# A TREATISE ON FINANCIAL CRISES CONTAGION: THE CASE OF AFRICAN SECURITIES EXCHANGES

RODRIGUE S. C. DOSSOU-CADJA[1,2]
Department of Economics and Social Sciences, Sapienza University of Rome & Paris School of Economics (PSE)

RITA L. D'ECCLESIA
Department of Economics and Social Sciences, Sapienza University of Rome

We model the dynamics of African financial markets' behaviour, in the current global context of international financial integration. In a framework of financial idiosyncratic shocks that takes for reference the last 2008 global financial crisis (GFC), the continent's main financial market indices have been linked to those of a representative sample of developed countries. A dynamic panel Probit model shows the existence of a fundamentals-based contagion, which occurs from developed markets to African markets, through financial and commercial links, foreign exchange markets, and several domestic economic performance variables. A DCC-GARCH and SVAR detect some asymmetric dynamics in the conditional correlations of returns, between developed and African markets, which is hence an evidence of a psychological or pure contagion game. A determined rule setting policy by African monetary Authorities, should strengthen resilience of the continent's financial markets to contagion from developed markets disorders.

Keywords: African financial markets, developed markets, fundamentals- based contagion, pure contagion, financial shocks, dynamic panel Probit, DCC-GARCH, SVAR, rule setting policy

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1 Sapienza University of Rome (Italy), Department of Economics and Social Sciences, and Paris School of Economics (PSE, France), PhD Student.

Corresponding Email: rodrigue.dossoucadja@uniroma1.it / rita.decclesia@uniroma1.it / rodrigue.dossoucadja@psemail.eu

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## 1. Introduction

The latest (2008) financial crisis marked a real turning point. Africa in general, and sub- Saharan Africa in particular, has made remarkable progress over the past decade in terms of growth and economic stability. Growth, which is essential for social inclusion, has reached an average rate of more than 6% over the last five years, inflation has fallen to less than 10% before the rise in fuel and food prices in 2008 and reserves have been built up (IMF, 2015). These positive developments have been driven by strong economic policies, a favor- able external environment resulting mainly from rising commodity prices, debt relief and aid from the international community. This economic progress, the result of so much effort, has nevertheless been called into question. Indeed, just like the rest of the world, Africa has suffered the effects of the recent international financial crisis. African exports fell by 18.2% and 45.4% respectively between 2007-2008 and 2008-2009 (AfDB, 2009), commodity prices fell, and remittances from migrant workers dropped (IMF, 2015). Global credit crunch and investor risk aversion have led to a reversal of portfolio investment flows, have discouraged foreign direct investment (FDI) and have made trade finance more expensive. The slowdown in economic activity has also increased credit risk and unproductive debt and, as a result, has weakened the balance sheets of African financial institutions (IMF, 2009; IMF, 2015). As shown in Figure1, African financial markets were also severely affected:

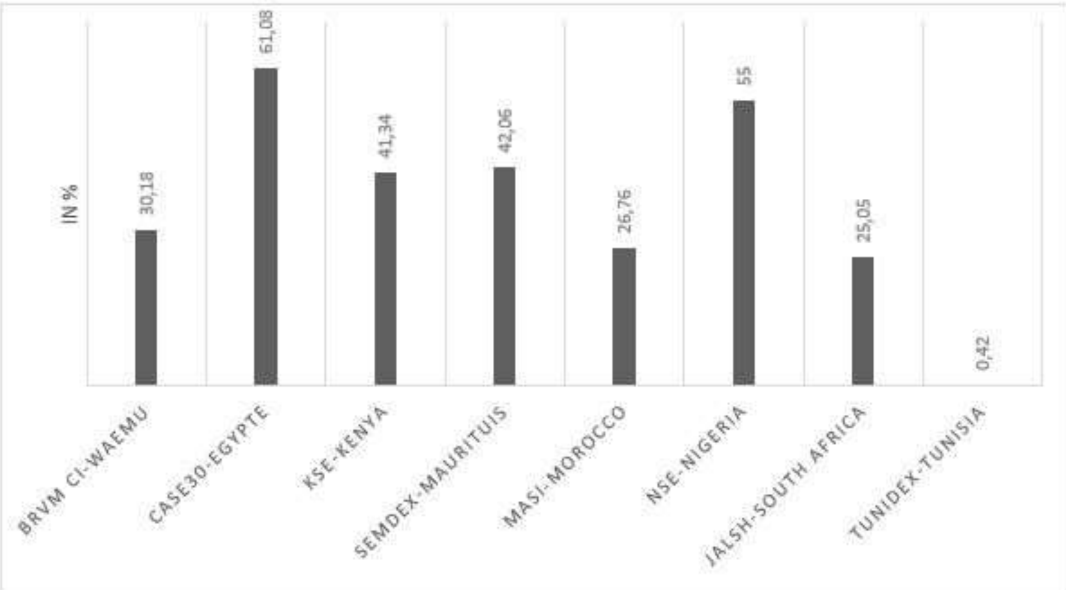


Figure 1. Losses in index points recorded by African financial markets be- tween 31/07/2008 and 13/02/2009; Source: AfDB, Department of Statistics, January 2009

The severity and magnitude of this 2008 financial crisis, as well as the speed of its spread across the world, raise concerns about the "contagion" phenomenon. Some of the main pe- culiarities of the contagion include that it spreads even to countries that have a healthy economic situation or limited commercial and financial links with the crisis-stricken country, and it generally generates significant social and economic costs, especially for countries with economies in transition that have limited means to prevent or cope with crises (Hemche, 2014). It is usually characterized by severe capital outflows, exchange rate pressures, rising interest rates, rising nominal and real exchange rate volatility, and a fall in stock values (Eichengreen and Rose, 1999), as is the case in Africa and shown in the figure above. In general, the phenomenon of contagion refers to the spread of a country's financial market disruptions towards the behavioral dynamics of other countries' financial markets. The theoretical literature identifies two main forms of contagion: a contagion that occurs through economic and financial links between countries ("fundamentals-based contagion" according to Kaminsky and Reinhart, 1999) and a psychological contagion characterized by the absence of economic links between countries ("pure contagion" according to Masson, 1999 or "shift contagion" according to Forbes and Rigobon, 2000). Thus, the economic and financial interdependencies between African and developed countries are a means of rapid transmission of financial shocks, because African financial markets, like those of developed and emerging countries, react immediately to "news". The international financial integration, which should also be a continent-wide integration, can then create an interdependence based on economic links, trust and the psychology of markets. The latter may trigger herd behaviors1. Recently, there has been a strong correlation between the confidence indices of the major industrialized countries as well as contagion effects between them, which justified the idea that trust could form a new basis for economic interdependence (Lahreche-Revil, 2003).

This paper deals with fundamentals-based contagion, and pure contagion which is characterized by the reaction of international investors following a crisis or a shock in another country. This later type of contagion has become more prominent amongst specialists in the field than the idea of a transmission via real links, even in the case of a strong commercial or financial interconnection. The rest of the paper is structured in seven sections. Section 2 presents a brief literature review around the concept of contagion. Section 3 is devoted to the presentation of the models as well as their estimation methods. Section 4 presents the data and variables, whilst Section 5 and 6 are respectively devoted to the analysis of fundamentals-based contagion and herd behaviours contagion on African financial. In Section 7, we provide some conclusions.

## 2. The Contagion Debate

Calvo and Reihnart, (1996) analyze contagion as "the transmission of a crisis to a particular country due to its real and financial interdependence with countries that are already experiencing a crisis". According to Eichengreen et al. (1996) contagion is "a systematic effect on the probability of a speculative attack which stems from attacks on other currencies, and is therefore an additional effect above and beyond those of domestic 'fundamentals' ". This definition is used in empirical works that try to model the occurrence of a crisis via the col- lapse of the exchange rate. In practice, this definition is adopted by countries that have experienced the crisis.

Another definition is also often used: "contagion occurs when volatility spills over from the crisis country to the financial markets of other countries". This definition analyzes volatility of financial markets by showing that the price volatility of financial assets increases during the period of financial disruption. Thus, this definition considers the rise in volatility as the determinant of the crisis. Therefore, contagion can be measured as the pass-through of this volatility from one market to another, that is, a prolongation of the uncertainty, on international financial markets.
These last two definitions study contagion in a general and very broad context, and they do not identify it in a precise way. In order to analyze contagion, the study period is divided into two sub-periods: the period of normality and the period of crisis. Park and Song (2001) identify contagion as "the spread of financial distress from one country to another. It is measured by the excessive co-movements of financial variables (such as exchange rates, stock prices and interest rates) in a given group of countries during a financial crisis".

"Contagion (shift contagion) occurs when the transmission channels change after a shock on the market". This definition explains that contagion is measured by identifying excessive co-movements in prices and quantities. This technique refers the outbreak of the crisis in the rest of the world to the significant increase in trans- mission mechanisms.

Another definition to better understand the last two and characterize contagion is as follows: "Contagion occurs when the co-movements are not explained by the fundamentals". According to Fratzscher (1999) "contagion is the transmission of a crisis that is not caused by the affected country's fundamentals (although, of course, the transmission has an impact on the country's fundamentals ex post) but by its 'proximity' to the country where a crisis occurred". This definition is used in models that investigate the existence of multiple equilibria when there is a coordination problem. Indeed, in this definition, the fundamentals cannot explain either the "timing" or the processes involved in transitioning from the good equilibrium to the bad one. "Contagion is a significant increase in the co-movements of the prices and quantities of financial assets across markets conditional on a crisis occurring in one market or a group of markets". This definition is very practical considering its quantitative dimension represented by the term "significant increase". It standardizes the concept of contagion to excessive co-movements. However, in a practical sense, it does not distinguish between excessive and normal co-movements in prices or quantities. So, a further attention is required on the type of co-movements.

Forbes and Rigobon (2001) propose. on these latter definitions and design their own definition which is much more used in contagion tests: "contagion is defined as a significant increase in cross-market linkages after a shock to an individual country (or group of countries)". They believe that "normal" periods and crisis periods are intrinsically different. Thus, the significant increase in the links between financial markets generates new transmission channels during the crisis period regardless of the fundamentals, which causes contagion. Favero and Giavazzi (2002) define contagion as a "significant change in the way that shocks are propagated across countries". Kaminsky and Schmukler (1999) defines contagion as the spread of investors' moods. Gochoco-Bautista (1999) defines contagion as the "spillover effects of domestic disorders in surrounding or affiliated economies". Masson (1999), on the one hand, emphasized the complementarity of self-fulfilling contagion (pure contagion) and fundamentals. On the other hand, he showed the existence of other mechanisms of propagation of financial crisis such as contamination through a competitive devaluation or a common shock (monsoonal effect). Forbes and Rigobon (2001) add the channel of financial links. Kaminsky and Reinhart, (2000) define a process of interdependence that allows the transmission of crisis in the context of a regional contagion. This interdependence can transmit local shocks (example: shock in a crisis-originating country) or global shocks through commercial or financial links. Dornbusch et al., (2000) consider this type of contagion in the strictest sense. It is sometimes called "fundamentals-based contagion" (Kaminsky and Reinhart, 2000). This alternative perspective to that of fundamentals holds that the recent financial disorders are mainly due to the commercial or financial interconnection of the affected economies with the crisis-originating country ('ground zero country'). Following the outbreak of a crisis in a first country, this interconnection often generates a high volatility of international capital movements, itself resulting from the change in the behavior of international investors as well as common creditors facing problems of risk and liquidity.
The scenario considered here (crisis caused by the spread), implies that the situation of a country affected by the crisis is not the determining cause. Crisis transmission from one country to another would tend to operate through the interdependence effect, that is, through mechanisms that do not depend on the fundamental characteristics of the affected economies. In sum, in the countries affected by this type of contagion, it is not the vulnerability of the economy that would provoke the crisis, but instead, transmission of the crisis would deteriorate their fundamentals (Hemche, 2014). Therefore, the mechanisms of interdependence or fundamentals-based contagion deal with common macroeconomic shocks whose spillovers are potentially global, and local shocks from one country to another neighboring country (of the region) transmitted through commercial links, third markets and financial links.

# 3. The Models

## 3.1. The Fundamentals-based Contagion Model.

To model the effect of the fundamentals-based contagion of the financial markets of developed countries on those of African countries, we used a regression model approach with dynamic binary dependent variable applied on balanced data panel, namely the Dynamic Panel Probit Model based on Caramazza et al. (2000, 2004), and Eichengreen et al. (1996) We introduce a dynamic lagged dependent variable in order to propose a dynamic model. Under the Efficient Markets Hypothesis (EMH) it would be impossible to beat the market. The EMH implies that stock returns be describe by Random Walk. Thus, limiting oneself to a static analysis of the dichotomous dependent variable would be a very restrictive assumption of the evolution of its latent variable which is the rate of return on the studied stock markets.

**Baseline Model**: Suppose we have $N$ financial markets on $T_i$ periods, and $(Y_i, t)$, $i = 1, 2, \ldots, N$ ; $t = 1, 2, \ldots, T$ , where $i$ denotes the financial market, and $t$ is the period, a discrete random variable defined by:

$$\tilde{Y}_{i,t} = \begin{cases} 1 \; if \; Y_{i,t} \geq 0 \\ 0 \; otherwise \end{cases}$$

with $Y^*_{i,t}$ a latent variable given by

$$Y^*_{i,t} = \theta^j Y^*_{i,t-1} + \beta^j X_{i,t} + \gamma^j Z_i + \alpha_i + \mu_{i,t} \quad (1)$$

with $\mu_{i,t} \sim N(\rho, \sigma^2)$.

In (1), $Y^*_{i,t}$ completely describes the unobserved behavior of financial market $i$ at time $t$ as a function of its lagged value $Y^*_{i,t-1}$, a vector of strictly exogenous time-invariant characteristics $Z_i$, and a vector of time-variant explanatory variables $X_{i,t}$. So $Y^*_{i,t}$ is indeed an indicator of the situation of financial market $i$ at time $t$, for example the daily market rate of return $i$. Also $\mu_{i,t}$ represents the normally distributed random disturbances $\beta^j$, $\theta^j$, and $\gamma^j$ are the parameter vectors to estimate, and $\alpha_i$ denotes a specific unobservable effect that accounts for the heterogeneity between the different financial markets in the sample. In the rest of the document, we ignore $Z_i$ for simplicity. Three methods have been suggested successively by Heckman (1981), Orme (1996), and Wooldridge (2002) for the estimation of regression models with dynamic binary dependent variable applied on panel data (particularly the Probit model in this case). Even if these three methods are similar with regard to the substance, their fundamental difference lies in the degree of simplicity and practicability of their algorithms. The method suggested by Heckman (1981) presents a very complex algorithm whose implementation requires a high level of programming knowledge, while the latter two present algorithms that are simpler to handle. For the practical estimation of the Dynamic Panel Probit model of fundamentals based contagion, we implemented on our data under WinRATS version 9.10, algorithms and estimation procedures described by Wooldridge (2002).

## 3.2. The Psychological or Pure Contagion Models DCC-GARCH and SVAR.

### *3.2.1. The DCC-GARCH*

The DCC model proposed by Engle (2002) involves two steps in the estimation of the conditional covariance matrix. In the first step, the variable volatility model consists in estimating the returns of the indices and the conditional variance obtained. In the second step, the residuals of the returns are transformed by their standard deviations estimated from the first step. The first part of the likelihood function in the equation represents the volatility, which is the sum of the individual probabilities of the GARCH model. In the first part, the log-likelihood function can be maximized with respect to the model parameters. Given the parameters estimated in the first step, the probability function in the second step, which contains the correlation parameters, can be maximized to estimate the correlation coefficients. The typical specifications underlying the conditional mean and the multivariate conditional variance of the returns are given as follows:

$$y_t = E(y_t|F_{t-1}) + s_t \qquad (2)$$

where $y_t = (y_{1,t}, \ldots, y_{m,t})^{j}$, $\eta_t = (\eta_{1,t}, \ldots, \eta_{m,t})^{j}$ is a sequence of independent and identically distributed (iid) random vectors, $F_t$ is past information available at time $t$, $D_t = \text{diag}(h^{1/2}, \ldots, h^{1/2})$, $m$ the number of returns, and $t = 1, \ldots, n$. The constant conditional correlation (CCC) model of Bollerslev (1990) assumes that the conditional variance of each return, $i = 1, \ldots, m$ follows a univariate GARCH process (see Engle (1982) and Bollerslev (1986),

$$h_{i,t} = w_i + \sum_{j=1}^{r} \alpha_{ij} \in_{i,t-j}^2 + \sum_{j=1}^{S} \beta_{ij} h_{i,t-j} \qquad (3)$$

where $\alpha_{ij}$ represents the ARCH effects or the short-term persistence of shocks to return $i$, and $\beta_{ij}$ represents GARCH effects or the impact of shocks to return $i$ on long run persistence, namely: $\sum_{j=1}^{r} \alpha_{ij} + \sum_{j=1}^{s} \beta_{ij}$

The conditional correlation matrix of CCC is $\Gamma = E(\eta_t\eta_t^{j}|F_{t-1}) = E(\eta_t\eta_t^{j})$, where $\Gamma = \{ Q_{ij}\}$ for $i, j = 1, \ldots, m$. From (2), $s_t s_t^{j} = D_t\eta_t\eta_t^{j} D_t$, $D_t = (\text{diag}Q_t)^{1/2}$, and $E(\eta_t\eta_t^{j}|F_{t-1}) = Q_t = D_t\Gamma D_t$, where $Q_t$ is the conditional covariance matrix. The conditional correlation matrix is defined as $\Gamma = D_t^{-1}Q_tD_t^{-1}$, and each conditional correlation coefficient is estimated from the standardized residuals in (2) and (3). As such, there is no multivariate estimation involved for CCC, except in the calculation of conditional correlations. Although the CCC specification in (3) is a computationally simple multivariate GARCH model, it assumes independence of conditional variances between returns and does not take into account asymmetric behavior. To account for interdependences, Ling and McAleer (2003) proposed a VARMA specification for the conditional mean in (2) and the following specification for the conditional variance:

$$H_t = W \sum_{i=1}^{r} A_i \vec{\epsilon}_{t-i} + \sum_{j=1}^{s} B_j H_{t-j} \qquad (4)$$

where $H_t = (h_{1t}, \ldots, h_{mt})^{j}$, $\dot{s} = (s^2, \ldots, s^2)^{j}$, and $W, A_i$ for $i = 1, \ldots, r$ and $B_j$ for $i = 1, \ldots, s$ are $m \times m$ matrices. As in the univariate GARCH model, VARMA-GARCH assumes that negative and positive shocks have identical impacts on the conditional variance. To account for asymmetric impacts of positive and negative shocks, Chang et al. (2002) proposed the VARMA-AGARCH specification for the conditional variance, that is:

$$H_t = W + \sum_{i=1}^{r} A_i \vec{\epsilon}_{t-i} + \sum_{i=1}^{r} C_i I_{t-i}\vec{\epsilon}_{t-i} + \sum_{j=1}^{s} B_j H_{t-j} \qquad (5)$$

where $C_i$ are matrices $m \times m$ for $i = 1, \ldots, r$ and $I_t = \text{diag}(I_{1t}, \ldots, I_{mt})$. where

$$I_{it} = \begin{cases} 0 \; if \; \epsilon_{it} \geq 0 \\ 1 \; otherwise \end{cases}$$

If $m = 1$, then (5) becomes the asymmetric GARCH model or Glosten's GJR, Jagannathan and Runkle (1992). The parameters of models (2), (3), (4) and (5) are typically obtained by maximum likelihood estimation (MLE) using a common normal density,

(6) $\hat{\theta} = arg \min_{\theta} \frac{1}{2} \sum_{i=1}^{n} (\log|Q_t| + \epsilon_t' Q_t^{-1} \epsilon_t)$

where $\theta$ denotes the vector of parameters to be estimated in the conditional log-likelihood function, and $|Q_t|$ denotes the determinant of $Q_t$. When $\eta_t$ does not follow a common multivariate normal distribution, equation (6) is defined as Quasi-MLE (QMLE). When the number of returns is $m = 1$, the univariate equivalent of (2) becomes GARCH (1,1): $\epsilon_t = \eta_t \sqrt{h_t}$

(7) $h_t = \omega + \sum_{j=1}^{r} \alpha_j \epsilon_{t-j}^2 + \sum_{j=1}^{s} \beta_j h_{t-j}$

where $\omega > 0$, $\alpha_j \geq 0$ for $j = 1, . . . , r$ and $\beta_j \geq 0$ for $j = 1, . . . , s$ are sufficient to ensure that the conditional variance $h_t > 0$. Since (7) can be written as an infinite expansion in $\epsilon_{t-j}^2$, a univariate GARCH (1,1) model is also known as an ARCH ($\infty$) model. Equation (7) assumes that a positive shock ($\epsilon_t > 0$) has the same impact on the conditional variance $h_t$ as a negative shock ($\epsilon_t < 0$). To account for differential impacts on the conditional variance between positive and negative shocks, Glosten et al. (1992) proposed the following specification for $h_t$:

(8) $h_t = \omega + \sum_{j=1}^{r} \left(\alpha_j + \gamma_j I(\epsilon_{t-j})\right) \epsilon_{t-j}^2 + \sum_{j=1}^{S} \beta_j h_{t-j}$

Which is a special case of (5), where $r = s = 1$, $\omega > 0$, $\alpha_1 \geq 0$, $\alpha_1 + \gamma_1 \geq 0$ and $\beta + 1 \geq 0$ sufficient conditions to ensure that the conditional variance $h_t > 0$. The short-term persistence of positive (negative) shocks is given by $\alpha_i$, $(\alpha_i + \gamma_i)$. When the conditional shocks $\eta_t$ follow a symmetric distribution, the expected short-term persistence is $\alpha_1 + \gamma_1/2$ and the contribution of shocks to the expected long-term persistence is $\alpha_1 + \gamma_1/2 + \beta_1$

Another specification that takes into account the asymmetries between positive and negative shocks is Nelson's EGARCH model (1991), namely:

(9) $\log h_t = \omega + \sum_{i=1}^{p} \alpha_i |n_{t-1}| + \sum_{i=1}^{p} \gamma_i n_{t-i} + \sum_{j=1}^{p} \beta_j \log h_{t-j}$

The DCC Model is given by:

(10) $Z_t = (1-\theta_1-\theta_2)\bar{Z} + \theta_1\eta_{t-1}\eta_{t-1}' + \theta_2 Z_{t-1}$

Where the second term in (10) is singular, and $\theta_1$, $\theta_2$ are scalar parameters. When $\theta_1 = \theta_2 = 0$, $\bar{Z}$ in (10) is equivalent to the CCC model. Since $Z_t$ in (10) is conditional on the vector of standardized residuals, (10) would be the conditional covariance matrix, and thus also the conditional correlation matrix if $\eta_t$ were a vector of independent and identically distributed random variables. However, there is no discussion of the properties of the development of the DCC model (although Engle (2002, p. 342) states that "**errors are a martingale difference by construction**" by suggesting how to estimate the model). Since (10) does not satisfy the definition of a conditional correlation matrix, Engle (2002) calculates the appropriate dynamic conditional correlation matrix as follows:

(11) $\Gamma_t^* = \left((diagZ_t)^{-1/2}\right)Z_t\left((diagZ_t)^{-1/2}\right)$

### *3.2.2. The SVAR*

The Sims (1980) VAR process in canonical representation could take the form of a VMA ($\infty$) process, and can even take the form of a structural VAR. Let Wt be the vector of structural shocks. These are economically interpretable shocks. We assume that the economy is represented by a vector of observable series $X_t = (X_{1t}, \ldots, X_{Nt})$. Each date $t$ is the result of the dynamic combination of $N$ past structural shocks $W_{1s}, \ldots, W_{Ns}$, $s \leq t$. The structural VAR representation is derived from the canonical VAR representation, assuming that the vector of canonical innovations $\epsilon_t$ is a linear combination of the structural innovations $W_t$ of the same date: $\epsilon_t = P W_t$ where $P$ is a change of basis matrix (invertible and of dimension $N \times N$) which must be estimated.

We consider the following canonical representation:

$$X_t = \sum_{i=1}^{p} \phi_i X_{t-i} + \epsilon_t$$

and one premultiplies the two sides by the matrix $\hat{p}^{-1}$ ($\hat{p}$ which is an estimator of P),

$$\hat{p}^{-1}X_t = \hat{p}^{-1}\sum_{i=1}^{p} \phi_i X_{t-i} + \hat{p}^{-1}\epsilon_t$$

which can also be written as :

$$X_t = X_t - \hat{p}^{-1}\sum_{i=1}^{p} \hat{p}^{-1}\phi_i X_{t-i} + \hat{p}^{-1}\epsilon_t$$

The expression of the structural VAR process is then written as follows:

$$X_t = \sum_{i=0}^{p} \phi_i X_{t-i} + \phi_t$$

with $\varphi_t = \hat{p}^{-1}s_t\varphi_0 = 1-\hat{p}^{-1}$, and $\varphi_i = \hat{p}^{-1}\varphi_t$ for $1 \leq i \leq p$. It can be seen that the estimation of the structural VAR model is based on the identification and estimation of realized shocks, since it is possible to go from estimated shocks to (economically interpretable) structural shocks by $\hat{W}_t = \hat{p}^{-1}s_t$ if the shocks have been correctly identified and their effects are significant and in line with the theory, then the economic interest of the impulse analysis is that it makes it possible to measure and anticipate the effects of an economic policy.

# 4. Data and Variables

## 4.1. Fundamentals-based Contagion Model.

### *4.1.1. Variables*

*** The dependent variable of our Dynamic Panel Probit model of contagion**

According to the perspective of the speculative composite market index of Caramazza et al (2000), we chose as speculative index on the financial markets in this study, the rates of return $R_{it}$ of the studied markets which are calculated as follows:

$$R_{it} = 100 \times \left(\frac{I_{i,t} - I_{i,t-1}}{I_{i,t-1}}\right)$$

with $I_{i,t}$: Stock index of market $i$ on day $t$[3], and $I_{i,t-1}$: Stock index of market $i$ on day $t-1$.

The financial markets that experienced crisis during the subprime crisis of 2007-2008 are identified as those having suffered a pressure on their rate of return, and this pressure is defined as exceeding a certain specific threshold during a period of 6 months from the start date of the subprime crisis (set at August 2007). During this period, at least one market of the sample suffered a significant depreciation of its rate of returns. The threshold is set at 1.645 times the combined standard deviation $\sigma$ of the calculated individual rate of return, plus the common average of the rates of return, so that for the entire panel sample of 21 stock markets, at least 5% of the values built around the fixed threshold are statistically higher than the monthly rates of return if these values are normally distributed[4]. Compared to this threshold, approximately 64% of the sample markets experience pressure on their rates of return in the average of six months after the onset of the subprime crisis in 2007. Thus, the dependent variable of fundamentals-based contagion in this study, named CONT, is formally expressed as follows:

$$CONT_{i,j} == \begin{cases} 1 \ if \ TIM_{it} = f(R_{it}) > 0 \\ 0 \qquad\qquad otherwise \end{cases}$$

The implementation of this method of building the dependent variable *CON T* was carried out with an algorithm developed with *R* version 3.3.1.

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***The explanatory variables**:

The phenomenon of fundamentals-based contagion occurs either through common shocks (Monsoonal effect) to the markets concerned (Forbes and Rigobon, (2000); Masson, (1998)), or through commercial links or third-party markets (Dornbusch and Ali (2000), Gerlach and Smet (1995), IMF (1999)), or through **financial links** (Van Rijckeghem and Weder (1999), IMF, (1999), Goldfajn and Valdesn, (1997), Kaminsky and Reinhart, (2000), Pritsker, (2000), etc.) To represent each of these possible channels, we chose the following explanatory variables:

- **The Financial Fragility Ratio (RFF)**: it is defined by the ratio of the short- term foreign debt to total foreign currency reserves. This ratio measures the inadequacy of a country or region's international reserves to withstand speculative attacks against its currency. This ratio is a benchmark indicator for Central Banks and is also widely used in the analyses of the IM, (Caramazza et al (2000)).
- **The real exchange rate in US$ (TCD)**: Eichengreen et al., (1996), Caramazza et al (2000, 2004) use it to represent financial links in contagion analysis.

[3] The stock indexes are collected from the Internet (Yahoo Finance, African- market.com, Johannesburg Stock Exchange, Investing.com) in US dollars to eliminate all problems associated with exchange rate fluctuations

[4] Indeed, this approach helps highlight a statistical significance for the occurrence of monetary crises in the sample countries during the period.

- **The growth rate of exports (TX)**: this is our commercial link variable. It is widely used in the empirical literature to represent commercial links in the analysis of fundamentals-based contagion.
- **The current account balance as a % of GDP (CCP)** : it captures the external sector of the economy. We use it as a secondary variable of commercial links in a similar manner to Caramazza et al (1996, 2000).
- **The lagged pressure on the rate of return (TIM1)**: we built it from the monthly data on the stock indices, according to the method of the IMF (Caramazza et al, 2000). This variable is the one that brings a dynamic into our panel Probit model.
- **The inflation rate (TINF): we use it as a monetary control variable in the model**. This approach is very common in the empirical literature on financial links between economies;
- **The GDP growth rate (TPIB)**: it captures the situation of the economy's real sector. We use it as a control variable in our model, just as it is used in the empirical literature on the analysis of fundamentals-based contagion.

#### *4.1.2. The Data*

The data used in this part are parted by Yahoo Finance, African-markets.com, Investing.com and the Johannesburg Stock Exchange (JSE). We select daily data on indices from January 1, 2005 to September 10, 2017, for 17 most significant African financial markets (South Africa, Egypt, Botswana, WAEMU, Nigeria, Kenya, Zambia, Zimbabwe, Ghana, Malawi, Mauritius, Morocco, Namibia, Rwanda, Tanzania, Uganda, Tunisia), and 7 financial markets of developed countries (United States of America (USA, Dow Jones 30), United Kingdom (UK, FTSE 100), Japan (NIKKEI 225), France (CAC 40), Italy (MIB 30), Germany (DAX), Spain (IBEX 35)). Due to the statistical processing problems related to the bad structuring of the daily format of these data on stock indices, we were obliged, to use their monthly averages over the period from January 2005 to December 2016[5], and also to discard three markets (Egypt, Zimbabwe and Ghana).

The rest of the data in this section come from the World Bank's World Development Indicators (WDI), the World Economic Outlook (WEO), the International Financial Statistics (IFS) of the International Monetary Fund (IMF), and of the FRED (Federal Reserve Bank of St. Louis). The annual data cover the period from 2005 to 2016. The following table provides a more concise summary of the variables and data sources.

[5] So we have a total of 144 first-degree observations on stock indices per market

Table 1. Summary of the study's variables and data sources (Source: Our works)

| Dependent variable Contagion (CONT) | | | |
|---|---|---|---|
| Independent variables | Notation | Sources | Expected signs |
| Time Pressure on the Rate of Return of the stock market (lagged latent variable) | TIM {1} | JSE Indices, Internet, FRED | + |
| Annual GDP growth rate | TPIB | WEO | − |
| Inflation rate (per year) | TINF | IFS | + |
| Current Account Balance as % of GDP | CCP | WEO | + |
| Effective Exchange Rate for 1 US$ | TCD | IFS | |
| Annual growth rate of exports | TX | WEO | − |
| Financial Fragility Ratio | RFF | WEO, IFS & FRED | |

### 4.2. Pure Contagion Model.

To estimate the pure contagion model, we work with weekly stock indices on the period from January 2005 to December 2016, a total of 653 weekly quotes per market. From these we calculate the weekly returns:

$$R_{it} = 100 \times \left(\frac{I_{i,t} - I_{i,t-1}}{I_{i,t-1}}\right)$$

with $I_{i,t}$: Stock index of market $i$ on week $t$, and $I_{i,t-1}$: Stock index of market $i$ on week $t-1$, and $R_{it}$: Return of market $i$'s stock index in week $t$. The main indices of the 14 African financial markets are as follows: BSE Domestic All Shares (Botswana), TUNIDEX (Bourse de Tunis), BRVM-10 (Bourse Régionale des Valeurs Mobilières: Ivory Coast-Benin- Burkina Faso-Mali-Niger-Senegal-Togo-Guinea-Bissau i.e. WAEMU), MASI (Morocco), Tanzania All Shares (Tanzania), FTSE/JSE 40 (South Africa), LSE (Zambia), Malawi SE (Malawi), RSE (Rwanda), Nairobi SE (Kenya), Namibian SE (Namibia), Nigerian SE (NSE), SEMDEX (SE of Mauritius), USE (Uganda).

We perform a principal component analysis (PCA) on all the indices collected for the 14 African markets in order to eliminate the multi-consideration of the strongly correlated indices of the DCC-GARCH model, and thus eliminate the issues of multicollinearity bias. The weekly rates of return of African financial market indices are introduced in a DCC- GARCH model along with those of the seven (7) developed country markets of the sample. This period is divided into three sub-periods:

1. Before the Subprime Crisis: from 1/5/2005 to 7/31/2007
2. Crisis period: from 8/1/2007 to 12/31/2011
3. Post Crisis period: from 1/1/2012 to 9/10/2017

The first period includes 120 observations, while the second contains 230 observations per market and the third period has 298 observations for each market. We estimate the DCC-GARCH and SVAR models.

## 5. Fundamentals-based Contagion on African Financial markets

Figure 2 below shows that more than 64% of all the studied stock markets (African markets and developed markets) experienced episodes of strong pressure on their rates of return after the onset of the subprime financial crisis in August 2007. This is particularly interesting and it increases curiosity as to what is the fundamental channel through which the transmission of the subprime shock occurred between developed and African markets.

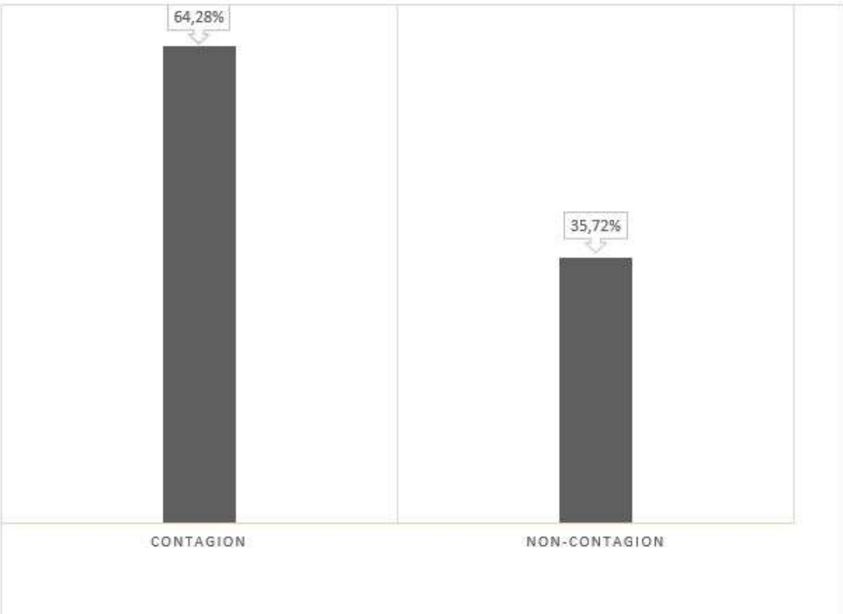



Figure 2. Distribution of the panel around the binary dependent variable CONT (Source: Our works)

The following Table 2 summarizes the estimations.

The estimated model 1 with fixed effects is preferred to models 2 and 3 following Hausman (1978)'s specification tests.

### 5.1. The Effect of the Past

The significance of the lagged latent variable TIM 1 in the model reflects the reality that the series of returns on the financial markets follow an AR(1) process. This result is consistent with the EMH which models returns in using an AR (1) model, and in particular the random walk. The negative sign of the coefficient of the lagged latent variable simply shows that the occurrence at a given date of fundamentals- based contagion on an African financial market is largely determined by the previous level of the pressure on rates of returns that it would have suffered: markets which suffered strong pressure on their returns in the past have a lower probability of fundamentals-based contagion. In contrast, those that experienced less pressure on their returns in the past have a higher probability of experiencing fundamentals-based contagion. This result means that African financial markets have a positive reaction to the fundamentals-based contagion of developed markets: this is a new empirical result.

Table 2. Results of the estimation of the Dynamic Panel Probit Model of fundamentals-based contagion (CONT)—Source: Our estimations under Win- RATS 9.10

| **Binary dependent variable: CONT** | | | |
|---|---|---|---|
| Variables | Model 1 | Model 2 | Model 3 |
| Cons__ | 0.0000*** (0.000) | −0.2704 (0.278) | 0.7649** (0.020) |
| TIM{1} | −0.0013*** (0.000) | −0.0008*** (0.002) | 0.0025*** (0.000) |
| TPIB | 0.0251** (0.025) | 0.0304*** (0.005) | 0.0792*** (0.050) |
| TINF | 0.0010 (0.866) | 0.0027 (0.658) | −0.0090 (0.692) |
| TX | 0.0004 (0.834) | −0.00000 (0.998) | 0.0036 (0.705) |
| CCP | 0.0231*** (0.000) | 0.0201*** (0.001) | 0.0460*** (0.010) |
| TCD | −0.0003*** (0.007) | −0.0003** (0.013) | −0.0002 (0.223) |
| RFF | 0.0075** (0.020) | 0.0041 (0.133) | 0.0049* (0.106) |
| Pseudo-$R^2$ | 0.66 | 0.45 | 0.28 |
| Significance | Prob LR = 0, 000 | Prob LR = 0.035 | Prob $LR$ = 0,000 |
| Obs : 252; Usable Obs :; Panel (12) : 21//12 | 231 | 231 | 231 |

****Significant at 1% level **Significant at 5% level * Significant at 10% level*

### 5.2. Signs of Coefficients

The estimated model 1 reveals a positive sign for all significant variables, except for the exchange rate (TCD) which displays a negative sign (Table 2). Thus, any increase in the growth rate of the economy, the financial fragility ratio, the current account balance, as well as any appreciation of the currency will increase the likelihood of fundamentals-based contagion from developed markets to African financial markets. Indeed, everything happens as if, respectively the rise of one of these variables or the appreciation of the currency, is likely to reinforce the validity of the transmission channel of fundamentals-based contagion represented by the variable in question. Thus, the reduction of the risk of fundamentals-based contagion of African financial markets by developed markets, in the event of financial crisis, is essentially conditional on the stability of the economy's growth rate, the ratio of financial fragility, the current account balance and the exchange rate.

The significance of the variables TPIB, CPP, TCD, RFF reveals that it is the domestic economic performance (TPIB), the situation of the external sector, notably the current account balance (CPP), the level of transactions on the foreign exchange market (TCD), the capacity of African economies to counter speculative attacks on their respective currencies, ie the degree of financial fragility of African economies (RFF), that determine the vulnerability of their financial markets to the fundamentals-based contagion of financial shocks from developed markets. The current account is the non-financial account of the balance of payments, which accounts for all non-financial exchanges between a country and the outside world. It includes the transactions on goods and the exchange of services; the difference between exports and imports of goods and services called Balance of goods and services, factor incomes (wages of employees and investment income) and current transfers. Its balance referred to here (CC) is given by the sum of the balance of goods and services ($X - M$), net factor income (RFN), and net transfer(TRN) (Manga Akoa, 1998). So we have: $CC = (X - M) + RFN + TRN$ . The empirical significance of the current account balance as a percentage of GDP (CCP) revealed by the estimated Model 1, reflects that non-financial trade with the outside, which is another measure of trade links between a country and the rest of the world, are a channel of international transmission of financial shocks from developed financial markets to those of Africa. This result is evidence that there is indeed a fundamentals-based contagion of financial shocks from developed financial markets to African financial markets, and this occurs through commercial links. Also, the significance of the financial fragility ratio (RFF) and the exchange rate (TCD) attest to the validity of the financial link channel when it comes to the fundamentals-based contagion experienced by African stock markets.

### 5.3. The Actual Transmission Mechanism

Despite the validity of the commercial link channel, the non-significance of the annual export growth rate (TX) in the estimated fundamentals-based contagion model is interpreted as follows: it is not only exports that are the determinants here, but rather the trade balance (that is, the combined effects of the annual change in exports and imports), or the general level of current transactions. This result is in line with the theoretical work of Manga Akoa (1998), which shows that there are interrelations between the four different types of macroeconomic accounts, namely the real sector accounts (Production), the external sector accounts (Balance of payments), the monetary situation (change in reserves, net domestic credit, money supply), and the public finance accounts (Table of Government Financial Operations, TOFE). Indeed, Manga Akoa (1998) shows that a shock on the external sector accounts, especially on current transactions (CC) for example, will have an automatic impact on the real sector through national savings and global investment, that is, the level of public and private investment and savings, and then will be transmitted to Government accounts through disposable income and public sector consumption and investment expenditures. The effects of such a shock will also affect the monetary situation at the Central Bank, including the level of reserves through the variation in net foreign assets, which are nothing other than the sum of the current account balance (equal to the gap between national savings and global investment) and capital movements (assuming that errors and omissions are zero). Henceforth, a financial shock triggered in a developed market affects the general level of the current transactions of African economies, destabilizes the real sector and the state financial position of these economies (significance of GDP growth rate, TPIB), and is then transmitted to the money market (destabilizing the monetary situation) through a decrease in net foreign assets. This decrease in net foreign assets, as a consequence, leads to a loss of international reserves, which reinforces the financial fragility of the African economy, that is, reinforces the inadequacy of the international reserves of the economy to counter a speculative attack against its currency: this activates the channel of financial links for the transmission of the shock (significance of the financial fragility ratio, RFF), and the foreign exchange market also receives the shock (significance of the exchange rate in dollars, TCD). Consequently, since such a financial shock, triggered on a developed market, imbalances the goods and services market (induced effects of current transactions), the labor market (induced effects of the real sector), the money market (monetary situation), the foreign exchange market (loss of reserves, financial fragility) of African economies, this imbalance is thus trivially transmitted to their stock markets (securities markets), is similar to a Walras'law[6] . Moreover, the interrelations between the various macroeconomic accounts found in our estimation results reflect that it suffices that only one of the detected channels be activated (the current account channel for example) for all others to also be activated one after the other: **there is thus a wake-up effect** that multiplies the probability of occurrence of a fundamentals-based contagion. Figure3below summarizes the mechanism of

[6]Since Walras's law, based on his theory of general equilibrium, states that "if there are n markets in the economy, and (n -1) markets are in equilibrium, then the $n^{th}$ market is in equilibrium", we think here that if there is disequilibrium on $n - 1$ markets, then there is disequilibrium on the $n^{th}$ market

fundamentals-based contagion in African financial markets.

To strengthen the resilience of their financial markets to the international transmission of financial shocks from developed markets, African economies as a whole have every interest in maintaining all the potential channels detected here in a stable interval: those are the GDP growth rate, the exchange rate, the financial fragility ratio and the current account balance. This means that the excessive upward or downward fluctuations of these variables have disastrous effects. Indeed, the excessive upward fluctuations of one of these variables (appreciation in the case of the exchange rate) affect all other variables in the same way (by virtue of the interrelations between the macroeconomic accounts), which multiplies the probability of occurrence of fundamentals-based contagion in African financial markets. This risk, when it occurs, destabilizes operations on the financial markets, and the destabilizing effects created are transmitted from the financial markets to the real economy, **which can lead to a recession**. In contrast, any uncontrolled decline in one of these variables (depreciation in the case of the exchange rate) is certainly favorable to the non-occurrence of fundamentals-based contagion on the financial markets, but will create in the medium-to-long term a recession without transiting through the stock markets, which will subsequently be affected. This means that in all cases, the favorable scenario is the stability of these variables.

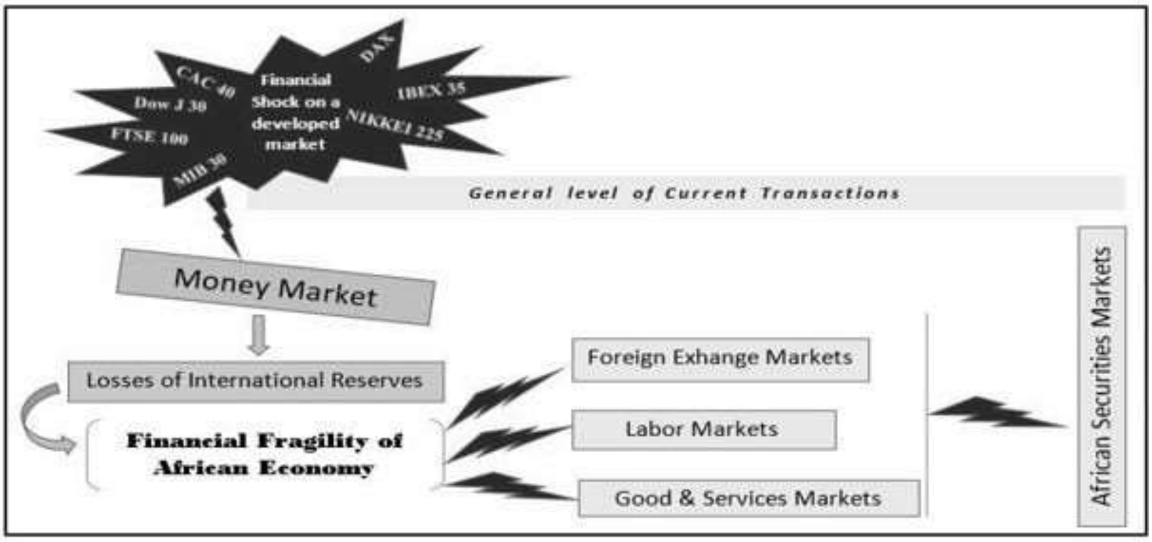



Figure 3. Mechanism of fundamentals-based contagion on African financial markets (Source: Authors)

## 6. Psychological Contagion on African financial markets

The analysis of Figure 4 reveals, on the one hand, that the average correlation coefficients of market rates of return increased during the period of subprime crisis, before falling again during the post-crisis period, whether between developed countries, or between the US market and African markets, the French (European) market and African markets, or be- tween the Japanese market and African markets. This is an indicator of the actual existence of a ”Dynamic Conditionnal Correlation” between developed and African markets, i.e. the confirmation of the ”pure contagion” hypothesis presumption. The estimation of the DCC- GARCH model will enable us to econometrically test this hypothesis. On the other hand, the analysis of Figure 4 shows that over the study period, the average correlations of returns between the markets of developed countries are much stronger (0.64 to 0.77) than the average correlations between developed markets and African markets (0.06 to 0.22). While developed countries are experiencing strong financial integration, most African countries (with the exception of emerging markets such as South Africa, Morocco, Tunisia and Egypt) are virtually

disconnected from the financial circuit.
To have a more accurate analysis, we estimate of the DCC-GARCH and the SVAR models. (Table 3) presents the estimations of the equations of the returns and conditional variance for the different markets concerned.

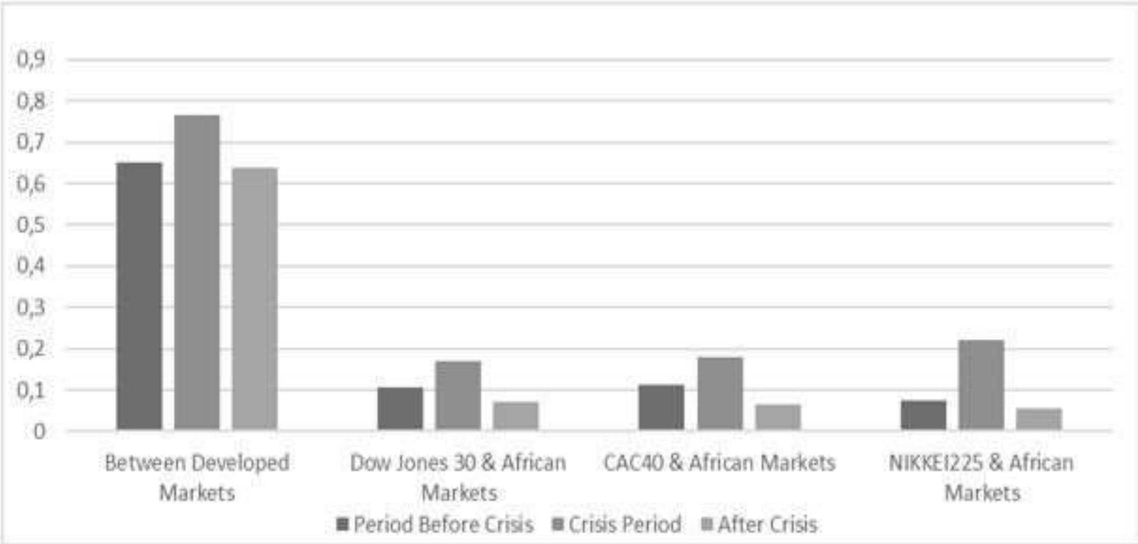



Figure 4. Dynamics of the average correlations of the rates of return between the studied financial markets (Source: Author)

The AR term ($Y_{t-1}$), the stock market return at time $(t-1)$ in the equation of returns, is generally significantly positive for African markets and significantly negative for developed markets. This result is in line with the elements stated in the theoretical literature. Indeed, the AR term is positive for emerging markets due to price fluctuation or partial adjustment, while it is negative for advanced markets due to positive market reaction. However, this term is not significant for South Africa, Japan and Germany. So we can say that these three markets are markets with almost no memory: these are very risky markets, even for the super forecaster. In the variance equations, the terms of the squared lagged residuals ($s^2{it-1}$) and the lagged conditional variance ($h_{it-1}$) are very significant (even at the 0.1% threshold), for all developed markets and all African markets (except for to African markets other than South Africa, for which only the conditional variance is not significant). This situation is consistent with the theory of volatility on financial markets and validates the choice of the GARCH specification. Moreover, the combination of this result with that of returns reveals that the South African, German and Japanese (Asian by extension) stock markets are markets without memory and more than risky. We note that the sum of the estimated coefficients (see last column) in the variance equation (B+ D), is close to one (or exceeds one, that is, statically equal to one) for all cases, which implies that volatility is very persistent on both developed and African stock markets. It would now be appropriate to proceed in a second step to the estimation and testing of dynamic conditional correlations between developed and African markets as shown in Figure 5.
AFIX is the variance-covariance matrix of standardized residuals (equations of returns), and BFIX is the unconditional variance-covariance matrix (equations of variances). GFIX is the change of basis matrix of Engle et al. (2006) which reflects the hypothesis of asymmetry in the estimated dynamic correlations. The estimation output above shows that all the estimated coefficients are statistically significant (at the 0.1% threshold) and positive for the AFIX, BFIX and GFIX variables, in both the DCC and ADCC models. This is the empirical confirmation of the hypothesis of existence of pure contagion effects between African financial markets and developed financial markets.

Table 3. Results of the first-step estimation of the GARCH(1,1) models (Source: Our estimations under WinRATS 9.10)

| | Equation of the return | | Equation of the variance | | | |
|---|---|---|---|---|---|---|
| $Y$ = INDEX | $\varphi$ = MEAN($Y$) | $A$ = coeff($Y_{t-1}$) | $C$ = Cons | $B$ = coeff($s^2_{it-1}$) | $D$ = coeff($h_{it-1}$) | Persistence = $B+D$ |
| RSA40<br>Prob → | 0.1911**<br>0.024 | 0.0129<br>0.586 | 0.3019**<br>0.015 | 0.8552***<br>0.000 | 0.1775***<br>0.000 | 1.0327 |
| BSE<br>Prob → | 0.1795***<br>0.000 | 0.5089***<br>0.000 | 0.1833***<br>(0.000) | 0.4397***<br>0.000 | 0.1371<br>0.288 | 0.5768 |
| NSE20<br>Prob → | 0.1086<br>0.218 | 0.2296***<br>0.002*** | 0.8896***<br>(0.001) | 0.6027***<br>0.000 | 0.0722<br>0.336 | 0.6749 |
| SEMDEX<br>Prob → | 0.0114<br>0.218 | 0.0820<br>0.000 | 0.1001**<br>0.040 | 0.9114***<br>0.000 | 0.0144<br>0.501 | 0.9258 |
| MASI<br>Prob → | 0.1313**<br>0.045 | 0.1769***<br>0.000 | 0.2553***<br>0.005 | 0.7572***<br>0.000 | 0.0000<br>0.999 | 0.7572 |
| TUNIDEX<br>Prob → | 0.2739***<br>0.000 | 0.0794**<br>0.020 | 0.1662***<br>0.000 | 0.8310***<br>0.000 | 0.0378<br>0.336 | 0.8688 |
| Uganda AS<br>Prob → | 0.3028**<br>0.024 | 0.0926**<br>0.014 | 1.2720***<br>0.001 | 0.7409***<br>0.000 | 0.1356***<br>0.006 | 0.8765 |
| CAC40<br>Prob → | 0.0615<br>0.500 | −0.0691***<br>0.000 | 0.5460***<br>0.000 | 0.8138***<br>0.000 | 0.3766***<br>0.000 | 1.1904 |
| DAX<br>Prob → | 0.2186**<br>0.021 | −0.0269<br>0.4747 | 1.0462***<br>0.000 | 0.6823***<br>0.000 | 0.4498***<br>0.000 | 1.1321 |
| DowJ30<br>Prob → | 0.1301**<br>0.044 | −0.0325*<br>0.108 | 0.2964***<br>0.000 | 0.7837***<br>0.000 | 0.3651***<br>0.000 | 1.1488 |
| IBEX35<br>Prob → | 0.0855<br>0.4232 | −0.0663***<br>0.000 | 0.3296***<br>0.000 | 0.9090***<br>0.000 | 0.2334***<br>0.000 | 1.1424 |
| NIKKEI225<br>Prob → | 0.1701**<br>0.108 | −0.0215<br>0.559 | 1.8180***<br>0.000 | 0.6017***<br>0.000 | 0.4197***<br>0.000 | 1.0214 |

****Significant at 1% level **Significant at 5% level *Significant at 1% level*

The significance of the coefficient of the asymmetry matrix GFIX of Engle et al. (2006) in the ADCC model reveals the asymmetry in the dynamic conditional correlations between African and developed markets: the dynamic conditional correlations are not reciprocal, they are transmitted in one direction only. This result clarifies the direction of the pure contagion existing between stock markets of developed and African countries: Either it is the developed markets that automatically transmit their volatilities to African markets, or the opposite, but not both directions. Economic theory shows that pure contagion goes from developed markets to emerging markets. It is ultimately the estimation of the structural VAR model that will allow us to empirically rule on the question of pure contagion direction between the market groups involved. The results of the Granger causality tests are reported in Table 4 to make the test results simple to read, we use the "+" and "–" notations. "+" means that a variable $Y$ (row) Granger causes a variable $X$ (column) (rejection of $H0$, $p$-value $< 5\%$) and "–" means that $Y$ does not Granger cause $X$ (no rejection of $H0$). Each of the developed markets Granger causes at least four African markets in the sample (with the exception of the Japanese market which causes only two African markets: Kenya and Tunisia). Conversely, apart from the Johannesburg Stock Exchange (JSE, South Africa), which causes the French, German and American markets, no African market causes a developed market. The South African market is the first and only real African economic power.

```
Two-step DCC - Estimation by BFGS
Convergence in    28 Iterations. Final criterion was  0.0000003 <=  0.0000100

Weekly Data From 2005:04:24 To 2017:09:10
Usable Observations                       647
Function Value                    -14948.7912

    Variable                        Coeff      Std Error      T-Stat      Signif
********************************************************************************
1.  AFIX                         0.1251173863 0.0281307345      4.44771  0.00000868
2.  BFIX                         0.7523799422 0.2277563867      3.30344  0.00095506

DCC BIC   30298.86794

Two-step ADCC - Estimation by BFGS
Convergence in    30 Iterations. Final criterion was  0.0000010 <=  0.0000100

Weekly Data From 2005:04:24 To 2017:09:10
Usable Observations                       647
Function Value                    -14946.1589

    Variable                        Coeff      Std Error      T-Stat      Signif
********************************************************************************
1.  AFIX                         0.0995432282 0.0322028959      3.09113  0.00199399
2.  BFIX                         0.5601607410 0.2008031768      2.78960  0.00527730
3.  GFIX                         0.1811095179 0.0452418478      4.00314  0.00006251

ADCC BIC   30300.07554
```

Figure 5. Results of the dynamic conditional correlation estimations in step 2 (Source: Our estimations under WinRATS 9.10)

Table 4. Summary of Granger causality tests (Source: Author)

| | BSE | CAC 40 | DAX | Dow J30 | MASI | NIKEI225 | NSE20 | RSA40 | SEMDEX | TUNIDEX | UGANDA | IBEX35 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BSE | | - | - | - | - | - | - | - | + | - | - | - |
| CAC 40 | - | | - | + | + | + | + | + | + | + | - | - |
| DAX | - | - | | + | + | + | + | - | + | + | - | - |
| Dow J30 | - | + | + | | + | + | + | + | + | + | - | + |
| MASI | - | - | - | - | | - | + | + | - | + | + | - |
| NIKKEI225 | - | - | - | + | - | | + | - | - | + | - | - |
| NSE 20 | - | - | - | - | - | - | | + | + | + | + | - |
| RSA 40 | - | - | + | + | + | - | + | | + | - | + | - |
| SEMDEX | + | - | - | - | - | - | + | + | | + | - | - |
| TUNIDEX | - | - | - | - | + | - | + | - | - | | - | - |
| UGANDA | - | - | - | - | + | - | - | - | - | - | | - |
| IBEX35 | - | + | + | + | - | - | + | - | + | + | + | |

This very important result is a confirmation of the economic theory which states that the direction of causality should be from developed markets to emerging markets. This empirical result is also a confirmation of the hypothesis that there is an asymmetric pure contagion effect between developed and African financial markets, which only occurs from developed markets to African markets. We also estimate the impulse responses (Figure 6) (over the total period divided into 12 periods, that is, 54 weeks per period, which is approximately 1 year 2 weeks), of 5 African financial markets (Morocco, Tunisia, South Africa, Kenya, Mauritius) during the shock on the US market (Dow Jones 30 index). We find that all markets react to a shock on the Dow Jones 30, each with a different amplitude.

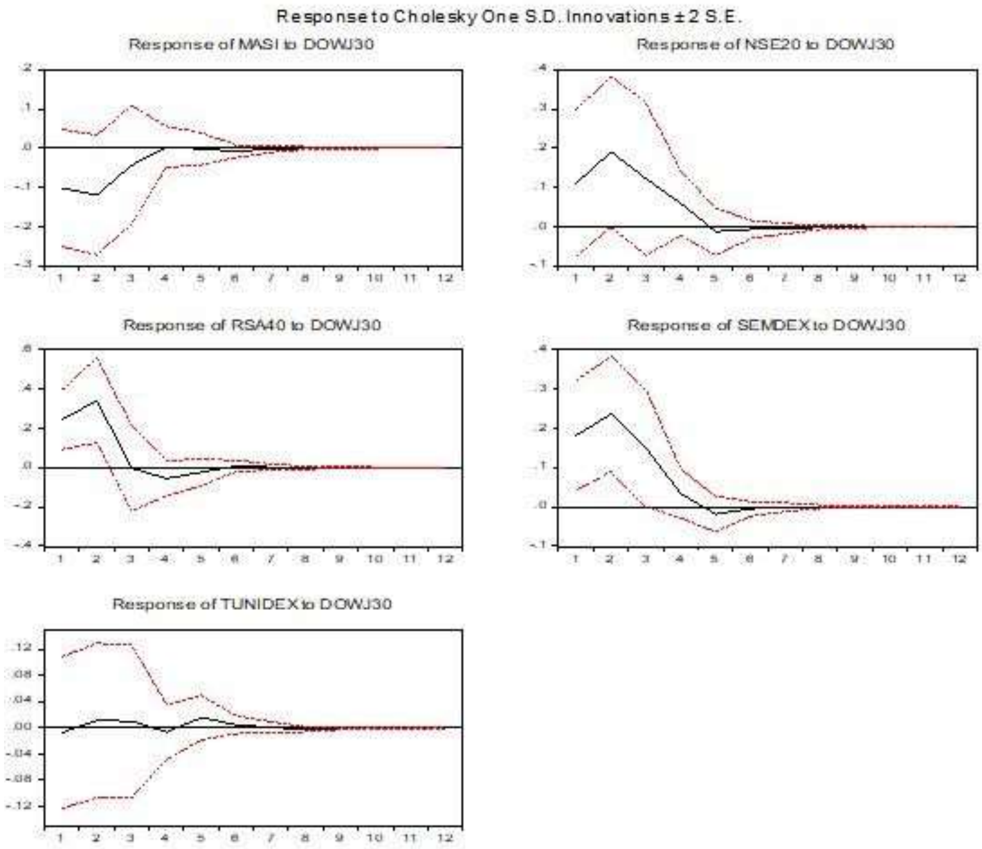



Figure 6. Responses of African financial markets following a financial shock triggered at the Wall Street (Source: Our works)

The analysis of these response functions suggests that the 5 African markets tend to have a negative reaction to the shock on the US market during the first 2 periods before returning to the positive reaction trend towards the end of the second period or the beginning of the third period. This is in line with the excellent performances (maximums) in terms of rates of return achieved by African markets during the period of subprime crisis. These response functions also show that the Casablanca Stock Exchange (Morocco) fully absorbs the shock on the DowJ30 at the Wall Street in the 4th period, that is, within 4 years and 2 months, while the Nairobi Stock Exchange (Kenya) fully absorbs the shock in the 7$^{th}$ period (within 7 years 3 months 1 week). The Johannesburg Stock Exchange (South Africa), the Mauritius Stock Exchange (Mauritius) and the Tunis Stock Exchange totally absorb the shock on the Dow Jones30 at the Wall Street in the 6th period (ie within 6 years 3 months). We can say that the pure contagion effects of the subprime crisis triggered on the Wall Street in August 2007 faded out on the Moroccan financial market around October 2011, on the Kenyan financial market around November- December 2014, and in the South African, Mauritian and Tunisian markets during December 2013-January 2014. This means that at this time, all the financial markets on the African continent at large have already completely gotten rid of the pure contagion effects of the subprime crisis.
Figure 7 represents the mean standard forecast errors of the rates of return, over all 12 periods, for the 5 African markets whose impulse responses are presented in figure 6.

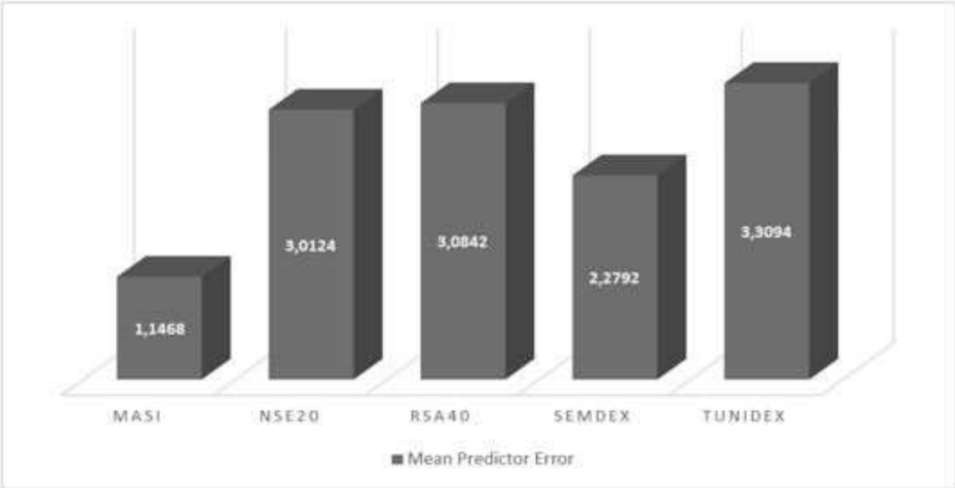



Figure 7. Mean Standard Forecast Errors over the Period (Source: Author from estimations under EViews 8.1)

Figure 7 reveals that the intra-sample forecast errors of the rates of return for the estimated SVAR model are rather low, with a mean over the period ranging from the minimum of 1.1488 for Morocco to a maximum of 3.3094 for Tunisia (talking about the 5 African markets in question). This reflects the good quality of our estimates: the SVAR adjustment is a good forecasting model. This is also why the FPE information criterion preferred p=2 for the SVAR (p). Table5 presents the breakdown of these estimated forecast errors over all markets in the sample. We find that on average, the innovations of the MASI account for almost 94% of the unexpected fluctuations in the Moroccan market returns. The share of fluctuations in the returns of the MASI index attributable to the innovations of the other stock indices is 1.81% for CAC40 and virtually negligible (less than 1%) for the other markets. These results show that the Moroccan stock market is a quasi-autonomous market which is independent of the volatility of other markets. As a result, the explanatory factors for fluctuations in MASI's returns following a shock on another market can only be the result of major disturbances within the Moroccan market and weakly those from the French market. The table also leads us to the same conclusion as in the Moroccan case for the Kenyan, Mauritian and Tunisian markets, whose own market volatilities respectively account for 88.38%, 79.39% and 94.02% of the new fluctuations in the rate of return following a shock.

Table 5. Breakdown of forecast errors (Source: Author )

| | MASI | NSE20 | RSA40 | SEMDEX | TUNIDEX |
|---|---|---|---|---|---|
| BSE | 0.722 | 0.430 | 0.417 | 1.318 | 0.120 |
| CAC40 | 1.810 | 5.631 | 43.680 | 7.230 | 1.050 |
| DAX | 0.238 | 1.070 | 1.158 | 0.769 | 0.144 |
| DOWJ30 | 0.646 | 0.940 | 2.125 | 2.750 | 0.020 |
| IBEX35 | 0.583 | 1.123 | 0.726 | 0.375 | 0.576 |
| MASI | 93.974 | 0.255 | 1.941 | 0.821 | 0.905 |
| NIKKEI225 | 0.027 | 0.197 | 0.393 | 2.842 | 0.433 |
| NSE20 | 0.394 | 88.380 | 1.365 | 2.382 | 1.151 |
| RSA40 | 0.599 | 0.357 | 46.265 | 1.469 | 0.962 |
| SEMDEX | 0.295 | 0.991 | 0.864 | 79.393 | 0.220 |
| TUNIDEX | 0.406 | 0.036 | 0.203 | 0.217 | 94.028 |
| UGANDA | 0.306 | 0.592 | 0.863 | 0.435 | 0.391 |
| TOTAL (%) | 100 | 100 | 100 | 100 | 100 |

These new fluctuations on these markets are secondarily explained for 5.63%, 7.23% and 1.05% respectively by fluctuations in the French CAC40 index. With regard to the South African market, the results show that the market itself accounts for 46.256% of the new fluctuations in its rate of return following a shock, and that 43.68% is attributable to fluctuations in the CAC40, 2.12% to those of the DowJ30, 1.16% to DAX, 1.94% to MASI and 1.36% to Kenya. It can be concluded that the Johannesburg Stock Exchange is the African market that is most integrated in the process of financial globalization, both continentally and globally, and that it is highly influenced by actions on the French market. Consequently, the explanatory elements of the fluctuations in JSE's returns following the subprime crisis are almost equally attributed, for around 50% each, to the JSE's own disturbances and to those on the Paris market.

In sum, the breakdown of forecast errors reveals that apart from South Africa, other African financial markets seem not to be effected by developed exhanges. It represents a weak integration of these financial markets in the process of financial globalization. Thus, the new fluctuations in the rates of return on African markets (others than South Africa) following to a financial shock on any other market, are overall explained by the consequent domestic financial troubles on each of these African markets. Moreover, because of the proximity between South Africa and Namibia revealed by the PCA, we can deduce here that South Africa and Namibia are the most integrated African countries in the financial globalization, and that the increase in the volatility of the rates of return on these markets (following a financial shock on a developed market) is half explained by the domestic financial disturbances on each of these markets, and the other half is explained by the disturbances on the Paris market.

## 7. Conclusion

Taking for technical reference the subprime crisis, this paper seeks to trace the mechanisms of its spread to African securities exchanges, and then to reveal the existence of contagion effects between developed and African financial markets. A dynamic panel probit model showed the validity of the two channels, namely financial links and commercial links in the propagation mechanism of financial shocks from developed markets to African ones. More specifically, these shocks are transmitted via the past level of pressure on market returns, excessive increases in the current account balance (balance of current payments), excessive exchange rate appreciation, uncontrolled domestic increases in economic growth, and the financial fragility of African economies which play a key role in the vulnerability of their financial fragility of African economies which plays a key role in the vulnerability of their financial markets. A DCC-GARCH model also revealed a significant increase in the dynamic correlations of the returns of developed markets with those of African markets in times of financial crisis. On the other hand, these results show the existence of an asymmetry in the dynamic correlations. Granger causalities confirmed the hypothesis of a pure contagion which occurs only from developed markets to African markets, exception to be made to the Johannesburg Stock Exchange (JSE), which is likely to cause some innovations on the rates on the French, German and US markets. The results suggest that a determined rule setting policy as to ensure financial stability. The target should be, stabilization of the exchange rate (a Currency Board regime), the economic growth rate, the financial fragility ratio and the current account balance of the balance of payments.

## APPENDICES

**Appendix 1**: Extracts from the SVAR model estimation results

F-Tests, Dependent Variable RSA40

| Variable | F-Statistic | Signif |
|---|---|---|
| RSA40 | 3.4854 | 0.0312419 |
| BSE | 1.7903 | 0.1677766 |
| NSE20 | 6.9926 | 0.0009928 |
| SEMDEX | 1.9027 | 0.1500405 |
| MASI | 6.6389 | 0.0014032 |
| TUNIDEX | 1.0820 | 0.3395636 |
| UGANDAAS | 2.3050 | 0.1006108 |
| CAC40 | 2.0183 | 0.1337573 |
| DAX | 3.1804 | 0.0422479 |
| DOWJ30 | 5.8535 | 0.0030306 |
| IBEX35 | 2.0433 | 0.1304668 |
| NIKKEI225 | 0.3014 | 0.7398655 |

VAR/System - Estimation by Least Squares
Weekly Data From 2005:05:01 To 2017:09:10
Usable Observations 646

| | |
|---|---|
| Dependent Variable RSA40 | |
| Mean of Dependent Variable | 0.2672153932 |
| Std Error of Dependent Variable | 2.7836337747 |
| Standard Error of Estimate | 2.6750568200 |
| Sum of Squared Residuals | 4443.8319029 |
| Durbin-Watson Statistic | 1.9979 |

| | Variable | Coeff | Std Error | T-Stat | Signif |
|---|---|---|---|---|---|
| 1. | RSA40{1} | -0.108952447 | 0.054978393 | -1.98173 | 0.04794973 |
| 2. | RSA40{2} | -0.108190442 | 0.054849343 | -1.97250 | 0.04899552 |
| 3. | BSE{1} | 0.022387909 | 0.103612895 | 0.21607 | 0.82900210 |
| 4. | BSE{2} | -0.185580899 | 0.104120171 | -1.78237 | 0.07517702 |
| 5. | NSE20{1} | 0.056005086 | 0.044833327 | 1.24918 | 0.21206834 |
| 6. | NSE20{2} | -0.157194203 | 0.044123129 | -3.56263 | 0.00039531 |
| 7. | SEMDEX{1} | -0.055727198 | 0.061269686 | -0.90954 | 0.36341830 |
| 8. | SEMDEX{2} | 0.109436705 | 0.060134912 | 1.81985 | 0.06926268 |
| 9. | MASI{1} | -0.145186865 | 0.056437525 | -2.57252 | 0.01032718 |
| 10. | MASI{2} | 0.158966360 | 0.056253795 | 2.82588 | 0.00486675 |
| 11. | TUNIDEX{1} | -0.046242766 | 0.071969882 | -0.64253 | 0.52076664 |
| 12. | TUNIDEX{2} | 0.097354100 | 0.071126722 | 1.36874 | 0.17157498 |
| 13. | UGANDAAS{1} | -0.023187445 | 0.030822480 | -0.75229 | 0.45216170 |
| 14. | UGANDAAS{2} | 0.060981656 | 0.031249624 | 1.95144 | 0.05145436 |
| 15. | CAC40{1} | 0.225946932 | 0.125881753 | 1.79491 | 0.07315356 |
| 16. | CAC40{2} | 0.133253348 | 0.125909618 | 1.05833 | 0.29031860 |
| 17. | DAX{1} | -0.242494113 | 0.102403868 | -2.36802 | 0.01818904 |
| 18. | DAX{2} | -0.094745297 | 0.103761558 | -0.91311 | 0.36154117 |
| 19. | DOWJ30{1} | 0.302293735 | 0.088672453 | 3.40911 | 0.00069397 |
| 20. | DOWJ30{2} | 0.050677447 | 0.087480537 | 0.57930 | 0.56259706 |
| 21. | IBEX35{1} | -0.131635938 | 0.066816967 | -1.97010 | 0.04927110 |
| 22. | IBEX35{2} | 0.026544933 | 0.067170682 | 0.39519 | 0.69284112 |
| 23. | NIKKEI225{1} | -0.034026275 | 0.050035599 | -0.68004 | 0.49673172 |
| 24. | NIKKEI225{2} | 0.016598897 | 0.049220902 | 0.33723 | 0.73605545 |
| 25. | Constant | 0.321913407 | 0.113610290 | 2.83349 | 0.00475383 |

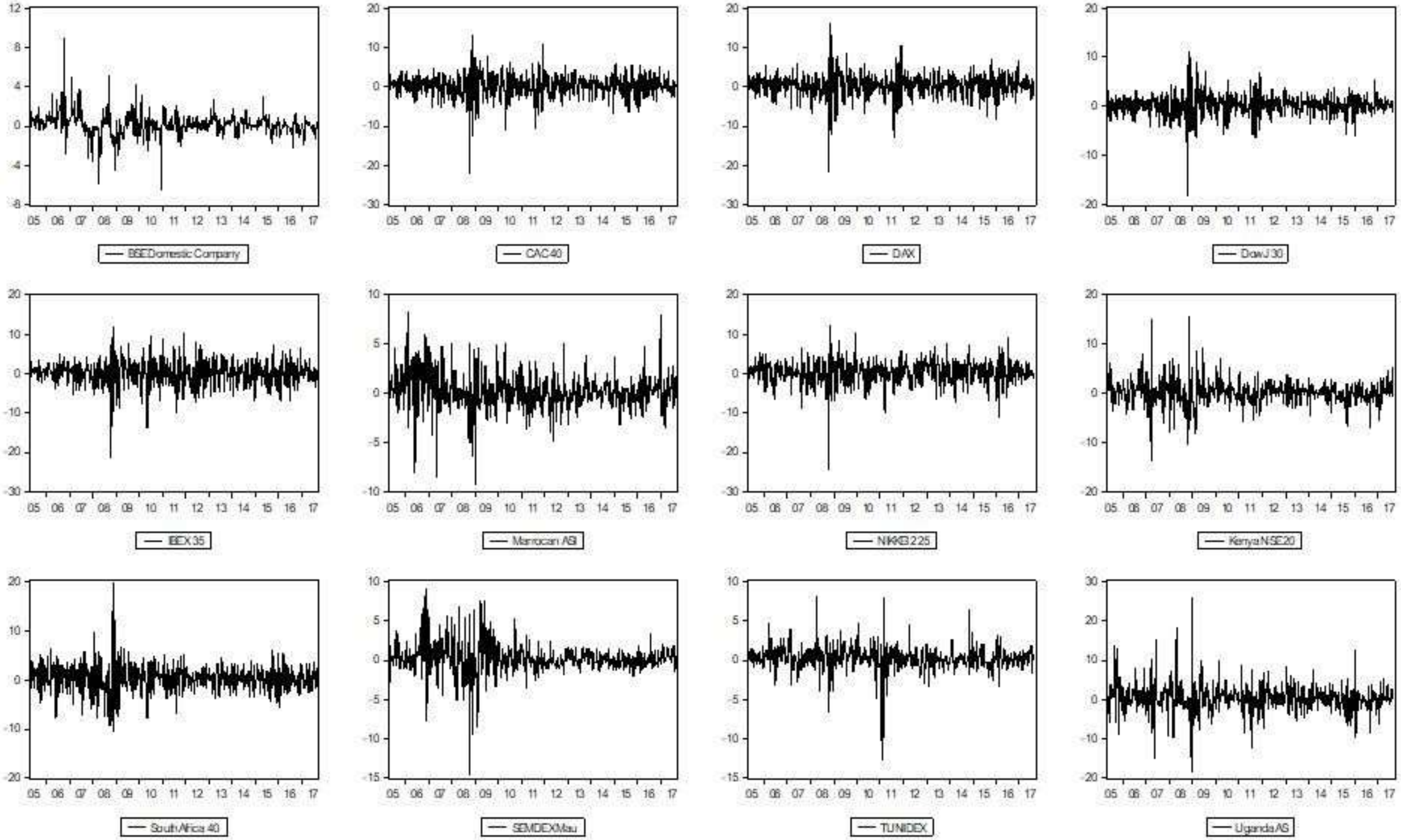
| | |
|---|---|
| Dependent Variable DOWJ30 | |
| Mean of Dependent Variable | 0.1450592360 |
| Std Error of Dependent Variable | 2.2467395373 |
| Standard Error of Estimate | 2.1975075832 |
| Sum of Squared Residuals | 2998.8335782 |
| Durbin-Watson Statistic | 1.9830 |

| Variable | Coeff | Std Error | T-Stat | Signif |
|---|---|---|---|---|
| 1. RSA40{1} | 0.081640091 | 0.045163689 | 1.80765 | 0.07114491 |
| 2. RSA40{2} | -0.087249835 | 0.045057677 | -1.93640 | 0.05327169 |
| 3. BSE{1} | 0.086664586 | 0.085115995 | 1.01819 | 0.30898233 |
| 4. BSE{2} | -0.042868407 | 0.085532713 | -0.50119 | 0.61641283 |
| 5. NSE20{1} | -0.010577765 | 0.036829713 | -0.28721 | 0.77404934 |
| 6. NSE20{2} | -0.013251943 | 0.036246300 | -0.36561 | 0.71478199 |
| 7. SEMDEX{1} | 0.076677688 | 0.050331866 | 1.52344 | 0.12815717 |
| 8. SEMDEX{2} | -0.042788202 | 0.049399670 | -0.86616 | 0.38673490 |
| 9. MASI{1} | -0.068260836 | 0.046362338 | -1.47233 | 0.14143738 |
| 10. MASI{2} | 0.071478090 | 0.046211408 | 1.54676 | 0.12242987 |
| 11. TUNIDEX{1} | -0.059486747 | 0.059121870 | -1.00617 | 0.31472491 |
| 12. TUNIDEX{2} | 0.023817472 | 0.058429230 | 0.40763 | 0.68368626 |
| 13. UGANDAAS{1} | -0.025408273 | 0.025320073 | -1.00348 | 0.31601852 |
| 14. UGANDAAS{2} | -0.042516480 | 0.025670964 | -1.65621 | 0.09818466 |
| 15. CAC40{1} | 0.025269147 | 0.103409432 | 0.24436 | 0.80703260 |
| 16. CAC40{2} | 0.097025035 | 0.103432323 | 0.93805 | 0.34858169 |
| 17. DAX{1} | -0.042183131 | 0.084122802 | -0.50145 | 0.61623424 |
| 18. DAX{2} | -0.044026049 | 0.085238119 | -0.51651 | 0.60568452 |
| 19. DOWJ30{1} | 0.114466275 | 0.072842710 | 1.57142 | 0.11659515 |
| 20. DOWJ30{2} | 0.025594261 | 0.071863574 | 0.35615 | 0.72184868 |
| 21. IBEX35{1} | -0.188305849 | 0.054888850 | -3.43068 | 0.00064202 |
| 22. IBEX35{2} | -0.005116481 | 0.055179420 | -0.09272 | 0.92615238 |
| 23. NIKKEI225{1} | -0.050188149 | 0.041103279 | -1.22103 | 0.22253977 |
| 24. NIKKEI225{2} | 0.059304939 | 0.040434022 | 1.46671 | 0.14296147 |
| 25. Constant | 0.162427616 | 0.093328662 | 1.74038 | 0.08228713 |

F-Tests, Dependent Variable DOWJ30

| Variable | F-Statistic | Signif |
|---|---|---|
| RSA40 | 3.9930 | 0.0189193 |
| BSE | 0.5200 | 0.5947553 |
| NSE20 | 0.1115 | 0.8944975 |
| SEMDEX | 1.4009 | 0.2471457 |
| MASI | 2.0724 | 0.1267510 |
| TUNIDEX | 0.5611 | 0.5708840 |
| UGANDAAS | 1.7642 | 0.1721775 |
| CAC40 | 0.4531 | 0.6358902 |
| DAX | 0.2542 | 0.7755819 |
| DOWJ30 | 1.2597 | 0.2844557 |
| IBEX35 | 5.8848 | 0.0029389 |
| NIKKEI225 | 1.9240 | 0.1468924 |

**Appendix 2**: Descriptive graphs of all the endogenous variables of the SVAR model



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