Exchange Volatility and Export Performance in Egypt: New Insights from Wavelet Decomposition and Optimal GARCH Model

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Abstract: This paper assesses the link between exchange volatility and exports in Egypt by combining wavelet analysis with an optimal GARCH model chosen among various extensions. The observed outcomes reveal that this relationship is complex and depends then widely to frequency-to-frequency variation and slightly to leverage effect and to switching regime. Indeed, it is well shown that at the low frequency, the coefficient associated to exchange rate volatility's effect on trade performance is more intense than that at the high frequency and conversely when subtracting energy share from the total of exports. We attribute the apparently conflicting results to the financial speculation, the composition of trade partners and the choice of a reference basket's currencies.

Keywords: Exchange volatility; exports; wavelet decomposition; optimal GARCH model.

1. Introduction

Several studies suggest that exchange adjustment can threaten the trade performance. For example, McKenzie (1998), Vergil (2002), Bahmani-Oskooee (2002) and Achy and Sekkat (2003), among others. Up to now, there are various studies investigating the linkage between exchange variability and exports thereby the general perception here raises an ambiguous link between changes in exchange rate and exports in total, sectoral or bilateral terms (Nabli and Varoudakis (2002), Achy and Sekkat (2003), Keller et al. (2004) and Sekkat (2012), for instance).

To explain these patterns (i.e. the ambiguous effect of exchange volatility on total, sectoral and bilateral exports as mentioned above), the economists have advanced the risk-averse, the absence of hedging instruments, the specialization and the degree of competitiveness as key reasons of the controversial relationship between the two considered variables, except Egert and Zumaquero (2007), Arezki et al. (2011) and Bouoiyour and Selmi (2013), etc…). They argue that this effect can also be due to the degree of dependency and the vulnerability to oil price ups and down. It is conceivable then that the existing empirical research in this area suggests that the current economic crisis can be a major source of weaknesses in the financial system, which can itself lead to a more intense effect of exchange volatility on exports performance. Taking somewhat different evidence comparable to the pool of existing literature on this subject, we assess this link depending to frequency-to-frequency variation.

By following this logic, we thought to revisit the exchange rate volatility effects on exports while trying to highlight additional explanations of these conflicting results. Alternatively, various questions can be raised: Does developing exchange market generally and Egypt particularly breed more or less relative price volatility? What does it reveal about the leverage effect, switching regime, exchange volatility and exports connection? Do exports react differently when moving from one frequency band to other?

The answers of these several questions mentioned above will enhance our understanding on the relationship between exchange rate volatility and exports performance in Egyptian case and enable us to contribute to the pool of existing literature by:

Hence, the remainder of this paper is as follows: Section 2 is a brief overview of exchange and trade policies in Egypt. Section 3 presents the methodology of this study. In section 4, we proceed to estimate the linkage between real exchange rate volatility and real exports returns by 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 the paper.

2. A brief update of exchange and trade policies in Egypt

Following the demise of the Bretton Woods system in 1973, particularly early 80's, Egypt had a fixed system of its currency against the U.S. dollar. In 1991, the monetary authorities have announced the adoption of a managed float. From 1997, the Egyptian exchange rate has undergone many external shocks as the Asian crisis in mid-1997 which led to capital outflows, a slowdown in the capital market and investment losses for investors. During 1998, world oil prices uncertainty strengthened the decrease of current account balance. Following these various economic tensions, the government decided in 2001 to restore the stability of market by announcing a system of crawling peg (e.g. Kamar, 2004).

As a result, it is seen from the Figure 1, a real depreciation of Egyptian pound. We notice also a slight devaluation of real exchange rate over 2001 mainly due to the choice of government to adopt a managed float. Briefly, the movements of these exchange rates can tell us the decisions taken by the Egyptian monetary authorities in terms of exchange rate policy.

Furthermore, Figure 2 allows us to assess clearly export performance in Egypt. It is worthy remarkable that the overall period is distinguished by an excessive volatile behavior of real exports. 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 also 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 until 2005. Perhaps, to remedy this situation and to mitigate the effects of possible highly excessive volatility of real exchange rate on exports, Egypt should dispose more proactive reforms (e.g. Bouoiyour and Selmi, 2012).

3. Wavelet decomposition and optimal GARCH model

This study seeks to evaluate differently the assumption about the possible existence of short run dynamic between changes in real exchange rates and real exports in Egypt by using wavelet decomposition[1] and optimal GARCH model[2].

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 and then it enables us to captures both time and frequency varying features. More precisely, it separates each series into its constituent frequency components. Wavelet method encompasses both time domain and frequency bands leading to assess each time series either in the short or long-run term. This approach is based on the mother wavelet denoted $\psi(t)$ that must satisfy this condition:

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

Then, the mother wavelet $\psi(t)$ is deleted, as follows:

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

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

Most importantly, the wavelet decomposition is a succession of low-pass and high-pass filters to the series in question. Unlike time domain analysis, wavelets can identify which frequencies are present in the data at any given point in time. Once a series has been decomposed into several frequency bands, time series can then be extracted for further analysis. The decomposition of each function in question $X(t)$ will be expressed as follows :

$$X(t) = \lfloor w_1(t), v_1(t), \ldots, w_j(t), v_j(t) \rfloor \quad (3)$$

Where $w_1(t)$ and $v_1(t)$ respectively wavelet high frequency and wavelet low frequency.

[1] We can refer also to Benhmad (2012) and Bouoiyour and Selmi (2013).
[2] All GARCH extensions used in this study are summarized in Appendix A.

3.2. Why GARCH models?

In this article, we empirically assess the linkage between real exchange rate uncertainty and real exports. It is well shown that: First, volatile supply leads to temporal changes in demand conditions and thereby to multiple commodity price regime that affect widely the relationship in question (see Bouoiyour and Selmi, 2013) which leads us to account the threshold effect in the considered model. Second, the possible intervention of monetary authorities in exchange market leads us to take into account to good and bad news and not only to the magnitude of shock. Third, the relationship between exchange volatility and exports can be either transitory or permanent. So, it can be important 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.

Indeed, this study intends to make contribution on this issue. It is of utmost importance to evaluate whether changes in real exchange rate have temporary, permanent, transitory, asymmetrical (i.e. with leverage effect) or nonlinear (i.e. switching regime or structural break) effects on real exports performance. This remains an untapped area of serious research.

3.3. Data sources and methodological framework

In our research, we carry out various GARCH extensions under different time scales to check if this relationship varies over time (i.e. from low frequency to high frequency). More precisely, we explore a bivarite GARCH model[3] without taking into account other determinants of exports because we thought according to recent works that when we use various explanatory variables, the studied link can be a reflect of underlying factors that can carry another impact of exchange uncertainty on exports (e.g. Bouoiyour and Selmi, 2012). Then, we built an indicator which replaces the simple changes of real exports in accordance with real exchange rate returns. This indicator is constructed by using the variance between the two latter variables.

We use monthly data for the period from 1994 to 2009 collected from Econstats™ and International Monetary Fund (IMF). The variables in question are as follows:

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

Where $r_{XPR\,t}$ is the return of real exports which is determined using the ratio between nominal exports and the export unit value.

[3] This method has been largely used recently to evaluate the linkage between the variability of dollar vis-à-vis various currencies and oil price returns (e.g. Narayan et al. (2007), Mansor (2011), Gosh (2011) and Selmi et al. (2012)).

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

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 prior conversion to a common numeraire (by using nominal exchange rate). Hence, the real effective exchange rate is expressed as follows:

$$REER_t = NEER_t\ (P^*_t/P_t) \tag{6}$$

To examine the linkage between exchange rate and exports in real terms, we will begin by a linear model considering the interaction between r_{XPR} *and* r_{REER}. The model is forward looking at time *t.*

$$r_{XPR_t} = \alpha + \beta r_{REER_t} + \varepsilon_t \tag{7}$$

Where ε_t the error term.

Thereafter, we applied GARCH model chosen depending to frequency-to frequency variation. It is of course widely shown that GARCH-type modeling allows us to have several results (Anderson et al. 2009, for instance).

To choose the best model, it will be valuable to use standard criteria such as the Akaike criterion, the Bayesian Information Criterion and Hannan and Quinn criterion. Their expressions are disponible in Table 1. These criteria evaluate the models based on the historical volatility. To the extent that the discrimination function differs from one test to another, the use of any criteria will give different results, as discussed later. There is not really an optimal model. The optimality remains concerning the choice of the test. But, we can see that the Bayesian criterion is more restrictive than the Akaike criterion, since it introduces more parameters in the model. It is more parsimonious than other criteria (e.g. Bouoiyour et al. 2012). Importantly, these criteria seem sufficient to judge the quality of the estimation.

4. Application and main findings

4.1. Preliminary analysis

The descriptive statistics of real effective exchange rate returns and those of real exports are reported in Table 2. The sample means of real exchange rate returns and those of real exports are negative. The measures of skewness and kurtosis indicate that distributions of returns of real exchange rate and real exports are positive. This implies that the returns of these series are skewed and leptokurtic relative to a normal distribution. The Jarque–Bera normality test indicates a high level. This means a reject of normality of considered variables.

It is also observable from Figure 3 that there is a positive relationship between changes in oil price and those of real exchange rate in Egyptian case. This result means that an excessive real exchange rate volatility accentuate the real exports' uncertainty (e.g. Bouoiyour and Selmi, 2012), but the relationship appears minor.

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

4.2.Main findings: Estimates with energy versus without energy

To assess the interaction between real exchange rate returns and those of real exports, we use wavelet decomposition into seven components (i.e. frequency bands from 1980:1 to 2009:10 (see Table 3). This wavelet decomposition is made with respect to symmlet basis[4].

Results of estimates of the optimal model chosen among various GARCH extensions (see Appendix A) under domain time and then under several frequency bands presented in the Table 3 are summarized in Table 4. The main results reveal that there is 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. Although, the real exchange rate is determined by many factors, studies on its fundamentals in developing countries emphasize that export performance-exchange rate uncertainty connection depends intensely to the inherently volatile behavior of oil prices (e.g. Egert and Zumaquero, 2007). By doing so (i.e. with the subtraction of its share from real exports and differential price), we show a negative and significant linkage between the two variables either in time domain or in all monthly frequencies in question. Let us explain in detail.

4.2.1. Time domain

Estimating the relationship in question (with energy) under time domain, we observe clearly from Table 4 that an increase of 10% in real exchange rate leads to a significant increase on real exports by 28.6%. There is therefore a positive and significant linkage

[4] See Appendices B and C.

between our key variables under all returns from 1994:1 to 2009:10 which is unexpected. However, this result changes substantively by subtracting the share of energy from overall exports. Indeed, we show that an appreciation of 10% of real exchange rate leads to a decrease of the level of exports by 1%. This implies that the energy's share in overall exports which presents 26% (see Sekkat, 2012) makes a difference in the considered relationship.

Let us check if this results that appears interesting, in the following, changes depending to several frequency bands by using wavelet decomposition.

4.2.2. Frequency bands

It is remarkable from Table 4 that the effect of real exchange rate returns on those of real exports is positive and significant under all considered frequencies (i.e. D1, D2, D3, D4, D5, D6 and D7). Hence, we observe that an appreciation of real exchange rate by 10% implies an increase in real exports by 36.9%, 25.4%, 26.3%, 17.9%, 37.5%, 13.9% and 12.22%, respectively depending to the different time scales in question. This result is also unexpected. As above mentioned in the case of time domain, the subtraction of energy leads also to different results but it appears that these latter do not change substantively depending to frequency-to-frequency variation in terms of the sign. Therefore, an appreciation of real effective exchange rate by 10% yielded to a decrease of real exports by 0.5%, 1.3%, 0.1%, 0.2%, 1.8%, 2.3% and 1.9%, respectively under D1, D2, D3, D4, D5, D6 and D7. Nonetheless, the magnitude of the effect depends to frequency transformations (for example, we can observe that at the lowest frequency, the coefficient associated to exchange rate volatility's effect on exports (with energy) is more intense than at the highest frequency presenting 36.9% and 12.22%, respectively and conversely for the case (without energy)).

Equally important, our results reported in Table 5 provide that the duration of persistence under time domain and all the frequencies in question is strong (with energy) and lower when subtracting the share of energy sector (without energy) implying a tendency to long memory process in the first one and to short memory process in the second one. Furthermore, without subtracting energy sector and under all returns as well as all frequency bands, the coefficient γ is positive implying that the effect of bad news is more intense than good news. Nonetheless, under all time scales and with subtracting energy sector's share, the coefficient γ is negative and significant which confirms the occurrence of asymmetry which itself more sensitive to good news than bad news. Accordingly, Figure 4 shows that the conditional variance between real exchange rate and real exports behaves better when we subtract the large share of energy from the total of Egyptian exports.

In sum, we notice that with energy, real exports react more to real exchange rate volatility at low frequency than high frequency. However, without energy, this relationship behaves differently and therefore seems more intense at high time scale than at low frequency band.

4.3.Discussion of results

The observed outcomes summarized above reveal that the interaction between exchange rate uncertainty and exports in Egyptian case depends considerably to upward and downward oil prices' fluctuations. This result seems hardly surprising because of the important proportion of energy in the total of exports of Egypt (i.e. 26%).

For all studied cases (i.e. without and with energy and under different considered time scales), we notice clearly that leverage effect (i.e. innovations either good or bad news) impacts more potentially real exchange rate returns effects on those of real exports than threshold order (i.e. structural breaks or shifts). More precisely, we show that with energy the magnitude of considered effect is equal to 35.34% (as average) when we take into account the sign of innovations comparable to 23.52% (as average) when we take into 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 1.83% (as average) for the first one and 1.26% (as average) for the second one.

Not surprisingly, in oil exporting economies that adopt managed exchange regime such as Egypt (e.g. Kamar, 2004), the adjustment in real exchange rate will come through changes in consumer prices. The rise in crude of oil leads to a rise in inflation and a fall in the oil price leads to a period of deflation. This implies that both rise and fall of crude of oil put inflationary pressures when the exporters are pegged in the dollar (e.g. Bouoiyour and Selmi, 2013). Hence, in oil exporting countries with basket currencies dominated by US dollar, the inflation and oil price uncertainty make them unable to adjust their currencies and lead to excessive swings in real exchange rates that affect immediately exports' evolution. This can outweigh a positive effect[5].

[5] 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."

Intuitively, the observed outcomes (with energy) show that exchange uncertainty's effect on real exports is greater at low frequencies. This may be mainly attributable to the speculative effects, i.e. the energy market is a large market relative to other commodities and the assumption of financial speculation may be evident.[6] This leads to an increase of comovement between the spot price of oil and oil futures prices. In related work, Buyuksakin et Harris (2011) test whether positions taken by speculators such as hedge funds and swap dealers cause changes in oil futures prices or excessive volatility. Alquist and Kilian (2010) and Fattouh et al. (2012) add 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.

Besides, when the domestic country carries most of its trade with a single major country, pegging the local currency to that of foreign country's currency can mitigate exchange rate uncertainty. Nonetheless, the effective exchange rate can capture the value's effects of the local currency vis-à-vis the currencies the trading partners of its main partner. Intuitively, Egyptian commodities exports may be affected by the euro's movements, especially because its main exports partner is Europe with share almost equal to 15.7% on the overall of exports (see Appendix D) even when international prices are quoted in dollar.

It is also important to add that Europe is also considered one of main exports partners of Egypt followed by USA and China. This implies that the oil price volatility can coincide with a great volatility of (euro/dollar). Accordingly, Appendix E reveals that exports to European Union, both are dominated by mineral and energy sectors which are denominated on dollar and their prices are characterized by the most inherently volatile behavior among all commodities in international market (see Arezki et al. 2011).

Admittedly, without energy, real exports react more to real exchange rate volatility at high frequency than low frequency. This may be due to various drawbacks associated to the choice of the pegged exchange rate regime in this country. Firstly, slow labor market adjustments in Egypt can produce dramatic and unsustainable current account imbalances. Secondly, for pegs, the choice of a reference basket of currencies involves decisions that are

[6] For more details about how speculators can be drivers of oil price uncertainty, we can refer to Buyuksakin and Harris (2011).

dependent on trade concentration, the degree of market openness, the size of the country and various other indicators that can outweigh the real effect of real exchange rate on real exports.

5. Conclusion

In this paper, we revisit the relationship between real exchange rate returns and those of real exports to check whether there is a significant short run dynamic between the latter key series and if this relationship varies depending to frequency bands. To investigate it, we combine wavelet analysis with an optimal model chosen among various GARCH extensions (i.e. linear versus nonlinear, symmetrical versus asymmetrical, etc…).

Our results reveal that the combination performed between wavelet analysis and optimal GARCH specification succeeded to enhance our understanding of the controversial link widely expected by several studies on this subject. 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 mainly attributable to the speculative effects that characterize the behavior of energy prices and the composition of exports partners dominated by Europe.

(ii) Without energy, this relationship between exchange volatility and exports performance behaves differently and therefore seems more intense at high time scale than at low frequency band that can be closely associated to the choice of exchange regime's drawbacks.

These results can be good signals for practitioners in exchange and trade policies in developing countries, generally and in Egyptian case, particularly. Intuitively, we argue that regulatory efforts would be a preferable way of dealing with the possible speculation of energy market and the inherently excessive volatile behavior of real exchange rate effects on export performance. The implementation of policy reforms to accelerate investment diversification or developing competitive non-oil sectors can also mitigate the vulnerability of Egypt to oil price shocks.

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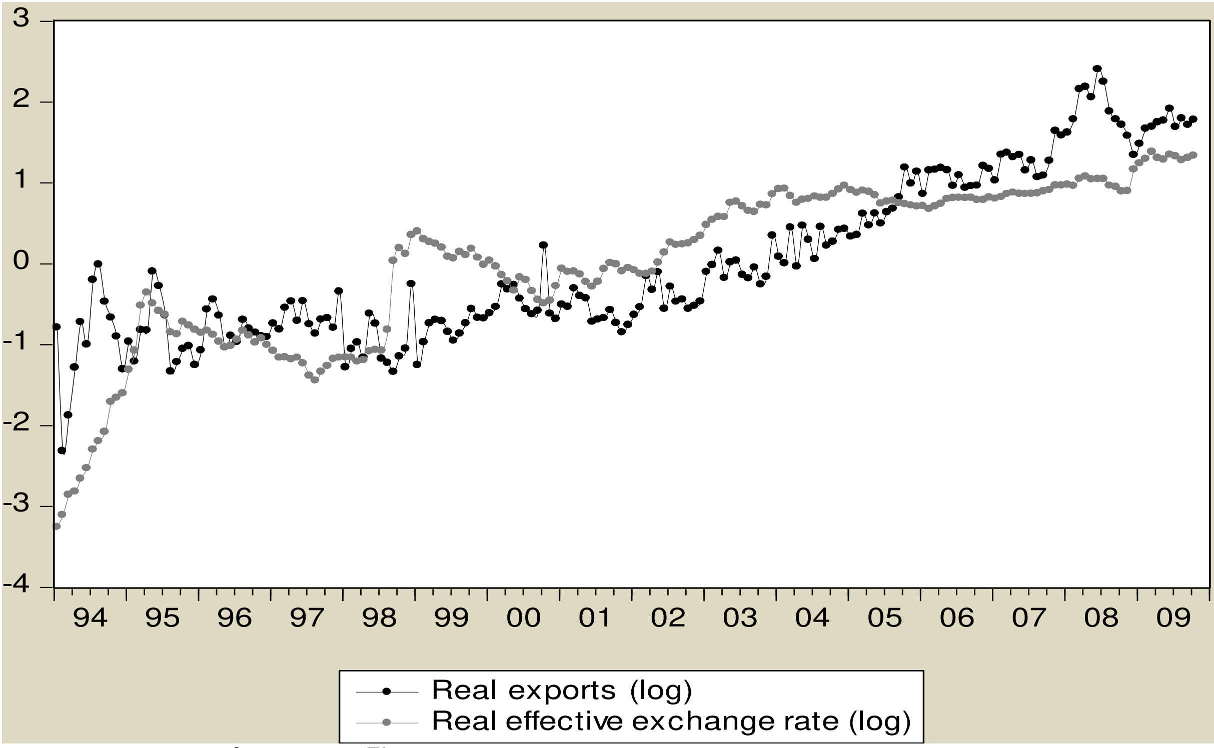
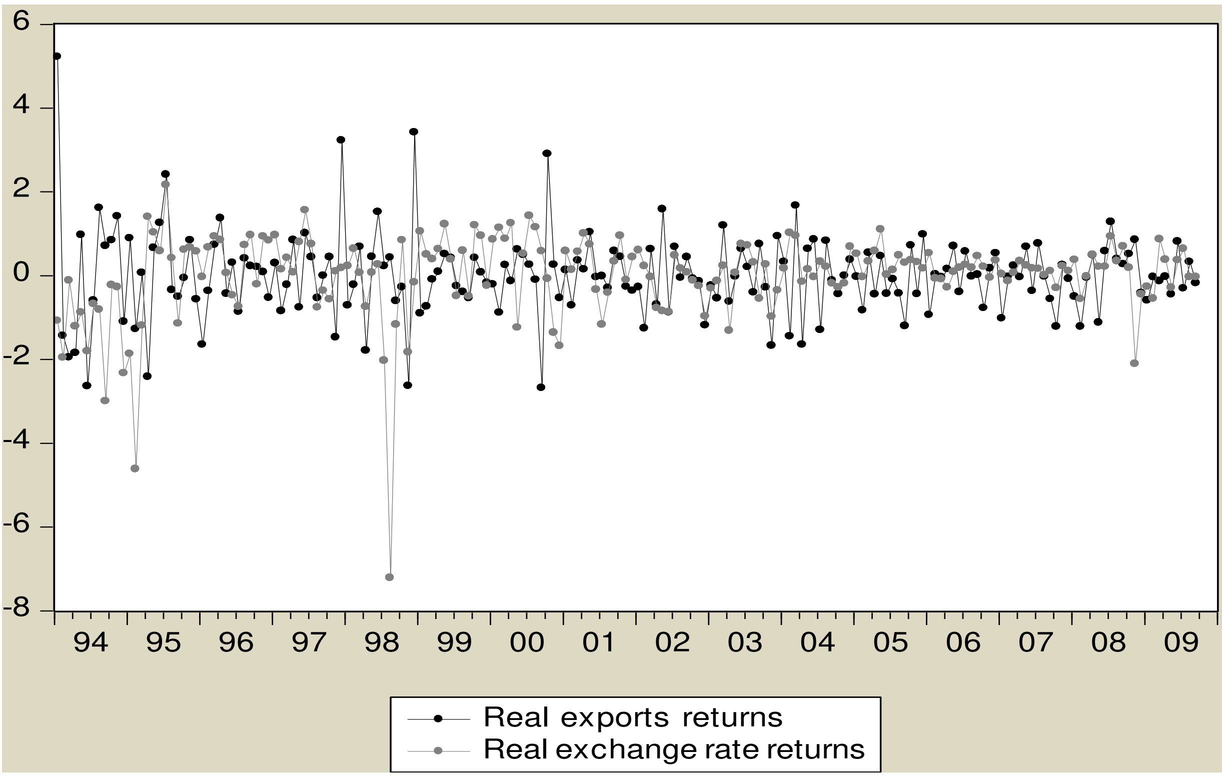
Figure 1. Real exports and real effective exchange rate (Normalized data)



Source: IMF, IFS and Econstats™.

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



Source: IMF, IFS and Econstats™ and authors'calculations.

Table 1. Criteria used on the choice of the optimal GARCH model

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

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

Table2. 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

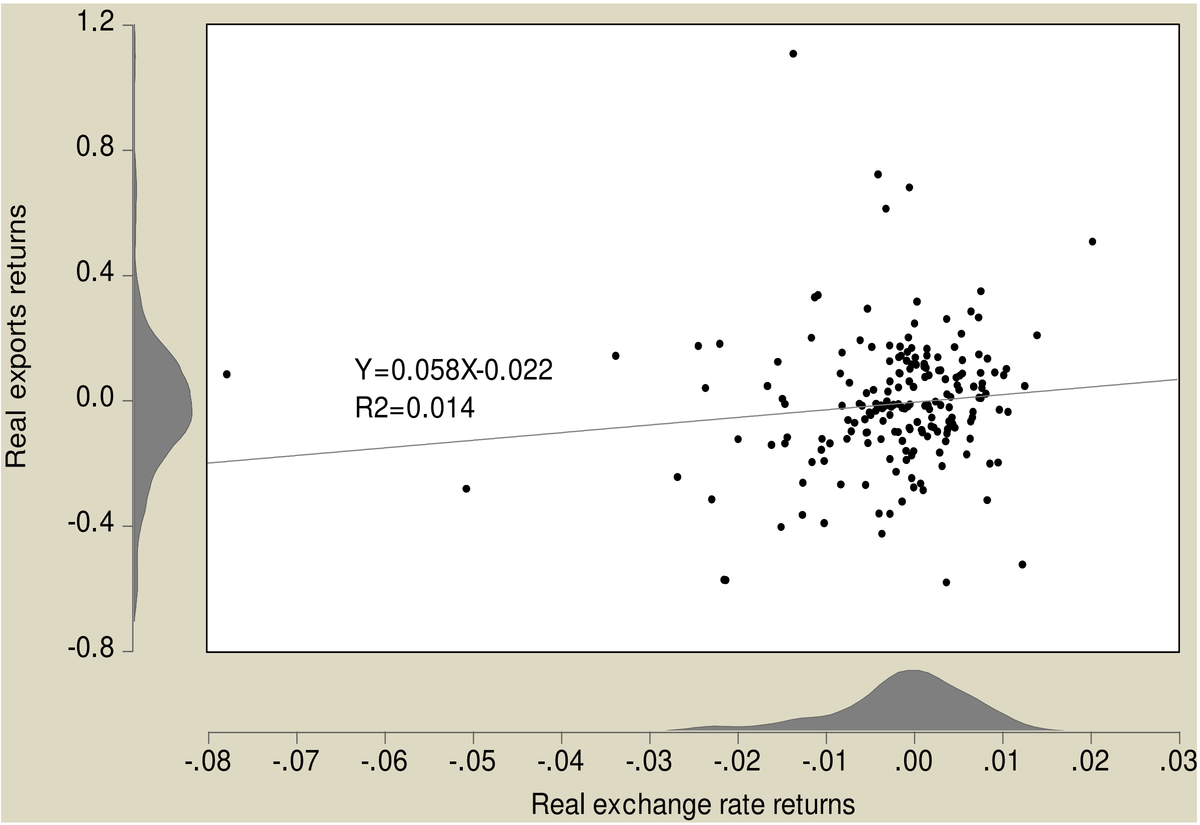


Table 3. Frequency bands

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

Table 4. The link between changes in real exchange rate and those of real exports: Parameters of optimal GARCH model

Dependent variable: r_{XPR}								
WITH ENERGY								
	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								
Constant	-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								

α_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)
α_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)
β_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)

WITHOUT ENERGY

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								
α_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)
α_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)
β_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)

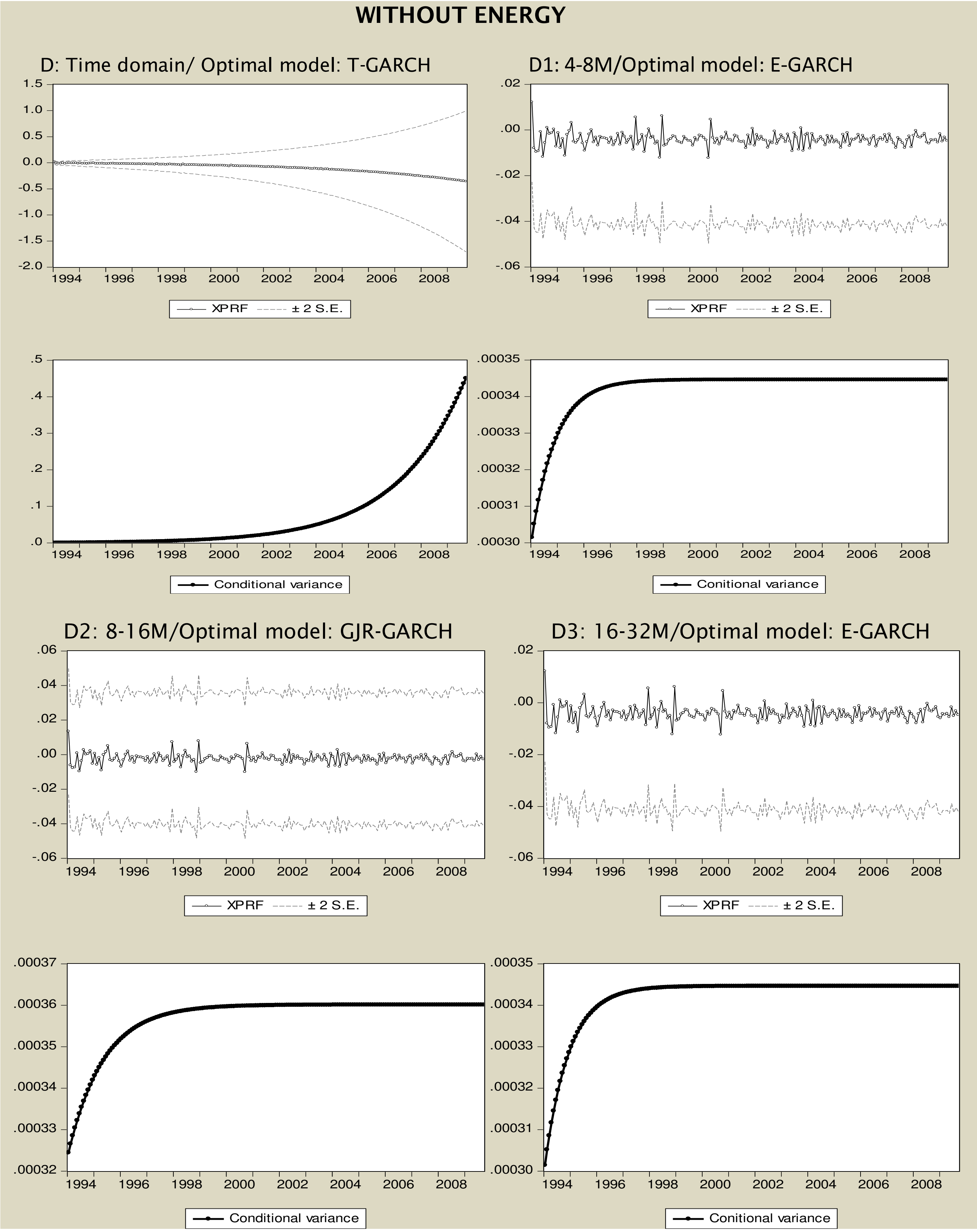
Note: standard deviations are in parentheses, *** significant at 1%, ** 5% * 10%. r_{XPR}: changes in oil prices; r_{REER}: changes in real effective exchange rate; w : The reaction of conditional variance; α : ARCH effect; β : ARCH effect; Y : Leverage effect.

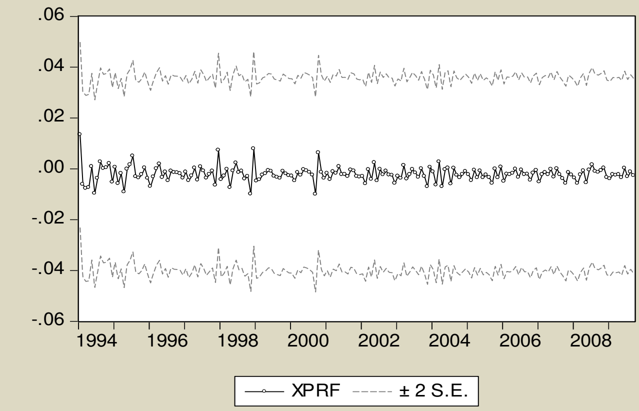
Table 5. Persistence of conditional variance

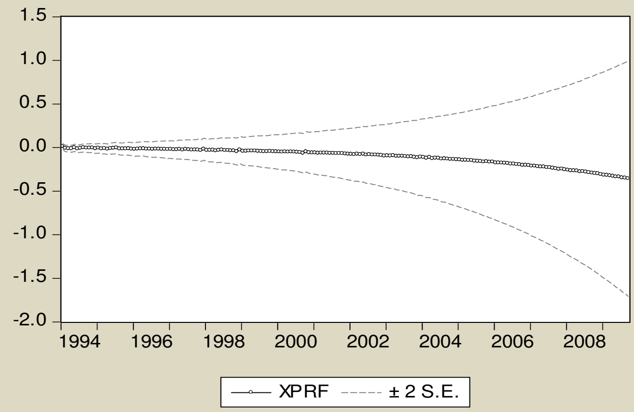
	D	D1	D2	D3	D4	D5	D6	D7
WITH ENERGY								
$\psi = \sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_j + 0.5\gamma$	1.300	0.797	0.838	0.991	0.996	0.879	0.777	0.410
$\omega = \sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_j$	0.810	0.510	0.727	0.608	0.856	0.806	0.572	0.080
$\theta = -\sum_{i=1}^{a} \alpha_i + \gamma$	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
α_0	0.046	0.008	0.009	-1.019	0.026	0.031	0.012	-0.747
γ	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
α_0	-3.74	8.9E-07	-1.320	-1.096	-0.093	-1.101	0.0051	-1.007
γ	-0.675	-0.658	-0.514	-0.603	-0.495	-0.609	-0.502	-0.619

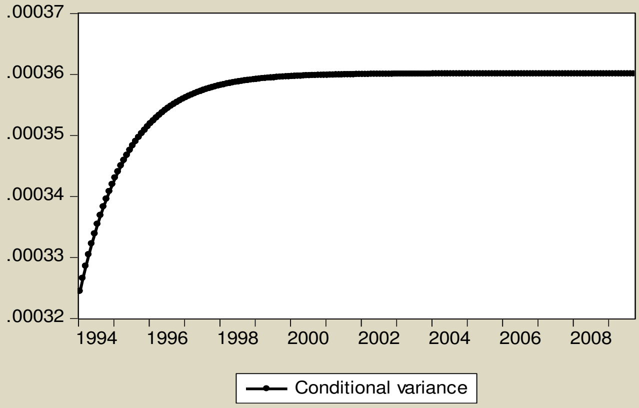
Note: ψ : **the duration of persistence;** ω: **the sum of ARCH and GARCH effects;** θ: **intensity of negative shock;** θ': **intensity of positive shock;** α_0 : **the reaction after shock;** γ : **the leverage effect.**

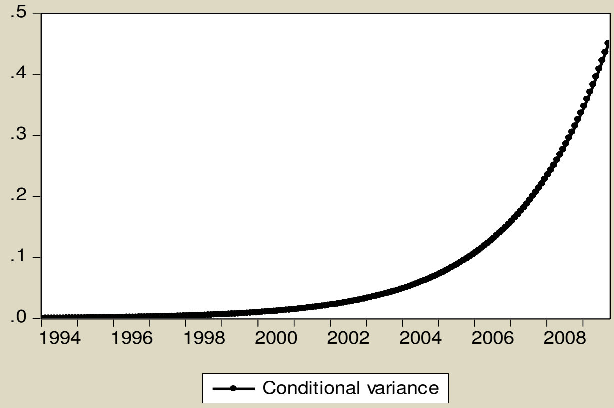
Figure 4. Conditional variance under Time domain and frequency bands by using optimal GARCH model



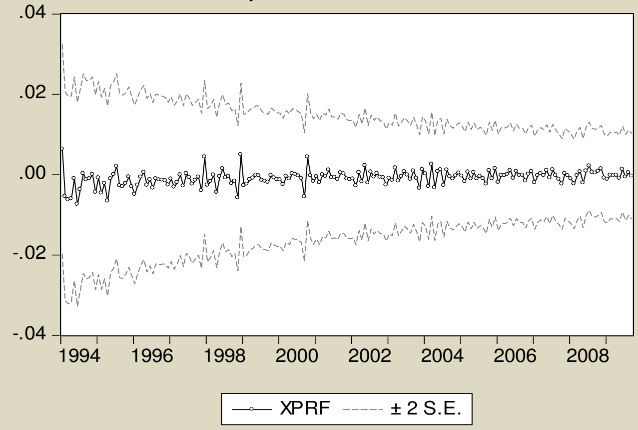


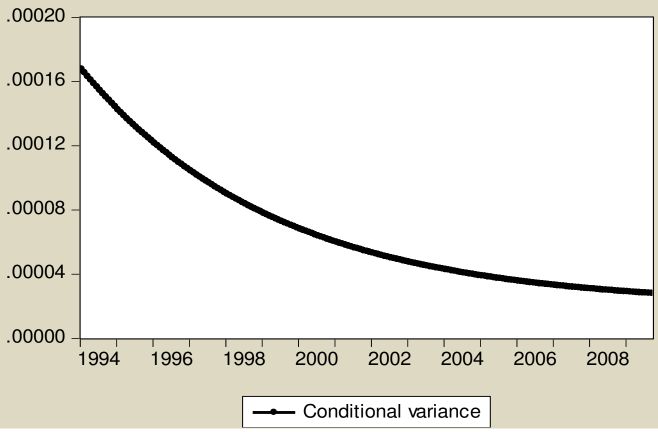




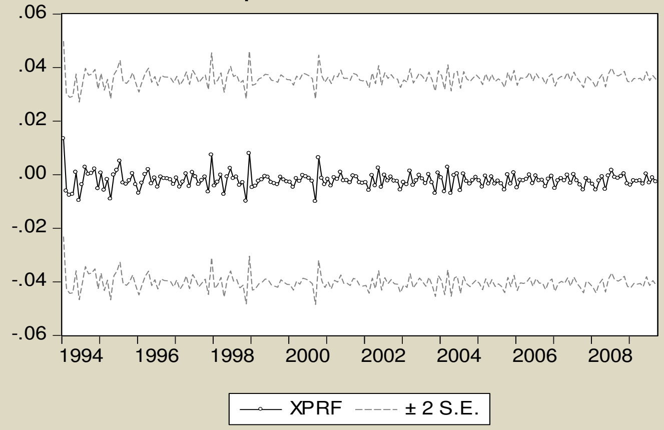


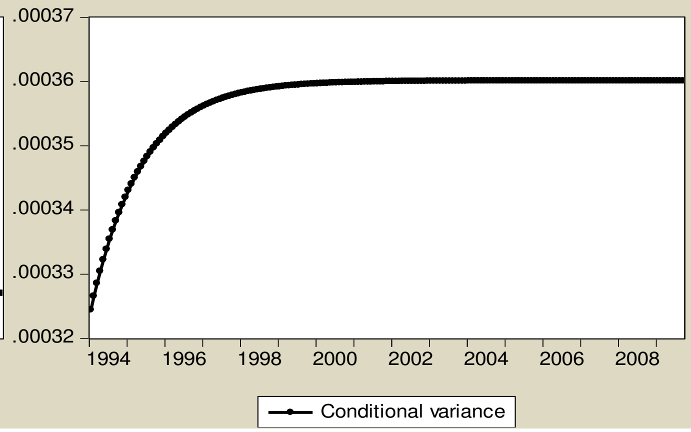
D4: 32-64M/Optimal model: T-GARCH



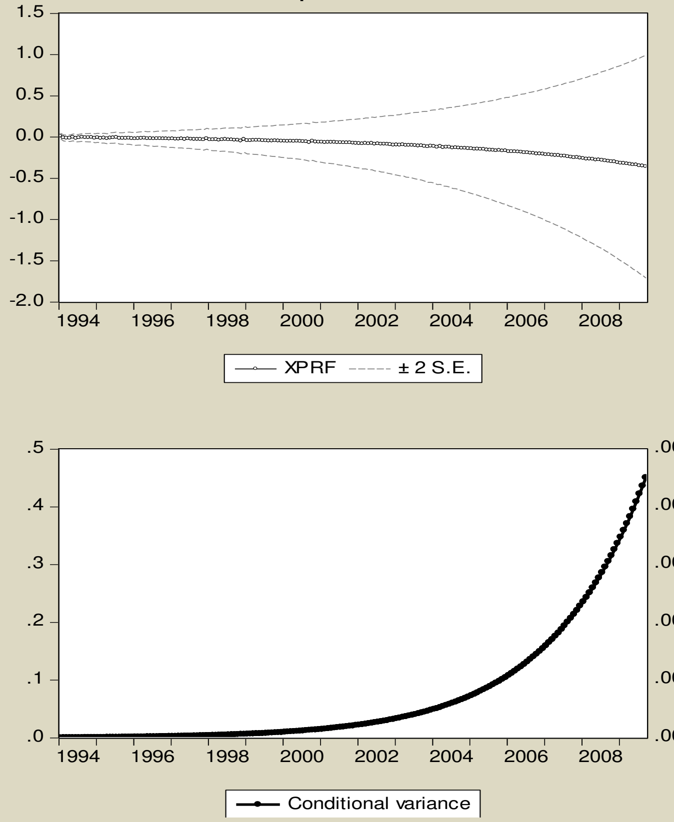


D5: 64-128M/ Optimal model: N-GARCH

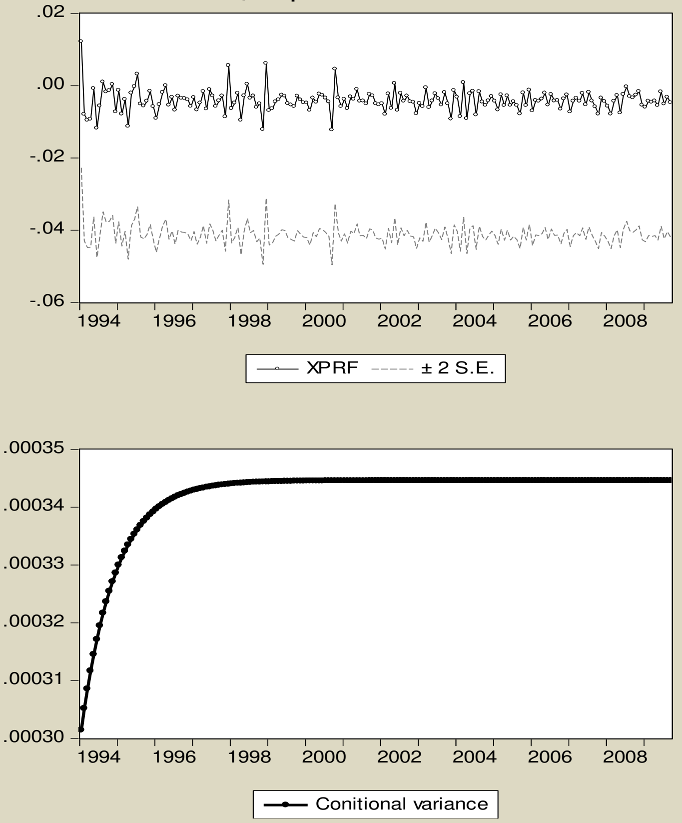




D6: 64-128M/ Optimal model: SA-GARCH

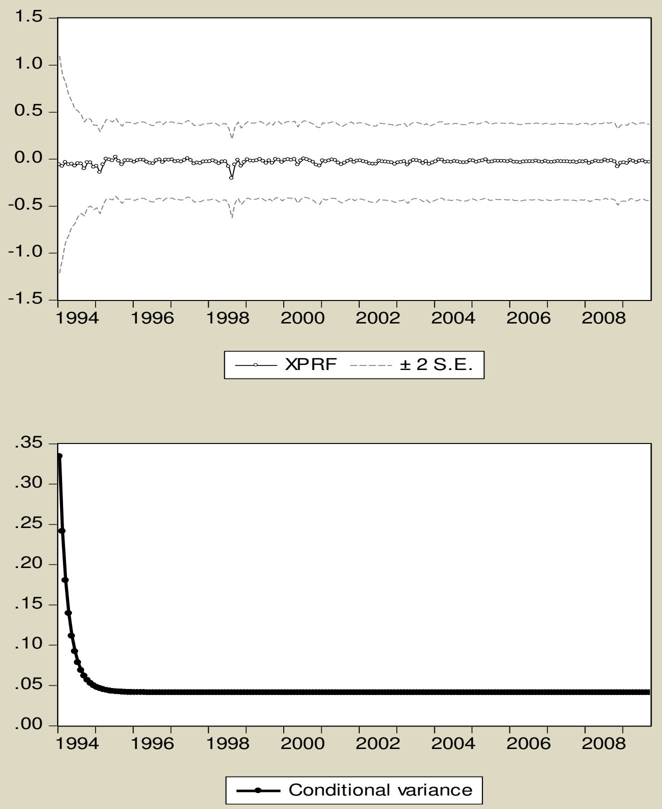


D7: >128M/ Optimal model: E-GARCH

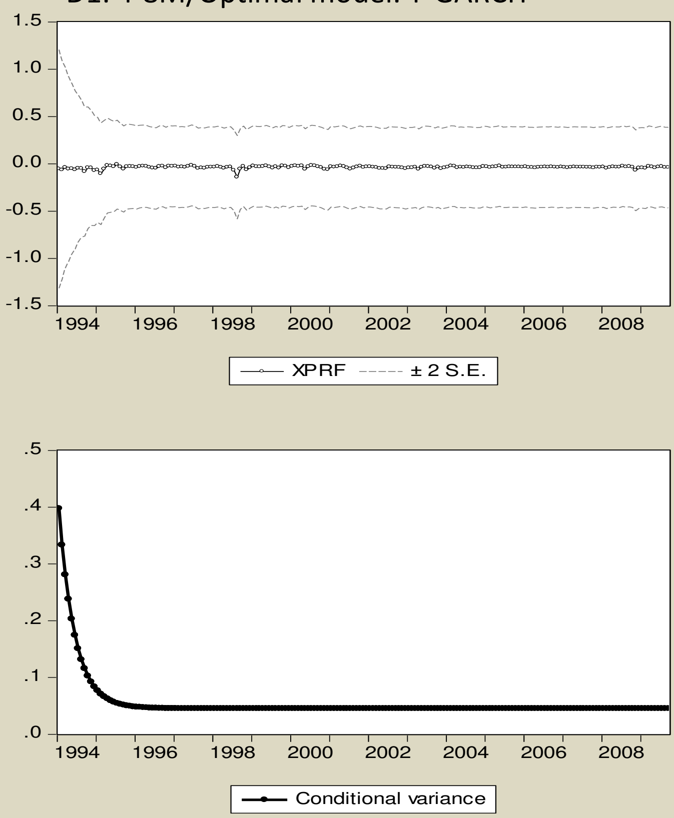


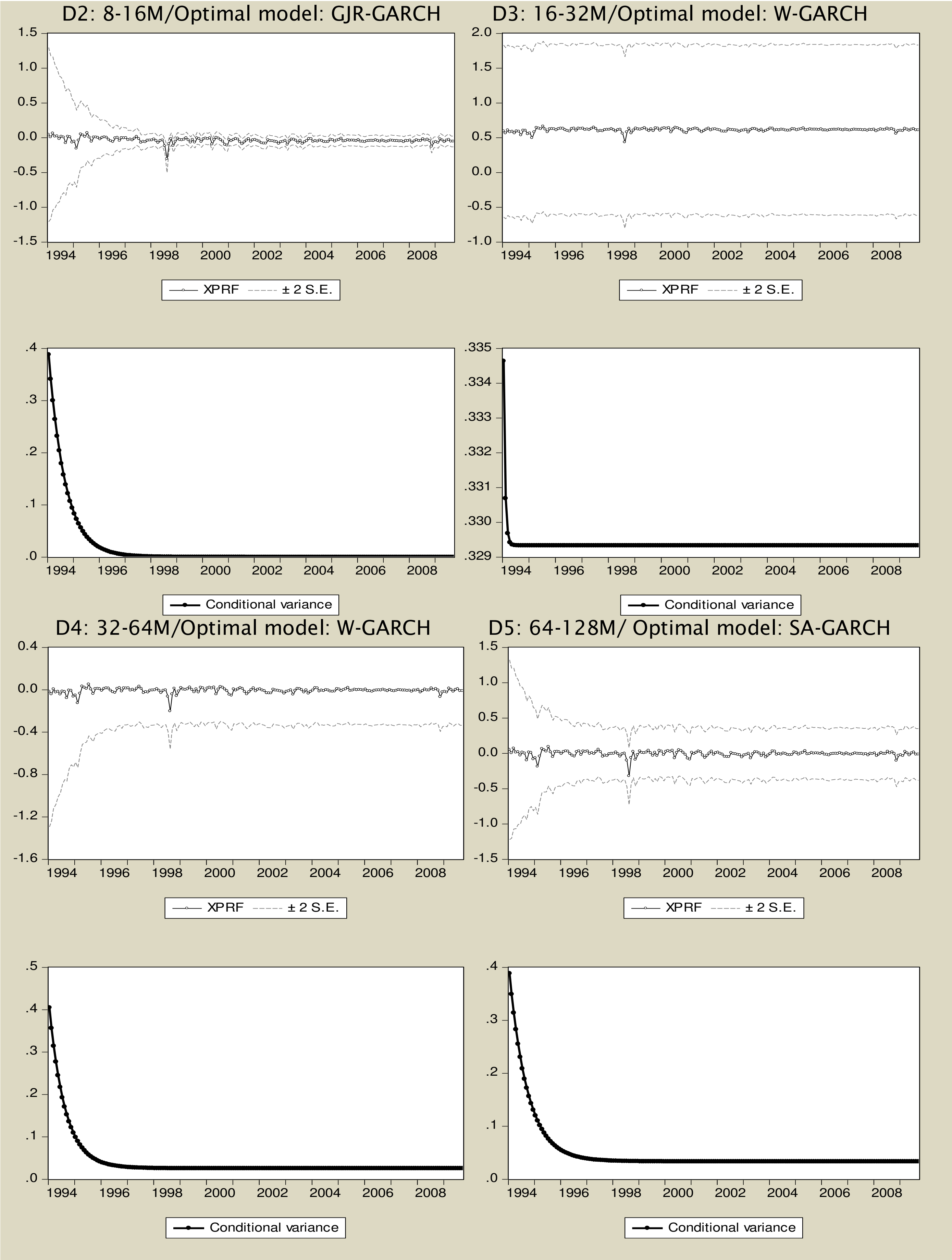
WITHOUT ENERGY

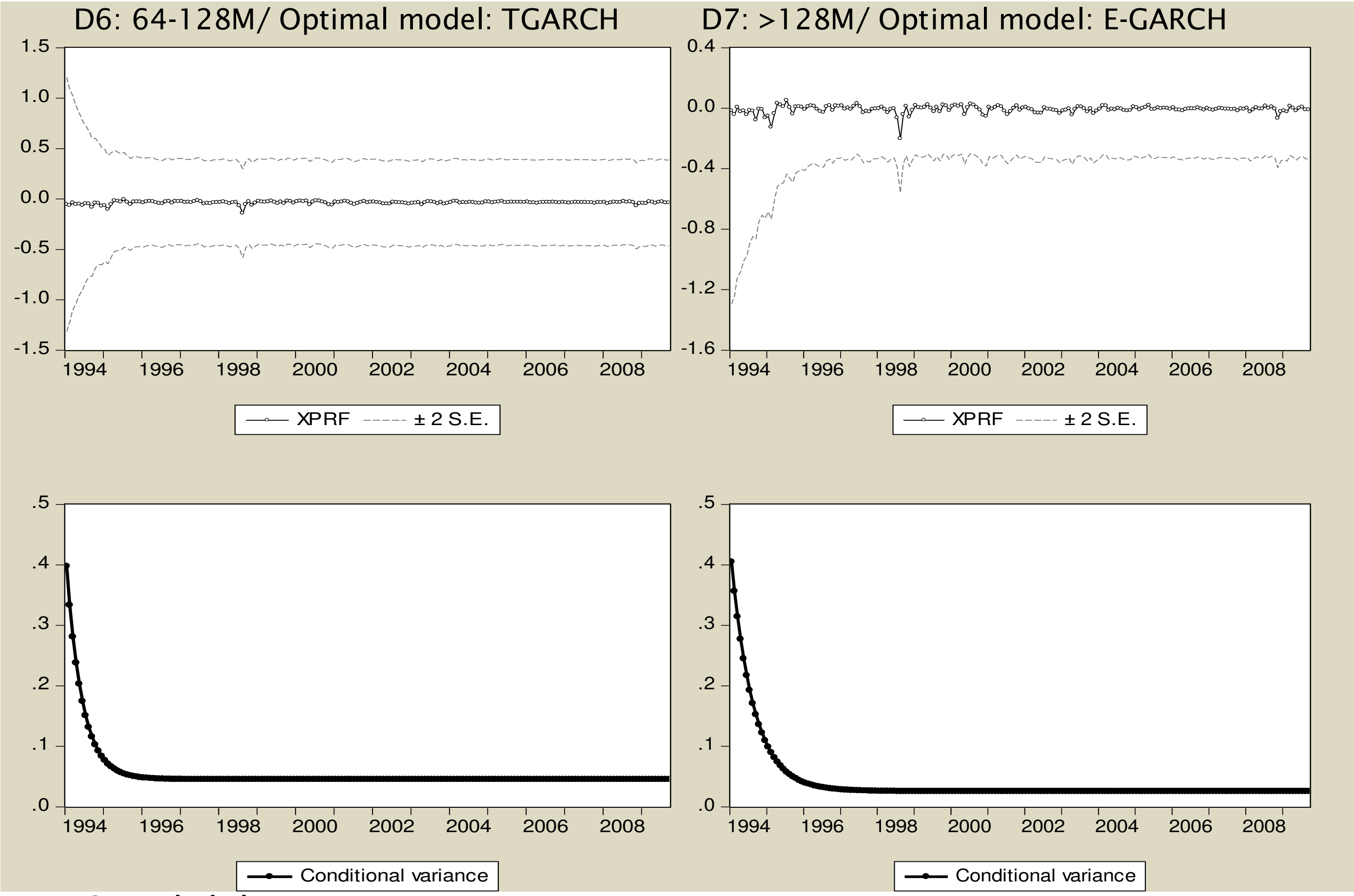
D: Time domain/ Optimal model: AP-GARCH



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




D2: 8-16M/Optimal model: GJR-GARCH
D3: 16-32M/Optimal model: W-GARCH
XPRF ± 2 S.E.
Conditional variance
D4: 32-64M/Optimal model: W-GARCH
D5: 64-128M/ Optimal model: SA-GARCH
XPRF ± 2 S.E.
Conditional variance



<u>Note:</u> Own calculation.

Appendices

Appendix A. A brief overview on GARCH extensions

The GARCH-type modeling has been very useful and valuable after the pioneering study of Engle (1982). The latter was among the first to model the conditional variance of time series. Bollerslev (1986) has generalized the work of Engle assuming that the conditional variance follows an ARMA process. Other extensions followed, Bollerslev (2008) and Anderson et al. (2009), among others.

The basic GARCH model is presented as follows:

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

Where $Var(\varepsilon_t | I_{t-1}) = \sigma_t^2$ r_t is the growth rate of each series (return of one action, for example), $\mu_t = E(r_t | I_{t-1})$ where I_t is the information available to date $t-1$. v_t is a sequence of random variables independently and identically distributed. Furthermore, v_t is assumed to follow either a normal standard distribution (Gauss), a standardized Student distribution (t) or a generalized error distribution (GED). It is possible to define, from the conditional variance σ_t^2, different models of volatilities or various GARCH extensions. We defined the standardized value ε_t as $z_t = \varepsilon_t / \sigma_t$.

In this paper, we use different specifications of u_t, ε_t and σ_t^2. According to Koksal (2009) and Bouoiyour et al. (2012), we can decompose the family of GARCH models in two subsets: linear GARCH models and nonlinear GARCH models. The first ones are based on a quadratic specification of the conditional variance of the errors. These are the ARCH (q), GARCH (p, q) and IGARCH (p, q) ... The second ones are characterized by asymmetric specification errors. These include, among others, EGARCH (p, q), GJR-GARCH (q) and TGARCH (p, q) models ... We can list the following specifications that seek to describe at best the behavior of the series.

a. ARCH

It is expressed as follows :

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \varepsilon_{t-i}^2 \tag{2}$$

b. GARCH (Standard GARCH)

Introduced by Bollerslev in 1986, the GARCH (General Autoregressive Conditional Heteroskedasticity) is an extension of the ARCH model developed by Engle (1982). The GARCH model is a representation of the autoregressive conditional variance process. This latter is written as follows:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2 \tag{3}$$

Where α_i , β_i and ω are parameters to estimate.

By using the lag operator, the variance is expressed as follows:

$$\sigma_t^2 = \omega + \alpha(L)\varepsilon_t^2 + \beta(L)\sigma_t^2 \quad (4)$$

Where $\alpha(L) = \sum_{i=1}^{p} \alpha_i L^i$ and $\beta(L) = \sum_{j=1}^{q} \beta_j L^j$.

If all the roots of the polynomial $|1-\beta(L)| = 0$, the variance becomes:

$$\sigma_t^2 = \omega(1-\beta(L))^{-1} + \alpha(L)(1-(L))^{-1}\varepsilon_t^2 \quad (5)$$

This equation can be seen as a process ARCH (∞).

c. I-GARCH (Integrated GARCH)

Introduced by Engle and Bollerslev (1986) and developed then by Nelson (1991). The Integrated Autoregressive Conditional Heteroskedasticity General model (I-GARCH) assumes the existence of a unit root in the process of conditional variance. This may be mainly due to changes in regimes that affect the level of variance. This model is enable to capture a long memory process in conditional variance, i.e there are autocorrelations of long process which are very persistent. For this extension, volatility tends to zero much slower for a long memory than a short memory process.

$$\sigma_t^2 = \omega + \varepsilon_{t-1}^2 + \sum_{i=1}^{q} \alpha_i(\varepsilon_{t-i}^2 - \varepsilon_{t-1}^2) + \sum_{i=1}^{p} \beta_j(\sigma_{t-j}^2 - \varepsilon_{t-1}^2) \quad (6)$$

We should add here that this process has a long-run persistence when the autocorrelation function is infinite, that is to say:

$$\lim_{n\to\infty} \sum_{j=-n}^{n} |\rho_j|$$

d. GARCH-M (GARCH in mean)

Another presentation of the GARCH model is the GARCH in mean (GARCH-M). It is a GARCH with moving average term. We test here if the variance can impact the average of future returns r_t . A GARCH in mean is presented as follows:

$$r_t = \mu_t + \varepsilon_t + \lambda\sigma_t^2 \quad (7)$$

Sometimes volatility affects the performance rather than the variance. If $\lambda \neq 0$, this implies the presence of serial correlation of returns, since the variance is serially correlated and closely dependent to the variance. Most studies on this issue have found inconclusive results regarding the nullity of λ . When $\lambda \neq 0$, there is not consensus on its sign.

e. SA-GARCH (Simple Asymmetric GARCH)

The Simple Asymmetric General Autoregressive Conditional Heteroskedasticity (i.e. SA-GARCH model) was developed by Bollerslev et al. (1993). This model belongs to the family of Fractional GARCH (F-GARCH specifications). A negative value of the leverage effect (γ_i) implies that the positive shocks lead to smaller increases in volatility comparable to negative shocks. It indicates that the conditional variance is represented like this:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q}(\alpha_i \varepsilon_{t-i}^2 + \gamma_i \varepsilon_{t-i}) + \sum_{i=1}^{p}\beta_j \sigma_{t-j}^2 \qquad (8)$$

f. E-GARCH (Exponential GARCH)

Introduced by Nelson in 1991, the Exponential General Autoregressive Conditional Heteroscedasticity (E-GARCH model) is a nonlinear GARCH model. It allows the inclusion of the asymmetry in the response of the conditional variance to innovation. In fact, this model introduces a form of asymmetry dependent not only on positive or negative sign of innovation, but also on the magnitude of this shock. Moreover, the EGARCH model has the advantage of not requiring the non-negativity of its parameters (to ensure the positivity of the conditional variance), unlike the standard GARCH.

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^{q}(\alpha_i z_{t-i} + \gamma_i (|z_{t-i}| - E(|z_{t-i}|)) + \sum_{i=1}^{p}\beta_j \log(\sigma_{t-j}^2) \qquad (9)$$

Where $E|z_{t-i}|$ is the expectation of the absolute value of standardized shocks on *t-1.*

It should be added that the left side is the logarithm of the conditional variance. This implies that the leverage effect is exponential, rather than quadratic, and then this guarantee that the forecasts of conditional variance have a positive values. The presence of leverage effect can be tested by the hypothesis $\lambda_i < 0$. If $\lambda_i \neq 0$, then when we check it, we can say that there is an asymmetrical effect.

g. P-GARCH (Power-GARCH)

The Power General Autoregressive Conditional Heteroscedasticity (P-GARCH) is a linear model proposed by Higgins and Bera (1992), which is characterized by parameters associated with high conditional standard deviations over φ. When $\varphi = 2$, P-GARCH model provides the same values of the conditional variance of simple GARCH (p, q). By using the P-GARCH extension, we can analyze a broader class of transformations of the linkage between the two series.

$$\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q}\alpha_i |\varepsilon_{t-i}|^{\varphi} + \sum_{i=1}^{p}\beta_j \sigma_{t-j}^{\varphi} \qquad (10)$$

h. AP-GARCH (Asymmetric Power GARCH)

The Asymmetric Power General Autoregressive Conditional Heteroscedasticity (AP-GARCH) was introduced by Ding et al. (1993). As the Simple asymmetric GARCH, this process also occurs in the family Fractional GARCH. For this model, there are no restrictions in the process of conditional variance like as Power GARCH. It is an asymmetric function of delayed disturbances, expressed as follows:

$$\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q} \alpha_i (|\varepsilon_{t-i}| + \gamma_i \varepsilon_{t-i})^{\varphi} + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^{\varphi} \tag{11}$$

i. GJR-GARCH

The GJR-GARCH model was introduced by Glosten, Jagannathan and Runkle (1993). It is a specification that captures the leverage and thresholds effects. In other words, the impact of disturbance is asymmetric, and therefore the dynamic of conditional variance depends on the sign of shock and not just on its magnitude. It is a nonlinear model that accounts the asymmetry in the response of the conditional variance after innovation either good or bad news.

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} (\alpha_i + \gamma_i I_{(\varepsilon_{t-i>0})}) \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2 \tag{12}$$

j. GJR power GARCH

It is an asymmetrical model (i.e. we notice the existence of leverage effect). It is a nonlinear model that describes the behavior of the conditional variance based on both good and bad news. The asymmetry of the volatility can be explained by the intervention of monetary authorities.

$$\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q} (\alpha_i + \gamma_i I_{(\varepsilon_{t-i>0})}) \varepsilon_{t-i}^{\varphi} + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^{\varphi} \tag{13}$$

Where φ is a paramater to estimate. If $\varphi = 2$, we found a GJR-GARCH model.

k. T-GARCH (Threshold GARCH)

Introduced by Tong (1990) and developed by Zakoin (1994), the autoregressive model with threshold order is a nonlinear model. We can say that there is a Threashold effect in each linkage when we have a level shift at which one series reacts differently to the second variable in question.This specification allows us to capture different regimes uder them we can see different effects of the series in question. Hence, theThreshold General Autoregressive Conditional Heteroskedasticity (T-GARCH model) can be expressed as follows:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} (\alpha_i |\varepsilon_{t-i}| + \gamma_i |\varepsilon_{t\_i}^{+}|) + \sum_{i=1}^{p} \beta_j \sigma_{t-j} \tag{14}$$

l. Q-GARCH (Quadratic GARCH)

The process of Quadratic General Autoregressive Conditional Heteroskedasticity (Q-GARCH model) was developed by Sentani (1995). It assumes the asymmetries in the response of conditional volatility to innovations. It can be written like this:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i} - b_i)^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2 \qquad (15)$$

Where the b_i are the parameters of the asymmetric variance. If the b_i are zero, we return to the traditional model $GARCH(p,q)$.

m. N-GARCH (Nonlinear GARCH)

The Nonlinear General Autoregressive Conditional Heteroscedasticity (i.e. NGARCH model) was introduced by Duan (1995). As its name suggests, it is a nonlinear model that analyzes the threashlod effect or a switch between one regime and others.

$$\sigma_t = \omega + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i} - \kappa_i)^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2 \qquad (16)$$

n. NP-GARCH (Nonlinear Power GARCH)

The Nonlinear Power General Autoregressive Conditional Heteroscedasticity (N-PARCH model) was initiated by Duan (1995) as an extension of the N-GARCH model. As its name suggests, it is a nonlinear model that takes into account the effect of the threshold order and not the leverage effect on the conditional variance, i.e. it does not analyze the signs of shock after both good and bad news. It is written as follows :

$$\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i} - \kappa_i)^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^{\varphi} \qquad (17)$$

o. AT-GARCH (Asymmetric Threshold GARCH)

As the Threashold GARCH, it is a specification that takes into account both the nonlinearity (i.e. threshold effect) and asymmetry (i.e. leverage effect). This model combines the characteristics of Threashold GARCH and Simple asymmetric GARCH presented above. It is written as follows:

$$\sigma_t = \omega + \sum_{i=1}^{q} \alpha_i |\varepsilon_{t-i}| I |\varepsilon_{t\_i} \geq \gamma_i|) + \delta \sum_{i=1}^{q} |\varepsilon_{t-i}| I(\varepsilon_{t-i} \prec \gamma_i) + \beta_j \sigma_{t-i} \qquad (18)$$

p. C-GARCH (Component GARCH)

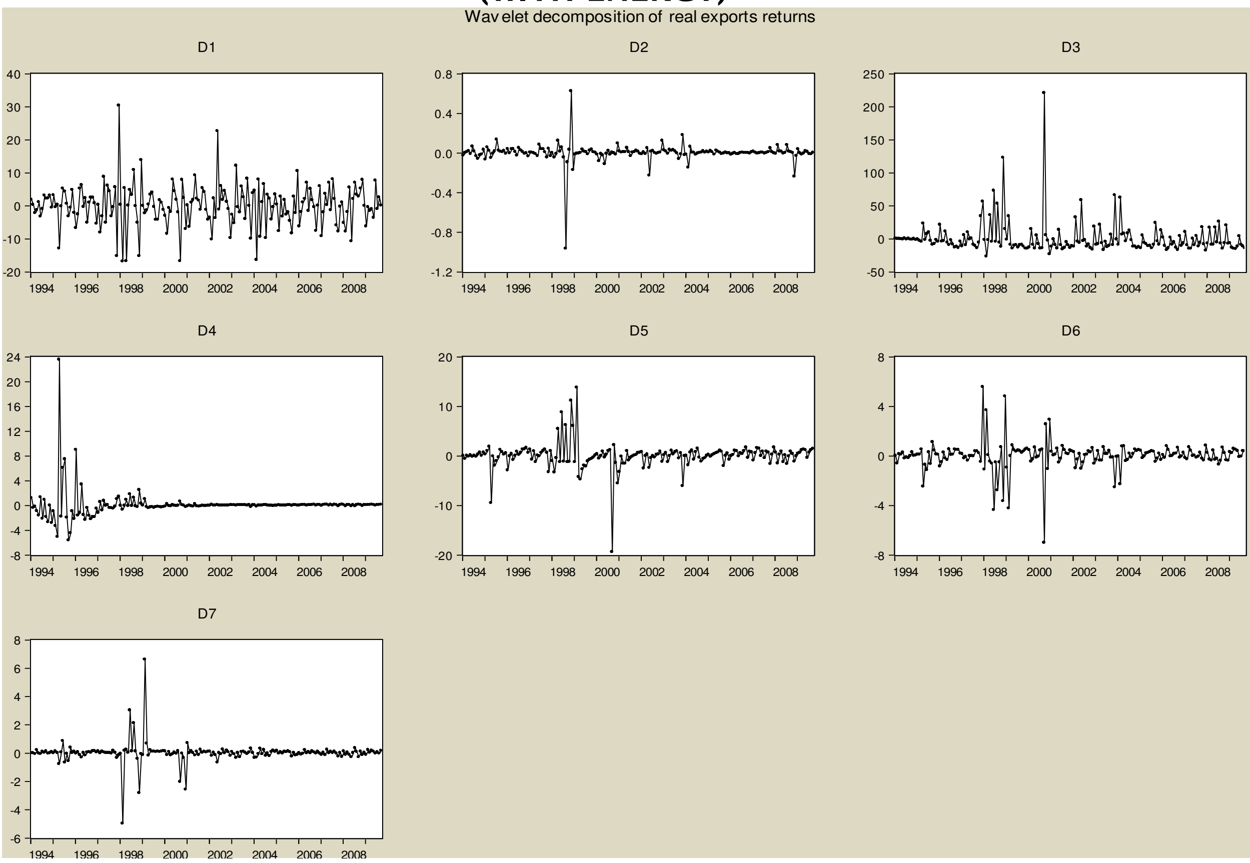
It is a linear and symmetric model which captures a long dependency between the volatility of the conditional variance and the unconditional variance. There is a great diffrence between Component GARCH (C-GARCH) and other GARCH extensions in terms of structure. More precisely, we decompose here the conditional volatility into a long-run time-varying trend component and a short-run transitory component (deviations from that trend). This specification is written as follows:

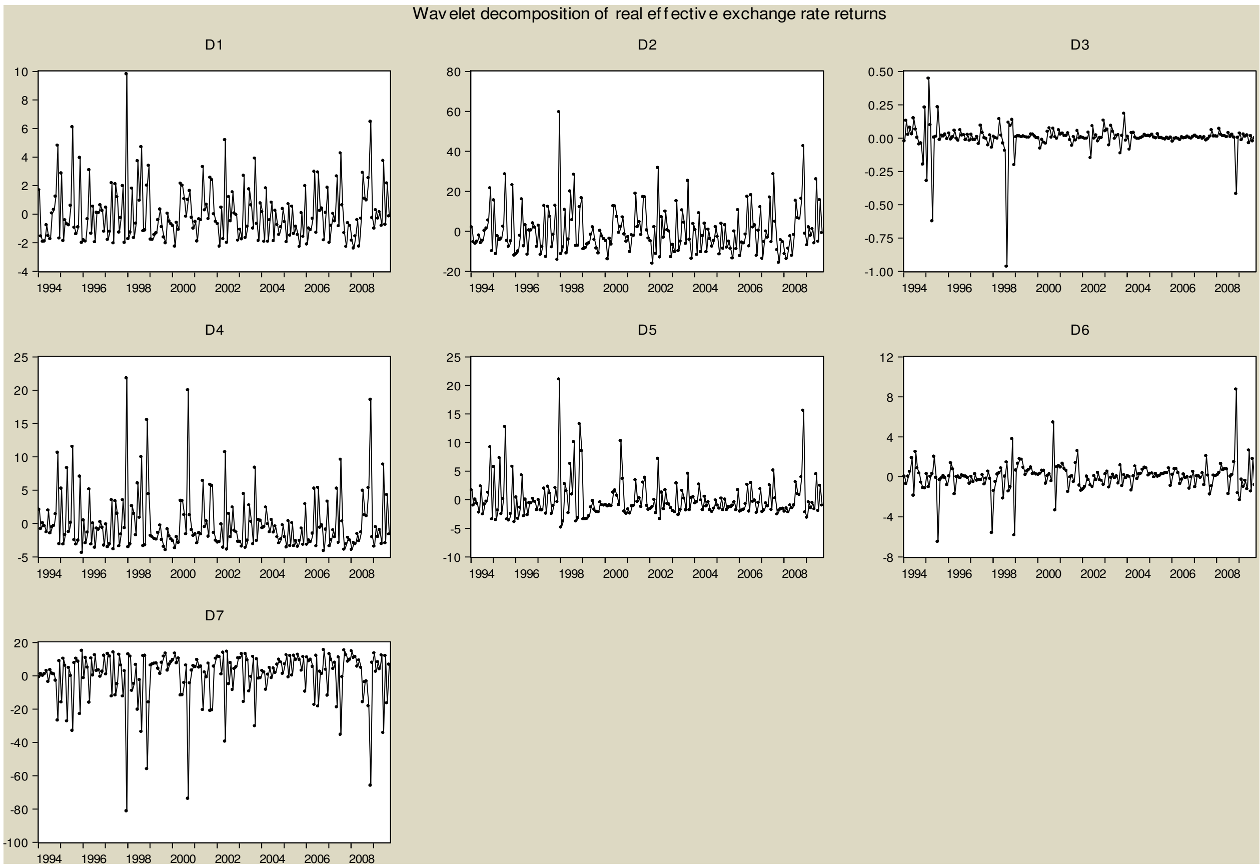
$$(\sigma_t^2 - \sigma^2) = \alpha(\varepsilon_{t-1}^2 - \sigma^2) + \beta(\sigma_{t-1}^2 - \sigma^2) \qquad (19)$$

Where the formula mentioned below presents the unconditional variance:

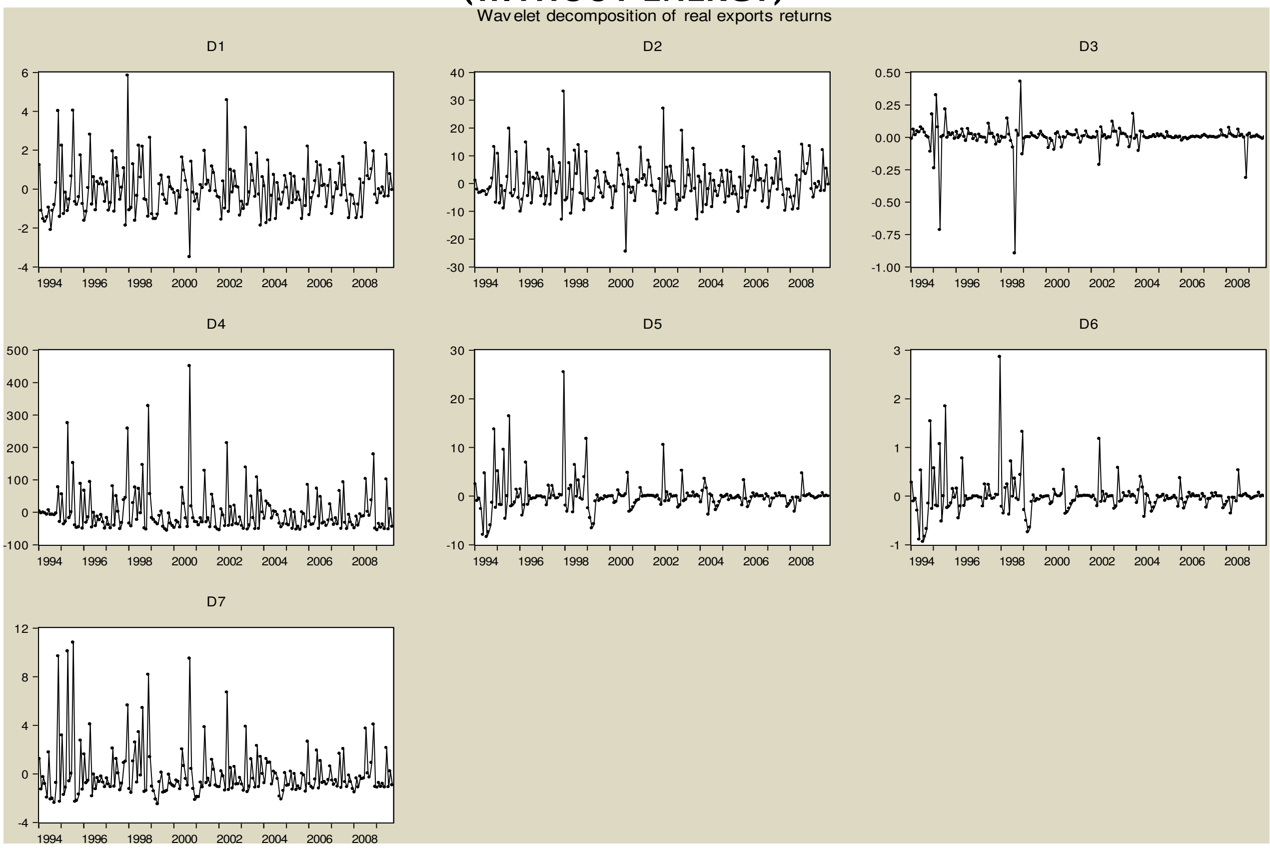
$$\sigma^2 = \omega / (1 - \alpha - \beta)$$

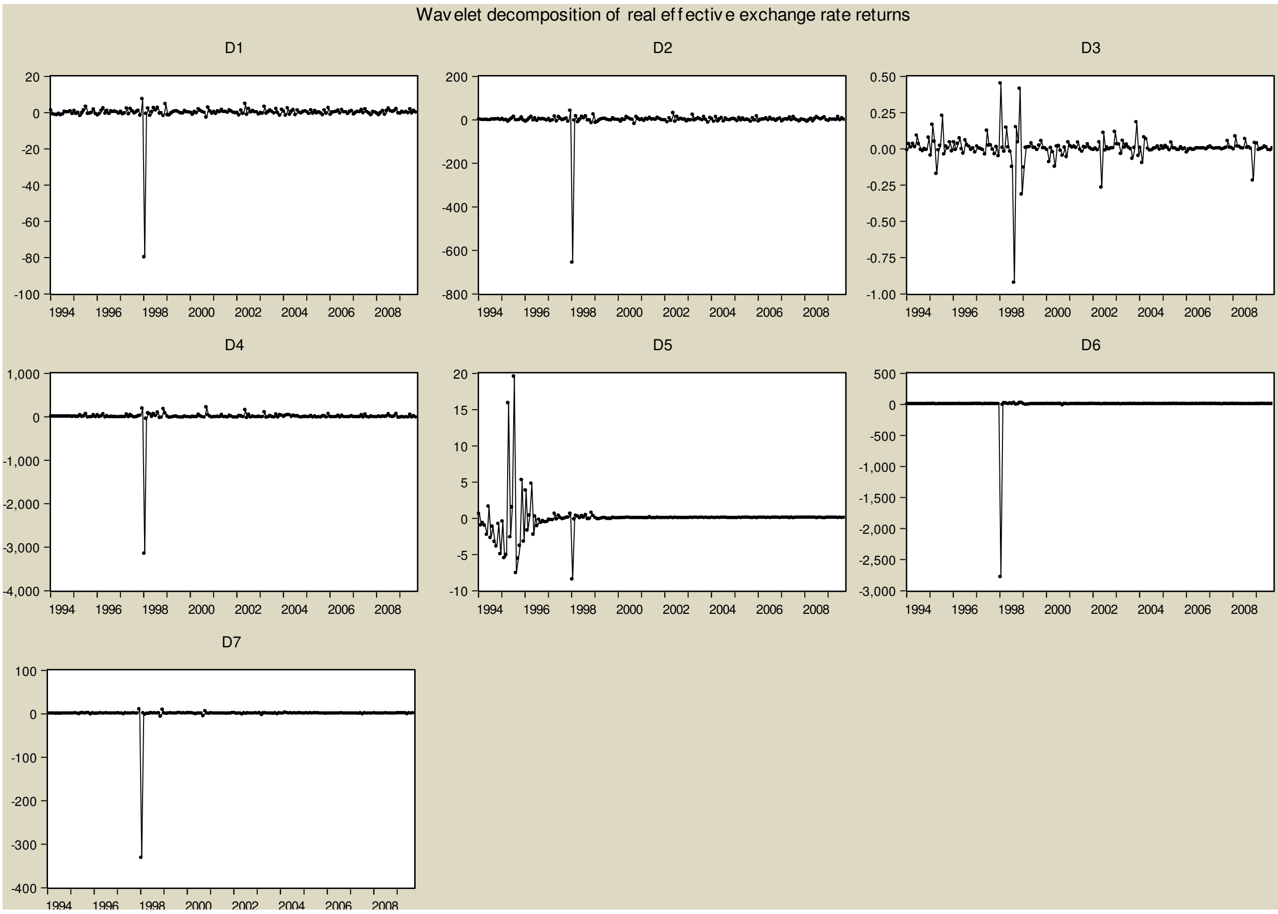
Appendix B. Wavelets of real exports and real exchange rate returns (WITH ENERGY)



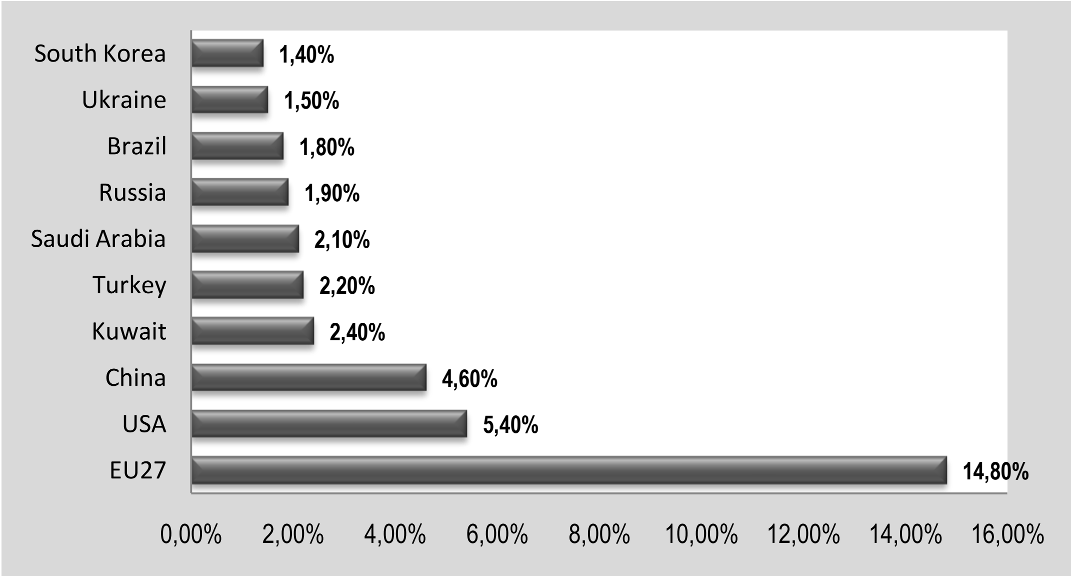


Appendix C. Wavelets of real exports and real exchange rate returns (WITHOUT ENERGY)



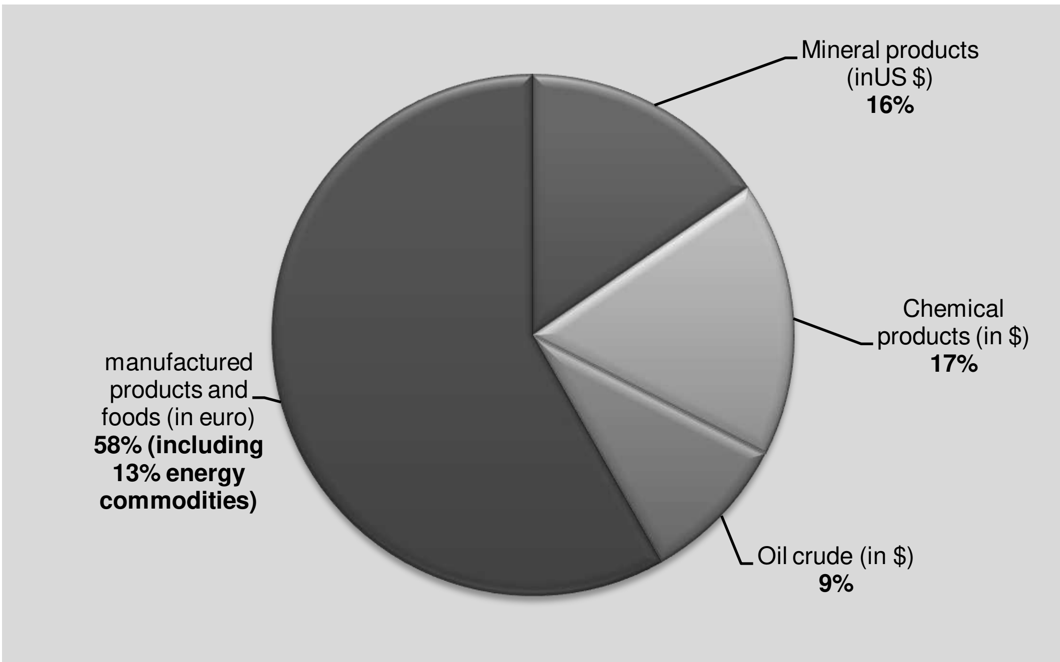


Appendix D. Egyptian main trade partners



Note: For more details, we can see this link:
http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_113375.pdf

Appendix E. Egyptian exports composition (to Europe)



Note: For more details, we can see this link:
http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_113375.pdf