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# **Exchange Rate Uncertainty and Export Performance in Egypt: New Insights from Wavelet Decomposition and Optimal GARCH Model**

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**Abstract:** To assess the link between exchange rate uncertainty and exports performance in Egypt, this article relies on an optimal GARCH model chosen by information criteria among decomposed series on a scale-by-scale basis (wavelet decomposition). The observed outcomes reveal that this relationship depends intensely on the frequency-to-frequency variation and slightly on the leverage effect and switching regime. Indeed, it is well shown that at the low frequency, the coefficient associated to exchange rate volatility's effect on exports is greater than that at the high frequency and conversely when subtracting energy's share. We attribute the apparently conflicting results to the co-movement between energy prices and those of other commodities, the excessive speculation and the composition of trade partners.

**Keywords:** Exchange rate uncertainty; exports; wavelets; optimal GARCH model.

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## 1. Introduction

The relationship between exchange rate uncertainty and exports performance has been investigated in several researches but no consistent results have been up to now found. The subject on how the exchange rate volatility impacts trade has been investigated and the results have varied widely. Some studies have found a negative interaction between currency risk and exports (e.g. McKenzie (1998), Vergil (2002), Nabli and Varoudakis (2002), Bahmani-Oskooee (2002) and Rey (2006), etc...). Others have found that higher risk associated with ups and downs exchange rate' movements can lead to great opportunity increasing exports performance (e.g. De Grauwe (1992) and Achy and Sekkat (2003), among others). More recently, Egert and Zumaquero (2007), Bouoiyour and Selmi (2013) argue that there is an ambiguous effect.

These empirical studies suggest that the link between exchange rate uncertainty and trade performance varies depending on risk-averse, the absence of hedging instruments, the specialization and the degree of competitiveness. To reconcile the mixed results of prior researches, using meta-regression analysis, Coric and Pugh (2010) provide evidence that the effect of exchange volatility on trade is likely to be adverse when measured in real rather than nominal term and when less developed rather than developing countries are considered.

Despite the many studies on this subject and the different estimation techniques used, analytical gaps remain, especially methodological ones. To contribute to this literature stream and while trying to highlight additional explanations of the conflicting results, we extend our examination beyond by assessing this link depending to frequency-to-frequency variation.

Alternatively, various questions can be raised. For example, To what extent exchange rate uncertainty affect Egyptian exports? Do exports react differently when moving from one frequency band to other? How to choose the optimal model to determine volatility?

The answers of these several questions will enhance our understanding on the relationship between exchange rate volatility and exports performance in Egyptian case and allow us to identify the main sources behind the study-to-study variation related to the focal linkage.

The remainder of this article proceeds as follows: Section 2 offers a brief overview of exchange and trade policies in Egypt. In section 3, we present our methodology. In section 4,

we estimate the linkage between real exchange rate volatility and real exports returns using wavelet decomposition and an optimal model among several GARCH extensions chosen by various information criteria. Additionally, we discuss our main results. Section 5 concludes.

## **2. A brief overview of exchange and trade policies in Egypt**

Since the demise of the Bretton Woods system in 1973, particularly early 80's, Egypt had a fixed system of its currency in relation to U.S. dollar. With the beginning of the economic reform program in 1991, government announced the adoption of managed floating regime (e.g. Kandil and Nergiz, 2008). From 1997, the Egyptian exchange rate has undergone numerous shocks such as the East Asian crisis and Luxor terrorist attack in 1997, the fall of oil prices in 1998 and the revival of tensions in the Middle East peace process in the end of 90's. These latter led to capital outflows, a slowdown in the capital market, a deterioration of the current account balance and a slowdown in tourism sector and economic growth. At this period, International Monetary Fund ranked Egypt as having conventional fixed peg (e.g. Kamar, 2004). In order to mitigate exchange rate-damaging, the Central Bank of Egypt decided to restore market stability by introducing a crawling peg system. This exchange regime allows the nominal exchange rate to move in a band within upper and lower limits. As a result, it is seen from the Figure 1, a real depreciation of Egyptian pound. Unfortunately, the aftermath of the New York terrorist attack and the subsequent wars on Afghanistan and Iraq darkened the investment's attractiveness of Egypt. All the above events put Egyptian pound under pressure.

Between 1995 and 2009, real exports exhibited great instability (see Figure 2). The World Trade Organization agreement signed with the European Union in 1995 allowed Egypt to develop its export competitiveness, improve its comparative advantages and provide a greater access to developing markets with growing concern for manufactured sector (e.g. Nabli and Varoudakis, 2002). This reform led it to consolidate its position in foreign trade during the period from 1996 to 2004 (e.g. Sekkat, 2012). However, the dismantling of the textile and clothing agreement and the accession of China into the World Trade Organization have degraded the position of this sector compared to previous years.

To mitigate possible detrimental effects of real exchange rate uncertainty on exports, especially after the announcement of the flotation of the pound on January 2003, Egypt should dispose more proactive reforms such as: (i) the implementation of policy reforms to accelerate

products' diversification, i.e. the diversification on non-oil sectors can limit real exchange rate appreciation (e.g. Espinoza and Prasad, 2012) ; (ii) an integration in international financial market allowing this country to smooth the adjustments of primary commodity prices and reduce costs of volatile exchange rate on exports performance (e.g. Gourinchas and Rey, 2007) ;(iii) more credible monetary policy to absorb several shocks and then to remedy an overvaluation of real exchange rate.

### 3. Wavelet decomposition and optimal GARCH model

Since the majority of researches on the link between exchange rate volatility and exports performance were always contradictory and inconclusive, this study seeks to clarify the inconsistent results. In so doing, we assess differently the relationship between changes in real exchange rates and those of real exports in Egypt using wavelet decomposition and optimal GARCH model<sup>2</sup>.

#### 3.1. Why wavelets?

Wavelets are “small waves” that grow and decay in a limited time period. Wavelet analysis involves the projection of the original series into several frequencies by separating each series into its constituent frequency components. This technique is a decomposition of time series into high frequency or noisy components and low frequency or trend components. Wavelet method allows us to extract the various time scales driving any macroeconomic variable in the time domain by decomposing it into its frequency band components. This can reflect structural changes that can happen over time and at a well-defined time scale.

This approach is based on the mother wavelet denoted  $\psi(t)$ , which must satisfy:

$$\int_{-\infty}^{+\infty} \psi(t) dt = 0, \int_{-\infty}^{+\infty} |\psi(t)|^2 dt = 1 \quad (1)$$

To quantify the importance of the wavelet decomposition into various frequencies, the mother wavelet  $\psi(t)$  gets deleted, so:

$$\psi_{u,s} = \frac{1}{\sqrt{s}} \psi\left(\frac{t-u}{s}\right) \quad (2)$$

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<sup>2</sup> All GARCH extensions used in this study are summarized in Table 1.

where  $u$  and  $s$  are the time location and frequency ranges, respectively, and  $\frac{1}{\sqrt{s}}$  indicates that the norm of  $\psi_{u,s}(t)$  is equal to unity.

The wavelet decomposition in turn is a succession of low and high-pass filters of the focal series. Unlike time domain analysis, wavelets can identify which frequencies are present in the data at any given point in time. Ultimately, we obtain the following wavelet representation of the function  $X(t)$ :

$$X(t) = [w_1(t), v_1(t), \dots, w_j(t), v_j(t)] \quad (3)$$

where  $w_I(t)$  and  $v_I(t)$  respectively wavelet high frequency and wavelet low frequency.

Considering several frequency bands, time series can be extracted for further analysis. Firstly, with wavelets analysis, we can differentiate between time periods for decision making. Secondly, since wavelets method enables to decompose a signal into multi-resolution components, it allows us to assess both real exchange rate and real exports data over well-defined time horizons. Thirdly, with this technique, we can approximate structural changes that can happen over time. Finally, the problem of temporal aggregation bias can be neglected because time series were decomposed into different time scales. Therefore, wavelets analysis provides a fresh look into the link between exchange rate uncertainty and exports performance by highlighting it over different and precise horizons.

### 3.2. Why GARCH models?

While modeling strategies have evolved over time to incorporate new developments in econometric analysis, no single measure of exchange volatility has dominated the literature (e.g. Haile and Pugh, 2011).

The formulation of linear and symmetrical GARCH models impose a sensitivity of the risk premium volatility. They do not include cyclical behavior or sudden shocks, that is why they are rather restrictive. However, for nonlinear GARCH models, the conditional variance follows two different processes depending on the sign of the error terms or according to the dynamics of the conditional standard deviation of returns (e.g. Zakoin, 1994). Instead, asymmetrical extensions describe the behavior of the conditional variance depending on good or bad news (e.g. Engle, 1990). These specifications are summarized Table 1.

In this study, we use 13 GARCH extensions while trying to choose the best model that can captures more how behave real exports after changes in real exchange rate. With regard to these various specifications, it is of utmost importance to evaluate whether changes in real exchange rate have temporary, permanent, transitory, asymmetrical or nonlinear effects on real exports performance. Therefore, we seek to examine if: (i) First, volatile supply leads to changes in demand conditions and thereby to multiple commodity price regimes. This yields to take into account the threshold effect in the focal linkage; (ii) the possible intervention of monetary authorities in exchange market leads us to take into account good and bad news and not only the magnitude of shock; (iii) the exchange rate volatility's effect on exports can be transitory or permanent. Thus, it seems appropriate to decompose the impact of changes in real exchange rate and those of real exports into a long run time varying trend and short run transitory deviations from trend.

### 3.3. Data sources and methodological framework

A central goal for this study is to check if the connection between real exchange rate uncertainty and real exports varies over time (i.e. from low to high frequency bands). We estimate various GARCH extensions and seek the optimal model that can best capture a significant relation on the basis of an historical evaluation. Intuitively, we explore a bivariate GARCH model<sup>3</sup> without taking into account other determinants of exports because instead of analyzing the effects of its fundamentals, as it is usually done (e.g. Achy and Sekkat (2003), Rey (2006), Egert and Zumaquero (2007), among others), we decompose here the two key variables at various scales of resolution using wavelet decomposition and then we study the focal relationship among the decomposed series matched to their scales. To do so, we built an indicator that replaces the simple changes of real exports in accordance with real exchange rate returns. This indicator is constructed using the variance between both variables in question.

We use monthly data for the period from 1994 to 2009 collected from Econstats<sup>TM</sup> and International Monetary Fund (IMF). Thus, we consider the following variables:

$$r_{XPR_t} = \log (XPR_t/XPR_{t-1}) \quad (4)$$

where  $r_{XPR_t}$  is the return of real exports determined using the ratio between nominal exports and the export unit value.

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<sup>3</sup> This method has been largely used recently to evaluate the link between the variability of dollar vis-à-vis various currencies and oil price returns (e.g. Narayan et al. (2007), Mansor (2011) and Gosh (2011)).

$$r_{REER_t} = \log (REER_t / REER_{t-1}) \quad (5)$$

where  $r_{REER_t}$  is the return of real exchange rate. The real exchange rate is constructed by dividing the trade-weighted foreign price level index by the corresponding domestic price level index, after converting the values to a common scale using nominal exchange rate.

$$REER_t = NEER_t (P^* / P_t) \quad (6)$$

To assess this link between real exchange rate returns and those of real exports under different time scales, we begin by a linear model which is forward looking at time  $t$ .

$$r_{XPR_t} = \alpha + \beta r_{REER_t} + \varepsilon_t \quad (7)$$

where  $\varepsilon_t$  is the error term.

Thereafter, we applied GARCH model chosen depending to frequency-to frequency variation. It is of course shown that GARCH-type modeling allows us to have several results (e.g. Anderson et al. 2009). The unobserved conditional variance has affected widely the development of various GARCH-type models (e.g. Engle, 1982). Several specifications have been advanced to capture different features that are thought to be important. For instance, some GARCH extensions allow the volatility to react asymmetrically to positive and negative shocks (e.g. Nelson, 1991), others consider only the magnitude of shocks (e.g. Bollerslev, 1986). This has created a need to understand clearly if the performance of GARCH models varies over time. Accordingly, a large strand of literature on financial engineering has attempted to check whether GARCH models vary depending to time periods (e.g. Engle et al. (1987), Tong (1990), Bollerslev et al. (1993), Bera and Higgins (1993), Campbell and Mackinlay (1997), Hansen (2001), among others).

The common conclusion is that across different time periods, there is a change in volatility's behavior over time, leading to a change in GARCH parameters. More precisely, the model is capable of accommodating systematic changes in the amplitude of the volatility clusters that cannot be explained by a constant-parameter GARCH model. Recently, Mazur and Pipien (2012) show that Financial markets data often exhibit volatility clustering and cyclical behavior, where time series show periods of high volatility and periods of low volatility.

Hence, in order to choose the best model, we use standard criteria such as the Akaike criterion, the Bayesian Information Criterion and Hannan and Quinn criterion. Table 2

summarizes their expressions. These criteria evaluate the models based on the historical volatility. The discrimination function differs from one test to another. There is not really an optimal model but the optimality remains concerning the choice of the test. These criteria seem sufficient to judge the quality of the estimation (e.g. Bouoiyour et al. 2012).

## **4. Application and main findings**

### **4.1. Preliminary analysis**

We report the descriptive statistics in Table 3. The sample means of real exchange rate returns and those of real exports are negative. Skewness and kurtosis measures indicate that distributions of the returns of both series are positive. Therefore, the returns of these series are skewed and leptokurtic relative to a normal distribution. The Jarque–Bera normality test indicates high levels, which means we reject the normality for both variables.

Figure 3 depicts a positive relationship between changes in real exchange rate and those of real exports in Egyptian case. This result means that excessive real exchange rate volatility accentuate the real exports' uncertainty, though this effect is weak.

With regard to our preliminary results, it is time to regress real exports returns on changes in real exchange rate.

### **4.2. Main findings: Estimates with energy versus without energy**

As we stated at the outset, we assess the linkage between real exchange rate returns and those of real exports using wavelet decomposition. We consider seven components or frequency bands, as we report in Table 4. This wavelet decomposition relies on a symmlet basis<sup>4</sup>.

Our estimates of the optimal model chosen among various GARCH extensions under time domain and several frequency bands are summarized in Table 5. We find a significant and positive effect of real exchange rate returns on those of real exports (with energy) in Egyptian case, which is theoretically and empirically unexpected. However, studies on its fundamentals in developing countries emphasize that export performance-exchange rate uncertainty connection depends intensely to the volatile behavior of oil prices (e.g. Egert and

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<sup>4</sup> See Appendix A.

Zumaquero, 2007). Based on this assumption, we thought to subtract the share of oil from real exports and differential price. By doing so, we show a negative and significant linkage between the two variables, both in time domain and across the monthly frequencies.

#### **4.2.1. Time domain**

For the time domain, we observe in Table 5 that an increase in the real exchange rate by 10% prompts a significant increase in real exports by 2.86%. Contrary to expectations, we uncover a positive and significant correlation between our key variables for all returns from January 1994 to October 2009. This result changes substantively when subtracting the share of energy from total exports and differential price. Thus, we find that an appreciation of real exchange rate by 10% leads to a decrease in the level of real exports by 0.1%. This implies that the energy's share in total exports, which presents 26% (see Sekkat, 2012), makes a difference in the considered relationship.

#### **4.2.2. Frequency bands**

For all considered frequencies (i.e. D1, D2, D3, D4, D5, D6 and D7), we find from Table 5 that the effect of real exchange rate returns on those of real exports is positive and significant. We observe that an increase in the real exchange rate by 10% yields an increase in real exports by 3.69%, 2.54%, 2.63%, 1.79%, 3.75%, 1.39% and 1.22%, respectively. This result is unexpected. The subtraction of energy leads to different results, which do not change substantively in terms of the sign from one frequency to another, whereas the magnitude of the effect depends to frequency transformations. Thus, an increase in the real effective exchange rate by 10% produces a drop in real exports by 0.05%, 0.13%, 0.01%, 0.02%, 0.18%, 0.23% and 0.19%, respectively during D1, D2, D3, D4, D5, D6 and D7. However, we notice that at the lowest frequency, the coefficient associated to exchange rate uncertainty's effect on exports (with energy) is more intense than at the highest frequency and conversely for the case without energy.

Equally important, for time domain and across all the frequencies, we note much greater persistence of the link in question (with energy) and lesser persistence (without energy), initiating the tendency to long memory process in the first case and to short memory process in the second one (Table 6). Furthermore, without subtracting energy, the coefficient

$\gamma$  is positive, which implies that the effect of bad news is more intense than that of good news. In contrast, with subtracting energy, the coefficient  $\gamma$  is negative and significant, which confirms asymmetry that is more vulnerable to good news than to bad news. As we depict in Figure 4, the conditional variance behaves better when we subtract energy's share.

Without energy, this relationship behaves differently and therefore seems more intense at high time scale than at low frequency band. This result seems hardly surprising because of the important proportion of energy in the total of exports of Egypt (i.e. 26%). In addition, the real exchange rate is defined as the differential price of a basket of traded and non-traded goods between the domestic and the foreign economy leading to a great vulnerability to the volatility of commodity prices including those of oil. Previous studies highlight a complex relationship between energy price and real exchange rate uncertainties, especially in oil exporting countries ; For example, Chen and Rogoff (2003), Engel and West (2005), Rogoff and Rossi (2010) and Bodenstein et al. (2011), among others.

#### **4.3. Discussion of results**

The varying results obtained with several time scales imply that the relationship between real exchange rate returns and changes in real exports is more complex than it may appear. Depending to frequency-to-frequency variation, it tends to be nonlinear and dependent on switching regimes (i.e. shifts and weights) or asymmetrical and dependent to leverage effects (i.e. good and bad news). As we depict in Table 4, the interaction between exchange volatility and exports (with energy) appears nonlinear at D, D2, D4 and D5 and asymmetrical under D1, D3, D6 and D7. Without energy, the link between both variables remain nonlinear in some frequencies and asymmetrical in other ones. At this stage, we can assert that the use of the best GARCH model among several GARCH extensions effectively differentiates all the effects<sup>5</sup>. This can help the Egyptian authorities to better understand the evolution of exchange rates and anticipate possible future shocks, including those related to changes in oil prices

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<sup>5</sup> The best model chosen should explain the nature of the effect of exchange uncertainty on exports in that period. More precisely, when the GARCH extension chosen by information criteria is T-GARCH or GJR-GARCH or N-GARCH, this implies that the variance between exchange rate and exports depends to switching regime (i.e. structural breaks). Additionally, if the model chosen is, for example the E-GARCH, this means that the conditional variance between variables depends to the sign of innovations (i.e. good or bad news).

In addition, for all studied cases (i.e. with and without energy and across different time scales), we note that the leverage effect impacts more the considered link than the switching regime. More precisely, we show that with energy the magnitude of exchange rate uncertainty's effect on exports is equal to 2.61% (as average) when we account the sign of innovations comparable to 2.35% (as average) when we account structural breaks in the process of volatility. At the same way but less important, without energy, real exchange rate volatility's effect on real exports is equal to 0.12% and 0.10%, respectively. Not surprisingly, in oil exporting economies that adopt managed exchange regime such as Egypt, the adjustment in real exchange rate will come through changes in consumer prices (e.g. Bouoiyour and Selmi, 2013). This implies that the differential price including that of oil price can make Egypt unable to adjust its currency and lead to excessive swings in real exchange rates that affect intensely exports performance<sup>6</sup>.

With energy, the exchange uncertainty's effect on real exports is greater at low frequencies. This can be attributed mainly to speculative effects. More precisely, the energy market is a large market relative to other commodities and the assumption of financial speculation may be evident.<sup>7</sup> This leads to an increase of co movement between the spot price of oil and futures prices. In related works, Alquist and Kilian (2010) and Fattouh et al. (2012) argue that the demand and supply shocks in the global oil market often entailed offsetting changes in oil inventories to reinforce then changes in oil prices, implying the presence of speculation. Furthermore, when the domestic country carries most of its trade with a single major country, pegging the local currency to the foreign one can mitigate exchange rate uncertainty. However, the effective exchange rate can capture the value's effects of the local currency vis-à-vis the currencies of the trading partners (see Ngouana, 2012). Thus, Egyptian trade may be affected by the euro's movements, especially because its main exports partner is Europe with share almost equal to 15.7% (see Appendix C). This implies also that the fluctuations of oil price denominated in dollar can coincide with a great volatility of euro. Accordingly, we depict in Appendix D that exports to European Union are dominated by

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<sup>6</sup> For details, we can refer to Sester (2007). This latter advance that “dollar pegs will not prevent the currencies of oil exporting economies from eventually appreciating in real terms.”

<sup>7</sup> For more details about how speculators can be drivers of oil price uncertainty, we can refer to Buyuksakin and Harris (2011).

mineral and energy sectors, which are denominated on dollar and their prices are characterized by volatile behavior among all commodities in international market (e.g. Arezki et al. 2011).

Intuitively, because the differential price make a difference in the link in question, the above finding may be intensely due to the co-movement between energy price and the prices of other commodities (e.g. Baffes, 2007), especially because excessive speculation affects more oil markets. Speculation is also considered as a source of co-movement excess (e.g. Kratshell and Schmidt, 2012). Without energy, there is only co-movement between the prices of commodities (i.e. without including energy commodity price) which speculation is less important (e.g. Baffes, 2010). This can be the main reason behind the more intense exchange uncertainty's effect on exports at high frequency band than low frequency.

Our results suggest that informations on respectively drivers and consequences of commodity prices' evolution including those of energy could be well recognised. Such information also about the exchange rate movements, the domestic and imported inflation rate and a clear understanding of the major channels through which oil price can affect real exchange rates and then real exports might be necessary. Egypt should improve coordination between monetary policy and fiscal policy to react quickly and effectively to external shocks..

## **5. Conclusion**

We have revisited the relationship between real exchange rate uncertainty and exports performance to check whether there is a significant short run dynamic between them. To do so, we combine wavelet analysis with an optimal model chosen among various GARCH extensions (i.e. linear versus nonlinear, symmetrical versus asymmetrical, etc...).

The results reveal that the combination performed between wavelet decomposition and optimal GARCH model effectively enhance our understanding on the controversial link widely expected either theoretically or empirically. In this study, we show two main interesting results:

- (i) With energy, real exports react more to real exchange rate volatility at low frequency than high frequency. We attribute this to the speculation, the co-movement between energy prices and those of other commodities and the composition of exports partners.

- (ii) Without energy, the relationship between exchange volatility and exports performance behaves differently and therefore appears more intense at high time scale. This confirms the major role of speculation in energy market comparable to other commodities.

To conclude, this article provides a starting point for policy advisors and practitioners in exchange and trade policies in Egypt. Regulatory efforts, especially, by protecting the competitiveness and the transparency of domestic energy market would be a preferable way of preventing the impact of excessive speculation on the relationship between real exchange rate on export performance. The implementation of policy reforms to accelerate investment diversification on competitive non-oil sectors can also mitigate the vulnerability of Egypt to oil price shocks.

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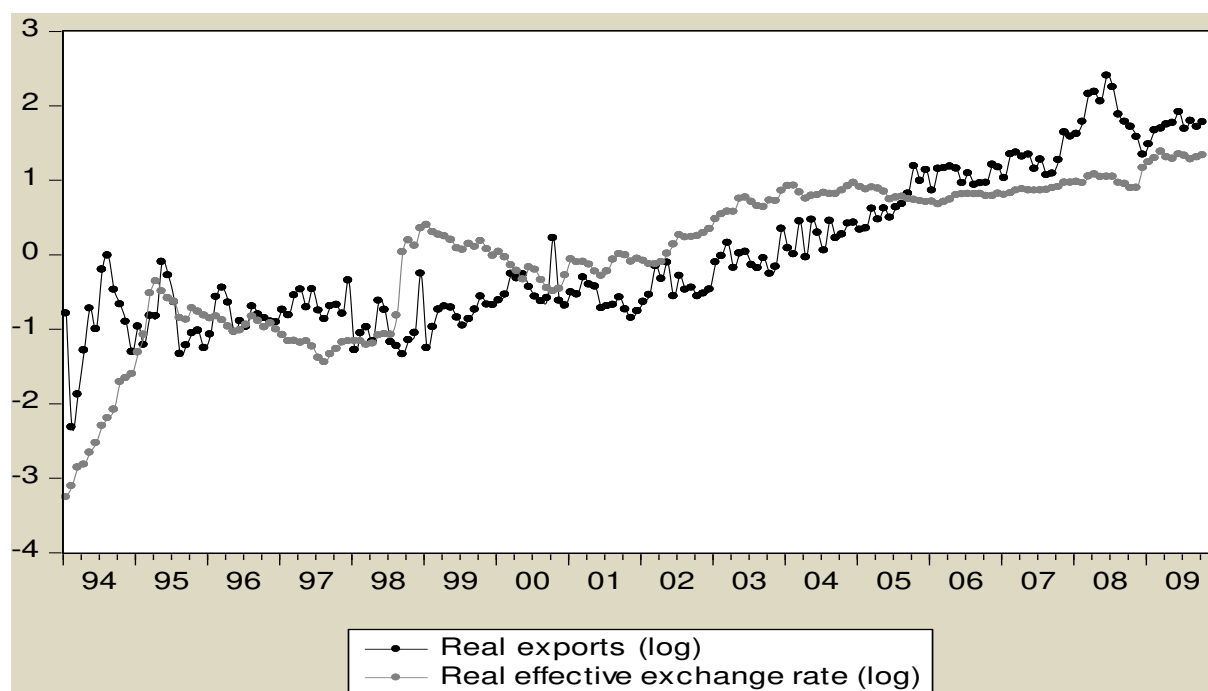
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**Table 1. GARCH extensions**

	linear	nonlinear	symmetric	Asymmetric
1. GARCH (Bollerslev, 1986) $\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$	x		x	
2. GARCH-M (GARCH in mean, Bollerslev et al. 1993) $r_t = \mu_t + \varepsilon_t + \lambda \sigma_t^2$	x		x	
3. C-GARCH (Component GARCH, Ding et al. 1993) $(\sigma_t^2 - \sigma^2) = \alpha(\varepsilon_{t-1}^2 - \sigma^2) + \beta(\sigma_{t-1}^2 - \sigma^2)$	x		x	
4. QGARCH (Quadratic GARCH, Engle and Ng, 1993) $\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i (\varepsilon_{t-i} - b_i)^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$		x	x	
5. IGARCH (Integrated GARCH, Engle and Bollerslev, 1986) $\sigma_t^2 = \omega + \varepsilon_{t-1}^2 + \sum_{i=1}^q \alpha_i (\varepsilon_{t-i}^2 - \varepsilon_{t-1}^2) + \sum_{j=1}^p \beta_j (\sigma_{t-j}^2 - \varepsilon_{t-1}^2)$	x		x	
6. AGARCH (Asymmetric GARCH, Engle, 1990) $\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i ( \varepsilon_{t-i}  + \gamma_i \varepsilon_{t-i})^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$	x			x
7. TGARCH (Threshold GARCH, Zakoian, 1994) $\sigma_t^2 = \omega + \sum_{i=1}^q (\alpha_i  \varepsilon_{t-i}  + \gamma_i  \varepsilon_{t-i}^+ ) + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$		x		x
8. GJR-GARCH (Glosten et al., 1993) $\sigma_t^2 = \omega + \sum_{i=1}^q (\alpha_i + \gamma_i I_{(\varepsilon_{t-i} > 0)}) \varepsilon_{t-i}^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$		x		x
9. GJR-PARCH (GJR power GARCH, Glosten et al. 1993) $\sigma_t^\varphi = \omega + \sum_{i=1}^q (\alpha_i + \gamma_i I_{(\varepsilon_{t-i} > 0)}) \varepsilon_{t-i}^\varphi + \sum_{j=1}^p \beta_j \sigma_{t-j}^\varphi$		x		x
10. EGARCH (Exponential GARCH, Nelson, 1991) $\log(\sigma_t^2) = \omega + \sum_{i=1}^q (\alpha_i z_{t-i} + \gamma_i ( z_{t-i}  - \sqrt{2/\pi})) + \sum_{j=1}^p \beta_j \log(\sigma_{t-j}^2)$				x
11. PGARCH (Power GARCH, Higgins and Bera, 1992) $\sigma_t^\varphi = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^\varphi + \sum_{j=1}^p \beta_j \sigma_{t-j}^\varphi$	x		x	
12. A-PGARCH (Asymmetric power GARCH, Ding et al., 1993) $\sigma_t^\varphi = \omega + \sum_{i=1}^q \alpha_i ( \varepsilon_{t-i}  + \gamma_i \varepsilon_{t-i})^\varphi + \sum_{j=1}^p \beta_j \sigma_{t-j}^\varphi$				x
13. NGARCH (Nonlinear GARCH, Duan, 1997) $\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i (\varepsilon_{t-i} - \kappa_i)^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$		x	x	

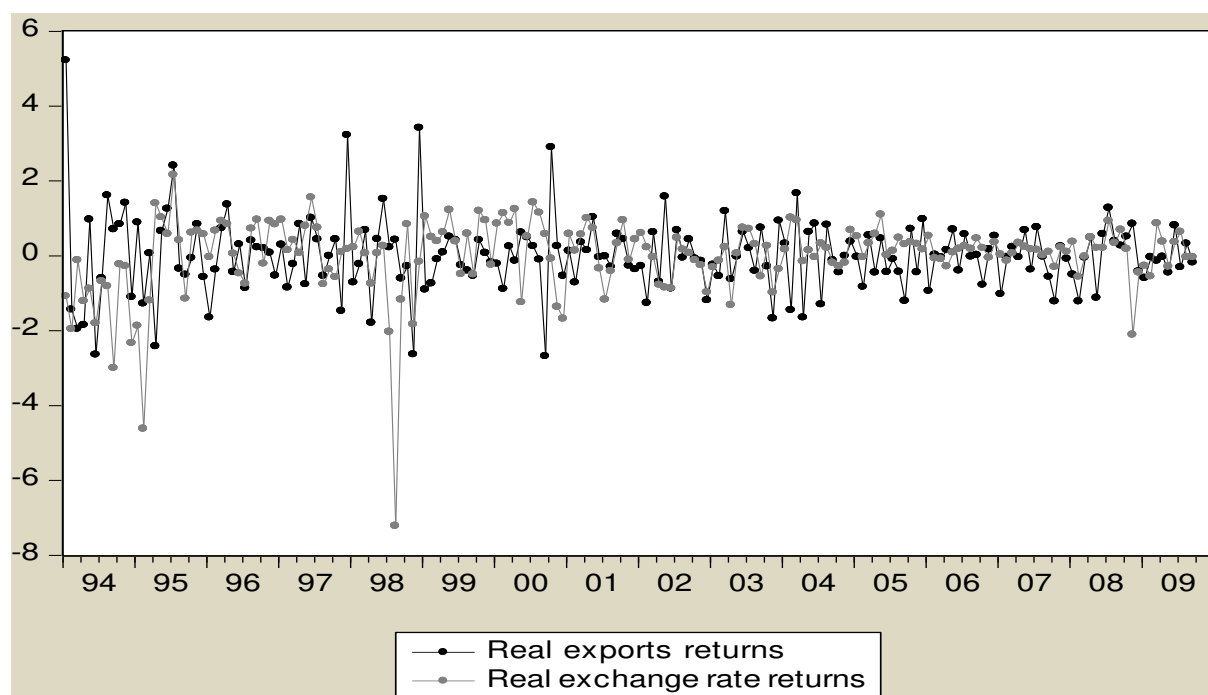
Notes:  $\sigma_t^2$ : conditional variance,  $\sigma_t$ : conditional standard deviation,  $\omega$ : reaction of shock,  $\alpha_0$ : reaction of shock,  $\alpha_1$ : ARCH term,  $\beta_1$ : GARCH term,  $\varepsilon$ : error term;  $I_t$ : denotes the information set available at time t;  $I_{t-1}$ : denotes the information set available at time t-1;  $z_t$ : the standardized value of error term where  $z_t = \varepsilon_{t-1} / \sigma_{t-1}$ ;  $\mu$ : innovation,  $\gamma$ : leverage effect;  $\sigma^2 = \omega / (1 - \alpha - \beta)$ : corresponds to the unconditional variance;  $b$ : quadratic order,  $\varphi$ : power parameter.

**Figure 1. Real exports and real effective exchange rate (Normalized data)**



Source: IMF, IFS and Econstats<sup>TM</sup>.

**Figure 2. Real exports and real exchange rate returns (Normalized data)**



Source: IMF, IFS and Econstats<sup>TM</sup> and authors' calculations.

**Table 2. Criteria used on the choice of the optimal GARCH model**

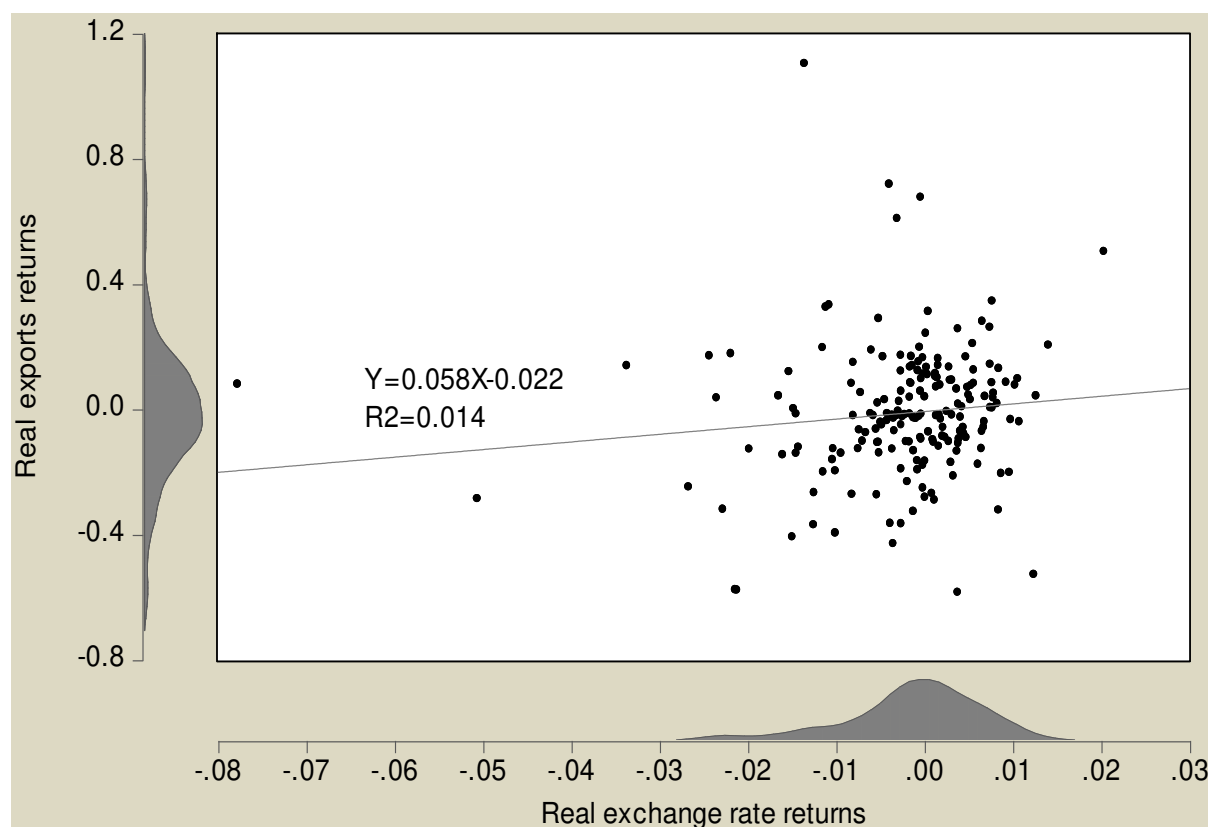
Akaike criterion :	$-2\log(vraisemblance)+2k$
Bayesian criterion :	$-2\log(vraisemblance)+\log(N).k$
Hannan-Quinn criterion :	$-2\log(vraisemblance)+2k.\log(\log(N))$

Note:  $k$  the degree of freedom and  $N$  the number of observations.

**Table 3. Descriptive statistics**

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	J-Bera
$r_{XPR}$	-0.0098	-0.0165	1.105350	-0.58324	0.213640	0.836873	7.647297	192.1405
$r_{REER}$	-0.0022	-0.0005	0.020377	-0.07770	0.010460	2.85336	18.53189	2156.226

Note:  $r_{XPR}$  : Real exports returns ;  $r_{REER}$  : Real exchange rate returns.

**Figure 3. First correlation between real exports and real exchange rate**

**Table 4. Frequency bands**

Scales	Monthly frequencies
D1	2-4
D2	4-8
D3	8-16
D4	16-32
D5	32-64
D6	64-128
D7	>128

**Table 5. The link between changes in real exchange rate and those of real exports:  
Parameters of optimal GARCH model**

<i>Dependent variable: <math>r_{XPR}</math></i>								
<b>WITH ENERGY</b>								
Time domain			Frequency bands (months)					
D	D1	D2	D3	D4	D5	D6	D7	
AP-GARCH	T-GARCH	GJR-GARCH	E-GARCH	N-GARCH	SA-GARCH	T-GARCH	E-GARCH	
Mean Equation								
<i>Constant</i>	-0.027*	-0.035**	-0.117*	-0.028*	-0.006	-0.008	-0.014**	-0.032*
	(-1.897)	(-2.408)	(-1.868)	(-1.964)	(-0.479)	(-0.767)	(-2.101)	(-1.876)
$r_{REER}$	0.286***	0.369*	0.254***	0.263***	0.179***	0.375***	0.139**	0.122***
	(3.393)	(1.842)	(3.728)	(3.251)	(3.717)	(3.717)	(2.355)	(3.111)
Variance Equation								
$\alpha_0$	0.046**	0.008**	0.009**	-1.019**	0.026***	0.031***	0.012**	-0.747**
	(2.550)	(2.947)	(2.620)	(-2.502)	(9.119)	(12.865)	(2.592)	(-2.195)
$\alpha_1$	0.207**	-0.064	0.226**	0.292*	0.856***	0.884***	-0.066	0.311**
	(2.355)	(-1.103)	(2.934)	(1.873)	(25.444)	(45.323)	(-0.885)	(2.000)
$\beta_1$	0.603***	0.574**	0.501***	0.316**	-0.0005	-0.078**	0.506**	-0.303***
	(3.854)	(2.922)	(3.682)	(2.631)	(-0.156)	(-3.681)	(2.004)	(-3.145)

$Y$	1.000*	0.574***	0.222**	0.767***	0.181	0.147**	0.410***	0.660***
	(1.698)	(4.820)	(2.934)	(8.250)	(0.459)	(2.398)	(3.617)	(3.441)
<b>WITHOUT ENERGY</b>								
Time domain			Frequency bands (months)					
	D	D1	D2	D3	D4	D5	D6	D7
	T-GARCH	E-GARCH	GJR-GARCH	E-GARCH	T-GARCH	N-GARCH	SA-GARCH	E-GARCH
Mean Equation								
$Constant$	-0.0003	-0.001***	-0.018*	-0.0005*	-0.0011	-0.007*	-0.0002	-0.016*
	(-0.579)	(-5.800)	(-1.641)	(-1.819)	(-0.459)	(-1.728)	(-0.891)	(-1.637)
$r_{REER}$	-0.010**	-0.005**	-0.013***	-0.001*	-0.002**	-0.018*	-0.023**	-0.019**
	(-2.913)	(-2.423)	(-4.259)	(-1.597)	(-2.315)	(-1.496)	(-2.119)	(-2.085)
Variance Equation								
$\alpha_0$	-3.74***	8.9E-07**	-1.320**	-1.096**	-0.093	-1.101	0.0051*	-1.007
	(-4.833)	(2.720)	(-2.099)	(-2.105)	(-1.303)	(-0.766)	(1.699)	(-0.832)
$\alpha_1$	0.768***	-0.098***	0.143*	0.228**	0.501*	0.223***	-0.10***	0.214*
	(5.372)	(-6.359)	(1.781)	(2.000)	(1.810)	(4.664)	(-3.254)	(1.653)
$\beta_1$	0.148*	0.755***	0.526***	0.174*	-0.101**	0.184**	0.513*	0.407**
	(1.615)	(4.622)	(9.703)	(1.918)	(-2.054)	(2.930)	(1.708)	(2.133)
$Y$	-0.675**	-0.658***	-0.514**	-0.603*	-0.495**	-0.609**	-0.502*	-0.619**
	(-2.926)	(-4.101)	(-2.832)	(-1.609)	(-2.223)	(-2.415)	(-1.688)	(-2.115)

Note: standard deviations are in parentheses, \*\*\* significant at 1%, \*\* 5% \* 10%.  $r_{XPR}$ : changes in oil prices;  $r_{REER}$ : changes in real effective exchange rate;  $w$ : The reaction of conditional variance;  $\alpha$ : ARCH effect;  $\beta$ : ARCH effect;  $Y$ : Leverage effect.

**Table 6. Persistence of conditional variance**

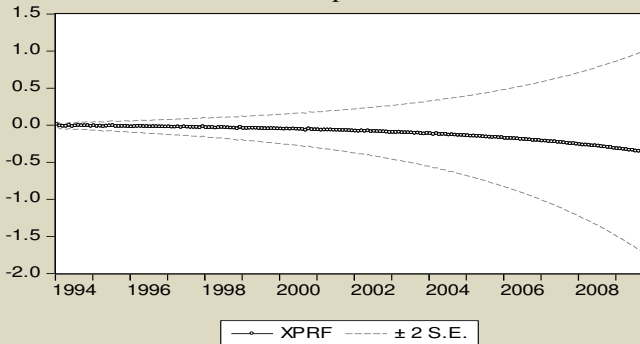
WITH ENERGY								
	D	D1	D2	D3	D4	D5	D6	D7
$\psi = \sum_{i=1}^q \alpha_i + \sum_{j=1}^p \beta_j + 0.5\gamma$	1.300	0.797	0.838	0.991	0.996	0.879	0.777	0.410
$\omega = \sum_{i=1}^q \alpha_i + \sum_{j=1}^p \beta_j$	0.810	0.510	0.727	0.608	0.856	0.806	0.572	0.080
$\theta = -\sum_{i=1}^a \alpha_i + \gamma$	0.793	0.638	-0.004	0.608	-0.675	-0.737	0.476	0.349
$\theta' = \sum_{i=1}^a \alpha_i + \gamma$	1.207	0.510	0.448	-0.024	1.037	1.031	0.344	0.971
$\alpha_0$	0.046	0.008	0.009	-1.019	0.026	0.031	0.012	-0.747
$\gamma$	1.000	0.574	0.222	0.767	0.181	0.147	0.410	0.660
WITHOUT ENERGY								
$\psi = \sum_{i=1}^q \alpha_i + \sum_{j=1}^p \beta_j + 0.5\gamma$	0.579	0.328	0.437	0.101	0.153	0.103	0.252	0.311
$\omega = \sum_{i=1}^q \alpha_i + \sum_{j=1}^p \beta_j$	0.916	0.675	0.669	0.402	0.400	0.407	0.503	0.621
$\theta = -\sum_{i=1}^a \alpha_i + \gamma$	-0.093	-0.578	-0.675	-0.831	-0.996	-0.832	-0.402	-0.833
$\theta' = \sum_{i=1}^a \alpha_i + \gamma$	0.093	-0.783	-0.371	-0.375	0.006	-0.386	-0.602	-0.405
$\alpha_0$	-3.74	8.9E-07	-1.320	-1.096	-0.093	-1.101	0.0051	-1.007
$\gamma$	-0.675	-0.658	-0.514	-0.603	-0.495	-0.609	-0.502	-0.619

Note:  $\psi$  : the duration of persistence;  $\omega$ : the sum of ARCH and GARCH effects;  $\theta$ : intensity of negative shock;  $\theta'$ : intensity of positive shock;  $\alpha_0$  : the reaction after shock;  $\gamma$  : the leverage effect.

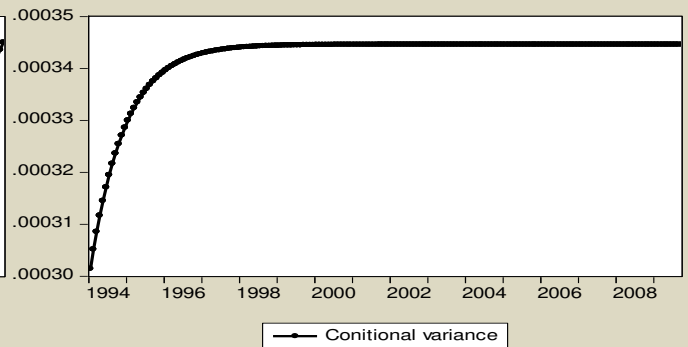
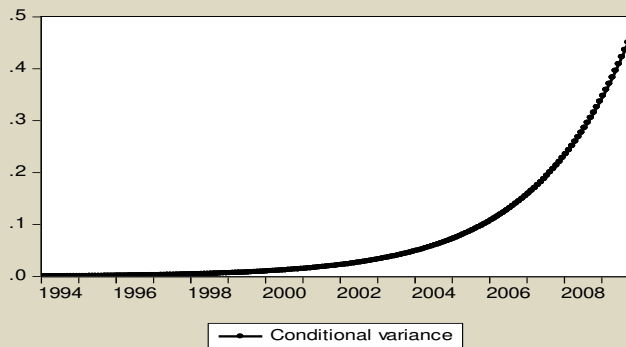
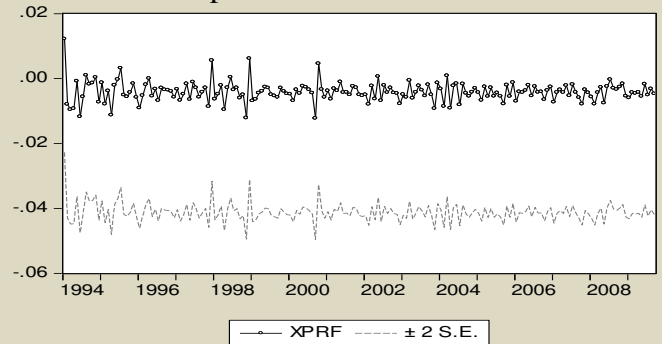
**Figure 4. Conditional variance under Time domain and frequency bands by using optimal GARCH model**

**WITHOUT ENERGY**

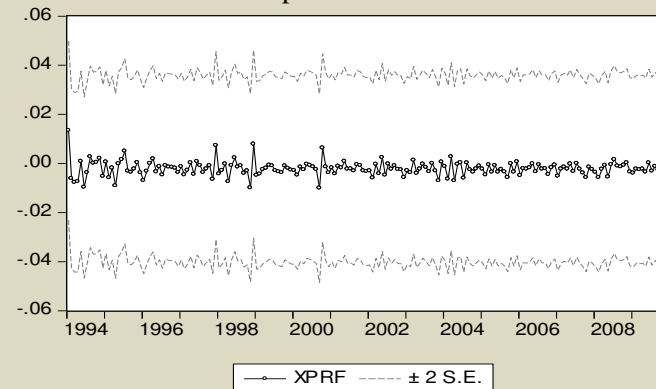
D: Time domain/ Optimal model: T-GARCH



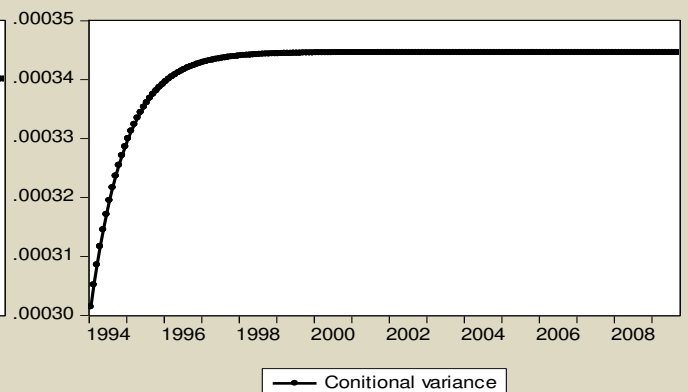
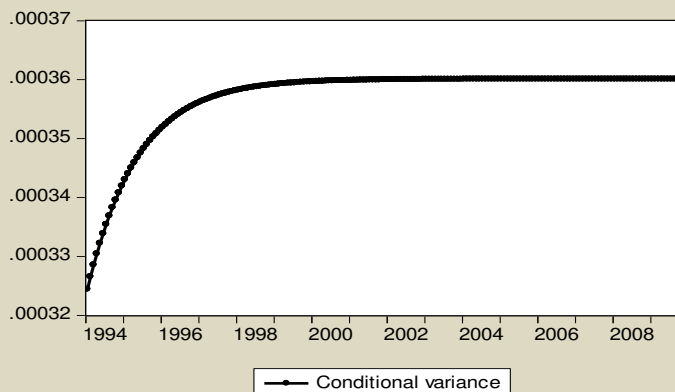
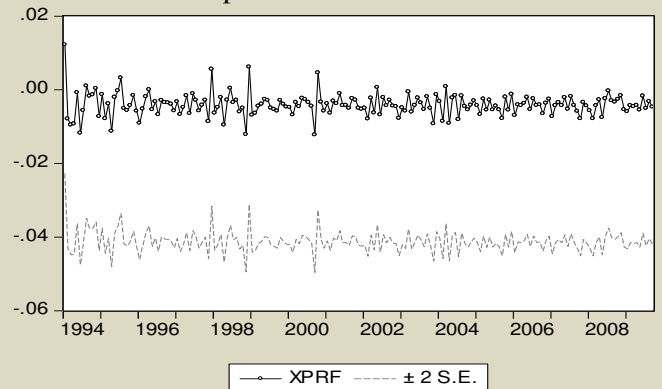
D1: 4-8M/Optimal model: E-GARCH

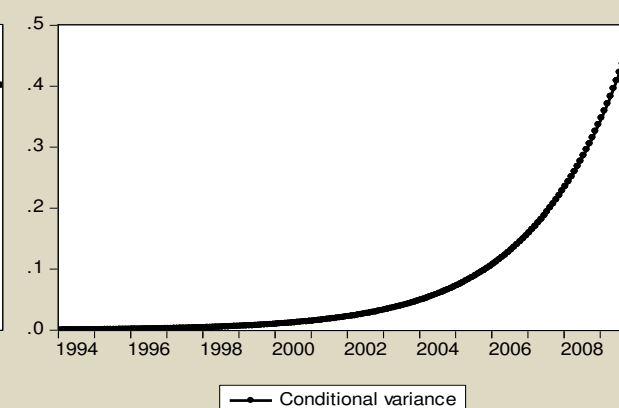
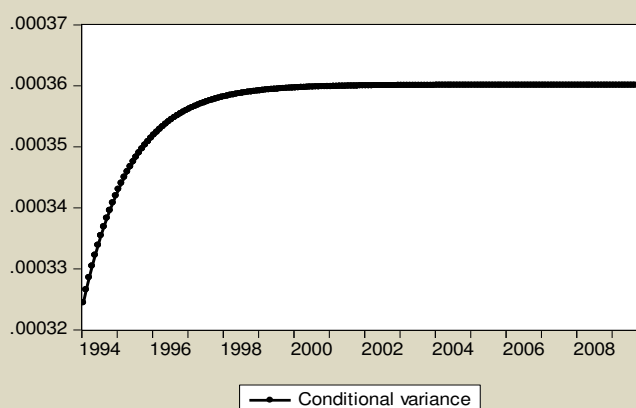
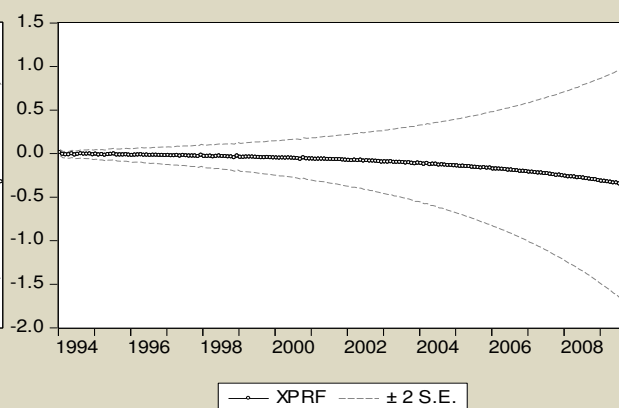
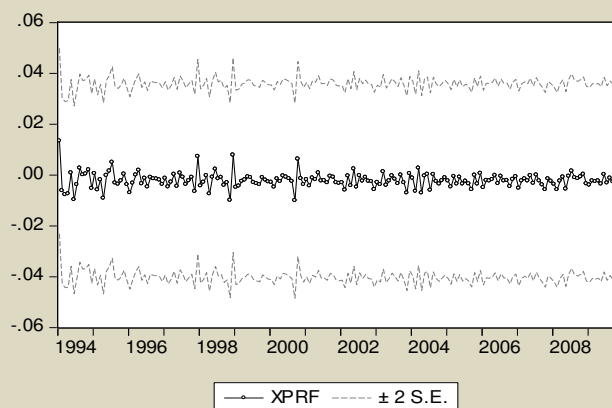


D2: 8-16M/Optimal model: GJR-GARCH



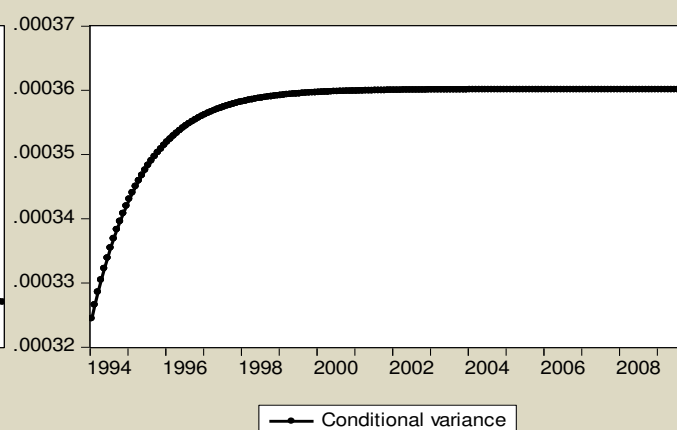
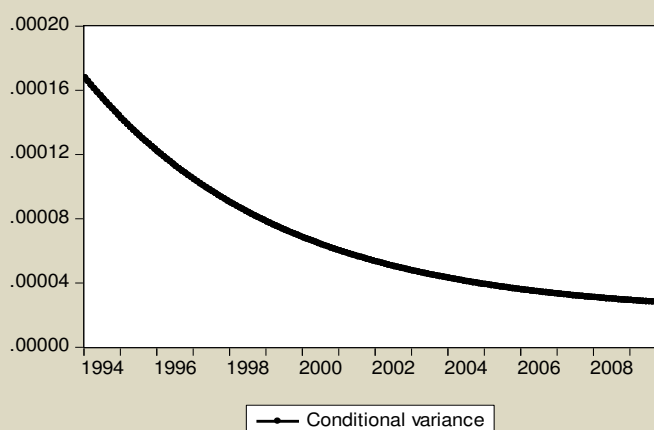
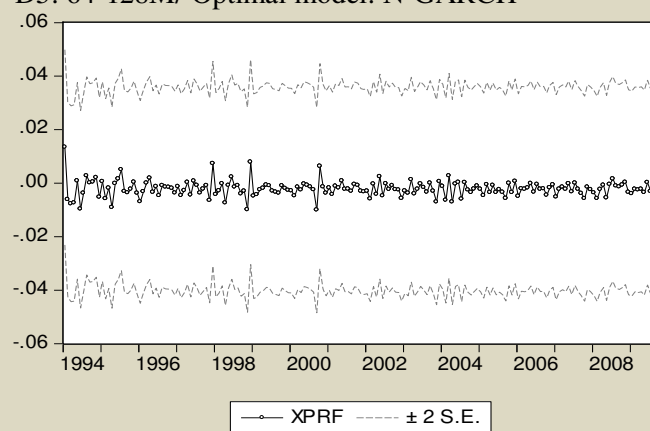
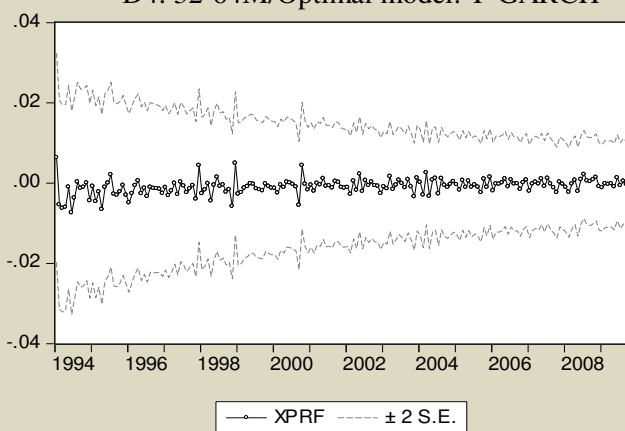
D3: 16-32M/Optimal model: E-GARCH



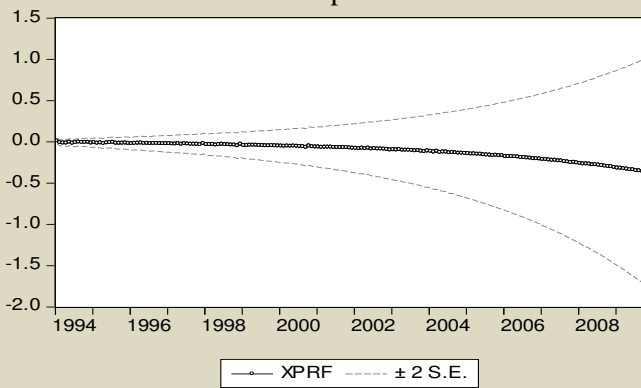


D4: 32-64M/Optimal model: T-GARCH

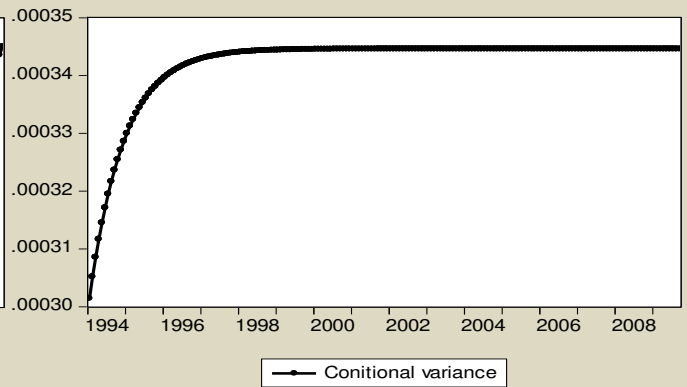
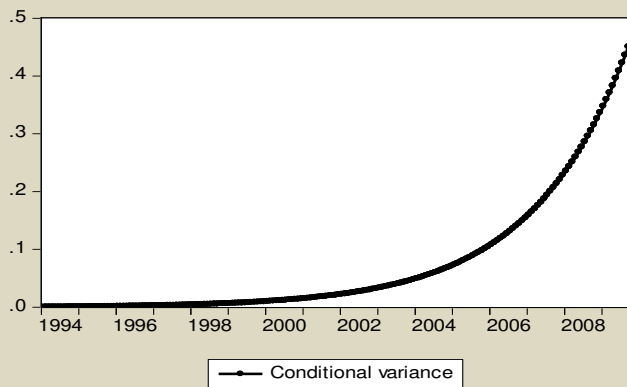
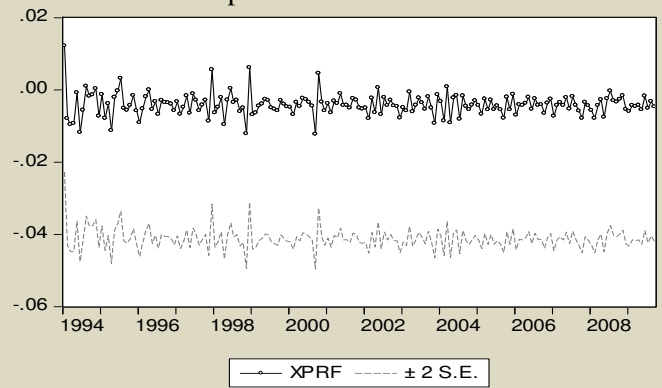
D5: 64-128M/Optimal model: N-GARCH



D6: 64-128M/ Optimal model: SA-GARCH

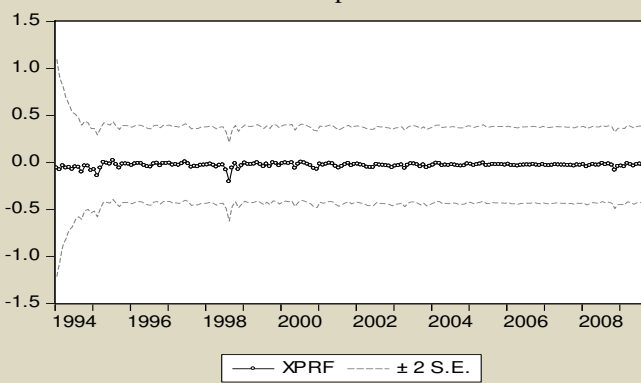


D7: >128M/ Optimal model: E-GARCH

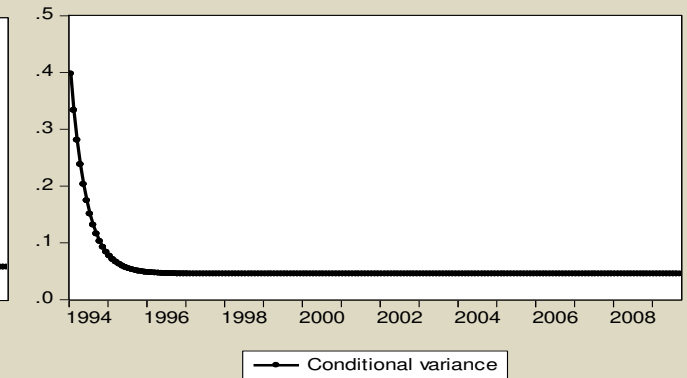
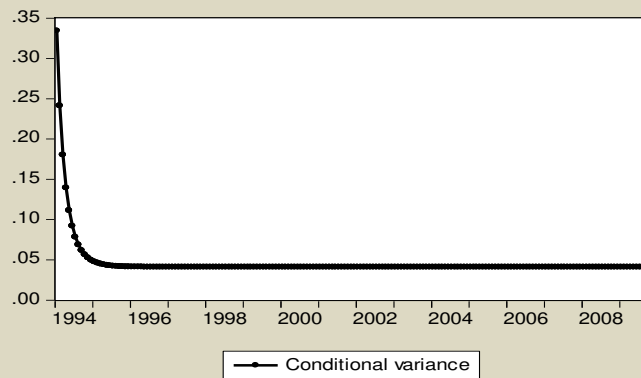
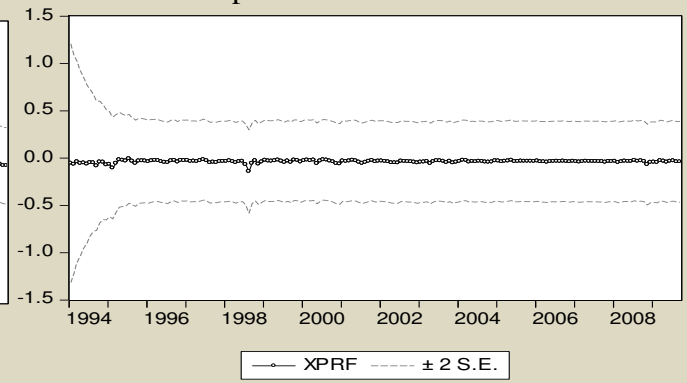


## WITHOUT ENERGY

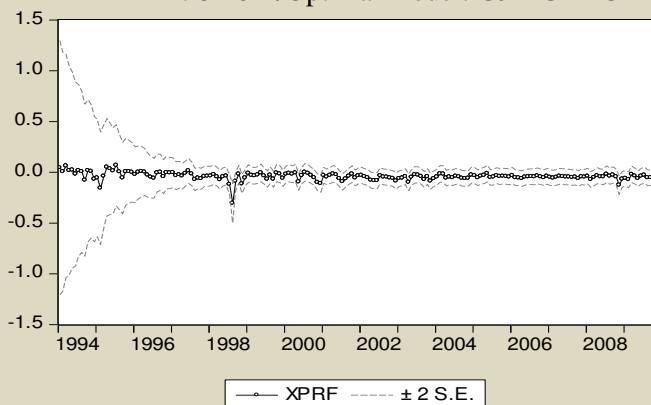
D: Time domain/ Optimal model: AP-GARCH



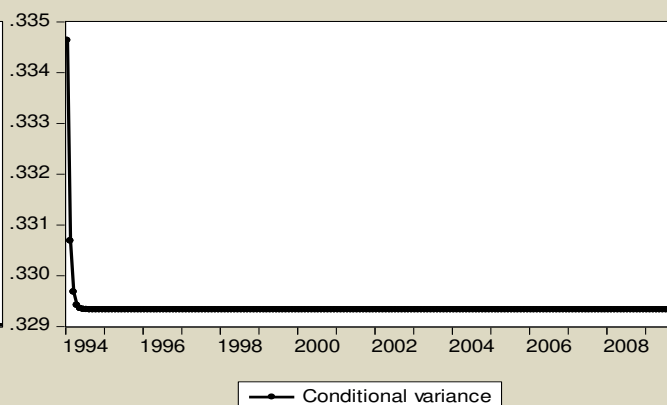
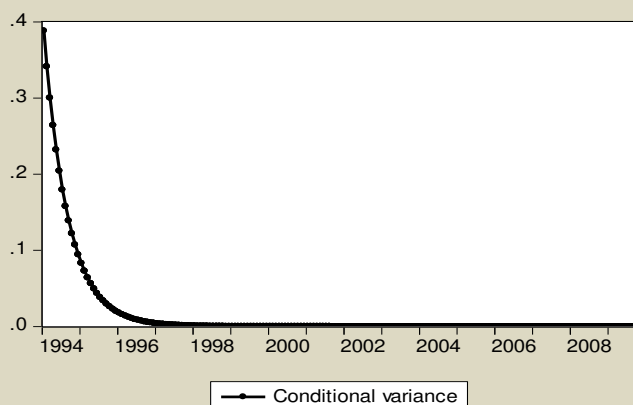
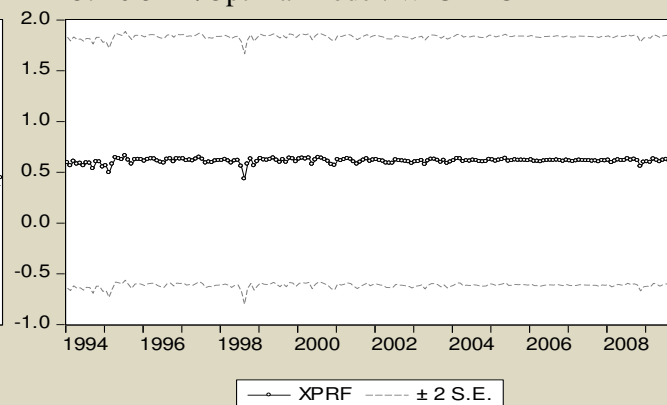
D1: 4-8M/ Optimal model: T-GARCH



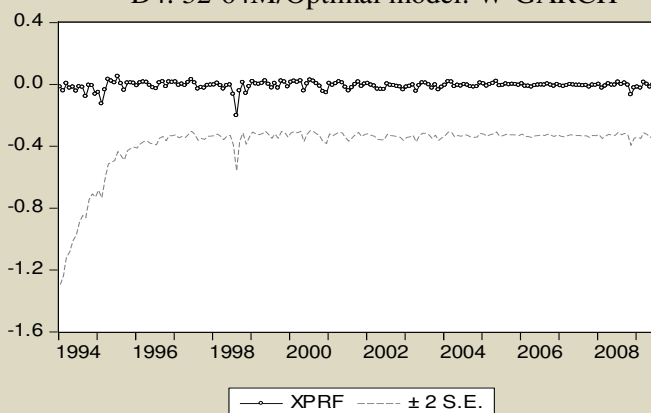
D2: 8-16M/Optimal model: GJR-GARCH



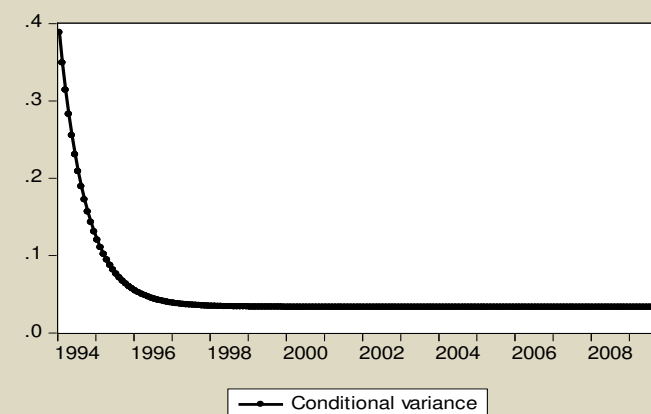
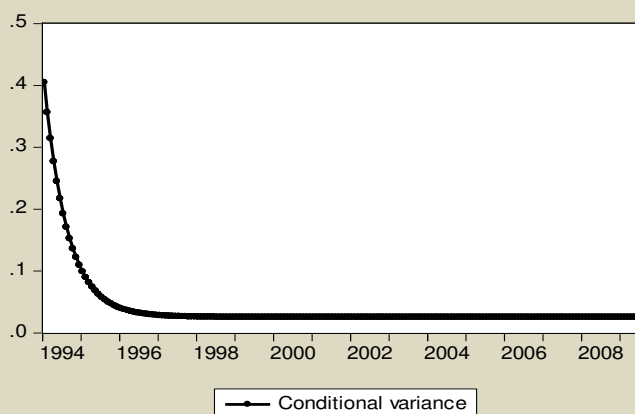
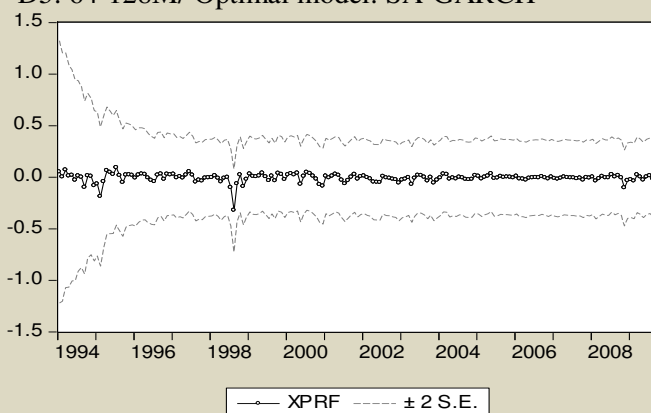
D3: 16-32M/Optimal model: W-GARCH

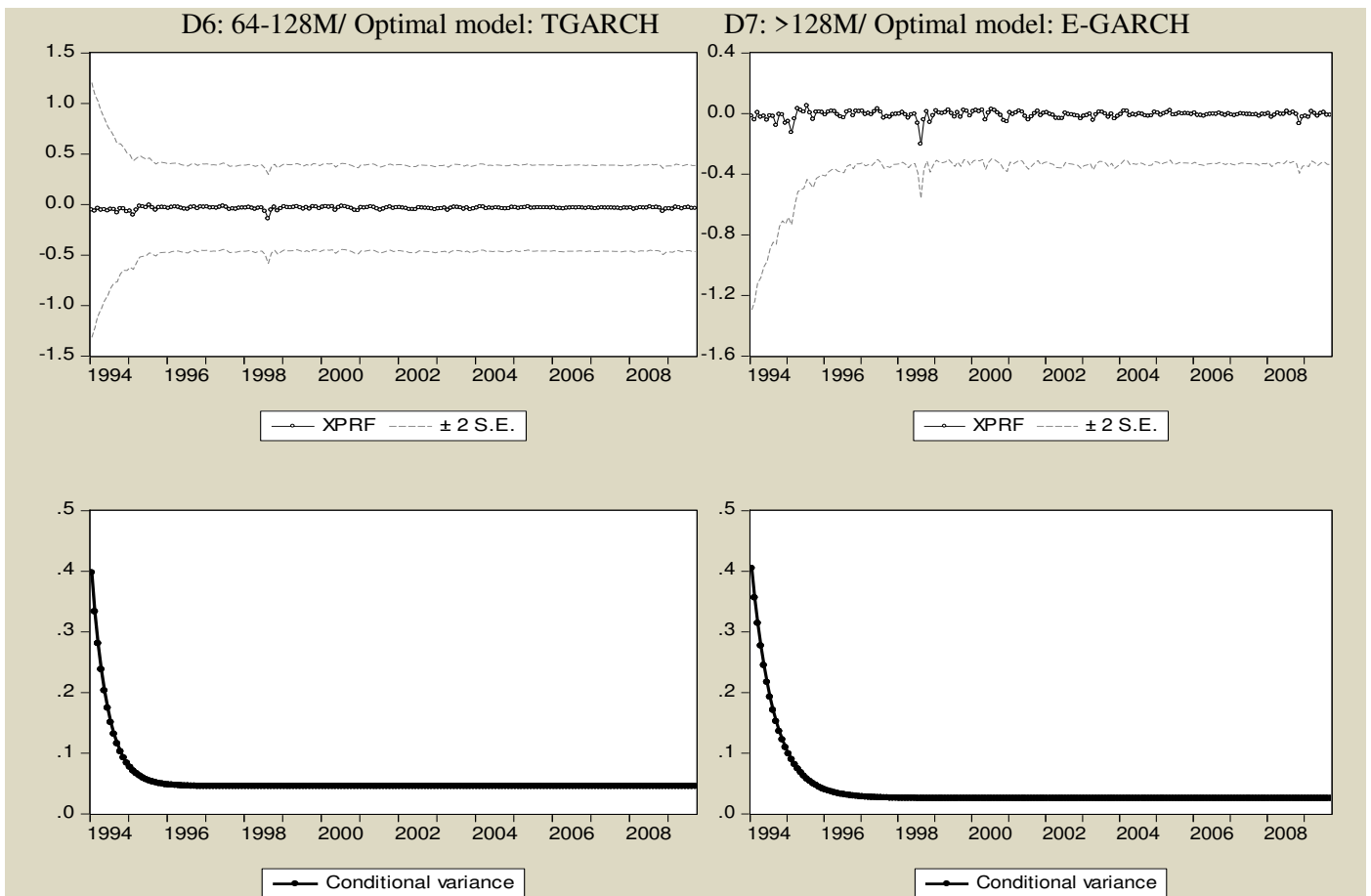


D4: 32-64M/Optimal model: W-GARCH



D5: 64-128M/ Optimal model: SA-GARCH

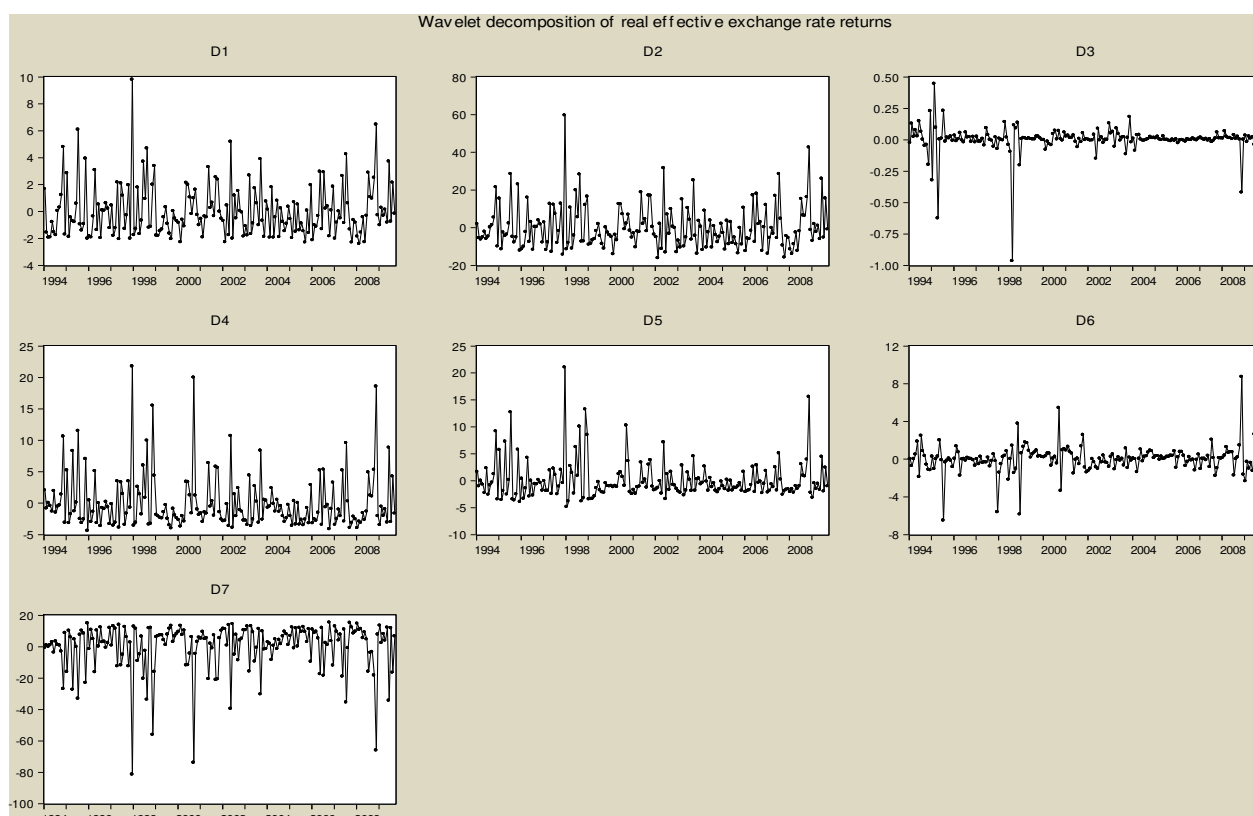
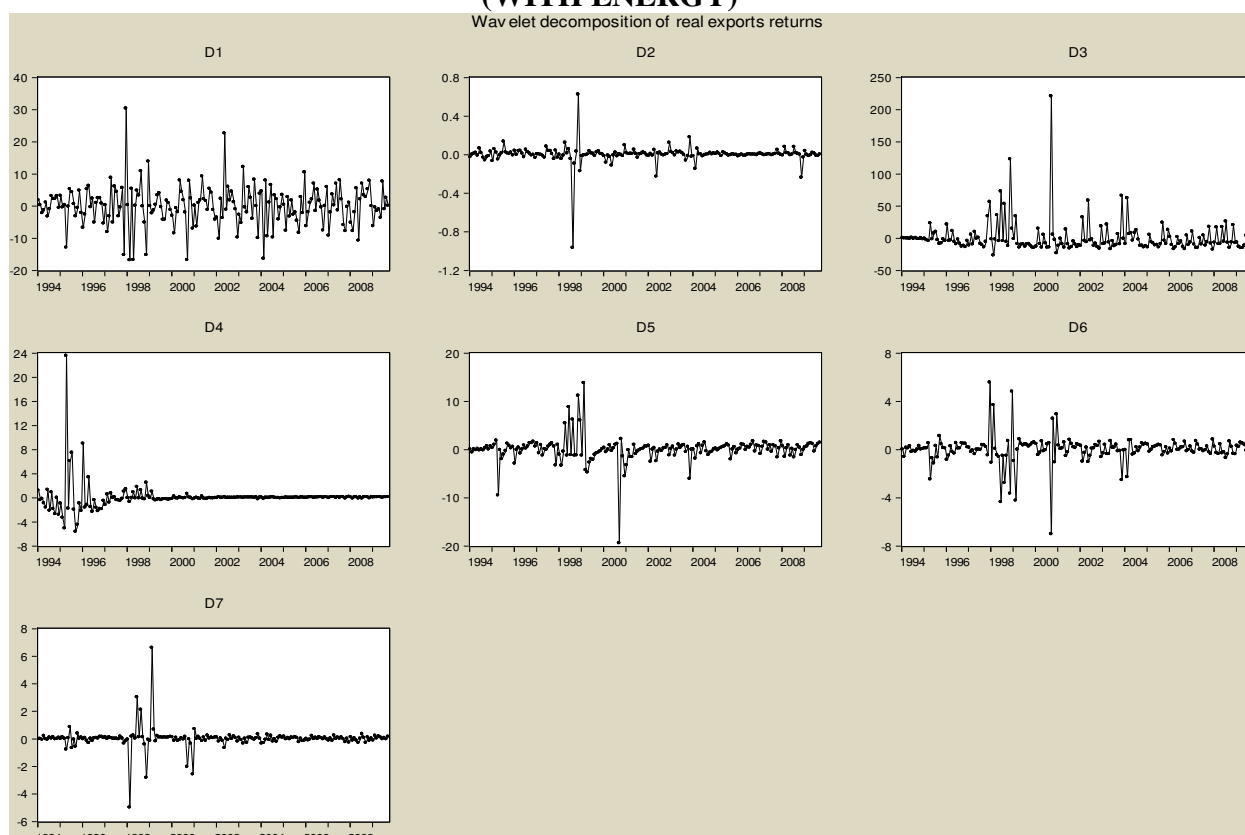




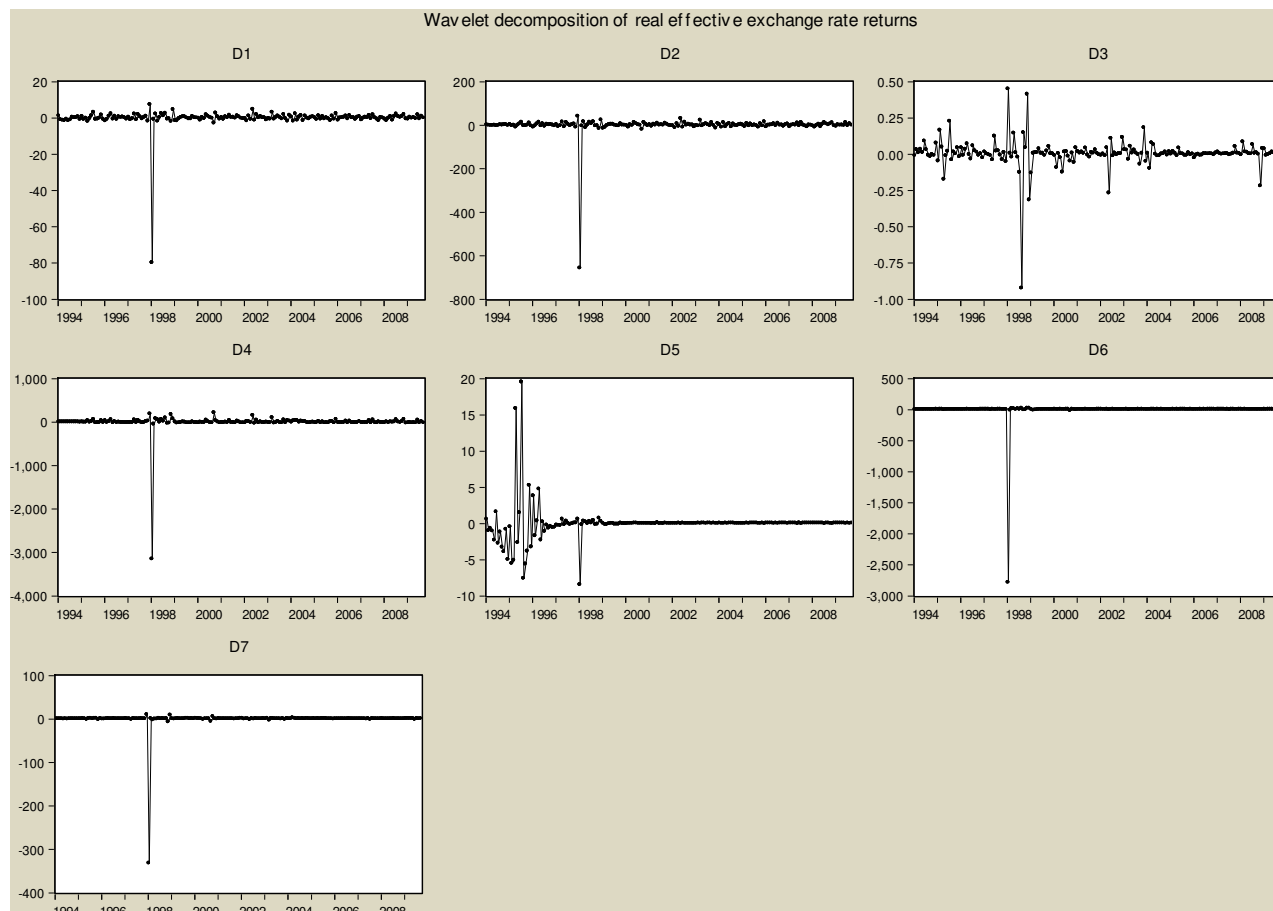
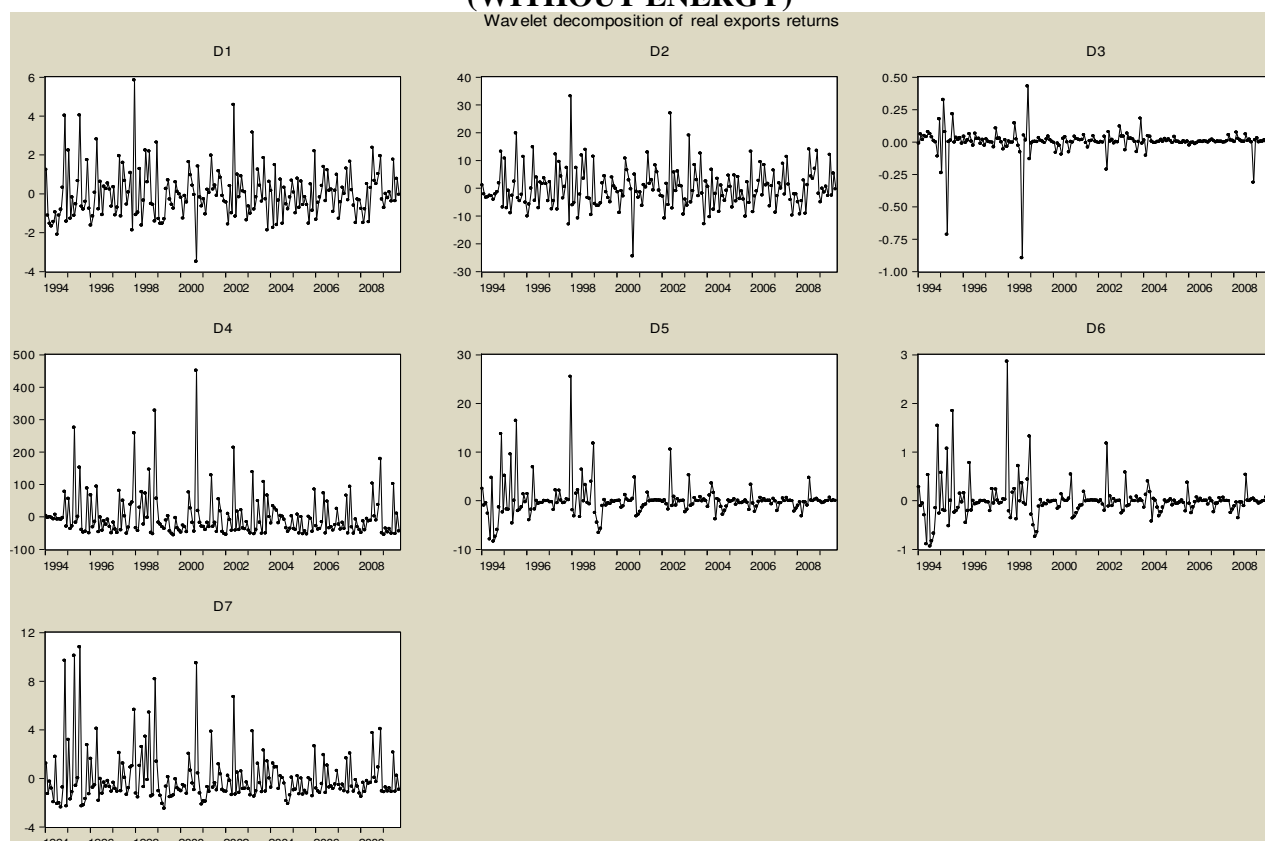
Note: Own calculation.

## Appendices

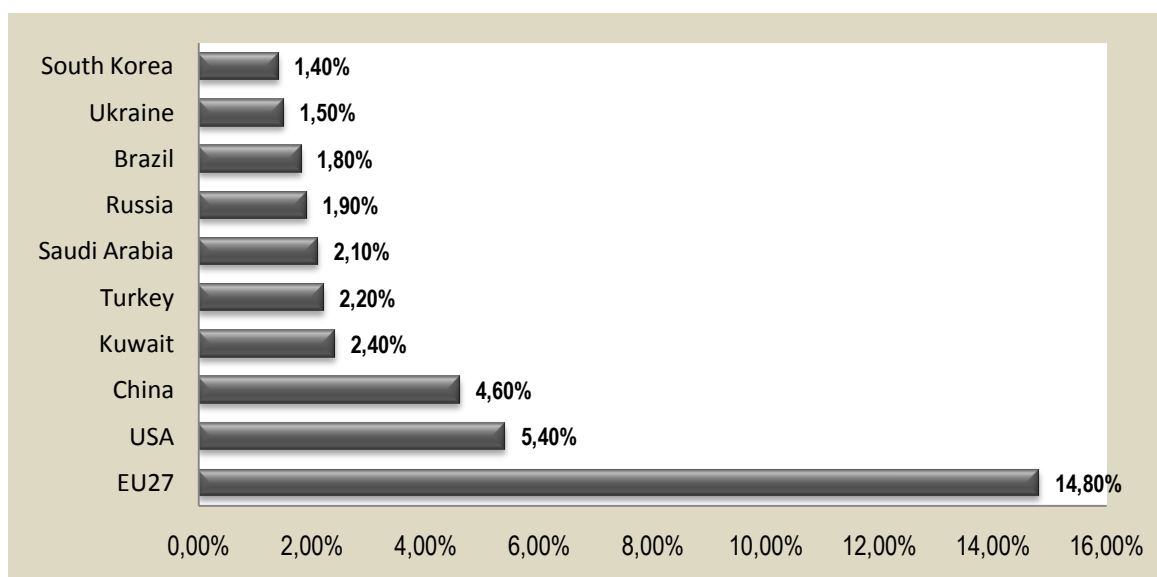
### Appendix A. Wavelets of real exports and real exchange rate returns (WITH ENERGY)



## Appendix B. Wavelets of real exports and real exchange rate returns (WITHOUT ENERGY)

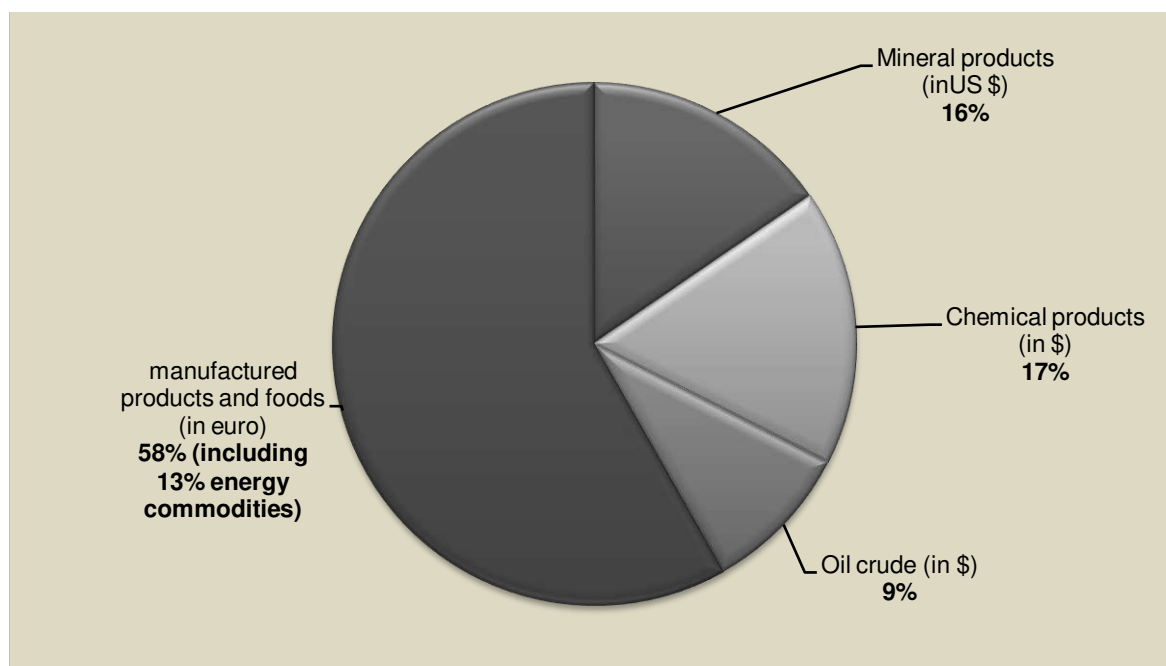


### Appendix C. Egyptian main trade partners



Note: For more details, see this link: [http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc\\_113375.pdf](http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_113375.pdf)

### Appendix D. Egyptian exports composition (to Europe)



Note: For more details, see this link: [http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc\\_113375.pdf](http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_113375.pdf)