MONEY SUPPLY AND INFLATION IN ALGERIA: A WAVELET BASED ANALYSIS

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ABSTRACT

The purpose of this study is to examine the relationship between money supply and inflation in Algeria using the wavelet analysis. In this study we have applied Maxima Overlap Discrete Wavelet Transform (MODWT), Multiresolution Analysis (MRA), wavelet correlation, Wavelet Coherence, and wavelet-based Granger causality test to analyse the relationship between the two variables during the period from January 2010 to November 2019. Our findings show strong links between money supply and inflation in both the short and long run, which support both the traditional and modern quantity theories of money. Additionally, time scale Granger causality analysis indicates the existence of causality from money supply to inflation over different time horizons. The outcomes of the current study should be of interest to Algerian monetary policymakers as they decide to sustain growth using unconventional monetary policy.

KEYWORDS: Money Supply, Inflation, Wavelet Analysis, Algeria.

JEL Classification : C40, E3, E4, E50

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عرض النقود والتضخم في الجزائر باستخدام تحليل المويجات

ملخص

تهدف هذه الدراسة إلى تحليل العلاقة بين عرض النقود والتضخم في الجزائر باستخدام تحليل المويجات (Wavelet analysis). في هذه الدراسة قمنا باستخدام كل من طريقة التحول المويجي المتقطع (MODWT)،وطريقة التحليل متعدد الدقة (Multiresolution Analysis) والارتباط المويجي (Wavelet Correlation)، وتماسك المويجات (Wavele tCoherence)، واختبار سببية Granger القائم على المويجات لتحليل العلاقة بين المتغيرين خلال الفترة من يناير 2010 إلى نوفمبر 2019. بينت نتائج الدراسة علاقة ارتباط قوية بين عرض النقود والتضخم على المدى القصير والطويل، وتدعم هذه النتائج كلا من النظرية الكمية التقليدية والحديثة للنقود. كما يشير تحليل سببيةGrangerإلى وجود علاقة سببية من عرض النقود باتجاه التضخم. نتائج الدراسة الحالية تعتبر مهمة لصانعي السياسة النقدية في الجزائري، خاصة في حالة ما إذا تم تبني سياسة نقدية غير تقليدية لدعم النمو الاقتصادي.

كلمات مفتاحية: عرض النقود، التضخم، تحليل المويجات، الجزائر

L'OFFRE DE MONNAIE ET L'INFLATION EN ALGÉRIE : UNE ANALYSE EN ONDELETTES

RÉSUMÉ

L'objectif de cet article est d'examiner la relation entre l'offre de monnaie et l'inflation en Algérie à l'aide de l'analyse par ondelettes. Dans cette étude, nous avons appliqué la transformée en ondelettes discrète (MODWT), Analyse multi-résolution(MRA), la corrélation des ondelettes, la cohérence des ondelettes et le test de causalité de Granger basé sur les ondelettes pour analyser la relation entre les deux variables au cours de la période de janvier 2010 à novembre 2019. Les résultats empiriques relèvent des liens étroits entre l'offre de monnaie et l'inflation à court et à long terme, ce qui soutient à la fois la théorie quantitative traditionnelle et moderne de la monnaie. L'analyse de causalité de Granger indique l'existence d'une causalité de l'offre de monnaie à l'inflation sur différents horizons temporels. Les résultats de la présente étude sont importants pour les responsables de la politique monétaire en Algérie, en particulier dans le cas où une politique monétaire non conventionnelle serait adoptée pour soutenir la croissance économique.

MOTS-CLÉS : Offre de monnaie, Inflation, Analyse en ondelettes, Algérie

INTRODUCTION

Inflation has always been a major global economic problem. It affects all aspects of the economy, including consumer spending, business investment, employment, government programs, and interest rates. Different economists have advanced different theories to explain inflation's causes. One of these theories is the Quantity Theory of Money (QTM). The QTM states that changes in the quantity of money and changes in the price level are proportional. Milton Freidman's famous dictum, "inflation is always and everywhere a monetary phenomenon" suggests that growth in money supply is inflationary, particularly in the long run. Since the last recession (2007

to 2009) policymakers have been more concerned about the return of inflation that might result from the quantitative easing policies implemented by central banks to energize the economy.

In this paper, we ask the question of whether there is a relationship between money supply and inflation in the long run in Algeria, as suggested by the quantitative theory of money. Algeria has experienced a substantial increase in the supply of money over the past decade. Statistics from Algeria's central bank (Bank of Algeria) show that Algeria's broad money (M2) has increased significantly over time, from DZD 8281 billion in 2010 to DZD 16637 billion in 2018; this means that Algeria's broad money has more than doubled in size over the last ten years. The sharp and sustained decline in oil prices since mid-2014 has led the government through the monetary authority to flood the country with easy money to finance the large fiscal deficits and avoid borrowing from the International Monetary Fund (IMF). According to official statistics, the central bank of Algeria has printed out of 55 billion US dollars' worth of bank notes between 2017 and 2019 to deal with the budget deficits. The IMF and the World Bank argued Algeria's unconventional financing policy would bring substantial inflationary pressures to the Algerian economy. Further, a long run money supply growth-inflation relationship suggested by the Quantity Theory of Money (QTM) raises concerns of a sustained increase in the price level.

The main focus of this study is to examine the association among money supply and inflation for Algeria using the wavelet analysis. Precisely, the present study applies the Maximal Overlap Discrete Wavelet Transform (MODWT) Multiresolution Analysis (MRA) to decompose each time series into several scales, and also uses wavelet correlation, wavelet covariance, wavelet power spectrum, and wavelet coherence to describe the co-movement between the study variables. Wavelet based Granger causality test is also adopted to investigate the causal relationship between money supply and inflation across different time horizons.

Concerning the case of Algeria many studies have investigated the nexus between money supply and inflation (Koranchelian, 2004;

Benbouziane and Benamer, 2004; Ben Naceur, 2012; Souissi, 2017). However, they have considered only the time domain analysis. Our study contributes to the existing literature by exploring the dynamic interaction between the two variables in the time-frequency domain.
The rest of the paper is organized as follows: section two discusses previous studies, section three describes the wavelet analysis methodology, section four outlines the data and discusses the empirical results and section five concludes.

1- LITERARURE REVIEW

When looking at the relationship between money supply and inflation, researchers generally use the famous quantity theory of money QTM, formulated by Fisher (1911). The traditional quantity theory of money QTM suggests a direct and proportional relationship between money supply and price level. The QTM is based on Fisher's equation of exchange expressed as: MV=PT

Where, M is money supply, V is the velocity of money, P is the average price level and T is the volume of transactions. Because the volume of transactions T is difficult to measure, contemporary economists replaced T by aggregate output level Y. Therefore, the equation of exchange in equation (1) can be transformed and written as: MV=PY.

The QTM assumes full employment in the economy. In addition, the theory assumes that both "V" and "Y" remains unchanged at least in the short run. Therefore, price level varies positively with money supply. Consequently, a rapid increase in the money supply leads to a rapid increase in the price level and vice versa. However, many economists argue that the QTM fails in the short run, and it holds in the long run. Freidman's (1956) modern QTM explicitly distinguishes between short run and long run effects of an increase in the money supply, notes that changes in the money supply affects output, employment and prices in the short run. In the long run, output and employment return to their national rates and only prices increase.

The relationship between money supply and inflation has been empirically investigated for many countries using different methods. The results obtained have yielded conflicting results.

Some studies found both unidirectional or bidirectional causation between money and prices. Brillembourg and Khan (1979) tested the money-inflation causality for the United States, and found unidirectional causality between the quantity of money and the rate of inflation. Similarly, Jones (1989) found feedback causation between the measures of money supply (M1 and M2) and prices for the United States. McCandless and Weber (1995) found strong correlation between the growth of the monetary base and inflation, while this correlation is greater in the long run, and less apparent in the short run. Grauwe and Polan (2005) found a strong significant positive correlation between long-run inflation and the money supply rate. However, this relation was more than proportional for high-inflation countries. Similarly, the results in Carstensen 2007 and Kaufmann and Kugler 2008 suggest robust long-run causal relationship between money supply and inflation for the Euro area. These results provide strong support particularly for the modern quantity theory of money that suggests a long run relationship between money supply and inflation.

Recently, many empirical studies found that the correlation between monetary aggregates and inflation weakened in industrialized countries in the 1990s, a period in which inflation across the world was relatively low and stable (Kahn and Benolkin, 2007; Hofmann, 2009; and Stock and Watson, 2006). In fact, since 1990 central banks have increased their focus on interest rates rather than inflation in order to conduct monetary policy (Bekiros and al, 2017).

In connection to the analysis of money-inflation nexus, Lucas (1980) highlighted the importance of the frequency domain when examining the link between money supply and inflation. Lucas (1980) investigated whether there is one to one relationship between money supply and inflation for the United States in the period of 1955-1975, and found that when low frequency components were extracted from the two-time series the one-to-one relationship between money

supply and inflation became clear. Since, many authors have used frequency domain techniques to examine the co-movement between money and inflation (e.g. Neumann and Greiber, 2004; Haug and Dewald, 2004; Gerlach 2003, 2004; Bruggeman et al., 2005; Assenmacher-Wesche and Gerlach, 2006, 2007; Benati 2009, Rua, 2012, Jiang and al, 2015, Tastan and Sahin, 2020).

For example, Rua (2012) investigated the relationship between money supply and inflation in the euro area using wavelet analysis, and found a strong link between the two variables at low frequencies, and that the leading properties of money supply with respect to inflation has deteriorated in recent years. Jiang and al (2015) deal with the issue of money-inflation link in China, demonstrating a positive one to one relation between money and inflation in the medium and long run. The findings of their study support the modern quantity theory of money. Tastan and Sahin (2020) carry out a similar investigation for Turkey. Their findings suggest a one-to-one relationship between money supply and inflation in the long run, as well as, bidirectional causation between the two variables at low frequencies.

For the case of Algeria, numerous studies have also focused on money and inflation relationship. All the studies have examined the money-inflation nexus using time-domain analysis techniques. For example, Koranchelian (2004) studied the determinants of inflation in Algeria, and found that inflation is positively related to money supply and exchange rate in the long run. Besides, the results show that M1 affects domestic prices in the short run. The author advised monetary authorities to pursue more prudent monetary policy to avoid the inflationary pressures on the economy. Benbouziane and Benamer (2004) examined the money-price relationship in the three Maghreb countries (namely Algeria, Morocco and Tunisia) using Granger causality test. The results indicated the absence of causality between money and prices in the case of Algeria.

Ben Naceur (2012) explores the short-and long-run determinants of inflation in Algeria between 2002 and 2011 using a VECM. The results

indicate that broad money (M2) is the most important determinant of long-term price changes followed by non-oil real GDP.

Souissi (2017) also investigates the determinants of inflation in Algeria between 2003 and 2016 using a VECM. The results suggest that both domestic macroeconomic policy and external factors are important determinants of inflation in the long run. While, in the short run, money supply appears to be the most important determinant of inflation than other policy factors. This paper makes a contribution to the existing literature by applying frequency-domains methods to investigate the dynamic relations between Algeria's money supply growth and inflation.

2- METHODOLOGY

In this section we provide a brief review of the main concepts of the wavelet theory relevant to our analysis, namely: Maxima Overlap Discrete Wavelet Transform (MODWT) Multiresolution Analysis (MRA), wavelet correlation, wavelet covariance, and wavelet Coherence.

2.1- The maxima overlap discrete wavelet transform (MODWT)

The Maxima Overlap Discrete Wavelet Transform (MODWT) represents a technique that is used to decompose signal into multilevel wavelet and scaling coefficients (Roushangar and Alizadeh, 2019). As discussed in Cornish et al. (2006) the MODWT has several advantages in comparison with the more conventional discrete wavelet transform (DWT). For example, the MODWT can handle any sample size data and translation-invariant, since a shift in the original time series results in a corresponding shift in the transform coefficients (Andries, Ihnatov and tiwari 2015). So, these properties make the MODWT perfect to time series analysis. The MODWT wavelet and scaling coefficients W_j and V_j are defined as:

$$W_{j,t} = \sum_{l=0}^{n-1} \tilde{h}_{j,l} X_{t-1} \bmod N \qquad (1)$$

$$j = 1,2,\ldots,L$$

$$V_{j,t} = \sum_{l=0}^{n-1} \widetilde{g}_{j,l} X_{t-1} \bmod N \qquad (2)$$

Where $\widetilde{h}_{j,t}$ is the MODWT wavelet filters ($\widetilde{h}_{j,l} = h_j / 2^{j/2}$), $\widetilde{g}_{j,l}$ the scaling filters ($\widetilde{g}_{j,l} = g_j / 2^{j/2}$), L the length of the filter, and j the level of decomposition.

The MODWT allows to perform a multiresolution analysis (MRA) to decompose the time series into a sum of sampler time series, named, Smooths S_j that captures the low-frequency dynamics, and detail D_j that capture the higher frequency characteristics. Hence, the original time series can be expressed as:

$$X = \sum_{j=1}^{J-1} D_j + S_j \qquad (3)$$

Where J is the number of multiresolution levels.

2.2- wavelet correlation and wavelet covariance

Wavelet correlation is a recent technique in financial time series analysis. The wavelet correlation of two stochastic processes $X, and Y$ is estimated using the MODWT coefficients for scale $\tau_j = 2^{j-1}$ through:

$$\hat{\rho}_{XY}(\tau_j) = \frac{\mathrm{cov}_{XY}(\tau_j)}{\hat{\delta}_X^2(\tau_j)\hat{\delta}_Y^2(\tau_j)} \qquad (4)$$

$\hat{\delta}_X^2(\tau_j)$ and $\hat{\delta}_Y^2(\tau_j)$ represent the wavelet variance of $X \ and \ Y$ at scale j .

$\mathrm{cov}_{XY}(\tau_j)$ is the wavelet covariance at scale j , which can be expressed as follows:

$$\mathrm{cov}_{XY}(\tau_j) = \frac{1}{\widetilde{N}_j} \sum_{t=L_j-1}^{N-1} \widetilde{d}_{j,t}^{\,x} \widetilde{d}_{j,t}^{\,y} \ldots\ldots\ldots\ldots\ldots (5)$$

2.3- The continuous wavelet transform (CWT)

Wavelet methods are relatively new tools to analyse non-linear and non-stationary economic and financial data. They have their roots in Fourier analysis, but overcome limitations of this method (Masset P., 2014). The wavelet analysis has some advantages over Fourier method as it combines information from both time and frequency domains simultaneously (Tastan and Sahin , 2020).

The continuous wavelet transform (CWT) is widely used for wavelet analysis, and is a powerful mathematical tool for analysing nonstationary time series in the time-frequency domain.

For a time series x(t) the Continuous Wavelet Transform (CWT) for wavelet ψ(t) is defined as:

$$w_{x,\psi}(\tau,s) = \int_{-\infty}^{+\infty} x(t)\frac{1}{\sqrt{|s|}}\psi^*\left(\frac{t-\tau}{s}\right)dt \ldots\ldots\ldots \quad (1)$$

Where:τ and s indicate the time and the frequency domain of the wavelet respectively.

ψ(t) is Morlet wavelet function, which is given as:

$$\psi(t) = \pi^{-\frac{1}{4}}\exp(i\varpi_0 t)\exp\left(-\frac{1}{2}t^2\right) \ldots\ldots\ldots \quad (2)$$

* denotes the complex conjugation of the Morlet wavelet.

The Wavelet Power Spectrum (WPS) of the continuous wavelet transform is defined as:

$$WPS_x(\tau,s) = |W_x(\tau,s)|^2 \ldots\ldots\ldots \quad (3)$$

The WPS depicts and measures the local variance of a time series at different time and scales.

2.4- Wavelet squared coherence (WSC)

The wavelet squared coherence technique is a useful tool to analyse the co-movements between two time series in both time scales and frequency bands.

The wavelet coherence between two time series X and Y is defined as (Nagayev and al,2016):

$$R_n^2(s) = \frac{\left|S(s^{-1}W_n^{XY})\right|^2}{S(s^{-1}\left|W_n^X(s)\right|^2).S(s^{-1}\left|W_n^X(s)\right|^2} \qquad (5)$$

Where: $R_n^2(s)$ is the squared wavelet coherence, its value ranges between 0 and 1, and measures the local linear correlation between two time series at a particular scale.

S : is a smoothing operator defined as:

$$S(W) = S_{scale}(S_{time}(W_n(s)))$$

Where S_{scale} represents smoothing along the wavelet scale axis, and S_{time} smoothing in time.

$W_n^{XY}(s)$ is the cross wavelet power, it is viewed as the local covariance of X and Y, where $W_n^{XY}(s) = W_n^X W_n^Y$, W_n^X and W_n^Y are continuous wavelet transform of two time series $X(t)$ and $Y(t)$ respectively.

Finally, the wavelet coherence phase difference is given by:

$$\phi_{X,Y} = \tan^{-1} \frac{I\left\{ W^{XY} \right\}_n}{R\left\{ W^{XY} \right\}_n} \qquad (6)$$

Where: I and R are the imaginary and real parts, respectively, of the smooth cross wavelet power spectrum. Phase differences are indicated by arrows on the wavelet coherence plots. Right arrows indicate time series are in phase, left arrows indicate series are anti-phase. When the arrows are pointing vertically upward, the first time series leads the second. Down arrows indicate that the second time series is leading.

3- DTA AND EMPIRICAL RESULTS

3.1- Data

The data used in this study consists of two time series, namely, Inflation (INF) and Broad Money (M2) for Algeria, covering the period from January 2010 to December 2019. The inflation rate is calculated as the monthly growth rate of the consumer price index. The money supply series is calculated as the monthly growth rate of M2 aggregate. All these data are sourced from the IMF's International Financial Statistics (IFS). Figure 1 plots the time movements of the

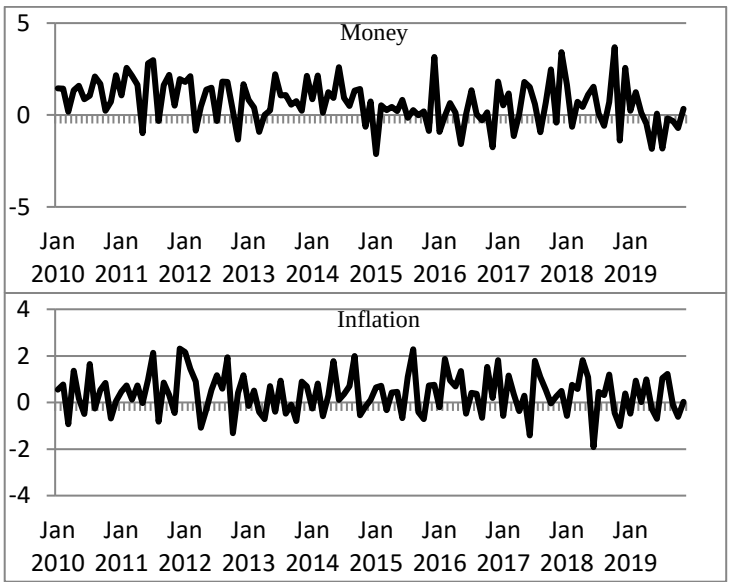
selected variables, while Table 1 reports the descriptive statistics. In general, relatively high volatility can be observed for money supply, as represented by greater standard deviation values, specifically around the time of the Arab spring protests of (2011-2013) and the oil price decline period (2016-2019), where the Algeria government responded by ramping up spending through increasing money supply. The evolution of inflation over the sample period shows a similar pattern as reported in Figure 1.

Table 1. Descriptive statistics.

	Inflation (INF)	**Money Supply Growth**
Mean	0.376464	0.6937964
Maximum	2.311662	3.689688
Minimum	-1.918221	-2.123639
Std. Dev.	.8615805	1.183757
Skewness	0.6670	0.9900
Kurtosis	0.5552	0.7972

Source: Own calculations

Figure 1. The growth rates of Money supply and Inflation (INF) in Algeria.



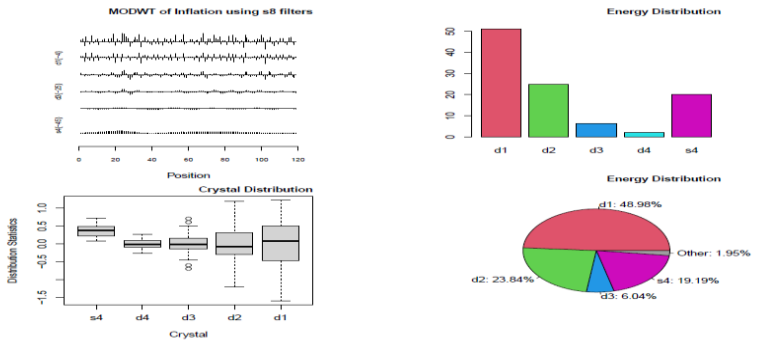
Source: Author's calculation based on World Bank data

3.2- Time scale and energy decomposition

The objective of this study is to examine the relationship between money supply and inflation in Algeria. Figures 2 and 3 plot the maximal overlap discrete wavelet transform (MODWT) multiresolution analysis (MRA) of inflation and money supply. Series are decomposed using the Daubechies' least asymmetric wavelet filter LA(8) (Daubechies, 1992). The maximum number of levels in the decomposition is 4 (J = 4) to achieve an optimal level balance between sample size and the length of the filter. The X axis corresponds to the samples from January 2010 to December 2019. In each figure, the details (D1, D2, D3, D4) and the smooth (S4) components of the original series are plotted. The wavelet details D1 to D4 are associated with cyclical movements of 2–4, 4–8, 8–16, and 16–32, months, respectively, and S4 represents the long-term trend.

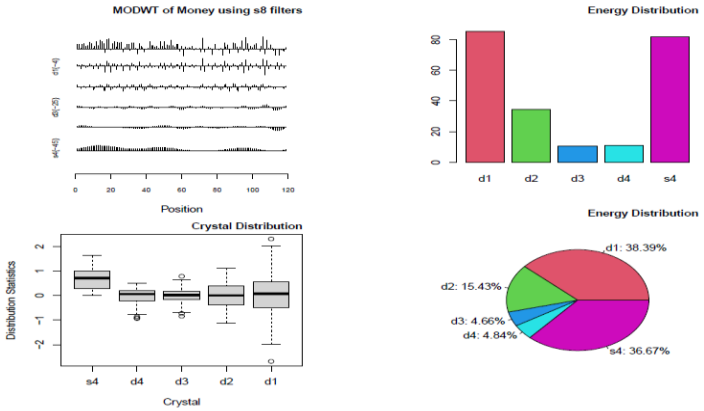
The MODWT plots for inflation and money supply in figures 2 and 3 show that there is a great peak in the original series, which is captured in D1, D2 and S4 components. The shocks get smaller in D3 and D4, and get greater in S4 for both inflation and money, meaning that the short term shocks affect the variation of inflation and money supply in the longer periods. The variation in both inflation and money supply in the longer periods, imply that there is long term risk that Algeria's quantitative easing policy launched since 2016 after the dramatic fall of oil prices would lead to increased inflation.

Figure 2. MODWT decomposition of Inflation on J = 4 wavelet levels



Source: Computed by the author based on R program

Figure 3. MODWT decomposition of Money on J = 4 wavelet levels



Source: Computed by the author based on R program

Table 2 presents the energy decomposition for inflation and money supply at different scales. The reported values are percentages of the overall energy. This energy decomposition allows us to analyse all movements for the variables under consideration in four major periods, namely, short run (D1+D2), medium run (D3), long run (D4) and very long run (S4). Table 2 shows that more than 70 percent of inflation variability is captured by scales 1 and 2 (i.e. in the short run). The very long run explains about 20 percent of the variance of inflation (i.e. S4=19.19 percent). For money supply series it is the short run that explains half of its variance (i.e. D1+D2=53.83 percent). Moreover, the very long run explains 36.67 percent of money supply variability (i.e. S4=36.67 percent). These results indicate that the variance in both series generally occur in the short and long run, means that both short run and long run capture a large part of the variances in inflation and money supply.

Energy crystal distribution of both time series, i.e. inflation and money supply is presented at the bottom of figures 2 and 3 respectively. The crystal energy distribution is a box plot for each of the series based on MODWT technique. The energy crystal

distribution Results indicate that the most of the energy is contained in the crystals of D1, D2 and S4 of around 90% for money supply and 92% for Inflation.

Table 2. Energy Decomposition for Inflation and Money supply

Wavelet scales	INF (%)	M2 (%)
D1 (2–4-month cycles)	48.98	38.40
D2 (4–8-month cycles)	23.84	15.43
D3 (8–16-month cycles)	6.04	4.66
D4 (16–32-month cycles)	1.95	4.84
S4 (above 32-month cycles)	19.19	36.67
Total	100	100

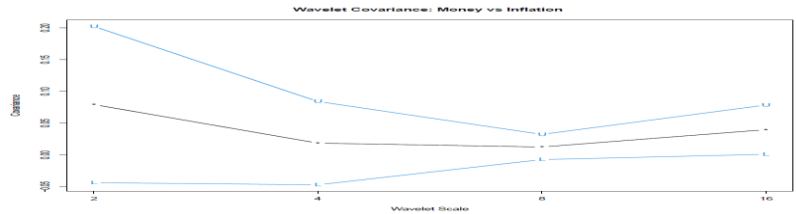
Source: Own calculations

3.3- wavelet covariance and correlation

In the second step the degree of association between inflation and money supply across different scales is examined by MODWT based wavelet covariance and wavelet correlation. Figures 4 and 5 report the results of wavelet covariance and correlation between inflation and money supply. Wavelet covariance results (Figure 4) indicate that at scales D1-D2 wavelet covariance decreases rapidly, and at scales D3-D4 wavelet covariance between money supply and inflation return decays gradually.

The wavelet correlation results (Figure 5) indicate that a high and significant positive relationship exists between inflation and money supply at all-time scales. The correlation between the two variables decreases at scales D1-D2, and increases rapidly at scales D3-D4. Overall, there is a general tendency of the correlation coefficients to move upward with scales. This finding confirms that money supply increases tend to have a positive effect on the price level and thus the rate of inflation in Algeria.

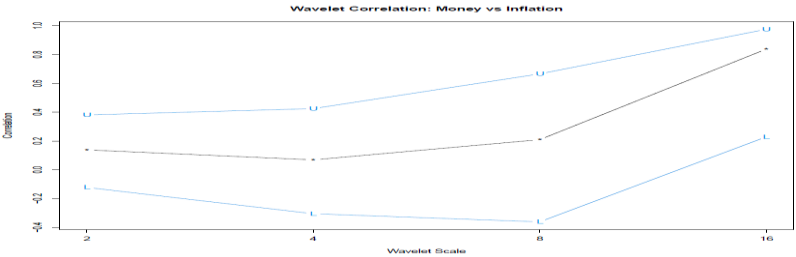
Figure 4. Wavelet covariance between inflation and money supply



Note: The upper and lower bound are represented with 'U' and 'L', respectively at the 95% confidence interval. The black dotted line represents the covariancebetween inflation and money supply (M2) in Algeria

Source: Author's own based on R program

Figure 5. Wavelet correlation between inflation and money supply



Note: The upper and lower bound are represented with 'U' and 'L', respectively at the 95% confidence interval. The black dotted line represents the correlation among inflation and money supply (M2) in Algeria

Source: Author's own based on R program

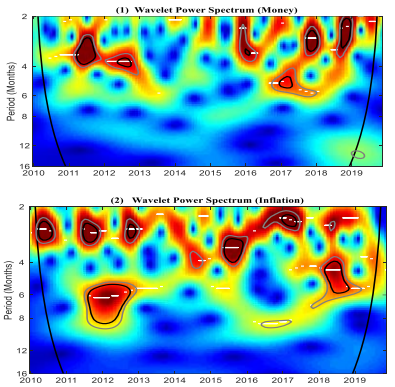
3.4- Wvelet power spectrum (WPS)

To examine the evolution of the variables' power/variance at different time scales the wavelet power spectrum (WPS) is plotted. Figure 6 shows the wavelet power spectrum of money supply (Money) and Inflation. The horizontal axis indicates the time dimension and the vertical axis depicts the frequency (in months). The color code indicates the strength of power that range from low power (in blue) to high power (in red). The regions within black lines represent significance level at 5 percent, within the grey lines at 10 percent. The white lines show the maxima of the undulations of the

wavelet power spectrum, therefore giving us accurate estimate of the cycle period.

Figure 5 clearly shows that Money supply and Inflation share so many common significant features in terms of wavelet power. The wavelet power spectrum of Money supply shows that this variable has high and significant fluctuations in the short run and medium run. We also observe that the strong variance of Money supply occurs over the periods 2011-2013 at 2-6 months of scale, and 2016-2019 at 2-6 months of scale. For Inflation in figure 4, the wavelet power spectrum shows also significant variations at the short run and medium run (2-12 months of scale) over the whole sample period. These finding are consistent with findings of MODWT analysis, with the variance of 58.5 and 78.76 percent occurs in short run and medium run for both Money supply and Inflation.

Figure 6. Continuous wavelet power Spectra of the Money and Inflation



Source: Author's own based on Matlab program

3.5- Wavelet coherence

The wavelet coherence results, presented in Figure 7, evaluate the level of co-movement within inflation-money supply nexus. In the wavelet coherence plot, the areas inside the thick black contours indicate statistically significant coherence levels. The color scale

represents the magnitude of R -squared. According to figure 6 there are many significant estimated coherencies between money supply and inflation.

First, in the short run corresponding to cycles of 2 to 4 months, we observe two significant and large areas of strong co-movement among Money supply and Inflation during the periods 2011-2012, 2017-2018, and 2019, where Money supply is leading Inflation. Other small islands with significant coherence are found for short run during 2015, where Inflation is slightly leading Money supply (the direction of the arrows is downward).

Therefore, the wavelet coherence analysis shows that there is a strong relationship between money supply and inflation in Algeria in the short run. This suggests that an increase in money supply has led to an increase in inflation in the short run. In fact, according to official statistics, the central bank of Algeria has printed out of 55 billion US dollars' worth of bank notes between 2017 and 2019.The Central Bank of Algeria has stated that some 20 billion dollars of the money it generated from unconventional financing was destined to finance the treasury deficit for 2017, 2018 and part of 2019. This means that the government was printing money to cover its spending shortfall. This increased the money supply and put upward pressure on prices.

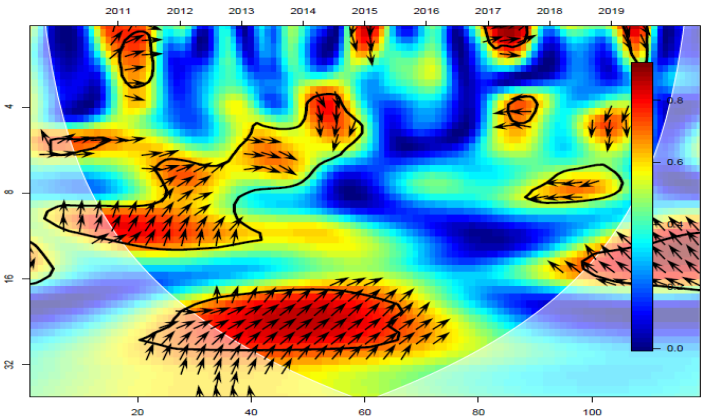
In the medium run corresponding to cycles of 4 to 16 months, we observe different situation. First, during the period 2010-2014, we see a large island of strong co-movement between the two variables, with the Money supply as the leading variable. Second, during the periods 2014-2015 and 2018-2019, we observe small islands of anti-phase movements.

In the long run (above 16 months cycles), the results are much coherent. An island of strong coherence from 2011 to 2017 is observed. The arrows are pointing upward to the right, showing that the variables are in-phase (i.e. moving in the same direction), and the money supply is leading. The rise in oil prices from 2011 to 2017 led to a significant increase in government revenue in Algeria. This increased government revenue allowed the Algerian government to increase spending on a variety of programs, including infrastructure, social programs, and public sector salaries. This increase in

government spending put upward pressure on prices, as it increased the demand for goods and services. In addition to the rise in oil prices, the Algerian government also increased its spending on subsidies for basic goods and services, such as food and fuel. This further increased the demand for goods and services, and put upward pressure on prices. The combination of the rise in oil prices and the increase in government spending led to a significant increase in inflation in Algeria from 2011 to 2017. Inflation reached a peak of 6.5% in 2016.

These findings of wavelet coherence approach confirm that Money supply is majorly having the positive influence over Inflation in medium run and long run. In the short run, there is an anti-phase situation where the inflation is leading and a phase situation where the money supply is leading. These findings are also consistent with the findings of wavelet correlation. Our findings based on the wavelet coherence approach imply that the relationship between money supply and inflation in the medium and long run supports the modern quantity theory of money.

Figure 7. The wavelet coherency and phase difference between inflation and money supply



Source: Author's own based on R program

3.6- Wavelet-based granger causality analysis

In this section, we combine the wavelet analysis and the granger causality test to analyse the causality between money supply and inflation. The Granger causality test based on MODWT allows us to investigate the causal relationship between money supply and inflation at the multi-scale level, i.e. in the short, medium and long run. Table 3 presents the results of the Granger causality at each time scale. The empirical results reported in table 3 show that Money supply Granger causes Inflation at all scale levels (i.e. in short, medium and long run). Inflation on the other hand Granger causes Money supply only at the medium time scale (D3) at 5 percent significance level. These findings suggest that unidirectional causality exists from Money supply to Inflation in the short, medium and long run, and bidirectional causality exists between the two variables in the medium run. These findings confirm the results of wavelet correlation and wavelet coherence. Furthermore, these findings are in complete agreement with Ben Naceur (2012) and Souissi (2017) that money supply has a positive impact on Inflation in Algeria in short, medium and long run.

Table 3. Multiscale Granger causality between Money and Inflation, based on LA(8) wavelet

Timescale	Periods (in months)	Money supply does not Granger cause Inflation	Inflation does not Granger cause Money supply
D1	2-4	2.5414	1.576
		(0.0248)**	(0.1619)
D2	4-8	2.8256	1.8921
		(0.0635)*	(0.1555)
D3	8-16	1.7286	2.3821
		(0.0937)*	(0.0181)**
D4	16-32	3.7679	1.0351
		(0.0128)**	(0.3811)
S4	above 64	2.8841	1.0153
		(0.0602)*	(0.3656)

*, ** and *** Indicate the rejection of the null hypothesis at the 10, 5 and 1% significance levels, respectively. P values are in parentheses.

Source: Author's own based on R program

CONCLUSION

Based on the wavelet analysis, this study investigates the relationship between money supply (M2) and inflation for Algeria by using monthly data covering the period from January 2010 to November 2019. The wavelet analysis allows us to investigate co-movement, correlation and lead lag relationship over different time scales.

Our empirical results from the maximal overlap discrete wavelet transform (MODWT) Multiresolution Analysis (MRA) reveal that most of the variance in both inflation and money supply exist in the short and long run. Evidence from MODWT wavelet correlation suggests a positive association between money supply and inflation at the short medium and long run. Moreover, the wavelet coherence analysis indicates that there is a co-movement between money supply and inflation, in short, medium and long run. It also proved that money supply is leading over inflation at most time scales.

From wavelet-based Granger causality analysis, we find that at all time scales money supply granger causes inflation. Evidence of causality was also detected from inflation to money supply at medium run. Generally, these results confirm both the traditional and modern quantity theory of money about the existing relationship between money supply and inflation in both short and long run.

Understanding the influence of money supply on inflation is important for the monetary authority in Algeria. Therefore, the study recommends that the government should review its easy money policy so as to contain excess supply of money in the economy. Further, the fiscal deficit should be financed through domestic bond issuance, and monetary policy should be tightened to contain inflationary pressures. In addition, these need to be complemented by some structural reforms to diversify the economy and replace imports with domestic production to boost growth and support price stability in the long run.

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