Nonlinearities and the nexus between inflation and inflation uncertainty in Egypt: New evidence from wavelet transform framework

Bouoiyour, Jamal and Selmi, Refk

CATT, University of Pau, ESC, Business School of Tunis

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Nonlinearities and the Nexus between Inflation and Inflation uncertainty in Egypt: New Evidence from Wavelet Transform Framework

Jamal BOUOIYOUR

CATT, University of Pau, France

Email: jamal.bouoiyour@univ-pau.fr

Refk SELMI

ESC, Business School of Tunis, Tunisia

Email: s.refk@yahoo.fr

Abstract :

The present study re-examines whether the direction of connection between inflation varies over time. To this end, we have used an optimal GARCH model among various extensions to determine an appropriate measure of inflation uncertainty and a nonlinear causality test approximated by Taylor within a wavelet transform framework. The shortest time horizon results (high frequencies) provide strong support for the Cukierman-Meltzer hypothesis, while there is strong evidence affirming the Friedman-Ball hypothesis at the highest time horizon (low frequencies). Possible explanations of the first outcome may be the unsustainability of prevailing fiscal policy following the oil price crash, the liability dollarization and the inefficiency of financial intermediation. However, the stabilization efforts since the mid-1990s and the deep of economic integration make Egypt more prone to external shocks and better equipped to cope with them, explaining therefore the second outcome.

Keywords:

Inflation; inflation uncertainty; time-frequency analysis.

1. Introduction

Inflation rate is a key determinant of economic decisions. Ups and down inflation movements can affect widely the decisions of businesses and consumers, leading to an uncertainty about inflation. As a result, the issue of the possible inflation costs and the challenges ahead have been and continues to be one of the most researched topics in macroeconomics both on the theoretical and empirical front. An area of contention of the relationship between inflation and its uncertainty is the direction of connection. One side of the debate is associated with Friedman (1977) and Ball (1992), showed that a rise in the average rate of inflation leads to more uncertainty about the future inflation rate. Other group including essentially Cukierman and Meltzer (1986) supported the opposite direction of causation. Pourgerami and Maskus (1987) offer different evidence that in the presence of rising inflation agents may invest more resources in forecasting inflation, reducing then inflation uncertainty. A formal analysis of this effect is presented also in the study of Ungar and Zilberfarb (1993). Table A.1 (Appendix) provides a detailed review of literature on this issue. It is well seen that the studies on the nexus between inflation and its uncertainty in developing countries are scarce and controversial. The mixed findings and the great resurgence of interest in the field of how to conduct monetary policy calls for a new look to this link in order to reach a clearer relationship between the two variables.

In this paper, we choose Egypt as case of study because in our knowledge there is only one research assessing this link in this country (Achour and Trabelsi, 2011). Using the state-space model with Markov switching specification and the local level model with standard GARCH, they conclude that there is a positive and significant link between both variables that runs from inflation uncertainty to inflation in the short run and dies out in the long-run, attributing it to the stabilization of monetary policy in Egypt. We attempt to revisit this nexus because we cannot assume that this result is conclusive for three main reasons: First, Egypt has undergone several shocks that can generate a climate of uncertainty Second, monetary authorities have different objectives determined stochastically over time that may lead to a trade-off between expanding output in favour of creating monetary surprises. Third, the step taken towards decreased central bank independence of Egypt in 2003 (Bouoiyour and Selmi, 2013) and the rapid increase in domestic credits during this period lowered the effectiveness of the stabilization policy.

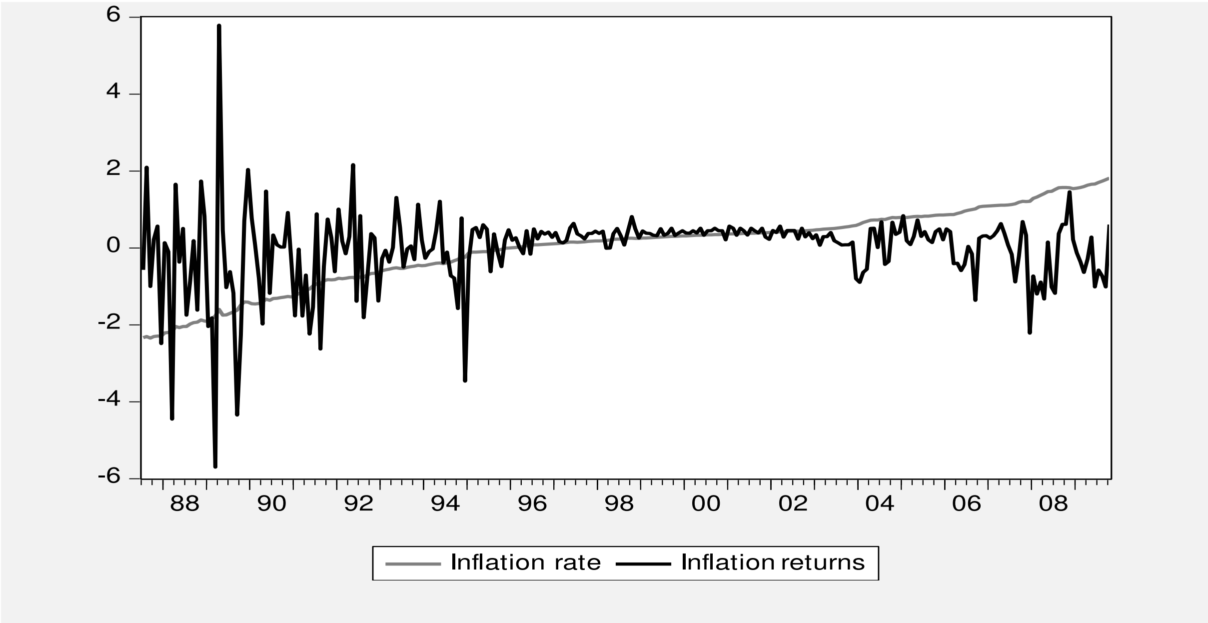
Our contribution to this debate is to point a clearer relationship between inflation and its uncertainty by examining whether there are substantial changes in the direction of connection between them over time. To this end, instead of standard deviation of inflation, an optimal GARCH model chosen among various GARCH extensions is used to determine an appropriate measure of inflation uncertainty. Then, we apply a nonlinear causality test within a wavelet transform framework.

The remainder of the paper is divided in five sections: The second section is a brief overview of Egyptian monetary policy. Section 3 presents our methodology. Section 4 discusses our main findings. Section 5 concludes and offers some economic implications.

2. Brief overview of monetary policy developments

Following the oil shock of 1985-1986, the fiscal deficit was accommodated through expansionary monetary policy leading to a great increase in inflation rate. Since 1990, the Egyptian exchange rate has undergone numerous shocks such as the East Asian crisis and Luxor terrorist attack in 1997, the fall of oil prices in 1998 and the revival of tensions in the Middle East peace process in the end of 90's. These events led to capital outflows, a slowdown in the capital market, a deterioration of the current account balance and a slowdown in tourism sector and economic growth (Kandil and Nergiz, 2008). Then and from 2001, the aftermath of the New York terrorist attack and the subsequent wars on Afghanistan and Iraq darkened the investment's attractiveness of Egypt, putting government under pressure. This has created a need to follow a policy of price stabilization since 1991 by implementing a structural adjustment program. Figure 1 clearly depicts the above events by showing that inflation surged over time. Therefore, the real reaction of inflation rate on the actions of policymakers requires a need to be revisited. This remains our main aim throughout the rest of the article.

Figure 1. Changes in inflation rate



Source: Econstats™.

3. Methodology

The current advances in econometric methods allow us to evaluate more accurately the direction of connection between inflation and inflation uncertainty depending to well defined time-horizons. Our methodology consists on choosing the optimal GARCH model among various GARCH extensions and to determine then the directional nexus between series by applying nonlinear causality test within wavelet transform framework.

3.1. Optimal GARCH model

Autoregressive Conditional Heteroscedasticity type modeling is the predominant technique used as volatility proxy. Theoretically, the unobserved conditional variance has affected widely the development of various GARCH-type models. Several specifications have been advanced to capture different features that are thought to be important in the process of conditional variance (Engle (1982), Bollerslev et al. (1993)). For example, some GARCH model allow the volatility to react asymmetrically to positive and negative shocks (Nelson, 1991), others consider only the magnitude of shocks (Bollerslev, 1986). In order to determine an effective proxy of uncertainty about future inflation, this study intends to make contribution by selecting an optimal GARCH among various extensions that allows us to effectively evaluate the focal relationship. To choose the best model, we use standard information criteria based on the historical evaluation such as the Akaike criterion, the Bayesian Criterion and Hannan and Quinn criterion and loss functions based on forecasting performance like Root Mean Square Error (RMSE) and Mean Absolute Error (MAE). Table A.2 (Appendices) summarizes the results revealing that the Exponential GARCH proposed by Nelson (1991) is the optimal model. This method depends not only on the magnitude of shock but also on the positive and negative sign of innovations. It is expressed as follows:

$$\log(\sigma_t^2) = \omega + \alpha\left|\frac{\mu_{t-1}}{\sigma_{t-1}}\right| + \gamma\frac{\mu_{t-1}}{\sigma_{t-1}} + \beta\log(\sigma^2_{t-1}) \quad (1)$$

where $\sigma_t{}^2$: conditional variance, ω: reaction of shock, α : ARCH term, β : GARCH term, μ : innovation, γ : leverage effect.

3.2. Wavelet decomposition

Wavelet analysis has created recently much excitement in economics and finance (i.e. to assess the nexus between oil price uncertainty and that of real effective exchange rate such as Tiwari et al. (2013) and to investigate the effect of real exchange volatility on exports performance as Bouoiyour and Selmi (2014), etc…). This method corresponds to oscillating functions that decay rapidly with time. It exhibits the time contribution of the different frequencies to the signal, to obtain then temporal frequency dependence and scale-by scale dynamic interactions between the key variables. Considering low (high time scales, long term) and high frequencies (low time scales, short term), we can differentiate between time horizons for decision making and we can approximate structural changes that can happen over time and then the problem of temporal aggregation bias can be neglected. This approach is based on the mother wavelet denoted $\psi(t)$:

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

To evaluate the nexus between inflation and inflation uncertainty in different time horizons, the mother wavelet gets deleted, we obtain therefore:

$$\psi_{u,s} = \frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right) \tag{3}$$

where *u* and *s* are the time location and frequency ranges, respectively.

Unlike time domain, wavelets can identify which frequencies are present in the data at any given point in time. Ultimately, we obtain the wavelet representation of the function *Y (t)*:

$$Y(t) = \lfloor w_1(t), v_1(t),...., w_j(t), v_j(t) \rfloor \tag{4}$$

where $w_1(t)$ and $v_1(t)$ are respectively the high frequency and the low frequency.

3.3. Nonlinear causality test

Several approaches have been developed to address the linearity assumption in Granger causality. Granger (1995) shows that the linear causality can vary across frequencies or under various periodicities. Hence, to test whether there is or not nonlinearity in the directional connection between inflation and its uncertainty, we use a Taylor approximation a proposed by Péguin-Feissolle and Teräsvirta (1999). This method is based on the nonlinear function y_t expressed as follows:

$$y_t = f^*(y_{t-1},\ldots,y_{t-q},x_{t-1},\ldots,x_{t-n},\theta^*)+\varepsilon_t \tag{5}$$

where θ^* is a parameter vector and ε_t ~ $nid(0,\sigma^2)$; the sequences x_t and x_t are weakly stationary. The functional form of f^* is unknown but we assume that is adequately represents the causal relationship between x_t and y_t. While trying to test noncausality hypothesis, we start by the fact that x_t does not cause y_t if the past values of x_t does not contain any information about y_t , we have therefore:

$$y_t = f(y_{t-1},\ldots,y_{t-q},\theta)+\varepsilon_t. \tag{6}$$

To test (6) against (5), we linearize f^* in (5) by expanding the function into a k-order Taylor series around an arbitrary fixed point in the sample space. We obtain:

$$y_t = \beta_0 + \sum_{j=1}^{q}\beta_j y_{t-j} + \sum_{j=1}^{n}\gamma_j x_{t-j} + \sum_{j_1=1}^{q}\sum_{j_2=j_1}^{q}\beta_{j_1 j_2} y_{t-j_1} y_{t-j_2} + \sum_{j_1=1}^{q}\sum_{j_2=1}^{n}\delta_{j_1 j_2} y_{t-j_1} x_{t-j_2}$$

$$+\sum_{j_1=1}^{n}\sum_{j_2=j_1}^{n}\gamma_{j_1 j_2} x_{t-j_1} x_{t-j_2} + \ldots + \sum_{j_1=1}^{q}\sum_{j_2=j_1}^{q}\cdots\sum_{j_k=j_k-1}^{q}\beta_{j_1\ldots j_k} y_{t-j_1}\ldots y_{t-j_k}$$

$$+\ldots+\sum_{j_1=1}^{n}\sum_{j_2=j_1}^{n}\cdots\sum_{j_k=j_k-1}^{n}\gamma_{j_1\ldots j_k}x_{t-j_1}\ldots x_{t-j_k}+\varepsilon_t^* \quad (7)$$

4. Main results

4.1. Preliminary analysis

Due to data restrictions, we use monthly data of consumer price index of the period spanning between 1987:M7 and 2009:M10 collected from Econstats™ and International Monetary Fund (IMF). The descriptive statistics are reported in Table 2. The sample means of inflation returns is positive. The skewness indicates a negative value, implying that inflation returns are skewed relative to a normal distribution. The Jarque–Bera test indicates a high level, meaning a reject of normality of these variables.

Table 2. Descriptive statistics of inflation rate

Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
4.377741	4.425683	4.784153	3.825811	0.251003	-0.450748	2.23676	15.58002

4.2. Inflation uncertainty and its persistence

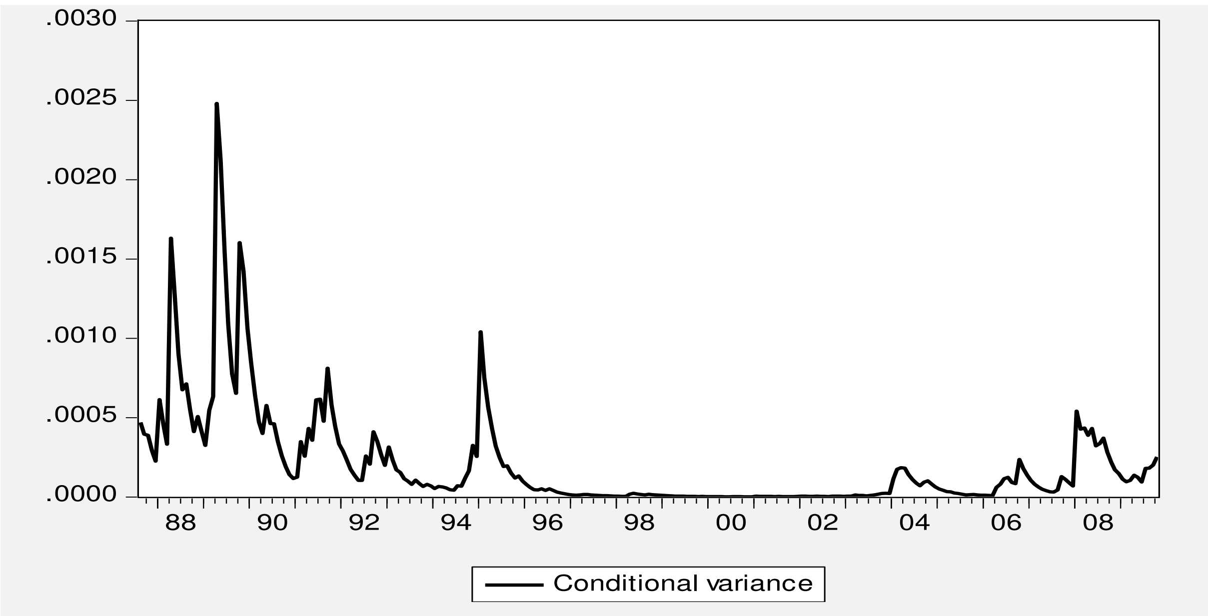
The optimal GARCH is the model with the lowest values of information criteria and loss-functions. Table A.2 (Appendix) reports the results revealing that the Exponential GARCH is more appropriate than others to measure inflation uncertainty. This highlights the importance of accounting for asymmetry when studying inflation instability, particularly for Egypt. It is well found from the application of Exponential GARCH that the lagged inflation rate returns ($r_{INF_{t-1}}$) affects positively and significantly those at date t (r_{INF_t}). An increase by 10% in lagged inflation lead to a rise in inflation returns by 1.98%. The uncertainty about future inflation seems persistent with duration ($\alpha+\beta+0{,}5\gamma$) equal to 0.83. The leverage effect (γ) is negative and significant, implying that the Egyptian inflation reacts more to good news than bad news.

Table 3. Conditional variance of inflation rate

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
C	-0.002486	0.000279	-8.905139	0.0000
$r_{INF_{t-1}}$	0.198394	0.063670	3.115975	0.0018
Variance Equation				
w	0.361423	0.077981	4.634732	0.0000
α	0.963428	0.049774	3.988546	0.0001
β	0.198572	0.010296	9.357752	0.0000
γ	-0.671316	0.126341	-5.313508	0.0000

Figure 2 reinforces the fact that there is sizeable and persistent inflation uncertainty especially after the oil shock of 1986-1987, implying the great sensitivity of inflation to the ups and down oil price movements. We notice also that the inflation uncertainty appears stronger between 1987 and 1994, became negligeable from 1996 to 2003 and slightly increased between 2004-2009, highlighting the monetary polcy development over time.

Figure 2. Inflation uncertainty using Exponential GARCH model



4.3. The direction of connection between inflation and its uncertainty

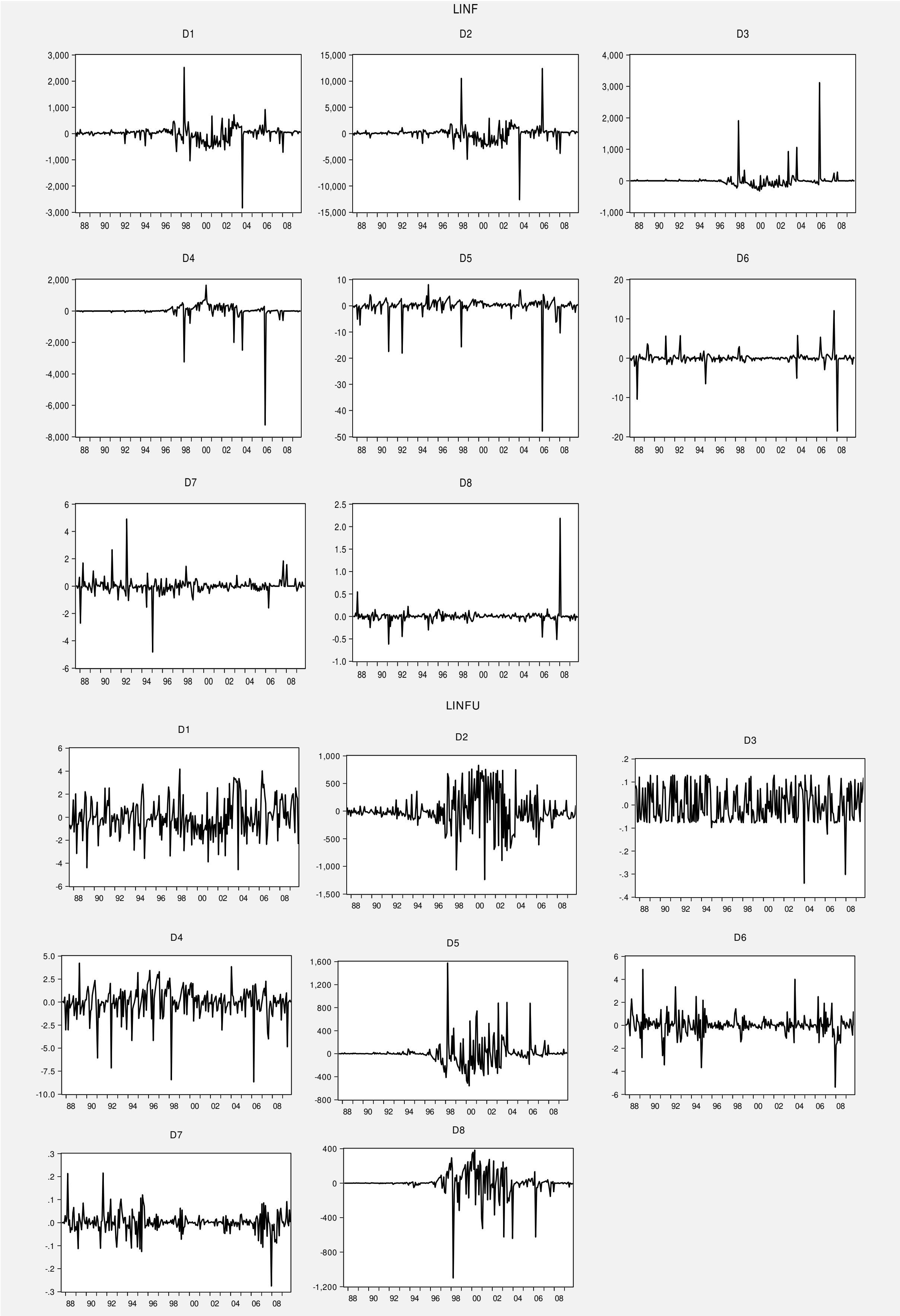
In our knowledge, there are no studies that explore wavelet approach in order to analyze the direction of connection between inflation and inflation uncertainty over specific time horizons. The considered frequencies are reported in Table 4.

Table 4. Time-frequencies

Scales	Monthly time-frequencies
D1	2-4
D2	4-8
D3	8-16
D4	16-32
D5	32-64
D6	64-128
D7	128-256
D8	>256

Figure 3 clearly depicts the great movements of inflation rate and its sizeable instability, which vary over time. More precisely, we show that both time series change substantially depending to time-frequency variation. We cannot say at this stage if greater inflation precedes inflation uncertainty or inversely. Thus, it will be important in the following to carry out Granger causality test to show the direction of connection. It seems also interesting to account for nonlinearity since as mentioned above Egypt has experienced several external shocks especially during the period between 1987 and 2001.

Figure 3. Wavelet decomposition of inflation rate and its uncertainty



Notes : *LINF* : Logarithm of inflation rate ; *LINFU* : Logarithm of inflation uncertainty.

Because several previous studies show that the traditional Granger causality test designed to capture linear causality is ineffective in detecting certain nonlinear causal links (Chen et al. (2004), Diks and Panchenko (2005), Hiemestra and Jones (1994), Hiemstra and Kramer (1997) and Péguin-Feissolle and Teräsvirta (1999)), a nonlinear causality test approximated by Taylor was applied at different time-frequencies to gauge properly whether the nexus between the key series depends to nonlinearity and frequency variations. It seems that nonlinearity is an important feature of the data either in terms of explaining the direction of connection within time domain or time scales. We choose here two lags because simulation produce favorable findings with few lags (Tiwari et al. 2012).

The results reported in Table 5 reveal that there is a nonlinear causal relation running from inflation to inflation uncertainty at the highest time horizons or low frequencies (*D1, D2 and D3*) with significant p-values (<5%). This implies that we support the Friedman Ball hypothesis in the long term. In addition, a revese link that runs from inflation uncertainty to inflation is found at time domain and at high frequencies or low time scales with significant p-values (<5%) at *D5, D6* and *D7* and (<10%) at *D, D4* and *D8*. This means that there is a strong support for the Cukierman-Meltzer hypothesis at the shortest time-horizon.

The observed findings may be explained as follows : At the shortest time horizon, Egypt has experienced external shocks that may have large inflation costs. The collapse in windfall revenues following the oil price crash in 1986-1987, the development of dollar shortages, the cyclicality of fiscal policy and the inefficiency of financial intermediation (Panizza, 2001), have reduced the effectiveness of monetary policy in mitigating shocks'effects, which may obviously generate a climate of uncertainty. This unstable situation provides incentives to surprise economic agents with drastic actions able to increase inflation rate, implying therefore that inflation uncertainty serves as inducer to inflation in low time scales, This means that the Cukierman-Meltzer hypothesis is a short term phenomenon.

Due to the possible harmful effects of external shocks on the whole economy, Egypt became vigorously engaged in a policy of inflation stabilization by achieving a structural adjustment program. As initial response, the fiscal deficit fell from 15,24% over the period of 1987-90 to 1.33% of GDP (as average) of the period 1998-2002 (Panizza, 2001). This has lessened the excessive inflation uncertainty. Unfortunately, Egypt has undergone the Luxor terrorist attack in 1997 and the domestic financial scandal in 1998. This has led to a use of an expansionary fiscal policy to cope with them. Despite this reform, the country does not succeed to remove completely the climate of uncertainty due to its inability to implement countercyclical fiscal policy and the weaker budgetary and fiscal institutions. However, the fact that Egypt has been increasingly integrating with the global economy will prompt to less inflation uncertainty (Howard (2000) and El-Refaie (2001)). These subsequent measures taken to stabilize the situation will make inflation as inducer to inflation uncertainty in the highest time horizons (low frequencies). This result is in line with the previous studies particularly Hermann et al. (2012). These authors argue that the Friedman Ball hypothesis is a long term phenomenon in the majority of developing countries especially those with low central bank independence.

Table 5. Nonlinear causality test

Time domain	Time-frequencies							
D :* *All returns	***D1* *2-4M***	***D2* *4-8M***	***D3* *8-16M***	***D4* *16-32M***	***D5* *32-64M***	***D6* *64-128M***	***D7* *128-256M***	***D8* *>256M***
H_0 :*Inflation* does not cause *inflation uncertainty*								
0.8609 (0.4417)	0.9989 (0.0475)	0.9985 (0.0010)	4.9706 (2.5E-6)	0.9844 (0.6063)	0.2963 (0.7438)	0.4472 (0.6395)	0.2014 (0.8176)	0.2431 (0.7843)
H_0 : *Inflation uncertainty* does not cause *inflation*								
2.2667 (0.0657)	0.2071 (0.8131)	0.6243 (0.5811)	0.4309 (0.6513)	0.9327 (0.0696)	3.5592 (0.0297)	3.1794 (0.0432)	4.3102 (0.0144)	2.4525 (0.0881)

Note s: (.): the p-value ; p-value<0.05 : ** ; p-value<0.1 : *.

5. Conclusion

We have re-investigated the direction of connection between inflation and its uncertainty in order to reach a clearer relationship between the two variables. Our contribution in this study is to assess whether there is substantial changes in the focal nexus over time. To this end, we have used an optimal GARCH model among various extensions to determine an appropriate measure of inflation uncertainty and a nonlinear causality test approximated by Taylor within a wavelet transform framework.

We show that there is a support for the Cukierman-Meltzer hypothesis at time domain (*D*) and the shortest time horizon (high time-frequencies: *D4, D5, D6, D7* and *D8*), while there is a strong evidence in favour of the Friedman-Ball hypothesis at the highest time horizon (low time-frequencies: *D1, D2* and *D3*). Hence, inflation uncertainty serves as inducer to inflation in the short-run (Cukierman-Meltzer hypothesis) and inversely in the long-run (Friedman-Ball hypothesis). We attribute the first finding to the unsustainability of prevailing fiscal policy following the oil price crash, the liability dollarization, the cyclicality of fiscal policy and the inefficiency of financial intermediation, and the second outcome to the price stabilization efforts and the deep of economic integration, which make Egypt better equipped to cope with external shocks.

Given that shocks may threaten the price stabilization process, especially with the aftermath of'Arab Spring', Egyptian government should implement drastic actions to enhance the credibility of monetary policy, to ensure effective allocation of resources, to mitigate the disruption in decisions and then to achieve effectively the transition towards inflation targeting. This seriously needs countercyclical monetary and fiscal policies, good budgetary and fiscal institutions and well regulated financial system.

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Appendices

Table A.1. A brief literature survey on inflation-inflation uncertainty nexus

Study	Studied countries	Model	Hypothesis
Okun (1971)	Panel of 17 OECD countries	Standard deviation and parametric causality test.	Countries with high average inflation display inflation uncertainty.
Friedman (1977)	Canada, France, Germany, Italy, Japan, United Kingdom and United States.	Standard average deviation and Granger causality test.	A rise in the average rate of inflation prompts more uncertainty about inflation.
Cukierman and Meltzer (1986)	France, Italy, Japan, Spain.	Game-theoretic model	Central Banks create inflation surprises when there is a great uncertainty about inflation.
Bollerslev (1986)	United States.	GARCH model	The conditional variance of inflation is lower when inflation level is highest.
Pourgerami and Maskus (1987)	07 Latin American countries.	Standard deviation and Granger causality test	A rise in inflation increases ressources'investment in forecasting inflation leading then to a drop of inflation uncertainty.
Devereux (1989)	Germany, Hungray, Indonesia, Korea, Netherlands, Sweden.	Barro-Gorden model	The inflation uncertainty can have an adverse effect on inflation.
Ball (1992)	G7 countries	Asymmetric information game model	Formal derivation of Friedman hypothesis
Cukierman (1992)	France, Japan, Germany, United States.	OLS with interactive terms	Central bank independence plays an important role in how interacts inflation level to its uncertainty.
Holland (1993)	Columbia, Germany, Hungray, Indonesia, Israel, Korea, Mexico, Netherlands, Sweden and Turkey.	Barro-Gorden model	The inflation uncertainty can have a positive impact on inflation via real uncertainty canal.
Ricketts and Rose (1995)	Canada	Markov-switching model	Inflation uncertainty increases widely during high inflation periods.
Baillie et al. (1996)	United Kingdom	ARCH model and linear causality test	Evidence in favour of Cukierman and Meltzer hypothesis above mentioned.
Grier and Perry (1998)	G7 countries	GARCH model and parametric causality test.	Unidirectional link that runs from inflation uncertainty to the level of inflation rate.
Nas and Perry (2000 a)	G7 countries	GARCH model	The changing in policymakers behaviour toward inflation can precipate the time-varying in the structure of inflation.
Nas and Perry (2000 b)	Turkey	Standard deviation and linear causality test	Inflation rate increases inflation uncertainty.
Grier and Perry (2000)	France, Germany, Japan, United Kingdom and United States.	GARCH model and parametric causality test.	Significant bidirectional link between inflation and inflation uncertainty.
Kontanikas (2004)	United Kingdom.	GARCH model.	The adoption of inflation targeting reduces the long-run effect of inflation uncertainty on the level of inflation rate.
Elder (2004)	Euro area.	GARCH model and VAR specification.	The linkage between inflation and inflation uncertainty

			depends intensely to studied time periods.
Bhar and Hamori (2004)	G7 countries.	Markov switching model	The relationship between inflation and its uncertainty depends considerably on whether the shock is transitory or permanent and differs depending to countries'characteristics.
Zeynel and Mahir (2008)	Jordan, Philippines, Turkey.	GARCH model.	Strong evidence in favor of Friedman-Ball hypothesis and weak evidence in accordance with Cukierman and Meltzer (1986).
Achour and Trabelsi (2011)	Egypt.	The state-space model with Markov switching heteroskedasticity.	Inflation uncertainty has a positive effect on inflation level in the short run but this effect dies out in the long run.
Hermann et al. (2012)	Panel of 22 emerging countries.	GARCH model and cointegration framework.	The nexus between inflation and its uncertainty is highly conditional to the degree of central bank independence.
Hachicha and Lean (2013)	Tunisia.	GARCH-in-mean and linear Granger causality test.	Inflation uncertainty has a positive and significant effect on inflation.
Bouoiyour and Selmi (2013)	Panel of 12 emerging countries.	GMM model with interactive terms.	Countries with high level of central bank independence and chosen pegged exchange regime as exchange policy tend to exhibit low and stable inflation.

Source: Authors'compulation.

Table A.2. The choice of optimal GARCH model

GARCH extensions	AIC	BIC	HQ	RMSE	MAE
Standard GARCH $\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2$	-6.780	-6.713	-6.753	0.01478	0.00838
GARCH-M (GARCH in mean) $r_t = \mu_t + \varepsilon_t + \lambda \sigma_t^2$	-6.794	-6.714	-6.762	0.01474	0.00836
C-GARCH (Component GARCH) $(\sigma_t^2 - \sigma^2) = \alpha\gamma(\varepsilon_{t-1}^2 - \sigma^2) + \beta(\sigma_{t-1}^2 - \sigma^2)$	-6.712	-6.671	-6.696	0.01485	0.00844
QGARCH (Quadratic GARCH) $\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i} - b_i)^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2$	-6.831	-6.751	-6.799	0.01469	0.00836
I-GARCH (Integrated GARCH) $\sigma_t^2 = \omega + \varepsilon_{t-1}^2 + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i}^2 - \varepsilon_{t-1}^2) + \sum_{i=1}^{p} \beta_j (\sigma_{t-j}^2 - \varepsilon_{t-1}^2)$	-6.753	-6.659	-6.715	0.01482	0.00862
A-GARCH (Asymmetric GARCH) $\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i (\lvert\varepsilon_{t-i}\rvert + \gamma_i \varepsilon_{t-i})^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2$	-6.837	-6.743	-6.799	0.01469	0.00833
T-GARCH (Threshold GARCH) $\sigma_t^2 = \omega + \sum_{i=1}^{q} (\alpha_i \lvert\varepsilon_{t-i}\rvert + \gamma_i \lvert\varepsilon_{t\_i}^{+}\rvert) + \sum_{i=1}^{p} \beta_j \sigma_{t-j}$	-6.755	-6.660	-6.717	0.01477	0.00838
GJR-GARCH $\sigma_t^2 = \omega + \sum_{i=1}^{q} (\alpha_i + \gamma_i I_{(\varepsilon_{t-i>0})}) \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2$	-6.751	-6.644	-6.708	0.01478	0.00838
GJR-PARCH (GJR power GARCH) $\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q} (\alpha_i + \gamma_i I_{(\varepsilon_{t-i>0})}) \varepsilon_{t-i}^{\varphi} + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^{\varphi}$	-6.745	-6.624	-6.797	0.01479	0.00334
E-GARCH (Exponential GARCH) $\log(\sigma_t^2) = \omega + \sum_{i=1}^{q} (\alpha_i z_{t-i} + \gamma_i (\lvert z_{t-i}\rvert - \sqrt{2/\pi})) + \sum_{i=1}^{p} \beta_j \log(\sigma_{t-j}^2)$	-7.064	-6.957	-7.021	0.01378	0.0076
P-GARCH (Power GARCH) $\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^{\varphi} + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^{\varphi}$	-6.838	-6.743	-6.799	0.01467	0.00832
A-PGARCH (Asymmetric power GARCH) $\sigma_t^{\varphi} = \omega + \sum_{i=1}^{q} \alpha_i (\lvert\varepsilon_{t-i}\rvert + \gamma_i \varepsilon_{t-i})^{\varphi} + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^{\varphi}$	-6.745	-6.624	-6.797	0.01479	0.00834
NGARCH (Nonlinear GARCH) $\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i} - \kappa_i)^2 + \sum_{i=1}^{p} \beta_j \sigma_{t-j}^2$	-7.021	-6.928	-6.984	0.04023	0.03547

Notes: σ_t^2 : conditional variance, σ_t : conditional standard deviation, ω : reaction of shock, α_0 : reaction of shock, α_1 : ARCH term, β_1 : GARCH term, ε : error term; I_t: denotes the information set available at time t; I_{t-1}: denotes the information set available at time t-1; z_t: the standardized value of error term where $z_t = \varepsilon_{t-1} / \sigma_{t-1}$; μ : innovation, γ : leverage effect; $\sigma^2 = \omega / (1 - \alpha - \beta)$: corresponds to the unconditional variance ; b : quadratic order, φ : power parameter.