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The Effects of Uncertainty on Inflation and Output Growth in Four African Oil-Rich Countries: Evidence from an Asymmetric Multivariate GARCH-M Model

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Abstract This study examines the impact of uncertainty on the levels of inflation and output growth for four African oil-rich countries, namely Algeria, Congo Republic, Gabon and Libya using an asymmetric multivariate GARCH-M model initiated by [21]. A number of important findings arise from this study. First, considering the impact of inflation uncertainty on inflation, Cukierman-Meltzer hypothesis is supported for Algeria and Gabon, while the stabilization hypothesis of [24] is supported for Congo Republic and Libya. Second, on the impact of output growth uncertainty on inflation, our findings support Devereux' hypothesis of a positive impact of output growth uncertainty on the level of inflation for Congo Republic and a negative impact of output growth uncertainty on the level of inflation for the rest of the countries. Third, a closer look at the impact of inflation uncertainty on output growth shows that Friedman's hypothesis of a negative impact of inflation uncertainty on output growth could not be supported for any country. In contrast, the hypothesis of a positive impact of inflation uncertainty on output growth suggested by [10] is supported for all the countries under study. Finally, concerning the impact of output growth uncertainty on output growth, Black hypothesis of a positive impact of output growth uncertainty on output growth is supported for Algeria, Gabon and Libya, while the views of [37] and [38] of a negative impact of output growth uncertainty on output growth are supported for Congo Republic. This is to the best of my knowledge the first attempt to examine the impact of uncertainty on inflation and output growth for these four African countries, namely Algeria, Congo Republic, Gabon and Libya. Further empirical investigations are therefore needed to shed more light on this issue.

Keywords Inflation, Growth, Uncertainty, Asymmetric Multivariate GARCH-M model, African oil-rich countries

1. Introduction

Examining the real effects of inflation has gained much importance in the past decades following the claim of [18] that inflation uncertainty could be considered to be part of the welfare costs of inflation. He argued that rising inflation is associated with high inflation uncertainty and that inflation uncertainty is detrimental to growth by rendering market prices system less efficient for coordinating economic activity, therefore making it difficult for economic agents to decide how to use their resources.

On the relationship between the level of inflation and inflation uncertainty, [1] supports [18] but [8] and [24] give contradicting views by suggesting existence of a reverse causality. [8] argue that an increase in inflation uncertainty leads to an increase in the level of inflation as policymakers create surprise inflation to stimulate output and [24] in his stabilization hypothesis points out that an increase in inflation uncertainty leads to a decrease in inflation as policymakers reduce the growth rate of money hence reducing inflation in order to reduce the effects of inflation uncertainty on the economy.

While a number of scholars (see for instance, [15], [19], [6]) support [18] on the negative growth effects of inflation uncertainty, [10] suggest a different view of a positive impact of inflation uncertainty on output growth. They argue that an increase in the variability of monetary growth, and therefore inflation, makes the return to money balances more uncertain and leads to a fall in the demand for real money balances and consumption. Hence, agents increase precautionary savings leading to an increase in investments which in turn boost output growth.

The impact of real uncertainty (output growth uncertainty) on output growth has also interested a number of scholars. While [17] argues that there is an independence relationship between the two, [2] and [3] suggest a positive impact of output growth uncertainty on output growth by arguing that high volatility will lead to increase in savings through precautionary motives which in turn cause an increase in investments. [37] and [38] on the other hand, suggest a negative impact of output growth uncertainty on output

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growth. According to them, large fluctuations in economic activity are more likely to increase the uncertainty regarding the long-run profitability of investments, making the returns to investments riskier and reducing hence the level of investments and therefore output growth.

The impact of output growth uncertainty on inflation is also discussed in the literature. [9] developed a model which predicts a positive impact of output growth uncertainty on the level of inflation. According to [9], the central bank usually creates surprise inflation to raise output, but this will be effective when the degree of wage indexation is low. He shows that an increase in the variance of real shocks which lowers the degree of wage indexation raises output growth volatility (uncertainty) and causes the level of inflation to increase.

A number of empirical studies have examined the effects of inflation uncertainty and output growth uncertainty on the levels of inflation and output growth, using either a simultaneous approach in GARCH-in-mean models (see, for instance [21], [22], [35], [34], [36], [23]) or two-step approach where uncertainty measures for inflation and output growth are initially generated using various types of GARCH models and then causality tests are conducted to examine the impact of uncertainty on inflation and output growth (see for instance, [16], [39], [27], [31], [33]).

In addition, most of existing studies use univariate GARCH models (see, for instance, [16], [34], [23], [14], [32]) or restrictive models of the covariance process such as CCC and DCC-GARCH model[1], diagonal VEC-GARCH model[2] or diagonal BEKK model (see [26], [27], [31], [7]). As [21] note, univariate models do not permit the joint generation of the uncertainty measures for inflation and output growth nor do they permit one to simultaneously examine their impacts on the levels of inflation and output growth, while the restrictive models can lead to misspecification problem.

[21] cautioned about using restrictive GARCH models that impose diagonality and symmetry restrictions on the conditional variance-covariance matrix. According to them, this might lead to misspecification problem hence wrong measures of inflation uncertainty and output growth uncertainty, and faulty conclusions regarding the impact of uncertainty on inflation and output growth. To address this problem, [21] proposed a model which allows testing for diagonality and symmetry in the conditional variance-covariance matrix instead of imposing them.

This study therefore follows [21] and applies an asymmetric multivariate GARCH-M model to simultaneously examine the effects of inflation uncertainty and output growth uncertainty on the levels of inflation and output growth in four African Oil-rich countries, Algeria, Congo Republic, Gabon and Libya. While a number of empirical studies exist on this subject, this is to the best of my knowledge the first study to analyze the effects of uncertainty on inflation and output growth for those four African countries.

The rest of the paper is organized as follows. Section 2 highlights the methodology used. Section 3 presents the estimation and diagnostic test results and section 4 concludes the study.

2. Methodology and Data

To examine the impacts of inflation uncertainty and output growth uncertainty on the levels of inflation and output growth in Algeria, Congo Republic, Gabon and Libya, this study follows [21] and uses an asymmetric BEKK [3] GARCH-M model in which the conditional means of inflation (π_t) and output growth (y_t) are in form of VARMA (Vector Autoregressive Moving Average) GARCH-M model, where the conditional standard deviations of output growth and inflation are included as explanatory variables in each conditional mean equation.

The specification of the conditional means of inflation (π_t) and output growth (y_t) is in equation (1), where, H_t is the conditional variance-covariance matrix, $h_{y,t}$ is the conditional variance of output growth, $h_{\pi,t}$ is the conditional variance of inflation, $h_{y\pi,t}$ & $h_{\pi y,t}$ are the conditional covariances between inflation and output growth, ε_t is the vector of error terms, μ is the matrix of constant terms, Γ_i is the matrix of Autoregressive coefficients, Ψ is the matrix of in-mean coefficients and Θ_j is the matrix of Moving Average coefficients. Important to note is that in GARCH models, uncertainty (volatility) is captured by the conditional variance which is just the variance of the one step ahead forecasting error.

In equation (2), A is a matrix of ARCH coefficients which captures the ARCH effects and B is a matrix of GARCH coefficients capturing the GARCH effects. The diagonal elements in matrix A show the impact of own past shocks on the current conditional variance and the diagonal elements in Matrix B represent the impact of own past volatility on the current conditional variance, while the off-diagonal elements in matrices A and B represent the volatility spillovers' effects ([40]).

Asymmetries in the conditional variance-covariance matrix is captured by the matrix D which is the matrix of asymmetric coefficients with $\omega_{y,t} = \min(\varepsilon_{y,t}, 0)$ and $\omega_{\pi,t} = \max(\varepsilon_{\pi,t}, 0)$. We note that the BEKK model becomes symmetric if asymmetric coefficients are

1 CCC and DCC-GARCH models are respectively Constant and Dynamic Conditional Correlation GARCH model of [4] and [12]. They both assume that in the matrices of ARCH and GARCH terms are diagonal

2 To simplify the VEC-GARCH model, Bollerslev, Engle and Wooldridge (1988) presented a GARCH model in which the matrices of ARCH and GARCH terms are diagonal

3 BEKK model is a multivariate GARCH model developed by [13] and was named after Baba, Engle, Kraft and Kroner.

statistically jointly equal to 0, $\delta_{ij} = 0$. It should also be noted that BEKK model is preferred because it ensures the positive definiteness of the conditional variance-covariance matrix unlike the other variants of multivariate GARCH models.

From the conditional mean equation (Equation 1), we can check how inflation uncertainty and output growth uncertainty affect the level of inflation and output growth. Assessing the impact of output growth uncertainty and inflation uncertainty on output growth is done by respectively testing the null hypotheses that $\psi_{11} = 0$ and $\psi_{12} = 0$.

A positive and significant ψ_{11} would mean a positive impact of output growth uncertainty on output growth, which is the Black hypothesis while a negative and significant ψ_{11} would imply a negative impact of output growth uncertainty on output growth, supporting the views of [37] and [38].

Similarly, a positive and significant ψ_{12} would mean a positive impact of inflation uncertainty on output growth which is Dotsey-Sarte hypothesis and a negative and significant ψ_{12} would mean a negative impact of inflation uncertainty on output growth which is Friedman hypothesis.

Similarly, testing the impact of output growth uncertainty and inflation uncertainty on the level of inflation is done by respectively testing whether $\psi_{21} = 0$ and $\psi_{22} = 0$. A positive and significant ψ_{21} would mean a positive impact of output growth uncertainty on inflation which is Devereux hypothesis while a negative and significant ψ_{21} would imply a negative impact of output growth uncertainty on inflation.

On the other hand, a positive and significant ψ_{22} would mean a positive impact of inflation uncertainty on inflation, which would support Cukierman-Meltzer hypothesis while a negative and significant ψ_{22} would mean a negative impact of inflation uncertainty on inflation, which is the stabilization hypothesis of [24].

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t$$

$$\varepsilon_t \sim (0, H_t) \quad (1)$$

$$H_t = \begin{bmatrix} h_{y,t} & h_{\pi y,t} \\ h_{y\pi,t} & h_{\pi\pi,t} \end{bmatrix}$$

$$Y_t = \begin{bmatrix} y_t \\ \pi_t \end{bmatrix}; \varepsilon_t = \begin{bmatrix} \varepsilon_{y,t} \\ \varepsilon_{\pi,t} \end{bmatrix}; \sqrt{h_t} = \begin{bmatrix} \sqrt{h_{y,t}} \\ \sqrt{h_{\pi,t}} \end{bmatrix};$$

$$\mu = \begin{bmatrix} \mu_y \\ \mu_\pi \end{bmatrix}; \Gamma_i = \begin{bmatrix} \Gamma_{11}^{(i)} & \Gamma_{12}^{(i)} \\ \Gamma_{21}^{(i)} & \Gamma_{22}^{(i)} \end{bmatrix};$$

$$\Psi = \begin{bmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{bmatrix}; \Theta_j = \begin{bmatrix} \theta_{11}^{(j)} & \theta_{12}^{(j)} \\ \theta_{21}^{(j)} & \theta_{22}^{(j)} \end{bmatrix}$$

The conditional variance-covariance matrix of an asymmetric BEKK model is written as

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B + D'\omega_{t-1}\omega_{t-1}'D, \quad (2)$$

where

$$C = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}; A = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}; B = \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix};$$

$$D = \begin{bmatrix} \delta_{11} & \delta_{12} \\ \delta_{21} & \delta_{22} \end{bmatrix}; \omega = \begin{bmatrix} \omega_{y,t} \\ \omega_{\pi,t} \end{bmatrix}$$

3. Empirical Results and Discussion

Monthly data on price and output levels for Algeria, Congo Republic, Gabon and Libya are used for the period February 1974-May 2012, February 1998-July 2006, February 1978-February 2012 and February 2001-June 2011, respectively according to data availability. Data were retrieved from International Financial Statistics (IFS) of the International Monetary Fund (IMF).

The price level is captured by Consumer Price Index (CPI) and output level is captured by Crude Petroleum Production Index. This is because high frequency data which are more appropriate with GARCH models are not available for GDP for most countries; a proxy for output level which can better capture the country's economic activity is therefore used. We use Crude Petroleum Production Index since our selected countries are oil-rich countries; oil sector in these countries is the major contributor to Gross Domestic Product (GDP).

Inflation rate is computed as the monthly difference of the logarithm of CPI, $\pi_t = [\log(CPI_t / CPI_{t-1})]*100$ and output growth is computed as the monthly difference of the logarithm of the production index (Y_t), $y_t = [\log(Y_t / Y_{t-1})]*100$.

Summary statistics in Table 1 show that both inflation, π and output growth, y are positively skewed and display platikurtic behavior for all the selected countries. In addition, [25] test rejects the null hypothesis of normality in both inflation and output growth series.

Preliminary tests for unit root, serial correlation and ARCH tests are conducted. In order to ascertain the order of integration of the series, an endogenous two-break unit root test of [28] and a non-parametric unit root test of [5] are used. [29] test is used to test for serial correlation in the series and squared series and LM-ARCH test of [11] is employed to test for the presence of ARCH effects in the data, that is, to test for conditional heteroscedasticity in the data, whether the variances of the series are time-varying. As [20] points out, one should be able to reject the null hypothesis of constant variance before estimating a GARCH model and generate uncertainty measures.

Unit root test results in Table 3 suggest that both [28] and [5] tests strongly reject the null hypothesis of a unit root in inflation and output growth series for all the countries under study. There is therefore no need to difference them when estimating the Mean equations of inflation and output growth in the estimation of the GARCH model.

Similarly, from Table 2, [29] test rejects the null hypothesis of no serial correlation in both the series and squared series of inflation and output growth for Algeria and Gabon. For Congo Republic, the null hypothesis of no serial correlation in the data and squared data is rejected only for output growth.

For Libya, [29] test fails to reject the null hypothesis of no serial correlation in both the series and squared series of inflation; for output growth however, the null hypothesis is rejected only in the data and not in the squared data. According to [21], the presence of serial correlation in the squared data is an indication of conditional heteroscedasticity in the data (time-varying variance). This should however be confirmed by ARCH test. From the same Table 2, LM-ARCH test of [11] strongly rejects the null hypothesis of no ARCH in both inflation and output growth for all the countries except for Libya, which would mean that inflation and output growth exhibit time-varying variance for all the countries except for Libya. However, when we consider the multivariate ARCH test (see Appendix 1), the null of no ARCH effects is strongly rejected for all the countries including Libya. Multivariate ARCH test results suggest therefore that the variances of inflation and output growth for all the countries are not constant but time-varying.

Table 1. Summary statistics

Panel A: Summary Statistics for Inflation					
Countries	Mean	Variance	Skewness	Excess Kurtosis	J-B Test
Algeria	0.7825	4.2858	0.458[0.000]	1.844[0.000]	81.287[0.000]
Congo Rep.	0.1027	4.5840	1.102[0.000]	7.743[0.000]	275.486[0.000]
Gabon	0.3198	2.5310	0.124[0.000]	22.364[0.000]	8129.006[0.000]
Libya	0.1430	2.5154	1.100[0.000]	4.550[0.000]	133.098[0.000]
Panel B: Summary Statistics for output growth					
Countries	Mean	Variance	Skewness	Excess Kurtosis	J-B Test
Algeria	0.0015	52.0492	-1.388[0.000]	14.459[0.000]	4155.27[0.000]
Congo Rep.	-0.2640	162.402	-0.421[0.000]	13.527[0.000]	780.797[0.000]
Gabon	0.0548	54.7701	0.044[0.000]	2.287[0.000]	89.283[0.000]
Libya	-2.0984	218.434	-6.728[0.000]	58.397[0.000]	18705.11[0.000]

Note: Summary Statistics were obtained using WinRATS Pro 8.0, between brackets [.] is the p-value

Table 2. Univariate serial correlation and ARCH test

Panel A: Univariate serial correlation and ARCH test for inflation					
Countries	Q(10)	Q(20)	$Q^2(10)$	$Q^2(20)$	ARCH (20)
Algeria	24.82 (0.005)	181.3 (0.000)	66.33 (0.000)	200.7 (0.000)	7.70 (0.000)
Congo Rep.	10.71 (0.379)	20.98 (0.397)	4.45 (0.924)	9.36 (0.978)	2.51 (0.003)
Gabon	34.00 (0.000)	48.90 (0.000)	66.40 (0.000)	67.18 (0.000)	3.65 (0.000)
Libya	13.80 (0.182)	24.20 (0.233)	1.38 (0.999)	3.80 (0.999)	0.19 (0.999)
Panel B: Univariate serial correlation and ARCH Effects test for output growth					
Countries	Q(10)	Q(20)	$Q^2(10)$	$Q^2(20)$	ARCH (20)
Algeria	122.5 (0.000)	364.6 (0.000)	50.65 (0.000)	54.14 (0.000)	2.55 (0.000)
Congo Rep.	26.40 (0.003)	37.51 (0.010)	23.38 (0.009)	24.82 (0.208)	1.77 (0.044)
Gabon	115.8 (0.000)	287.5 (0.000)	46.73 (0.000)	56.07 (0.000)	1.68 (0.033)
Libya	29.87 (0.000)	31.79 (0.045)	4.44 (0.92)	4.45 (0.999)	0.63 (0.877)

Note: Tests performed using OxMetrics 6.30. Between parentheses (.) are the P-values.

Table 3. Unit root test results

Country	Lee-Strazicich Unit Root Test			Breitung Test	
Panel A: Unit root tests for Inflation					
	τ Stat	BREAKS		B(n)/n	C.V (5%)
Algeria	-13.95***(3)	1989m7	1995m2	0.00152[0.000]	0.01039
Congo Rep.	-11.26***(0)	2000m2	2000m11	0.00084[0.000]	0.01004
Gabon	-10.29***(3)	1983m7	1988m2	0.00132[0.000]	0.01030
Libya	-11.04***(0)	2008m4	2009m5	0.00754[0.035]	0.01004
Panel B: Unit root tests for output growth					
Country	Lee-Strazicich Unit Root Test			Breitung Test	
	τ Stat	BREAKS		B(n)/n	C.V (5%)
Algeria	-13.70***(5)	1998m2	2002m3	0.00012[0.000]	0.01039
Congo Rep.	-13.82***(0)	2000m5	2001m6	0.00007[0.000]	0.01004
Gabon	-13.51***(10)	1989m9	1998m3	0.00008[0.000]	0.01030
Libya	-8.91***(0)	2007m6	2010m7	0.00700[0.094]	0.01004

Note: Lee-Strazicich Test was performed using WinRATS Pro 8.1 while Breitung test was performed using EasyReg software. Between parentheses (.) are the optimal lags used in L-S test, selected using the usual criteria and brackets [.] are the p-values for Breitung test. For L-S Test, 1% C.V is -5.823; 5% C.V is -5.286 and 10% C.V is -4.989 for the model allowing for a shift in intercept and change in trend slope. P-values reported in brackets [.] for Breitung Test are based on 1000 simulations.

After the preliminary tests, following [21], a multivariate asymmetric GARCH model is estimated [4], asymmetric BEKK GARCH-M model is used, to examine the impacts of inflation uncertainty and output growth uncertainty on the levels of inflation and output growth. In GARCH models, uncertainty is usually captured by the conditional variance of the variable which is just the variance of the one step ahead forecasting error.

Table 4 presents the estimation results of asymmetric BEKK GARCH-M model for Algeria[5].

Prior to any interpretation of the estimation results, it is advised to check for the adequacy of the GARCH model estimated, in other words to check whether the conditional mean and the conditional variance-covariance equations are well specified. To achieve this, the diagnostic tests, namely Ljung-Box and McLeod-Li tests are used.

Diagnostic test results are in panel C of Table 4. Ljung-Box test indicates that at 5 percent, there is no serial correlation of 5^{th} and 10^{th} order in the standardized residuals of inflation and output growth Mean equations. Similarly, McLeod-Li test indicates that the squares of the standardized residuals of inflation and output growth equations are also serially independent at 5 percent, implying that there are no remaining ARCH/GARCH effects. The conditional mean and conditional variance-covariance equations are hence well specified.

In addition, some coefficient restriction tests are done in order to check whether some of the coefficients in the Mean equation and in the conditional variance-covariance matrix are redundant. In this regard, the coefficient restrictions tests results presented in panel B of Table 4 show that the hypotheses of Diagonal VARMA, no GARCH, no GARCH-M, no Asymmetry and Diagonal GARCH are all rejected at 1 percent significance level.

This suggests that none of the terms included in the conditional mean and variance-covariance matrix equations are redundant. Coefficient restriction tests confirm that the form of the mean equation adopted (Vector Autoregressive Moving average, VARMA plus the in-mean coefficients included) captures properly the dynamics of inflation and output growth in Algeria and that the form of the conditional variance-covariance matrix adopted (asymmetry and non-diagonality) captures also adequately the dynamics of the conditional variance of inflation and conditional variance of output growth.

Likewise, the diagnostic tests and coefficients restriction tests for the rest of the countries, Congo Republic, Gabon and Libya (see appendix 2, 3 and 4) suggest that the estimated asymmetric BEKK GARCH-M model is well specified and that the forms of mean equation and conditional variance-covariance matrix adopted capture well the dynamics of inflation and output growth and of their conditional variances. The conditional standard deviations of inflation and output growth capturing inflation uncertainty and output growth uncertainty are in Appendix 8 and 9.

It is to be noted that the coefficients restriction tests confirm that the conditional variance-covariance matrix is heteroskedastic since the hypothesis of no GARCH was rejected. In addition, assuming symmetry and diagonality in the conditional variance-covariance matrix could have led to misspecification since the hypotheses of no asymmetry and diagonal GARCH were rejected.

Since the estimated asymmetric GARCH-M Model of inflation and output growth is well specified for all the countries, we generated uncertainty measures for inflation and output growth captured by the estimated conditional standard deviation of inflation and output growth. Appendices 5 and 6 present respectively the figures of

4 In estimating the mean equation, we consider $p = q = 2$ and the diagnostic tests confirm that the mean equation is well specified with that lag order.

5 For convenience, the estimation results for the rest of the countries, Congo Republic, Gabon and Libya, are presented in the appendices.

inflation uncertainty and output growth uncertainty for the 4 countries under study.

For Algeria, the figures show that the greatest inflation uncertainty (volatility) and output growth uncertainty (volatility) appear in 2009 probably due to the presidential elections organized in Algeria in 2009 after a controversial change in the constitution allowing the then president to run for a third term which he eventually won[6]. This might have been behind the raised uncertainty in the country because of the fear of social explosion in a country where the unemployment was 70 percent among the young adults.

Another reason behind the increase in uncertainty about inflation and output growth in 2009 might have been the fall in oil price from \$140 to \$40 which had taken place in an economy which is 90 percent dependent on hydrocarbons[7]. High inflation uncertainty can also be seen in 1981, 1983 and 1987 and uncertainty about output growth seems to have been high in 1983 and 2003. For the rest of the periods, uncertainty about both inflation and output growth seems to have been low.

The graphs of inflation uncertainty and output growth uncertainty for Congo Republic indicate that for the period of study, inflation uncertainty was highest in the mid-1998 probably due to the civil war of the period 1997-1999, while output growth uncertainty was highest in the mid-2001. For the rest of the period, uncertainty about inflation and output growth was relatively low.

Inflation uncertainty and output growth uncertainty in Gabon have been generally low apart from some periods of high uncertainty (volatility) such as 1989 and most of the decade 1990 with 1989 being the period of the highest uncertainty for both inflation and output growth.

High uncertainty in this period can be attributed to political uncertainty caused by overstaying in power by president Bongo who was then serving the fourth term, creating popular discontent with the regime manifested in frequent riots which reached a high point in 1989[8].

As far as Libya is concerned, uncertainty about inflation and output growth has been low except in 2011 where inflation uncertainty and output growth uncertainty were at their highest levels probably due to the recent political crisis in the country during the wave of the Arab spring. *Apart from 2011, the low inflation uncertainty in Libya is due to the monetary policy regime pursued which consists on keeping its currency, Libyan dinar, pegged to a basket of currencies, keeping inflation low as well as its uncertainty.*

Since our estimated asymmetric BEKK GARCH-M model is well specified for all the countries under study, we can then proceed to analyze the impacts of inflation uncertainty and output growth uncertainty on the levels of inflation and output growth.

As indicated in the methodology, analyzing the impact of inflation uncertainty on the level of inflation is done by examining the sign and the significance of ψ_{22} in equation 1. The estimation results indicate that ψ_{22} is statistically significant at 1% level (p-value = 0.000) for all the countries under study, positive for Algeria $(\psi_{22} = 0.2679)$ and Gabon $(\psi_{22} = 0.1871)$ and negative for Congo Republic $(\psi_{22} = -0.2767)$ and Libya $(\psi_{22} = -0.0614)$. The findings hence support Cukierman-Meltzer hypothesis (positive impact of inflation uncertainty on inflation) for Algeria and Gabon, and the stabilization hypothesis of [24] (negative impact of inflation uncertainty on inflation) for Congo Republic and Libya.

Similarly, testing the impact of output growth uncertainty on the level of inflation is done by examining the sign and the significance of ψ_{21}. The results indicate that ψ_{21} is statistically significant at 1% level (p-value = 0.000) for all the countries under study, positive for Congo Republic $(\psi_{21} = 0.0549)$ and negative for Algeria $(\psi_{21} = -0.0080)$, Gabon $(\psi_{21} = -0.0763)$ and Libya $(\psi_{21} = -0.0129)$, supporting [9] hypothesis (positive impact of output growth uncertainty on the level of inflation) for Congo Republic and a negative impact of output growth uncertainty on the level of inflation for the rest of the countries.

In addition, examining the impact of output growth uncertainty and inflation uncertainty on output growth is done by respectively assessing the sign and the significance of ψ_{11} and ψ_{12}. The results show that ψ_{11} is statistically significant at 10% level for Algeria and at 1% for Congo republic, Gabon and Libya. ψ_{11} is positive for Algeria $(\psi_{11} = 0.0120)$, Gabon $(\psi_{11} = 1.2201)$ and Libya $(\psi_{11} = 0.0604)$, and negative for Congo republic $(\psi_{11} = -4.4786)$, supporting Black hypothesis of a positive impact of output growth uncertainty on output growth for Algeria, Gabon and Libya, and for Congo Republic, the views of [37] and [38] of a negative impact of output growth uncertainty on output growth are supported.

Finally with regard to the impact of inflation uncertainty on output growth, the results suggest that ψ_{12} is positive and statistically significant at 1% level for all the countries under study, $\psi_{12} = 1.7443$ for Algeria, $\psi_{12} = 0.2886$ for Congo republic, $\psi_{12} = 0.2141$ for Gabon and $\psi_{12} = 0.0580$ for Libya. The results therefore support [10] hypothesis of a positive impact of inflation uncertainty on output growth for all the countries under study. [18] hypothesis of a negative impact of inflation uncertainty on output growth is not supported for any country.

6 http://carnegieendowment.org/2009/04/13/lessons-from-algeria-s-2009-presidential-election/i8t

7 http://blogs.reuters.com/global/2009/02/24/is-bouteflika-set-for-a-hollow-victory-in-algeria-election/

8 http://www.infoplease.com/encyclopedia/world/gabon-history.html

Table 4. Asymmetric BEKK GARCH-M Model for Algeria

Panel A: Conditional Mean Equations

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t, \text{ where } \varepsilon_t \sim (0, H_t)$$

$$\mu = \begin{bmatrix} 1.4830 \\ (0.000) \\ 0.2475 \\ (0.000) \end{bmatrix}; \Gamma_1 = \begin{bmatrix} \text{-}0.4183 & \text{-}8.8184 \\ (0.000) & (0.000) \\ \text{-}0.1441 & 1.0118 \\ (0.000) & (0.000) \end{bmatrix}; \Gamma_2 = \begin{bmatrix} \text{-}0.2212 & 2.1791 \\ (0.000) & (0.000) \\ \text{-}0.0152 & \text{-}0.9892 \\ (0.000) & (0.000) \end{bmatrix}; \Psi = \begin{bmatrix} 0.0120 & 1.7443 \\ (0.083) & (0.000) \\ \text{-}0.0080 & 0.2679 \\ (0.000) & (0.000) \end{bmatrix};$$

$$\Theta_1 = \begin{bmatrix} \text{-}0.1813 & 8.3120 \\ (0.000) & (0.000) \\ 0.1354 & \text{-}1.0340 \\ (0.000) & (0.000) \end{bmatrix}; \Theta_2 = \begin{bmatrix} \text{-}0.0480 & \text{-}1.8602 \\ (0.000) & (0.000) \\ \text{-}0.0634 & 0.9873 \\ (0.000) & (0.000) \end{bmatrix}$$

Panel B: Conditional Variance-Covariance

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1} A + B' H_{t-1} B + D'\omega_{t-1}\omega'_{t-1} D$$

$$C = \begin{bmatrix} 3.9125 & 0 \\ (0.000) & \\ 0.0220 & \text{-}0.00001 \\ (0.576) & (1.000) \end{bmatrix}; A = \begin{bmatrix} 0.6491 & \text{-}0.0118 \\ (0.000) & (0.290) \\ \text{-}0.8433 & 0.2657 \\ (0.000) & (0.000) \end{bmatrix}; B = \begin{bmatrix} 0.1258 & 0.0179 \\ (0.083) & (0.000) \\ 0.3213 & 0.9609 \\ (0.000) & (0.000) \end{bmatrix}; \; D = \begin{bmatrix} \text{-}0.8083 & 0.0162 \\ (0.000) & (0.318) \\ 0.4985 & 0.0162 \\ (0.244) & (0.895) \end{bmatrix}$$

$$\textit{Diagonal VARMA}: [H0:\ \Gamma_{12}^{i} = \Gamma_{21}^{i} = \theta_{12}^{i} = \theta_{21}^{i} = 0, i = 1,2,\ \ \chi^2(8) = 154414.5(0.000)]$$

$$\textit{No GARCH}: [H0:\ \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0, \forall i, j;\ \ \chi^2(12) = 257628.7(0.000)]$$

$$\textit{No GARCH}-M: [H0:\ \psi_{ij} = 0, \forall i, j;\ \ \chi^2(4) = 9411.1(0.000)]$$

$$\textit{No ASYMMETRY}: [H0:\ \delta_{ij} = 0, \forall i, j;\ \ \chi^2(4) = 568.5(0.000)]$$

$$\textit{Diagonal GARCH}: [H0:\ \alpha_{12} = \alpha_{21} = \beta_{12} = \beta_{21} = \delta_{12} = \delta_{21} = 0, \forall i, j;\ \ \chi^2(6) = 106.3(0.000)]$$

Panel C: Diagnostic Tests

	Ljung-Box Q(4)	McLeod-Li(4)	Ljung-Box Q(10)	McLeod-Li(10)
$z_{y,t}$	8.2933 (0.081)	0.7651 (0.943)	17.7035 (0.060)	19.056 (0.039)
$z_{\pi,t}$	7.1720 (0.127)	4.0602 (0.397)	14.9275 (0.134)	15.7449 (0.107)

Source: The Results from our estimations using WinRATS Pro 8.1. Between parentheses (.) are the p-values.

4. Conclusions

This study examines the impacts of uncertainty about inflation and output growth on the levels of inflation and output growth for four oil-rich African countries, namely Algeria, Congo Republic, Gabon and Libya using a multivariate asymmetric GARCH-M model initiated by [21].

A number of important findings arise from this study. Concerning the impact of inflation uncertainty on inflation, Cukierman-Meltzer hypothesis (positive impact of inflation uncertainty on inflation) is supported for Algeria and Gabon, while the stabilization hypothesis of [24], that is, negative impact of inflation uncertainty on inflation, is supported for Congo Republic and Libya. In examining the impact of output growth uncertainty, our findings support [9] hypothesis (positive impact of output growth uncertainty on the level of inflation) for Congo Republic and a negative impact of output growth uncertainty on the level of inflation for the rest of the countries.

Another result is that, in as far as the impact of inflation uncertainty on output growth is concerned, [18] hypothesis of a negative impact of inflation uncertainty on output growth could not be supported for any country. In contrast, [10] hypothesis of a positive impact of inflation uncertainty on output growth is supported for all the countries under study. Finally, a closer look at the impact of output growth uncertainty on output growth shows that Black hypothesis of a positive impact of output growth uncertainty on output growth is supported for Algeria, Gabon and Libya, while for Congo Republic, the views of [37] and [38] of a negative impact of output growth uncertainty on output growth are supported.

This is to the best of our knowledge the first attempt to examine the impact of uncertainty on inflation and output growth for these four African countries, namely Algeria, Congo Republic, Gabon and Libya using a simultaneous approach. Further empirical studies are therefore needed to check the consistency of these findings by for instance applying the two-step approach.

Appendices

Appendix 1. Multivariate ARCH Effects test

COUNTRIES	LM (4)	LM(8)	LM(12)
Algeria	377.75[0.000]	216.73[0.000]	138.31[0.000]
Congo Rep.	197.17[0.000]	104.09[0.007]	63.11[0.003]
Gabon	258.04[0.000]	284.01[0.000]	318.19[0.000]
Libya	3096.8[0.000]	2249.7[0.000]	1989.4[0.000]

Source: Tests were performed using WinRATS Pro 8.1. Between brackets [.] are the P-values for the tests

Appendix 2. Asymmetric BEKK GARCH-M Model for Congo Republic

Panel A: Conditional Mean Equations

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t, \text{ where } \varepsilon_t \sim (0, H_t)$$

$$\mu = \begin{bmatrix} \text{46.7291} \\ (0.000) \\ \text{-0.0749} \\ (0.000) \end{bmatrix}; \Gamma_1 = \begin{bmatrix} \text{-0.7106} & \text{-0.1391} \\ (0.000) & (0.000) \\ 0.0217 & \text{-0.0116} \\ (0.000) & (0.000) \end{bmatrix}; \Gamma_2 = \begin{bmatrix} 0.1026 & \text{-0.4356} \\ (0.000) & (0.000) \\ \text{-0.0394} & 0.3367 \\ (0.000) & (0.000) \end{bmatrix}; \Psi = \begin{bmatrix} \text{-4.4786} & 0.2886 \\ (0.000) & (0.000) \\ 0.0549 & \text{-0.2767} \\ (0.000) & (0.000) \end{bmatrix};$$

$$\Theta_1 = \begin{bmatrix} \text{-0.0939} & 0.2690 \\ (0.000) & (0.000) \\ \text{-0.0543} & 0.2535 \\ (0.000) & (0.000) \end{bmatrix}; \Theta_2 = \begin{bmatrix} \text{-1.0085} & 0.6077 \\ (0.000) & (0.000) \\ 0.0879 & \text{-0.7633} \\ (0.000) & (0.000) \end{bmatrix}$$

Panel B: Conditional Variance-Covariance Matrix

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1} A + B' H_{t-1} B + D'\omega_{t-1}\omega'_{t-1} D$$

$$C = \begin{bmatrix} 6.6847 & \\ (0.000) & 0 \\ 0.9417 & \text{-0.0893} \\ (0.000) & (0.000) \end{bmatrix}; A = \begin{bmatrix} 0.0995 & 0.0206 \\ (0.000) & (0.000) \\ 0.0691 & 0.8384 \\ (0.000) & (0.000) \end{bmatrix}; B = \begin{bmatrix} 0.7694 & \text{-0.0804} \\ (0.000) & (0.000) \\ \text{-0.2053} & 0.0360 \\ (0.000) & (0.000) \end{bmatrix}; \text{ D} = \begin{bmatrix} \text{-0.0269} & 0.0033 \\ (0.000) & (0.064) \\ \text{-0.0645} & 0.2714 \\ (0.000) & (0.000) \end{bmatrix}$$

$$\textit{Diagonal VARMA}: [H0:\ \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0, i = 1,2,\ \ \chi^2(8) = 55339071.8(0.000)]$$

$$\textit{No GARCH}: [H0:\ \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0, \forall i,j;\ \ \chi^2(12) = 3.040436\text{e+}010(0.000)]$$

$$\textit{No GARCH} - M: [H0:\ \psi_{ij} = 0, \forall i,j;\ \ \chi^2(4) = 1.418720\text{e+}010(0.000)]$$

$$\textit{No ASYMMETRY}: [H0:\ \delta_{ij} = 0, \forall i,j;\ \ \chi^2(4) = 12481.2(0.000)]$$

$$\textit{Diagonal GARCH}: [H0:\ \alpha_{12} = \alpha_{21} = \beta_{12} = \beta_{21} = \delta_{12} = \delta_{21} = 0, \forall i,j;\ \ \chi^2(6) = 6261836.9(0.000)]$$

Panel C: Diagnostic Tests

	Ljung-Box Q(5)	McLeod-Li(5)	Ljung-Box Q(10)	McLeod-Li(10)
$z_{y,t}$	0.9511 (0.966)	0.1230 (0.999)	3.5988 (0.963)	0.6772 (1.000)
$z_{\pi,t}$	5.8756 (0.318)	3.7096 (0.591)	8.8888 (0.542)	6.1629 (0.801)

Source: Results from our estimations using WinRATS Pro 8.1. Between parentheses (.) are the p-values.

Appendix 3. Asymmetric BEKK GARCH-M Model for Gabon

Panel A: Conditional Mean Equations

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t, \text{ where } \varepsilon_t \sim (0, H_t)$$

$$\mu = \begin{bmatrix} \begin{matrix}-7.3567\\(0.000)\end{matrix} \\ \begin{matrix}0.5597\\(0.000)\end{matrix} \end{bmatrix}; \Gamma_1 = \begin{bmatrix} \begin{matrix}0.7798\\(0.000)\end{matrix} & \begin{matrix}-0.1567\\(0.000)\end{matrix} \\ \begin{matrix}0.0875\\(0.000)\end{matrix} & \begin{matrix}0.6536\\(0.000)\end{matrix} \end{bmatrix}; \Gamma_2 = \begin{bmatrix} \begin{matrix}0.1460\\(0.000)\end{matrix} & \begin{matrix}-1.1228\\(0.000)\end{matrix} \\ \begin{matrix}-0.0276\\(0.000)\end{matrix} & \begin{matrix}-0.5218\\(0.000)\end{matrix} \end{bmatrix}; \Gamma_3 = \begin{bmatrix} \begin{matrix}0.0660\\(0.000)\end{matrix} & \begin{matrix}0.1500\\(0.000)\end{matrix} \\ \begin{matrix}-0.0227\\(0.000)\end{matrix} & \begin{matrix}0.0501\\(0.000)\end{matrix} \end{bmatrix};$$

$$\Psi = \begin{bmatrix} \begin{matrix}1.2201\\(0.000)\end{matrix} & \begin{matrix}0.2141\\(0.000)\end{matrix} \\ \begin{matrix}-0.0763\\(0.000)\end{matrix} & \begin{matrix}0.1871\\(0.000)\end{matrix} \end{bmatrix}; \Theta_1 = \begin{bmatrix} \begin{matrix}-1.3805\\(0.000)\end{matrix} & \begin{matrix}0.2981\\(0.000)\end{matrix} \\ \begin{matrix}-0.0798\\(0.000)\end{matrix} & \begin{matrix}-0.6135\\(0.000)\end{matrix} \end{bmatrix}; \Theta_2 = \begin{bmatrix} \begin{matrix}0.3837\\(0.000)\end{matrix} & \begin{matrix}1.1557\\(0.000)\end{matrix} \\ \begin{matrix}0.0774\\(0.000)\end{matrix} & \begin{matrix}0.6518\\(0.000)\end{matrix} \end{bmatrix}$$

Panel B: Conditional Variance-Covariance Matrix

$$C = \begin{bmatrix} \begin{matrix}5.7360\\(0.000)\end{matrix} & 0 \\ \begin{matrix}-0.0143\\(0.000)\end{matrix} & \begin{matrix}0.5157\\(0.000)\end{matrix} \end{bmatrix}; A = \begin{bmatrix} \begin{matrix}0.0243\\(0.000)\end{matrix} & \begin{matrix}-0.0223\\(0.000)\end{matrix} \\ \begin{matrix}0.0138\\(0.000)\end{matrix} & \begin{matrix}0.6735\\(0.000)\end{matrix} \end{bmatrix}; B = \begin{bmatrix} \begin{matrix}-0.3289\\(0.000)\end{matrix} & \begin{matrix}0.0142\\(0.000)\end{matrix} \\ \begin{matrix}0.3538\\(0.000)\end{matrix} & \begin{matrix}0.5214\\(0.000)\end{matrix} \end{bmatrix}; \text{ D} = \begin{bmatrix} \begin{matrix}0.1761\\(0.000)\end{matrix} & \begin{matrix}0.0473\\(0.000)\end{matrix} \\ \begin{matrix}0.2650\\(0.000)\end{matrix} & \begin{matrix}-0.9483\\(0.000)\end{matrix} \end{bmatrix}$$

$$\textit{Diagonal VARMA}:[H0:\ \Gamma_{12}^i = \Gamma_{21}^i = \theta_{12}^i = \theta_{21}^i = 0, i = 1,2,\ \ \chi^2(10) = 2.608253\text{e+}009(0.000)]$$

$$\textit{No GARCH}:[H0:\ \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0, \forall i,j;\ \ \chi^2(12) = 4.573840\text{e+}009(0.000)]$$

$$\textit{No GARCH} - M:[H0:\ \psi_{ij} = 0, \forall i,j;\ \ \chi^2(4) = 2.964330\text{e+}011(0.000)]$$

$$\textit{No ASYMMETRY}:[H0:\ \delta_{ij} = 0, \forall i,j;\ \ \chi^2(4) = 121453296.5(0.000)]$$

$$\textit{Diagonal GARCH}:[H0:\ \alpha_{12} = \alpha_{21} = \beta_{12} = \beta_{21} = \delta_{12} = \delta_{21} = 0, \forall i,j;\ \ \chi^2(6) = 19929558.5(0.000)]$$

Panel C: Diagnostic Tests

	Ljung-Box Q(5)	McLeod-Li(5)	Ljung-Box Q(10)	McLeod-Li(10)
$z_{y,t}$	2.1933 (0.821)	5.2722 (0.383)	13.0478 (0.221)	13.6473 (0.189)
$z_{\pi,t}$	5.0119 (0.414)	0.4106 (0.995)	14.6000 (0.147)	9.2204 (0.511)

Source: Results from our estimations using WinRATS Pro 8.1. Between parentheses (.) are the p-values.

Appendix 4. Asymmetric BEKK GARCH-M Model for Libya

Panel A: Conditional Mean Equations

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t, \text{ where } \varepsilon_t \sim (0, H_t)$$

$$\mu = \begin{bmatrix} \begin{matrix}-0.4271\\(0.000)\end{matrix} \\ \begin{matrix}0.1792\\(0.000)\end{matrix} \end{bmatrix}; \Gamma_1 = \begin{bmatrix} \begin{matrix}0.2055\\(0.000)\end{matrix} & \begin{matrix}1.7509\\(0.000)\end{matrix} \\ \begin{matrix}-0.2096\\(0.000)\end{matrix} & \begin{matrix}0.9803\\(0.000)\end{matrix} \end{bmatrix}; \Gamma_2 = \begin{bmatrix} \begin{matrix}0.6340\\(0.000)\end{matrix} & \begin{matrix}-1.7321\\(0.000)\end{matrix} \\ \begin{matrix}-0.1916\\(0.000)\end{matrix} & \begin{matrix}-0.2789\\(0.000)\end{matrix} \end{bmatrix};$$

$$\Psi = \begin{bmatrix} \begin{matrix}0.0604\\(0.000)\end{matrix} & \begin{matrix}0.0580\\(0.000)\end{matrix} \\ \begin{matrix}-0.0129\\(0.000)\end{matrix} & \begin{matrix}-0.0614\\(0.000)\end{matrix} \end{bmatrix}; \Theta_1 = \begin{bmatrix} \begin{matrix}-0.9295\\(0.000)\end{matrix} & \begin{matrix}-2.6606\\(0.000)\end{matrix} \\ \begin{matrix}0.1632\\(0.000)\end{matrix} & \begin{matrix}-1.1817\\(0.000)\end{matrix} \end{bmatrix}; \Theta_2 = \begin{bmatrix} \begin{matrix}0.0995\\(0.000)\end{matrix} & \begin{matrix}2.9092\\(0.000)\end{matrix} \\ \begin{matrix}0.0784\\(0.000)\end{matrix} & \begin{matrix}0.1164\\(0.000)\end{matrix} \end{bmatrix}$$

Panel B: Conditional Variance-Covariance Matrix

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + D'\omega_{t-1}\omega'_{t-1}D$$

$$C = \begin{bmatrix} \begin{matrix}1.7680\\(0.000)\end{matrix} & 0 \\ \begin{matrix}0.0033\\(0.085)\end{matrix} & \begin{matrix}-0.3411\\(0.000)\end{matrix} \end{bmatrix}; A = \begin{bmatrix} \begin{matrix}1.4453\\(0.000)\end{matrix} & \begin{matrix}-0.0105\\(0.000)\end{matrix} \\ \begin{matrix}0.6832\\(0.000)\end{matrix} & \begin{matrix}0.0036\\(0.040)\end{matrix} \end{bmatrix}; B = \begin{bmatrix} \begin{matrix}0.0595\\(0.000)\end{matrix} & \begin{matrix}-0.0292\\(0.000)\end{matrix} \\ \begin{matrix}-0.6247\\(0.000)\end{matrix} & \begin{matrix}0.7769\\(0.000)\end{matrix} \end{bmatrix}; D = \begin{bmatrix} \begin{matrix}0.1211\\(0.000)\end{matrix} & \begin{matrix}0.0007\\(0.0009)\end{matrix} \\ \begin{matrix}0.2808\\(0.000)\end{matrix} & \begin{matrix}0.7753\\(0.000)\end{matrix} \end{bmatrix}$$

$$Diagonal\ VARMA : [H0:\ \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0, i = 1,2,\ \ \chi^2(8) = 5.457733\text{e+}009(0.000)]$$

$$No\ GARCH : [H0:\ \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0, \forall i,j;\ \ \chi^2(12) = 696187181.4(0.000)]$$

$$No\ GARCH-M : [H0:\ \psi_{ij} = 0, \forall i,j;\ \ \chi^2(4) = 443590062.9(0.000)]$$

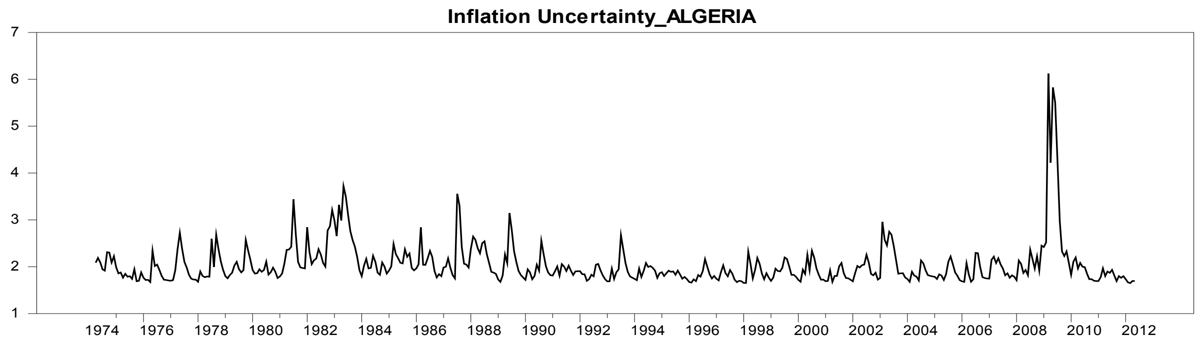
$$No\ ASYMMETRY : [H0:\ \delta_{ij} = 0, \forall i,j;\ \ \chi^2(4) = 28533392.8(0.000)]$$

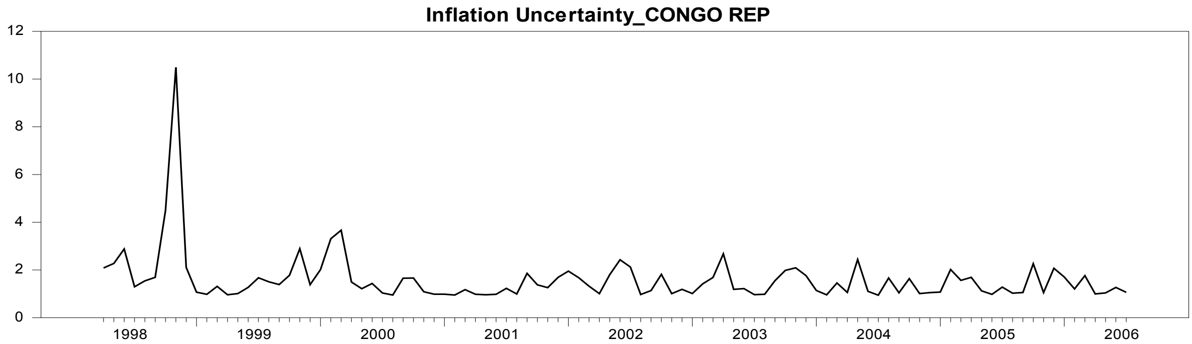
$$Diagonal\ GARCH : [H0:\ \alpha_{12} = \alpha_{21} = \beta_{12} = \beta_{21} = \delta_{12} = \delta_{21} = 0, \forall i,j;\ \ \chi^2(6) = 3078853.9(0.000)]$$

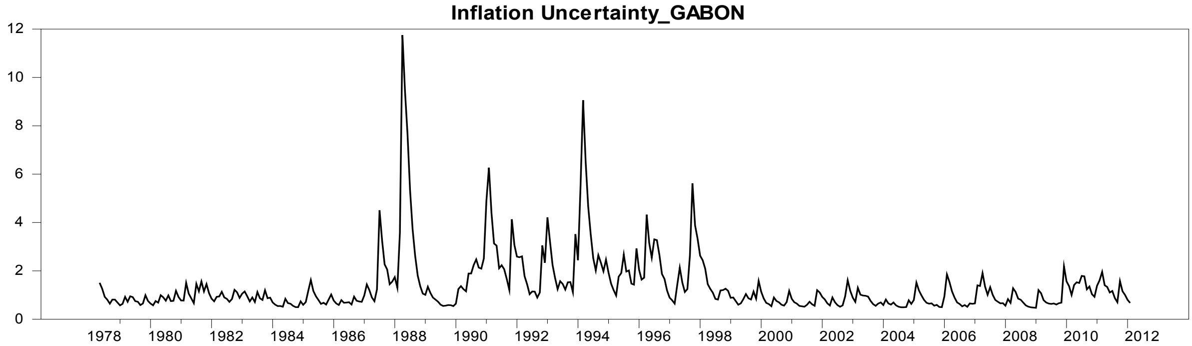
Panel C: Diagnostic Tests

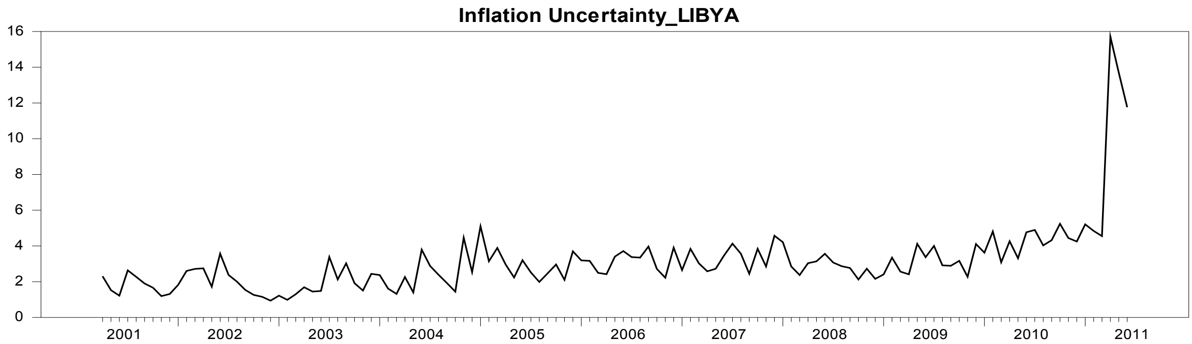
	Ljung-Box Q(5)	McLeod-Li(5)	Ljung-Box Q(10)	McLeod-Li(10)
$z_{y,t}$	4.9480 (0.422)	9.4231 (0.093)	12.0796 (0.279)	15.3112 (0.121)
$z_{\pi,t}$	4.7074 (0.452)	3.8269 (0.574)	6.5237 (0.769)	16.2883 (0.091)

Source: Results from our estimations using WinRATS Pro 8.1. Between parentheses (.) are the p-values.

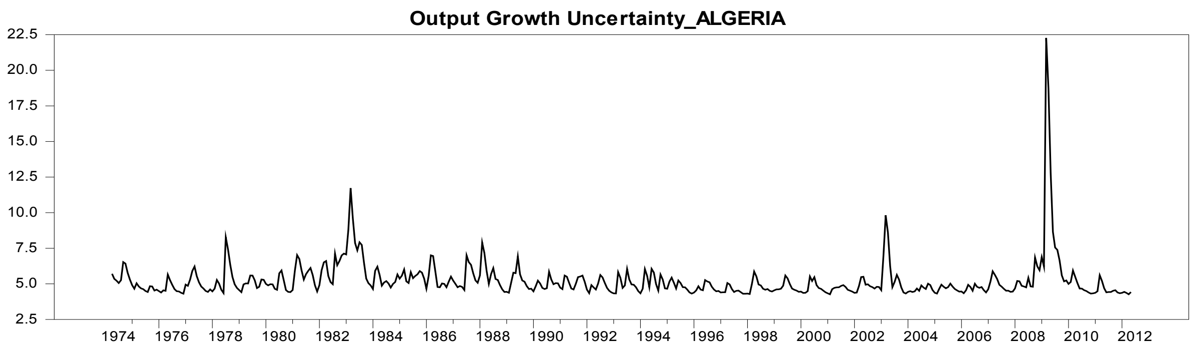


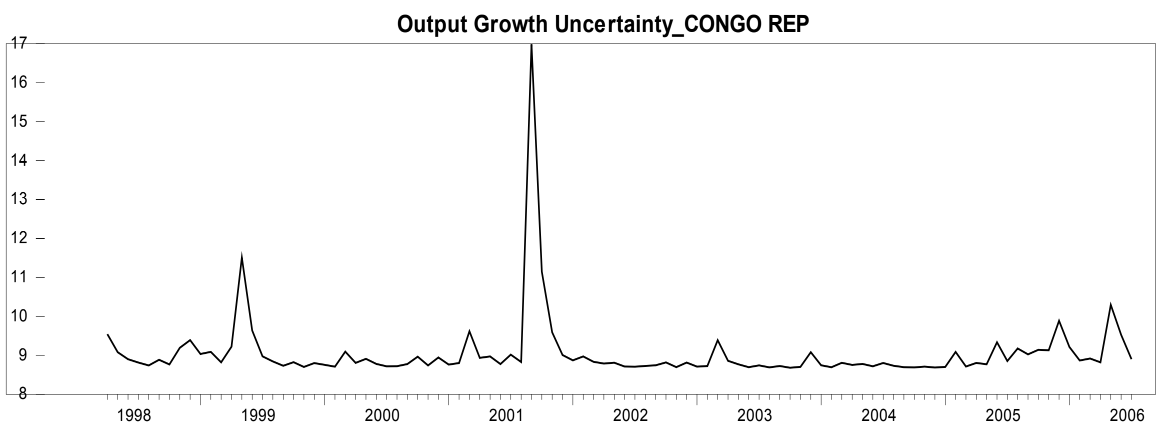


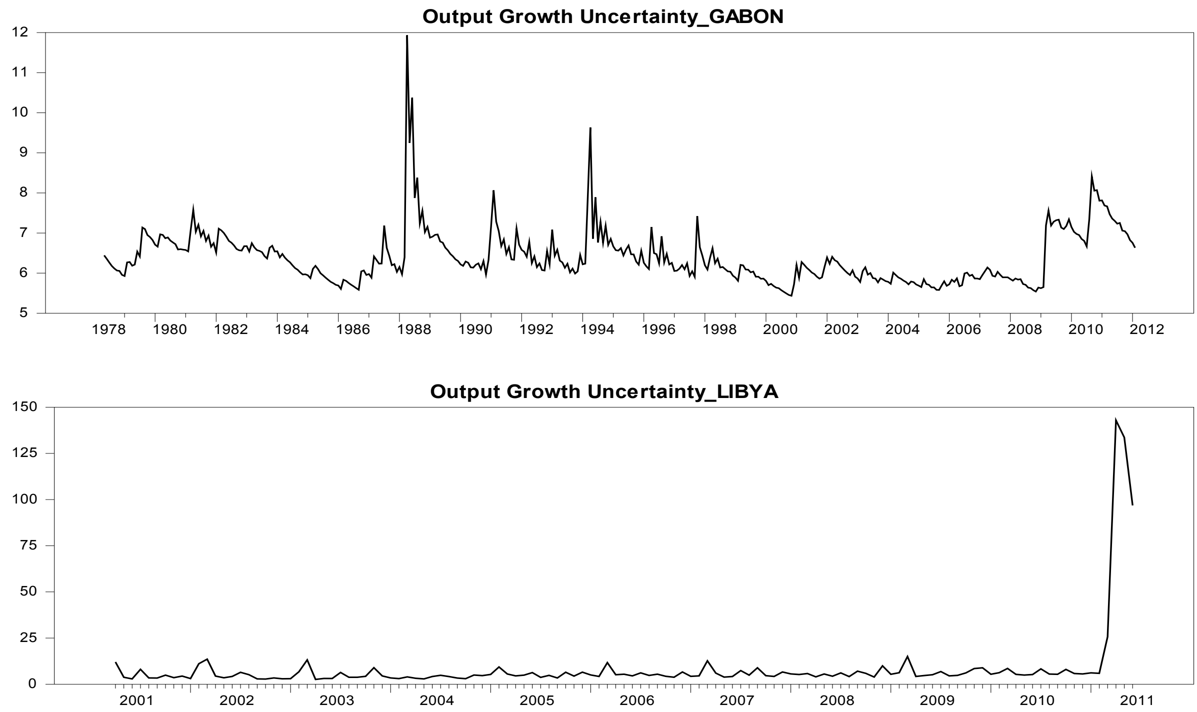




Appendix 5. Inflation uncertainty







Appendix 6. Output Growth Uncertainty

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