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Research Article

The Impact of the Exchange Rate Volatility on Stock Markets Dynamics in Tunisia and Turkey: An Artificial Neural Network Analysis

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Abstract: The present research provides an overview of links between exchange rate volatility and the dynamics of stock market returns in order to identify the influence of several macroeconomic variables on the volatility of stock markets, useful for political decision makers as well as investors to better control the portfolio risk level. More precisely, this research aims to identify the impact of exchange rate volatility on the fluctuations of stock market returns, considering two countries that belong to the Middle East and North Africa (MENA) zone: Tunisia and Turkey. Previous works in the literature used very specified and short periods of study, many important variables were neglected, and most of the earlier research was concentrated on the developed countries. In this research, we integrate several control variables of stock market returns that have not been simultaneously studied before. In addition, we spread out our research period up to 15 years including many events and dynamics. Generalized Autoregressive Conditional Heteroskedasticity (GARCH) and multiple regression models are first employed. Then, an Artificial Neural Network (ANN) is used and compared with the results of the multiple regression. Hence, the results show that for both Tunisia and Turkey, exchange rate volatility has a significant effect on stock market fluctuations.

Keywords**:** volatility, exchange rate, MENA, Stock market return, GARCH, artificial neural network

JEL Codes: F31, F62, F65, G15

1. Introduction

From long ago, the analysis and explanation of the exchange rate volatility's impact on the factors determining the economic status of countries was the research topic for several finance practitioners in the literature (Amano & van Norden, 1998; Taylor, 2001). However, this question still seems to be debated till today. In particular, various studies have investigated the impact of exchange rate volatility on the dynamics of stock market returns. Similarly, identifying the factors that stimulate stock market returns is very important and of major interest to investors and decision-makers. The present study aims at identifying the impact of both exchange rate and relative prices uncertainty on the fluctuations of stock markets prices, considering two countries that belong to MENA zone, which are Tunisia and Turkey.

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Exchange rate volatility has increased dramatically since the introduction of the floating rate regime in the early 1970s. As a result, there is more uncertainty in the relationship between foreign exchange markets and international stock markets.

Hence, the effect of the exchange rate on stock index returns has been studied in several works, namely Solnik (1984), who proposed that, in the long-run, the stock market and the foreign exchange market are separated, since no proof can be found showing that these two variables are related. this study has been proven later on in part of Sahadudheen's (2013) study in 2013 who examines the effect of volatility in both rupee-dollar and rupee-euro exchange rates on stock prices in India using daily data from 3-Apr-2007 to 30-Mar-2012. Adopting a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) developed in 1982 by Robert F. Engle, and Exponential GARCH (EGARCH) model, the study suggests a negative relationship between exchange rate and stock prices in India. Even though India is a major trade partner of European Union, the study couldn't find any significant statistical effect of fluctuations in Euro-rupee exchange rates on stock prices, while the effect of fluctuations in Dollar-rupee exchange rates on stock prices is highly significant.

Yet, most of those studies have focused particularly on the US and developed markets. As an example, Inci and Lee (2014) have revealed that exchange rates have a significant impact on the stock prices of some countries' developments. They considering data for 5 European countries (France, Germany, Italy, Switzerland, United Kingdom), the United States of America, Canada and Japan.

Indeed, in the past, only a limited number of researches have been carried out on the emerging markets and especially in the MENA zone, concluding with contradictory results, in the literature we found on the one hand, Sevuktekin and Nargelecekenler (2007) and Aydemir and Demirhan (2009) who initiate a positive and two-way causality relationship between the exchange rate and the stock market index in Turkey. On the other hand, Arize et al. (2000) argued that there is no direct link between the exchange rate and stock prices, and argued that the exchange rate has an impact on international trade that affects stock prices.

Several gaps in the literature have been identified, indeed, previous works used very specified and short periods of study, a lot of important variables were neglected, and all results were contradictory.

In this article we propose to focus our attention on 2 countries of the Middle East and North Africa (MENA) which are Tunisia and Turkey. Tunisia opted for a fixed exchange rate policy until 1986 and then for an intermediate exchange rate policy. The country's objective has always been to maintain or improve its external competitiveness in order to support its current account. Since the early 1990s, the Tunis Stock Exchange (TSE) Authority has undertaken a large number of reforms to improve the liquidity and efficiency of the Tunisian stock market. Yet, the first four years after the 2011's revolution have been fatal for the Tunis stock exchange, the offshore companies as well as those who aimed at the domestic market have experienced a severe deterioration. After so many years of instability, Tunisia won the Novel peace price in 2015, and was triumphed as being the only country building democracy from the Arab Spring uprisings of 2011. Meanwhile, reform momentum has picked up, as demonstrated by the design of performance contracts for public sector managers to improve governance and the approval of the Competition and Investment Laws (Charfeddine & Ajmi, 2013). The performance of the Tunis Stock Exchange continues to improve from year to year, as evidenced by the 2017 report published by the Tunis Stock Exchange (TSE) "The overall result of the year 2017 of 69 companies out of 81 listed, has improved by 24.5% compared to the year 2016, to reach an amount of 1,748 MD against 1,404 MD. Among these 69 companies, 60 have recorded profitable results". While the Turkish lira is losing its value intensively. In fact, it has lost 40% of its value against the dollar and the euro in a single year. Domestic and foreign investors are gradually losing confidence in the country's economy and are abandoning their investments in securities, seeking to withdraw from the market as soon as possible to limit their losses. This situation leads to severe losses in the Turkish stock market. Thus, by the end of 2016, the Capital Markets Board revised its strategic agenda then launched new reforms and took relevant decisions in order to protect and ensure investors from the risks caused by excessive volatility. In accordance with steadiness in word economic situation during the same period, as well as the stability in the political situation in Turkey, the performance of the BIST was well improved. It is observed through the statistics published in the 2017's report, which present an increase of 52% in net profit comparied to 2016 (Source: Borsa Istanbul official website).

Our research is part of a theoretical structuring of previous works in the literature that have dealt with the same subject and an empirical analysis of the exchange rates volatility and their impact on the fluctuations of a stock market index for two countries in the MENA region. We integrate several determinants of stock market indices (interest rate, inflation rate, gold price, oil price) in our empirical examination that have not been used simultaneously before, and we spread out our research period up to 15 years which present a large sample of 181 observations for every series. This period of time includes a lot of events and dynamics that affected the stock markets in both countries.

Therefore, it will be useful to empirically investigate the relationship between our variables. Firstly, their volatilities are determined using GARCH (1.1) model. Then, a multiple regression model will be clarified, which examines the impact of exchange rate and relative prices volatilities on stock market fluctuations. Finally, a neural regression (ANN) will be employed and we compare the results of these two types of regression. It's worthy to mention that the ANN model was rarely used in previous studies to investigate the relationships between macroeconomic variables and stock market return.

Our study is of major interest for both portfolio managers and economic policymakers as it allows them to, not only, anticipate the risk while investing in stock markets, but also, anticipate public decisions (monetary or interest rate policy) for the sake of financial market stability. Therefore, it will be useful to empirically explore knowledge about the influence of the volatility of the selected macroeconomic variables on the dynamic of stock markets.

The remainder of this paper is presented as follows: Section 2 reviews related literature which is divided into two parts: literature for general countries and literature specific to MENA zone; Section 3 provides details about our adopted methodology, it illustrates data, describes variables and empirical models (GARCH, multiple regression and neural regression) used for this study. Section 4 discusses the empirical results for both Tunisia and Turkey and we give some economical explanations to our findings. Finally, Section 5 summarizes the main conclusions of this paper and also highlights the perspectives of our future research.

2. Previous research

At a time when the dollar was convertible into gold, the foreign exchange market was one of the quietest markets.

However, nowadays the exchange rate is increasingly fluctuating and it is impossible to predict it with certainty in the current (floating) exchange rate system. Indeed, this fluctuation will have major effects on the financial market.

In the literature, several authors have asserted the existence of a relationship between the exchange rate and the stock index. Yet, the results of each study are sometimes different and even contradictory.

2.1 *Literature for general countries*

On the one hand, among the first works dealing with exchange rate uncertainty is Aggarwal (1981), the authors used US monthly data and made simple regressions. The results of this study showed that stock prices and exchange rates are positively correlated. The authors explained this relationship by the fact that the stock market was an efficient information process incorporated into the exchange rate.

On the other hand, Soenen and Hennigar (1988) following Aggarwal (1981) and conducted their study on the American market between 1980 and 1986, they used a cointegration test as well as simple regressions. However, these authors found that the influence of the exchange rate on the US stock price was rather negative because they took a larger sample than that of Aggarwal (1981), which can be considered the most accurate because it is closest to reality with a larger and wider sample.

Caporale et al. (2002) made a research on the casual relationship between stock prices and exchange rates volatility. They focused their study on four East Asian countries (Japan, South Korea, Indonesia and Thailand) using BEKK-GARCH model. Their finding reveals that before 1997 East Asian crisis stock prices lead to exchange rates negatively in Japan and South Korea and positively in Indonesia and Thailand. While during the post-crisis period they identified a bidirectional relationship between exchange rate and stock market volatility.

Ozair (2006) who investigates the direction of causality as well as short-run dynamics and long-run equilibrium relationship between stock prices and exchange rates using quarterly data for the period across 1960-2004. This study applies techniques of the unit root, cointegration and Standard Granger causality tests to examine the relationship between these two financial variables. The empirical results reveal that there is no causal linkage and no cointegration between the stock prices and exchange rates as suggested under Traditional and Portfolio approaches.

Considering calm and turbulent periods while using Markov Switching (MS) modeling, Chkili et al. (2011) studied the relationship between these two macroeconomic variables after the subprime crises for four emerging regions (Hong Kong, Singapore, Malaysia, Mexico) by dividing the period into two phases (turbulent and calm). Following the application of the MS-EGARCH model introduced by Henry (2009) in order to investigate the relationship between short term interest rates and the UK equity market he came to a conclusion that the relationship between stock markets and foreign exchange markets is regimental and that stock price volatility responds asymmetrically to events. In addition, exchange rate changes play an important role in determining the transition between quieter and more turbulent periods in emerging equity markets.

Naifar and Al Dohaiman (2013) studied the impact of oil price and its volatility on stock markets returns of the Gulf Cooperation Council (GCC) countries using Markov regime-switching model. They also explored the relationship between oil price, interest rates and inflation rates before and during the subprime crisis by applying several copula models. The authors find out that the relationship between GCC stock market returns and oil price volatility is regime dependent. They proclaim an asymmetric dependent relationship between inflation rates and crude oil prices as well as a significant symmetric dependence between crude oil prices and the short-term interest rate as well during the financial crisis.

Korhonen and Peresetsky (2015) conducted their study on Russia, Poland, Czech Republic and South Africa using monthly data for a period running from October 1997 until February 2002. A part of this work was interested by the impact of the oil prices on the stock market. They found out that this variable has a sporadic effect especially on the Russian stock market.

Jain and Biswal (2016) conducted a study on the relationship between global prices of gold, crude oil, the USD-INR exchange rate, and the stock market in India. Based on the 10-year daily data, they used the DCC-GARCH models (Dynamic Conditional Correlation, Engle (2002)) to study the relationship between the exchange rate and the Sensex30 Indian stock index, which indicates that there is a correlation between these two variables. Their results showed that a depreciation of the Indian Rupee causes a fall in Sensex30.

During the same year, Sui and Sun (2016) aimed to examine the dynamic relationship between local stock market returns, exchange rates, the BRICS zone (Brazil, Russia, India, China, and South Africa). The authors have been able to find significant effects between exchange rates and stock market returns by the VAR model, suggesting that exchange rate volatility can affect the performance of a firm or an industrial sector. Thus, an appropriate exchange rate can stabilize the stock market, especially during the financial crisis.

Lee and Cho (2017) concentrated on countries in the Pacific Basin region such as Australia, China, Hong Kong and more others in order to explain to dynamic comovements of its stock markets. They employed the quantile regression to detect the relationship between stock markets and macroeconomic variables used as its determinants. The authors captured significant impacts of almost all the exogenous variables used (inflation rate, interest rate, exchange rate, capital market development, U.S Treasury bill rate) on stock markets comovements.

Shahzad et al. (2018) studied the dependence relationship and risk spillovers between oil and Islamic stock markets for the Islamic Market World Index, Islamic indices of USA, UK, Japan and the Islamic Financials sector index. They employed for this purpose different static and dynamic copula functions in the first step, then the Value at Risk (VaR), the Conditional Value at Risk (CoVaR) and the delta Conditional Value at Risk (ΔCoVaR) were used to quantify the risk spillovers between oil and Islamic stock markets. They concluded that a positive dependence structure does exist between the oil price changes and the Islamic stock markets and it has significantly increased after the global financial crisis of 2008-09.

Chowdhury et al. (2017) confirmed the existence of a relationship between nine macroeconomic variables and the liquidity level of eight emerging stock markets in Asia. They also proclaimed that some markets are more sensitive to local macroeconomic news than world factors. VAR and panel regression models are used in this study.

Da Salles (2019) made a research on the relationship between crude oil prices and stock market in Brazil. He explains in particular, the influence that international crude oil prices have on the Brazilian stock market using the bivariate volatility model.

The ANN has been used previously in numerous works in order to predict the stock market prices or the exchange rate (Guresen et al., 2011; Moghaddam et al., 2016; Qiu et al., 2016) while papers about the association between macroeconomic variables and sock market returns using this methodology are very scant. As for as, Rastogi (2016) studied the long-term relationship between gold, crude oil, rupee-dollar exchange rate and stock market return in india using data from January 2000 to March 2015. The author employed Cointegration analysis using Johansen's Cointegration tests as well as Neural Network analysis after elaborating the elementary tests. A significant long-term Cointegration has been reported between the four markets highlighted by this study.

2.2 *Literature specific to MENA zone*

Focusing on MENA zone, Aydemir and Demirhan (2009) investigate the causal relationship between stock prices and the exchange rates, using data from 23 February 2001 to 11 January 2008 about Turkey. The reason of selecting this period is that exchange rate regime is determined as floating in this period. The results of an empirical study using VAR model (Sims 1980) indicate that there is a bidirectional causal relationship between exchange rate and all stock market indices. Yet, this study doesn't explore the period post subprime crises, and used an old and antic model.

The model used by Parsva and Lean (2011) included interest rates, inflation rates and oil prices as the main determinants of stock prices in Egypt, Iran, Jordan, Kuwait, Oman and in Saudi Arabia. Using monthly data from 2004 to 2010, they estimated their model using the Johansen cointegration model and the Granger causality test. They found that, in the long run, all variables are wedged. In the short and long term, there is a two-way causality between stock prices and exchange rates for Egypt, Iran and Oman before the crisis. In Kuwait causality is unidirectional ranging from exchange rates to short-term stock prices. By comparing the pre- and post-subprime period, the authors found that there were not many differences in the behavior of exchange rates and stock returns.

Adjasi et al. (2011) made a study to investigate the relationship between stock prices and exchange rate movement in seven African countries among Tunisia. They used Vector Error Correction Model (VECM) cointegration and impulse response analysis to determine the long- and short-run linkages between stock prices and exchange rates. Cointegration analyses indicate a long-run relationship between stock prices and the exchange rate in Tunisia, where exchange rate depreciation drives down stock prices. A short-run error-correction model also shows similar results.

Lately, Cifter et al. (2020) made a research on the relationship between oil prices and real stock returns considering nine countries that belong to MENA zone (Tunisia, Jordan, Morocco, Egypt, Qatar, Israel, Saudi Arabia, Kuwait and Oman). They employed the linear and nonlinear panel Autoregressive Distributed Lag (ARDL) and they used an extended version of the APT. Their findings prove the impact of oil prices on stock returns.

Yet, the studies that focused on MENA zone, doesn't take into consideration a large sample, which could better explain the impact of the exchange rate's volatility on the stock market's return. Previously, the authors do not integrate several determinants of stock market indices in their empirical examination simultaneously. The ANN was not used in a similar issue never before for countries from MENA zone.

In this article, a large sample of 15 years, including 181 monthly observations, is taken into consideration in order to better reflect the reality we integrate several determinants of stock market indices in our empirical examination that have not been used simultaneously before in research.

Based on the empirical studies discussion, we propose the following a priori expectations for the variables effect on stock market (Table 1).

Table 1. Expected impact of macroeconomic variables on the dynamics of stock market returns

Variables	Impact on the dynamics of stock market returns
Exchange rate	Positive
Inflation rate	Positive
Interest rate	negative
Gold price	Inexistent
Oil price	Positive

3. Methodological issues

Given that the empirical studies of predecessors are most often focused on developed markets, our study can be considered among the few studies that analyse the impact of exchange rate volatility on fluctuations in stock market returns for both Tunisian and Turkish markets that were not studied before. Moreover, we integrate several determinants of stock market indices (Exchange Rate, Interest Rate, Inflation Rate, Gold Price and Oil Price) in our empirical examination that have not been used simultaneously before in research.

3.1 *Data sources and variable construction*

The data of this study covers a full sample period from January 2002 to January 2017. Most of studies in the literature were based on monthly data (Tsai, 2012), Muhammad et al. (2002), Mohsen Bahmani-Oskooee and Saha (2016). Similarly to these studies, we used monthly data to clearly detect the change of regime and consequently it will be much easier to interpret the movements of our time series, which include stock market prices returns, exchange rates, inflation rates, interest rates, Gold prices and petrol prices index in Tunisia and Turkey.

The collected time series contain 181 observations per series. The dependent variable in this paper represents the stock market log-returns. In our study, we focus on the following stock market indices: The TUNINDEX is considered to be an index of the yield type (dividends are reinvested), which measures the general trend of the market of the Tunis Stock Exchange. The Borsa Istanbul 100 index is a weighted capitalization index composed of companies from the Turkish national market (dividends are also reinvested). In order to achieve our target, we are meant to integrate the independent variables, which seem to be the source of markets volatilities.

The nominal effective exchange rate: in our study, we are interested in analyzing nominal exchange rate volatility, which measures the relative price of two currencies, as used by Bahmani Oskooee (2016) in order to take into account inflationary effects, since the real exchange rate policy involves periodically adjusting the nominal exchange rate in order to keep the real effective exchange rate constant in order to preserve the competitiveness of the country. This variable is also used by (Aydemir & Demirhan, 2009; Jain & Biswal, 2016)

Inflation Rate (CPI): Reflects the costs of a basket of goods and services purchased by the average consumer. For our study we collected data on the consumer price index which measures inflation for each country. Numerous authors explored this variable in their paper regarding the importance it reveals for the determination of stock market dynamic (Hatemi & Irandoust, 2002; Bahmani-Oskooee & Saha, 2016).

The risk-free interest rate: our data concerning the nominal interest rates with 3 months of maturity. These rates are presented by the central banks of each country. A lot of papers were concerned by this variable (Moumni, 2006).

The gold price: Due to the lack of availability of this data for each country, we have taken into account in our research the world price index of USD/LINGOT gold.

The oil price index: We used the brent which serves as a global benchmark in the equity markets of Western Europe, Africa, the Mediterranean and the Middle East. Brent is considered as the Benchmark that fundamentalists and experts in the field use in order to index well-defined tariffs to oil from the North Sea countries exploiting northwestern Europe (Park & Ratti, 2008; Haugom et al., 2014). It is usually traded at the Intercontinental Exchange (ICE) in London.

All these data are transformed by natural logarithm and they are collected from Data Stream.

$$return_{i,t} = \text{In}\left(\frac{P_{i,t}}{P_{i,t-1}}\right), \tag{1}$$

where:

$P_{i,t}$: is the price index for the market i at time t.

Our model includes, as well as the explanatory variables mentioned above, the volatility of each and every one. Since the volatility is not an observed variable, it is estimated by a GARCH (1,1) model, described below.

3.2 *Specification tests*

3.2.1 *Unit root tests*

To avoid the problem of spurious regression, this paper performs two unit root tests for the stock price index, exchange rate and the other relative prices.

In the first step, Augmented Dickey and Fuller (1979) was adopted for this purpose.

We used three equations of the Unit root test:

• No constant, no trend:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{2}$$

• Constant, no trend:

$$\Delta y_t = C + \gamma y_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{3}$$

• Constant and Trend:

$$\Delta y_t = C + \gamma y_{t-1} + \delta_t \sum_{i=1}^{n} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{4}$$

Unlike the ADF test, the Hadri test (2000) is based on the null hypothesis of stationarity. It is a test of the Lagrange multiplier to test the null hypothesis of stationarity of the series $y_{i,t}$ (for i = 1 … N) against the alternative hypothesis of unit root.

-H_0: Stationarity, the time series does not have Unit root.

-H_a: No stationarity, the time series have Unit root.

Hadri (2000) considers the following two models:

$$y_{i,t} = r_{i,t} + \varepsilon_{i,t}, \tag{5}$$

$$y_{i,t} = r_{i,t} + \beta_i t + \varepsilon_{i,t}. \tag{6}$$

3.3 *Empirical models*

Under this subsection, we are interested by illuminate the models used for this research, so first we induce the GARCH (1.1) model, which permits us to evaluate the variances of each variable integrated in our final model. Then, the multiple regression model is explained and we represent the regression model adequate with our objective. Finally, we introduce the diagnostic tests used in this paper in order to study the stationnarity and the heteroscedasticity between variables.

3.3.1 *Model for the independent variables volatilities: GARCH (1,1) model*

Before analyzing the relationship between exchange rate and stock market return, it is first necessary to determine the volatilities of our variables. Therefore, we use the GARCH model which allows us to identify the dynamics of each variable in long term.

Since its development by Engle and Bollerslev (1986), the GARCH specification (1.1) has proved to be an adequate representation for most financial time series.

By definition, the GARCH model (1.1) is presented in two equations:

The mean equation: which provide the log returns of the stock market indices:

$$R_t = \mu + \varepsilon_t,$$

$$\varepsilon_t \mid I(t-1) \sim D(0, \sigma_t^2), \tag{7}$$

where:

R_t: are the stock market indices log-returns at the time t.

μ: is the average value of returns.

ε_t: are the error terms.

I(t – i): is the information set up to time t – i.

σ_t^2: is the conditional variance of the error terms.

The variance equation: that depends not only on the volatility of returns but also on past volatilities:

$$\sigma_t^2 = \omega + \alpha_1 + \beta\sigma_t^2, \tag{8}$$

where:

ω: Constant term parameter; ω >= 0;

α and β are parameters >= 0;

σ_{t-i}^2: the past conditional variance.

3.3.2 *Model for the market volatility 1: Multiple regression model*

This model allows us to estimate the coefficients of each variable as well as their volatilities in order to analyze the long-term impact of these variables on the uncertainty of stock market returns.

The multiple linear regression models can be represented by the following equation:

$$Ln(\sigma_{Rt}) = \alpha_0 + \alpha_1 Ln(\sigma_{R(t-1)}) + \alpha_2 Ln(z_t) + \alpha_3 Ln(Inf_t) + \alpha_4 Ln(Int_t) + \alpha_5 Ln(Gold_t) + \alpha_6 Ln(Oil_t) + \beta_2$$

$$Ln(\sigma z_t) + \beta_3 Ln(\sigma Inf_t) + \beta_4 Ln(\sigma Int_t) + \beta_5 Ln(\sigma GOLD_t) + \beta_6 Ln(\sigma Oil_t) + \varepsilon_t, \tag{9}$$

where:

σ_{Rt}: the volatility of the returns of stock market indices calculated using GARCH model over our considered period for this study.

$\sigma_{R(t-1)}$: The volatility of returns of delayed stock indexes.

z_t: The nominal exchange rate at time t.

Inf_t: Inflation rate at time t.

Int_t: Interest rate at time t.

$Gold_t$: Gold price at time t.

Oil_t: Oil price at time t.

α_0, α_i, β_j are unknown parameters to estimate.

σz_t: the volatility of the nominal exchange rate calculated using GARCH model at the moment t.

σInf_t: the volatility of the inflation rate calculated using GARCH model at time t.

σInt_t: the volatility of the interest rate calculated using GARCH model at time t.

$\sigma GOLD_t$: the volatility of the gold price calculated using GARCH model at time t.

σOil_t: the volatility of the oil price calculated using GARCH model at time t.

ε_t: it is the error term that follows the reduced normal centred distribution.

This model was manipulated following an iterative estimation procedure.

The results obtained from each estimation were analysed, then, the least significant variable ws removed in order to obtain a model where all variables are significant.

3.3.3 *Model for the market volatility 2: Neural regression*

The classical linear regression model presented previously does not reveal all the explanatory power of the variables. In order to improve the productivity of the model, we suggest in the following to use an artificial neural network modelling, which accounts for a nonlinear relationship as well as combined variables effects. Thus, we use a standard neuron network, a hidden layer of neurons whose number is to be determined optimally using prediction error.

The neural model is written as follows:

$$\sigma_{R_t} = ANN[Ln(\sigma_{R(t-1)}), Ln(ƶ_t), Ln(Inf_t), Ln(Int_t), Ln(Gold_t), Ln(Oil_t),$$

$$Ln(\sigma ƶ_t), Ln(\sigma Inf_t), Ln(\sigma Int_t), Ln(\sigma GOLD_t), Ln(\sigma Oil_t); \theta] + \varepsilon_t, \tag{10}$$

where:

ANN(,): represents the neural network.

θ: its vector of unknown parameters.

Otherwise:

$$\sigma_{R_t} = \beta_0 + \sum_{j=1}^{q} \beta_j g(\omega_t \gamma_j) + \varepsilon_t \tag{11}$$

$$\sigma_{R_t} = \beta_0 + \sum_{j=1}^{q} \frac{\beta_j}{1+\exp[-\gamma_{j,0} + \gamma_{j,1} R_t + \ldots + \gamma_{j,k} \sigma_{Oil_t}]'} + \varepsilon_t \tag{12}$$

where:

$\omega_t = (1, R_t, ƶ_t, Inf_t, Int_t, Gold_t, Oil_t, \sigma ƶ_t, \sigma Inf_t, \sigma Int_t, \sigma GOLD_t, \sigma Oil_t)$: Vector of explanatory variables at time t.

$\gamma_j = (\gamma_{j,0}, \gamma_{j,1}, \gamma_{j,k})'$: Vector of unknown parameters, j = 1, …, q.

The model is estimated by minimizing the sum of the squared residuals. It is therefore a non-linear least squares estimation. Since the sum of the squared residuals is a complex function of the parameters, conventional optimization algorithms (downward gradient, for example) have difficulty converging, especially because of the problem of many local minima. Thus, we use a combination of random search and descending gradient search in order to obtain a solution to the minimization problem.

The estimated matrix is as follow:

$$\left(\hat{\theta}, \hat{\beta}\right) = Argmin \sum_{i=1}^{n} \widehat{\varepsilon_i^2} \tag{13}$$

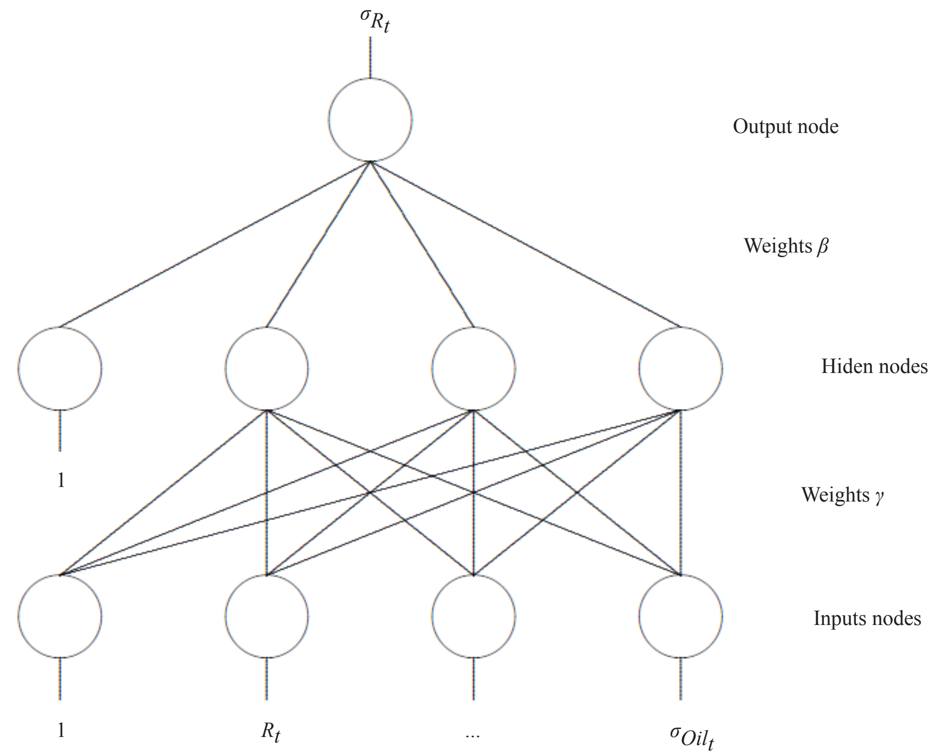
where:

θ and β are two vectors of unknown parameters.

ε_t^2: i.i.d. N (0, $\sigma_{\varepsilon_t}^2$).

On the one hand, in the random research we use 100,000 iterations. On the other hand, for the choice of the number of neurons of the hidden layer, it would be necessary to determine them optimally. Unlike other classical models, the AIC and BIC type information criteria are not very suitable for this type of model, because the number of parameters explode with the number of neurons, leading to the systematic choice to choose the minimum neuron. To exploit the power of ANNs, we decide to use the number of explanatory variables twice as the number of neurons in the hidden layer.

As we did for the classical linear regression model, we delete successively one by one the variables without explanatory power (their suppression does not increase the error of prediction, or even decreases it), until we retain only variables that contribute to the model.



Source: PiCTeX, LaTex Package

Figure 1. Graphical description of the Artificial Neural Network

ANNs are considered as a black box, certainly effective in terms of modeling, but difficult to interpret.

We believe that this criticism is unfounded. Indeed, similar to the Probit and Logit models, it is adequate to simply calculate the marginal effects of the explanatory variables on the dependent variable at the average values of variables. Thus, we provide the average marginal effects of each explanatory variable at the average point of the other variables. These marginal effects are quite comparable to the beta coefficients of linear regression, which are also the marginal effects of the explanatory variables in the particular case of the linear model.

3.4 *Diagnostic tests*

3.4.1 *ARCH heteroscedasticity test*

ARCH test was introduced by Engle and based on two hypotheses:

H0: Homoscedasticity vs H1: Heteroscedasticity.

3.4.2 *Breusch-Godfrey serial correlation LM test*

Breusch-Godfrey test is used for analyzing the autocorrelation of the errors in a regression model. It is applied on the residuals from the considered model.

H0: There is no autocorrelation vs H1: There is autocorrelation.

3.4.3 *Jarque-Bera normality test*

H0: Residuals are normally distributed vs H1: Residuals are not normally distributed.

4. Empirical results and discussion

In this section, the principal findings of this paper are explored and the results that are obtained using EVIEWS are discussed.

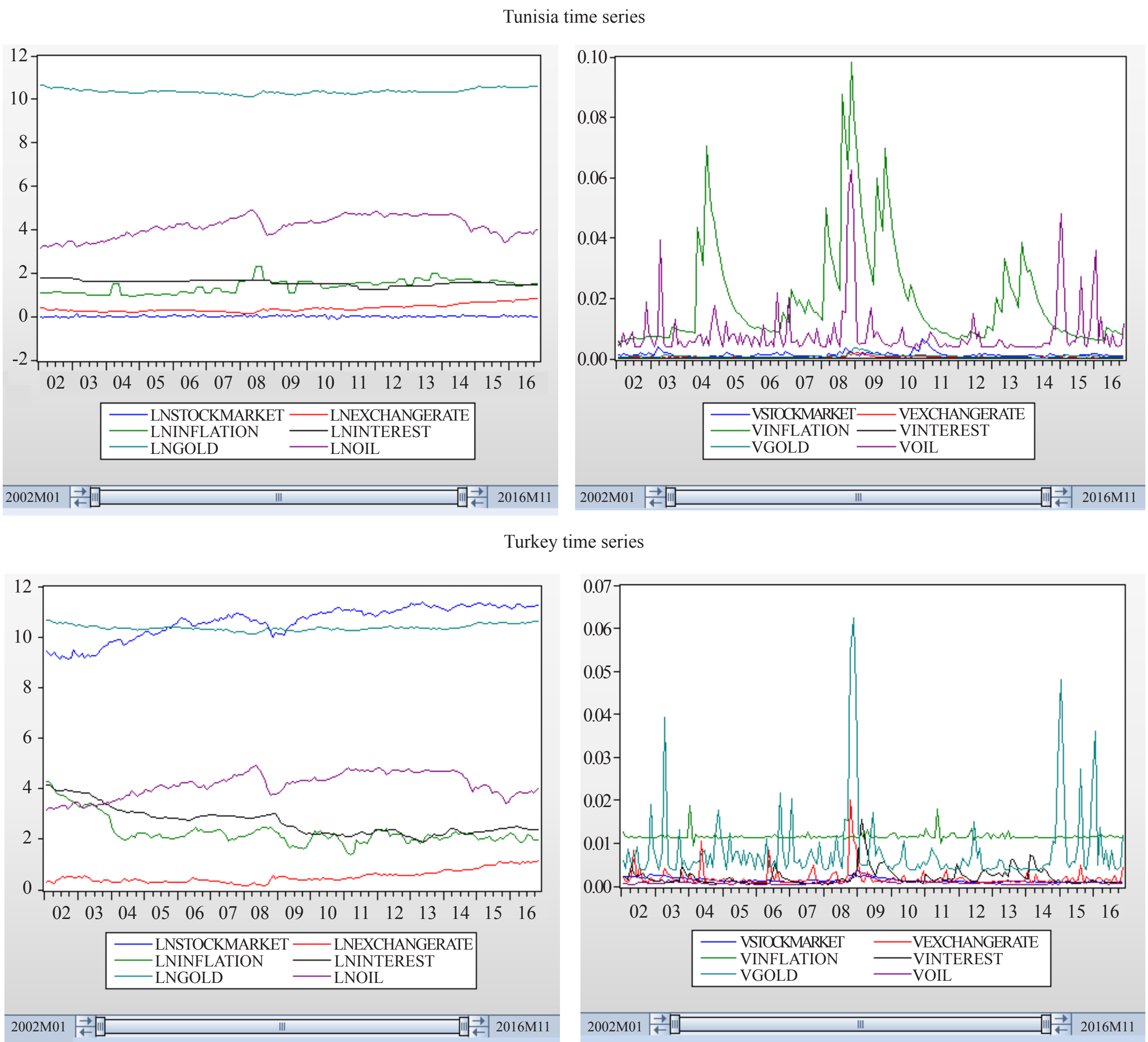
First of all, the Unit Root and the Hadri's tests are presented to verify the stationnarity of our time series which is an important hypothesis for the multiple regression estimation.

Secondly, we look into the descriptive statistics to describe our sample.

Then, it is fundamental to verify the basic assumptions for the multiple regression model, so the normality is highlighted, as well as the residual heteroscedasticity.

Finally, The GARCH, the multiple regression as well as the ANN results are analysed, and we'll end up by the validity tests presentation.

4.1 *Descriptive statistics*



Source: Basic Graph, Eviews 8

Figure 2. Graphical description of the time series over the study period from January 2002 to January 2017

Applied to a sample composed of 181 observations for both countries, the analysis of descriptive statistics proposes to offer an objective representation on the evolution and the risk level of the data used in our empirical study.

We propose to present the graphs of the chronological fluctuations of our variables as well as their volatilities in Figure 2. Table 2 shows the descriptive statistics of data. The presented values are calculated on logarithmic data. We can conclude from the results drawn in Table 2, that our explanatory variables do not follow the normal distribution.

Table 2. Descriptive statistics

Variables	countries	Mean	Median	Skewness	Kurtosis
Stock prices log-returns	Tunisia	0.01 (0.0366)	0.01	-0.16	5.09
	Turkey	10.60 (0.6450)	10.80	-0.89	2.64
Exchange rate log-returns	Tunisia	0.38 (0.1722)	0.32	1.01	3.08
	Turkey	0.52 (0.2535)	0.44	0.10	3.12
Interest rate log-returns	Tunisia	1.55 (0.1267)	1.56	-0.46	2.91
	Turkey	2.70 (0.5479)	2.51	0.94	3.13
Inflation rate log-returns	Tunisia	1.40 (0.3037)	1.48	0.25	2.62
	Turkey	2.28 (0.5415)	2.13	1.86	6.27
Gold log-returns	Global	10.37 (0.1144)	10.34	0.51	2.78
Oil log-returns	Global	4.15 (0.4809)	4.17	-0.36	2.03
σ Stock prices	Tunisia	0.001 (0.0008)	0.001	3.20	15.93
	Turkey	0.001 (0.0005)	0.001	1.11	3.09
σ Exchange rate	Tunisia	0.0004 (0.0003)	0.0003	3.13	14.86
	Turkey	0.002 (0.0021)	0.001	5.24	38.49
σ Interest rate	Tunisia	0.0002 (3.08E-05)	0.0002	-5.10	29.83
	Turkey	0.002 (0.0020)	0.001	3.14	16.86
σ Inflation rate	Tunisia	0.02 (0.0177)	0.01	0.02	0.01
	Turkey	0.01 (0.0008)	0.01	5.83	46.52
σ Gold prices	Global	0.001 (0.0005)	0.001	3.03	13.73
σ Oil prices	Global	0.01 (0.0088)	0.005	3.82	19.05

Note: σ: volatility
Standard Deviation is reported in (.)
Source: Stats table, Eviews 8

4.2 *Results of unit root tests*

The test results shown in Table 3 confirm that all the variables are stationary for Tunisia. While, ADF test on Turkey's time series show that only the stock markets returns index is not stationary.

After obtaining the difference, all variables are confirmed to be stationary.

Table 3. ADF Unit root test results

Test ADF			
Tunisia			
Level			
	None	With constant	With constant and trend
σ stock market	-2.5303** (0.0114)	-4.9461*** (0.0000)	-4.9367*** (0.0004)
σ ƶ	-1.6114 (0.1008)	-3.2743** (0.0176)	-3.2603* (0.0764)
σ Int	-0.4662 (0.5122)	-12.1490*** (0.0000)	-12.1997*** (0.0000)
σ Inf	-2.0569** (0.0384)	-3.3028** (0.0162)	-3.3470* (0.0622)
σ Gold	-1.3953 (0.1512)	-3.2964** (0.0165)	-3.2878* (0.0717)
σ Oil	-4.9316*** (0.0000)	-7.2839*** (0.0000)	-7.2702*** (0.0000)

Turkey						
	Level			First difference		
	None	With constant	With constant and trend	None	With constant	With constant and trend
σ stock market	-1.5302 (0.1180)	-2.2371 (01940)	-2.6746 (0.2485)	-12.3450*** (0.0000)	-12.3446*** (0.0000)	-12.3137*** (0.0000)
σ ƶ	-4.2632*** (0.0000)	-9.0493*** (0.0000)	-9.0750*** (0.0000)			
σ Int	-3.4731*** (0.0006)	-5.2942*** (0.0000)	-5.2894*** (0.0001)			
σ Inf	-0.1039 (0.6465)	-17.1977*** (0.0000)	-17.1525*** (0.0000)			
σ Gold	-1.3953 (0.1512)	-3.2964** (0.0165)	-3.2878* (0.0717)			
σ Oil	-4.9316*** (0.0000)	-7.2839*** (0.0000)	-7.2702*** (0.0000)			

Notes: statistical significant at: *10%, **5%, ***1% levels
MacKinnon (1996) P-values are reported in (.)
σ: volatility
Source: ADF unit root test, Eviews 8

Table 4 presents the results of Hadri's Unit Root test for all our time series. At a classical 5% significance level, it shows different the results from those shown by ADF test presented in table1. In the case, we take into consideration the

Hadri's test results since the ADF test isn't that robust to the non-normality and Hadri's test is a panel test thus it is more perform.

Table 4. HADRI unit root test results (Panel Data)

Variables	Level	1st difference
σ stock market	2.5396 (0.0055)	-1.3318* (0.9085)
σ ƶ	-0.2128* (0.5843)	
σ Int	-0.3180* (0.6248)	
σ Inf	0.1597* (0.4366)	
σ Gold	-0.2569* (0.6014)	
σ Oil	-0.8391* (0.7993)	

Notes: statistical significant at: *10%, **5%, ***1% levels
σ: volatility
Source: Hadri unit root test, Eviews 8

4.3 *Results of GARCH modelling*

Table 5. Volatilities estimations using the GARCH (1.1) model

Tunisia						
Parameter	Stock market index	Exchange rate	Inflation rate	Interest rate	Gold price	Oil price
	0.0003 (0.1516)	4.30E-05 (0.1335)	0.0097 (0.2210)	9.01E-05 (0.0000)	6.09E-05 (0.2263)	0.0004 (0.2805)
	0.1450 (0.0697)	0.1089 (0.2498)	0.0172 (0.9994)	0.0126 (0.5529)	0.1225 (0.9034)	0.1827 (0.0381)
	0.6685 (0.0002)	0.7925 (0.0000)	0.5792 (0.0667)	0.9086 (0.0000)	0.7640 (0.0000)	0.6286 (0.0000)
+*	0.8135	0.9014	0.5964	0.9212	0.8865	0.8113
Turkey						
Parameter	Stock market index	Exchange rate	Inflation rate	Interest rate	Gold price	Oil price
	-4.73E-05 (0.1114)	0.0011 (0.0000)	2.0984 (0.0000)	0.0003 (0.1001)	6.11E-05 (0.2202)	0.0004 (0.2805)
	0.0359 (0.6003)	0.8150 (0.0004)	0.9386 (0.0000)	0.4887 (0.0000)	0.0669 (0.4244)	0.1827 (0.0381)
	0.8912 (0.0000)	-0.0768 (0.5612)	-0.2802 (0.8780)	0.4658 (0.0225)	0.7638 (0.0000)	0.6286 (0.0000)
+*	0.926	0.7382	0.6584	0.9545	0.8307	0.8113

*: A measure of the volatility's persistence
Source: GARCH estimation, Eviews 8

The GARCH (1.1) model is estimated on the time series. The results for both Tunisia and Turkey are presented in Table 5.

The results obtained by the GARCH model for both Tunisian Turkey's data indicate that information on the volatility of the previous period has an impact on the current volatility.

Adding to that, the volatility clustering is being detected for the interest rate in Tunisia as well as for exchange rate and inflation rate in Turkey.

4.4 *Results of multiple regression and neural regression estimations*

The estimation regression method is Ordinary Least Squares (OLS) in this section. The checking points are whether the stock market dynamics are affected by the following prices. The results are shown in Table 6.

4.4.1 *Final model for Tunisia*

$$\sigma_{Rt} = \alpha_0 + \alpha_1 Ln(\sigma_{R(t-1)}) + \alpha_2 Ln(\text{ƶ}_t) + \beta_1 Ln(\sigma \text{ƶ}_t) + \beta_2 Ln(\sigma GOLD_t) + \beta_3 Ln(\sigma Oil_t) + \varepsilon_t \quad (14)$$

4.4.2 *Final model for Turkey*

$$\sigma_{Rt} = \alpha_0 + \alpha_4 Ln(Int_t) + \beta_2 Ln(\sigma \text{ƶ}_t) + \beta_4 Ln(\sigma Int_t) + \beta_5 Ln(\sigma GOLD_t) + \varepsilon_t \quad (15)$$

Table 6. Linear regression results studying exchange rate volatility and relative prices impacts on the stock market returns fluctuations

Tunisia			
Variables	Coefficients	t-statistics	P value
σ ƶ	2.1486	4.7800	0.0000***
σ Int	1.7889	0.8137	0.4170
σ Inf	-0.0054	-1.3846	0.1609
σ Gold	-0.5532	-2.2888	0.0233**
σ Oil	0.0171	1.7273	0.0863*
ƶ	-0.0092	-3.1724	0.0020***
Turkey			
Variables	Coefficients	t-statistics	P value
σ ƶ	0.0734	3.4787	0.0006***
σ Int	0.0328	1.6821	0.0949*
σ Inf	-0.0424	-1.0816	0.2802
σ Gold	0.2170	2.6658	0.0085***
σ Oil	0.0067	1.1552	0.2530
Int	-0.0021	-2.6250	0.0123**

Notes: statistical significant at: *10%, **5%, ***1% levels
σ: volatility
Source: Linear regression estimation, Eviews 8

As mentioned in the methodology, for the neural regression it is advisable to calculate the average marginal effects and to compare it to the beta coefficients of the linear regression. To do so, we proceeded in 3 steps: first, the derivative of the neural regression is considered, then we determine the marginal effects at all sample points and we end up calculating the average of the marginal effects. It's well to mention that this method is better than calculating the marginal effect at the sample mean point, which can fall into a disordered special case of the derivative. The results are presented in Table 6.

Table 7. Comparison between linear regression and neural regression results

	Tunisia	
	Linear regression	Neural regression
R^2	21%	64%
	beta	Average marginal effect
Constant	5.50E-05	
σ Int	1.7889	24.21854713
σ Inf	-0.0054	0.00647579
σ ƶ	2.1486	0.83790548
σ Gold	-0.5532	0.57017696
σ Oil	0.0171	
	Turkey	
	Linear regression	Neural regression
R^2	33%	52%
	beta	Average marginal effect
Constant	0.0002	
σ Int	0.0328	0.01111217
σ Inf	-0.0424	-0.14929348
σ ƶ	0.0734	0.01045640
σ Gold	0.2170	0.31049280
σ Oil	0.0067	

σ: volatility
Source: Neural regression: Software Gauss Tanagra "TANAGRA-Un logiciel de data mining, de statistique et d'analyse de données pour l'enseignement et la recherche (univ-lyon2.fr)"
Linear Regression: Eviews 8

From Table 7, it can be seen that the R^2 of the neuronal regression is larger than those of the linear regression. Neural regression can detect small effects of certain variables in return, and especially detect much more significant effects of shifting volatility shocks from most macroeconomic variables to the volatility of financial markets (spillover effects). In addition, the signs of these effects are more consistent (positive).

Results shown in the Table 7 indicate that the volatility of the exchange rate is significant, which implies that it has an impact on stock market dynamics, which proves the results of the study conducted by Charles et al. (2011).

Overall, the volatility of Tunisian stock market prices is defined by the volatility of Exchange rate, Gold and oil prices. Those variables are significant and have an important impact on the dynamic of the Tunisian stock market.

On the one hand, manufacturing industries play an important role in Tunisia's economy (textiles, agro-food and electro mechanics) from an extrovert perspective, in fact, a large number of the companies are totally or partially exporters. Consequently, it's meaningful that the volatility of the exchange rate influences the stock market price dynamic. Especially since, after the revolution and the events that shook the Tunisian economy, the decrease in exports level compared to the importation of goods was heavily noticed, in other words, the commercial balance has declined since the revolution which damaged the value of the national devise abroad. This down yard has massively harmed the stock market in Tunisia which suffer till today.

On the other hand, there is apparent evidence that in turbulent periods with economic uncertainty, as equity prices fall gold price rises and attention focuses on gold (and other precious metal) as a safe haven. Yet, it doesn't prevent that, lately the demand for gold decrease because of the very high prices of this metal resulting from the depreciation of the Tunisian dinar, which affects the stock market volatility and it approves our empirical results. These results can also be explained by the fact that foreign investors who usually take positions in gold futures to safeguard their investments, can't anymore use that strategy as the gold prices are no longer stagnant which lead them to invest in another country, accordingly the stock market will be damaged.

Furthermore, Tunisia has a reserve of oil that is likely to cover all of its consumption without falling under the obligation to import to meet the needs of its population, however, being manipulated by the United States of America, the price of a barrel of oil has fallen sharply in recent months. Certainly, it is the happiness of motorists who pay less to refuel, but the situation gets worse when oil prices can no longer cover their production costs, so the fluctuation of the oil prices impacts the stock market returns dynamics when to the production levels. Bouri et al. (2017) conducted a study to examine the relationship between the gold, crude oil and India price indices between June 2009 and May 2016 using implied volatility indices. Generally, the main results highlight the close links between the implied volatilities of gold and oil and those of the Indian stock market, and more particularly, they pointed out that the volatility of gold prices causes fluctuations in the stock market indices.

We can notice based on finding for Turkey's Data, that it's very closed to those established for Tunisia. In fact, exchange rate volatility as well as Gold prices volatility are very significant, while interest rate volatility is significant at a level of 10%.

In the main, we can settle that only the volatility of the exchange rate, the volatility of gold prices and the interest rate fluctuation have an influence on the dynamics of the Turkish stock market returns, while other prices are statistically non-significant.

Actually, the decrease in demand for gold because of the very high prices of this metal resulting from the depreciation of the Turkish lira, approves our empirical results.

These findings could be explained by the rising inflationary pressures and the high volatility of the money supply, as well as, the deterioration of the geopolitical situation and the slowdown in the euro area economy.

4.5 *Validity tests: Regression and ANN residuals tests*

4.5.1 *Results for ARCH heteroskedasticity test*

Table 8. Results of heteroscedasticity test (Regression Residuals)

Tunisia	
F-statistic	P-value
0.0102	0.9195
Turkey	
F-statistic	P-value
1.58E-05	0.9968

Notes: statistical significant at: *10%, **5%, ***1% levels
Source: Eviews 8

Table 9. Results of heteroscedasticity test (ANN Residuals)

Tunisia	
F-statistic	P-value
62.0972	0.9419
Turkey	
F-statistic	P-value
11.2278	0.1293

Notes: statistical significant at: *10%, **5%, ***1% levels
Source: Eviews 8

4.5.2 *Results for Breush-Godfrey serial correlation test*

Table 10. Results of serial correlation test (Regression Residuals)

Tunisia	
F-statistic	P-value
0.7122	0.4921
Turkey	
F-statistic	P-value
0.4545	0.6355

Notes: statistical significant at: *10%, **5%, ***1% level
Source: Eviews 8

Table 11. Results of serial correlation test (ANN Residuals)

Tunisia	
F-statistic	P-value
10.3114	0.6384
Turkey	
F-statistic	P-value
15.3399	0.9237

Notes: statistical significant at: *10%, **5%, ***1% levels
Source: Eviews 8

4.5.3 *Results for Jarque-Bera normality test*

Table 12. Results of normality test (Regression Residuals)

Tunisia	
Jarque-Bera	P-value
805.4632	0.0000***
Turkey	
Jarque-Bera	P-value
6815.770	0.0000***

Notes: statistical significant at: *10%, **5%, ***1% level
Source: Eviews 8

Table 13. Results of normality test (ANN Residuals)

Tunisia	
Jarque-Bera	P-value
245.9353	0.0000***
Turkey	
Jarque-Bera	P-value
48.8430	0.0000***

Notes: statistical significant at: *10%, **5%, ***1% level
Source: Eviews 8

According to the above findings, it is to mention that the residuals of the considered regression model are not correlated and do not follow a Gaussian distribution (Table 9-13). However, according to the ARCH test the homoscedasticity of the residuals is acclaimed (Table 8).

5. Conclusion and perspectives

The main objective of this study is to identify the impact of exchange rate and other macroeconomic variables volatilities on stock markets dynamics for both Tunisia and Turkey. For this purpose, we choose a comparative methodology. On the one hand we use the GARCH and the multiple regression and on the other hand the artificial neural network is applied. Similar studies are very limited, they focused particularly on developed countries using specified and short periods of study, and they also neglected a lot of important variables. In order to fill these gaps and contribute to the existent literature we integrate simultaneously 5 macroeconomic variables that define the stock market dynamic in our empirical model, in addition, we explored a large sample of 15 years for both Tunisian and Turkish markets that were not studied in the previous works. That's why we give an overview with an extremely convincing argument to prove the existence of a relationship between those macroeconomic variables and the stock market dynamics.

The empirical results show firstly for the case of Tunisia; the volatility of the exchange rate has a significant effect on the fluctuations of the stock market prices. As well as the gold and the oil prices volatility. Yet all the other stock market's determinants were statistically insignificant.

Secondly, based on Turkey's data, we pointed out that the volatility of the exchange rate and the interest rate have a positive impact on the volatility of Turkey's nominal market returns dynamics, and similarly to Tunisian results, Gold price volatility has an impact on Turkish stock market dynamic as well.

Tunisia was badly hit by the revolution of the Arab Spring 2011, which affect the financial, economic and political instability. Consequently, this turbulent phase influenced the investor's behaviour what made the decrease in the exchange rate and relatively it affected the financial market.

Being ranked the leading economic power in the Middle East and the fifteenth in the world in 2010, Turkey lived in prosperity and financial stability until early 2016. In fact, Turkey had strongly suffered not only from political instability but also from a deteriorating of business climate and the fall of the Turkish lira caused essentially by the terrorism and the weak growth in the euro area. These events go by affect negatively the exchange rate and the interest rate. Thus, Investors on the Turkish financial market are increasingly threatened by the political and economic instability which constitutes a danger to their strategic objectives.

It would be essential for the Tunisian and Turkish governments to avoid political turmoil, debt problems, corruption and to control interest rates, as well as to provide a favorable and secure environment for foreign investors because they can affect the volatility of stock market returns which subsequently causes the economic and financial instability of the country. In fact, during our study period there two countries have handled several events which lead to a riskier economic environment. For example, the transitory period that has most marked the Tunisian financial market which is the revolution of 2011, this event was accompanied by waves of demands and protests that led to the end of a presidential period of the Dictator Ben Ali. As well, in 2013, Turkey experienced protest movements against the presidential power, the stock market has seen the biggest loss of a day for a decade.

This article can be extended by investigating the spillover effects between exchange rate volatilities and stock markets dynamics for 5 or more countries among the MENA zone in order to better reflect the reality of these markets while using a multivariate GARCH model (DCC-GARCH for example), or further, we propose to use the Bayesian approach to explore the relationship between stock markets and the most important macroeconomic variables for the case of the Mediterranean Basin.

Conflict of interest

The authors declare that they have no conflicts of interest.

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