	3.836	3.771
	(3.773)	(3.748)	(6.485)	(6.430)
Portfolio share	− 0.00146	− 0.00138	0.00464	0.00479
	(0.00217)	(0.00214)	(0.00373)	(0.00363)
Export share	1.735	0.854	− 4.384	− 2.504
	(3.632)	(2.001)	(6.242)	(2.381)
Trade openness	− 0.0638	− 0.0401	0.0186	0.0362
	(0.0662)	(0.0571)	(0.114)	(0.0813)
GFC	− 0.324	− 0.339	− 0.602	− 0.607
	(0.266)	(0.264)	(0.457)	(0.452)

Table 7 continued

	Return spillovers		Volatility spillovers	
	Fixed effect	Random effect	Fixed effect	Random effect
CCM	0.892***	0.902***	− 0.134	− 0.130
	(0.332)	(0.330)	(0.571)	(0.566)
Constant	1.551***	1.556***	2.089***	2.015***
	(0.128)	(0.132)	(0.219)	(0.145)
Chi2	0.54		0.19	

Standard errors in parentheses

GFC 2008 global financial crisis, *CMC* commodity markets collapse

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

dependency of these African markets to the tourism sector can explain this result. A sudden change in exchange rate can cause a reduction on tourist arrivals so that the uncertainty rapidly increases in Mauritius and Morocco. The Effects are also significant and positive for directional spillovers in Botswana and Tanzania. The WAEMU equity market is the only African market where the US$/Euro exchange rate significantly reduces inward spillover effects. This finding can only be explained by the fact that the legal tender of the WAEMU is pegged to the euro.

The global financial crisis and the collapse of commodity markets in 2015 have significantly impacted the connectedness in Egypt, Botswana, South Africa and Mauritius. The econometric regressions show that the crash of commodity markets has significantly decreased both the return and the volatility connectedness is many African markets. Our results show that commodity market price movements tend to reduce the connectedness between African and world markets. The 2015 market turmoil caused a significant decrease in inward spillovers in Africa. The Nigerian market is the lone exception because many listed companies in this country depend on the oil sector. The decline of oil prices has then led to a collapse of the stock market as in international markets. By contrast, the global financial crisis (GFC) significantly increased inward return spillovers while reducing inward volatility spillovers in some African markets (WAEMU, Tanzania, Zambia, Morocco, Mauritius, Nigeria).

6 Summary and concluding remarks

The main goal of this study was to examine return and volatility spillovers from international and regional equity markets to Africa. This topic is of interest to financial practitioners who are interested in determining with relative accuracy how a shock to one market influences the dynamic adjustment of return and volatility in African markets. We employ a network methodology advocated by Diebold and Yilmaz (2009, 2012, 2014) with daily data ranging from January 04, 2007 till September 19, 2019. Overall, our spillover results uncover weak transmission of external shocks to African markets. The highest share of return and volatility variance in African equity markets is explained by own-market variables except in Egypt, Mauritius, and South Africa. Our

empirical results also suggest that African markets are net receivers for both return and volatility spillovers. Comparing the magnitude of return and volatility spillovers, our estimates show that uncertainty from foreign equity markets spread more forcefully than return. In a dynamic approach, econometric regressions show that high spillovers emerged during the 2008 global financial and the 2012 European debt crisis. Some peaks also appeared when structural economic reforms or measures increasing market efficiency were made in African economies.

The linear panel models used to assess spillover channels show that trade and financial exposure are not significant channels through which foreign shocks spread to African equity markets. Only global factors (commodity prices and exchange rate) are able to explain return and volatility spillovers in Africa.

The empirical results have interesting portfolio diversification implications. The weakness of inward spillovers in African financial markets suggests that there are hedging possibilities between African equity markets and world markets. Specifically, the fact that commodity (oil and metal) prices have negative effects on inward spillovers in African markets can lead to the design and implementation of successful hedging strategies by portfolio managers through efficient asset allocation between mining firms listed in Africa and manufacturing companies listed on major or emerging markets.

Appendix

See Table 8.

Table 8 List of equity markets trading hours. *Source*: Wikipedia, African Securities Exchanges Association 2014

World exchanges	Country	City	Δ	Local time		UTC	
				Open	Close	Open	Close
New York stock exchange (NYSE)	US	New York	− 5	09:30	16:00	14:30	21:00
Toronto stock exchange (TSX)	Canada	Toronto	− 5	09:30	16:00	14:30	21:00
Mexican stock exchange (MSE)	Mexico	Mexico City	− 6	08:30	15:00	14:30	21:00
Bolsa de Valores de São Paulo (BVSP)	Brazil	São Paulo	− 3	10:00	17:30	13:00	20:00
Frankfurt stock exchange (FWB)	Germany	Frankfurt	1	08:00	20:00	07:00	19:00
European stock exchange (Euronext)	France	Paris	1	09:00	17:30	08:00	16:30
London stock exchange (LSE)	UK	London	0	08:00	16:30	08:00	16:30
Moscow exchange (MOEX)	Russia	Moscow	3	10:00	18:45	07:00	15:45
Casablanca stock exchange (CSE)	Morocco	Casablanca	0	09:00	15:40	09:00	15:40
Johannesburg stock exchange (JSE)	South Africa	Johannesburg	2	09:00	17:00	07:00	15:00
Nigerian stock exchange (NSE)	Nigeria	Lagos	1	09:30	16:00	09:00	15:00
Tunis stock exchange (TSE)	Tunisia	Tunis	1	09:00	14:10	08:00	13:10
Egyptian exchange (EGX)	Egypt	Cairo	2	10:30	14:30	08:30	12:30
Bourse Régionale des Valeurs Mobilières (BRVM)	WAEMU	Abidjan	3	09:00	15:00	06:00	12:00
Lusaka stock exchange (LuSE)	Zambia	Lusaka	2	11:00	14:00	09:00	12:00
Botswana stock exchange (BSE)	Botswana	Gaborone	2	10:30	13:30	08:00	11:00
Bombay stock exchange (BSE)	India	Mumbai	+ 5.5	09:15	15:30	03:45	10:00

Table 8 continued

World exchanges	Country	City	Δ	Local time		UTC	
				Open	Close	Open	Close
National stock exchange of India	India	Mumbai	+ 5.5	09:15	15:30	03:45	10:00
Stock exchange of Mauritius (SEM)	Mauritius	Port Louis	4	09:00	13:30	05:00	09:30
Hong Kong stock exchange (HKEX)	Hong Kong	Hong Kong	8	09:30	16:00	01:30	08:00
Shanghai stock exchange (SSE)	China	Shanghai	8	09:30	15:00	01:30	07:00
Tokyo stock exchange (TSE)	Japan	Tokyo	9	09:00	15:00	00:00	06:00

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