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Abstract

The study investigates the relationship between money supply and inflation and Turkey by employing wavelet analysis, mainly continuous wavelet analysis, cross wavelet transforms and wavelet coherence and phase-difference, for the period from 1987 to 2019. Our main finding confirms the modern quantity theory of money about the existence of a relationship between inflation and money supply in the short-run and long-run, and also confirms the traditional quantity theory of money about the existence of a relationship in the long run. The phase difference confirms the existence of a bidirectional relationship between money supply and inflation. The result is consistent with both the traditional quantity theory of money in the long run and the modern quantity theory of money in the short-run and long-run in terms of the existence of a relationship between money supply and inflation.

Keyword: Money supply, inflation, wavelet analysis, Turkey, the quantity theory of money.

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1. Introduction

In Turkey, policymakers have employed monetary and fiscal policy instruments as navigators to guide the country's economic policies in response to the economic situation and public finance. However, their effects were limited and this is evident from the successive crises that impacted the country, which prompted the signing of agreements with the International Monetary Fund (IMF) aimed at containing these crises. However, the economic crisis suffocated the country due to of the significant amount of external debt and the rising inflation as the Turkish government was close to bankruptcy at the beginning of the millennium (Tursoy, 2019). Monetary policy-makers were quick to devise new programs and strategies to target inflation and contain these crisis along with the IMF and in line with these reforms, in 2005, 6 zeros were removed from the local Turkish currency thus creating the “New Turkish Lira” (Bankası, 2005).

Turkish policy in terms of targeting inflation has experienced many deviations, where these deviation were not necessarily the result of mistaken economic policies, where Global crises, as global production and demand decreased, and the rise in oil prices affected Turkey being an oil importer (Durmuş, 2018). Turkish economic policymakers attempted to deal with these challenges by directing the monetary and fiscal policy tools in the country and established new monetary policies aimed at reducing Turkey's vulnerability to external shocks and that also took into account inflation stability along with financial stability (Kayıkçı & Kaplan, 2019).

The monetary authority can make a significant contribution to fostering economic stability by establishing a steady course and ensuring it follows this course. By making the direction one of steady but modest increase in the amount of money, this can make a significant contribution to preventing any inflation or price deflation. However, the government’s policies of increasing spending and trying to reach full employment as well as subsequent mistakes made by the Central Bank are the factors that led to the increase in the money supply that caused inflation (Friedman, 1968). It is of paramount importance for policymakers to ensure that policies to combat inflation are enforced in a stable way to ensure the financial stability needed for low inflation and sustainable economic growth.(Koyuncu, 2014)

The importance of inflation as a macroeconomic factor in the literature is derived from its capacity to represent monetary policy's efficiency and effectiveness in affecting the macroeconomy. Specifically, the degree to which inflation influences production growth or economic conditions has proven to be a subject of significant importance to any Central Bank regarding price stability. Generally, the empirical evidence largely appears to lend support to the idea that inflation is counterproductive to economic growth and that price stability, described as a low and stable inflation rate, is an essential prerequisite for achieving economic growth (Mavikela et al., 2019).

Reacting to economic conditions is considered as a task of monetary policy, and an interesting tool that is normally employed by monetary policy is the money supply. The detection of the presence of a causal relationship between money supply and inflation is a popular area of economic research in a growing number of developing and developed countries. Generally, the causality between money supply and inflation is believed to be unidirectional from money supply to inflation (Göçmen, 2016). The nature of the relationship between money supply and inflation in Turkey is not entirely clear due to the limited amount of studies that have dealt with this topic. The majority of researchers have neglected the relationship between money supply and inflation in Turkey, and most of them have also not taken into account time-frequency, which could provide important information about this relationship and how they interact in the frequency domain. In this study, we investigate the causality between money supply and inflation rate in Turkey and attempt to provide new insights regarding the direction of this relationship by employing wavelet analysis; wavelet analysis has a feature that reveals information in time-frequency that cannot obtained by normal analysis. We also employ cross wavelet analysis and phase deference to determine the lead lag relationship and to recognize the causality direction.

Since it is not always possible to obtain significant information from normal analysis of a data series, where the data's frequency contain also involves significant data information can’t appear in time domain, wavelet analysis has become a popular tool for analysing time series due to its ability to facilitate the understanding about data in both time domain and frequency domains.

Our main finding confirms the modern quantity theory of money about the existence of a relationship between inflation and money supply in the short run and long run, and also confirms the traditional quantity theory of money about the existence of a relationship in the long run. The phase difference confirms the existence of a bidirectional relationship between money supply and inflation.

This paper is structured as follows. Sections 2 provides a literature review and examines previous studies on the relationship between money supply and inflation. Section 3 explains the methodology used in the study. In Section 4, the data are described and the results discussed, while the conclusion is presented in Section 5.

2. Literature review

Inflation refers to the situation where more money is being paid for the same goods or services. Although we have the ability to determine whether an economy is suffering from inflation, there is currently no consensus regarding what triggers it. Keynesian economists explain the relationship between money supply and inflation via demand-pull and cost-push and Demand-pull-inflation. Monetarists indicate that inflation occurs as a result of an increase in the money supply (Abdullah et al., 2020). As central banks are primarily focused on maintaining price stability, money flows have been assigned less importance. However, it seems that there less interest in concerning money supply go hands in hands with inflation to keeping inflation down and steady.(King, 2001)

Researchers who are interested in studying the nexus between money supply and inflation have generally used the most famous version of the quantity equation of exchange formulated by Fisher (1911). The Fisher and Brown (1911) equation is expressed as

$$M(V_T) \equiv P_T(T)$$

Where M is money in circulation, V_T is the transaction velocity of circulation, P_T is the average price level of transaction and T is the total transaction per period. The left-hand side symbolizes money supply, while the right side symbolizes money demand. A higher supply of money leads to a higher price and vice versa. Consequently, a shift in the supply of money will lead to a price change. In other words, if a country faces high inflation rates, decreasing the amount of money supply will reduce inflation and vice versa when there is disinflation and deflation (Ditimi et al., 2017). The relationship between money supply and inflation is linked with money demand and money supply, where the expenditure surplus that is not met by increasing output will lead to an increase in prices, since the raise in expenditure changes the prices rather the quantity (Strano, 2003).

Fisher and Brown (1911) assumed that as monetary authorities increase the level of currency (money supply) in the market, deposits must increase by the same ratio, while the velocity and quantity of goods remain constant. This is expressed as:

$$\mathrm{M}(\overline{\mathrm{V}}) = \mathrm{P}(\overline{\mathrm{Y}})$$

Changing the supply of money given the constancy of velocity and output will result in equivalent proportionate inflation rate changes (Su et al., 2016). However, many economists argue that monetary theory does not hold in the short-run and it focuses on the long-run properties of the economy rather than the short-run dynamics. Monetarists are sceptical about the potential of using monetary policy to achieve short-term stability (Meyer, 2001).

Money growth in the long-term has an impact on inflation, as promoted by the quantity theory of money, where a growth in price level precedes an increase in money supply. However, empirical evidence on the connection between money growth and inflation and the effectiveness of money in terms of forecasting inflation is controversial (Vladova & Yanchev, 2015).

The modern monetary theory claims that inflation is driven by an increase in the money supply that is greater than money demand, whereas changes in income and price are driven by money. Milton Friedman argued that inflation is monetary and monetary policy should be focused on reducing inflation. Consequently, money increase is generally believed to have a significant long-term influence on any country's economic activities (Ditimi et al., 2017).

In order to explain the nature of the relation between money and inflation, many researchers have studied it using different methods. Differences in their empirical results are due to different countries, methodologies and methods of analysis. Next, we will briefly review some studies about the nexus between money supply and inflation.

Abdullah et al. (2020) attempted to identify the determinants of inflation in Kuwait during the period from 1979 to 2015 and examined whether inflation is affected by exchange rate, interest rate, taxation, current account, unemployment, GDP and money supply using multiple regression analysis. The study results showed that a change in the inflation rate is positively significant with money supply.

Ditimi et al. (2017) investigated the impact of a rise in money supply on inflation in Nigeria using the co-integration autoregressive dynamic error correction model approach. Their findings showed that the money supply does not have a considerable effect on inflation in either the short run or long run while the Granger causality test indicated that there was no causality between money supply and inflation in either direction during the study period, which was 1970 to 2016. In contrast, Sasongko and Huruta (2018) found a causality between money supply and inflation rate by using the Granger causality method, but only a one-way causality whereby money supply affected inflation and not vice versa. The study aimed to determine the casual relationship between money supply and inflation in Indonesia during the period from 2007 to 2017.

Jiang et al. (2015) investigated the relationship between money supply and inflation rate in China for the period from the mid-1990s to the early 2000s using novel wavelet analysis. The study results support the modern quantity theory of money that money growth and inflation rate are positively related, although in the short run, this positive relationship deviated due to temporary shocks. Also in China, Su et al. (2016) examine the relationship between money supply and inflation rate by using bootstrap Granger full sample causality and sub sample rolling causality. The study aimed to verify whether the Chinese economy supported the quantity theory of money. The varying rolling-window approach applied in this research showed that the money supply had a positive and negative impact on inflation in several sub-periods and vice versa. The findings of the study were consistent with the modern quantity theory of money. By using wavelet analysis, Jiang et al. (2015) found that money growth has a positive effect on inflation in China with the existence of some deviations. The study results confirmed the modern quantity theory of money.

Vladova and Yanchev (2015) examined the relationship between dynamic money supply (currency in circulation, M1, M2) and prices in Bulgaria during the period 1998 to 2012 using three econometric methods, namely dynamic cross correlations, Granger causality test in the framework unrestricted VAR models and Johansen cointegration. The study concluded that there was a two-way relationship between money supply and price dynamics.

Nguyen (2015) investigated the effect of fiscal deficit and broad money supply M2 on inflation in nine Asian countries over the period 1985 to 2012 using a pooled mean group estimation-based error correction model and the general method of moments. The main finding was that the money supply M2 had a positive impact on inflation according to the pooled mean group method.

Regarding Turkey, Koyuncu (2014) investigated the impact of budget deficit and Money supply (M2) on inflation using Johansen cointegration and Granger causality during the period from 1987 to 2013. The Granger causality test showed a one-way relationship from Money supply to inflation but there was no evidence indicating that the direct cause of inflation was the money supply. Also, the Johansen test revealed that there was no cointegration between the series.

Rua (2012) investigated the relationship between money growth and inflation over the period 1970 to 2007 in the euro area using wavelet analysis. The study results showed a strong association between money supply and inflation in the short-term (low frequency) and this relation become stronger at long-term development than short-term fluctuation of business cycle.

3. Methodology

This section presents the methodology used in the study, namely wavelet analysis including continuous wavelet transform, cross wavelet transforms and wavelet coherence. Wavelet analysis has become a popular tool in analysing time series due to its ability to provide a better understanding for data in both time domain analysis and frequency domain analysis.

It is not always possible to obtain significant information from normal analysis of a data series. Sometimes the data's frequency also contains significant information. The Fourier transformation (FT) measures the frequency-amplitude of the data in the time domain, but it does not indicate when this frequency occurred in time. All frequency components take place at any point in time in the case of stationary data, but this is not true for non-stationary data. FT, therefore, is not suitable for non-stationary data, so wavelet analysis is considered as an alternative to the Fourier transformation. Wavelet analysis can handle non-stationary data and has the ability to provide information simultaneously in both time and frequency (Jeet & Vats, 2017).

Continuous wavelet transforms (CWT) is considered a useful tool for extracting information from the time series and data self-similarity detection. CWT produces many wavelet coefficients C, which can represent a function of two factors, namely scale and position $C(scale, position)$. A specific wavelet ψ is obtained by projection onto the tested time series x(t)

$$C(scale, position) = \int_{-\infty}^{\infty} x\, t\psi(scale, position, t)dt$$

Any value consonant with the region of the time series x(t) could be taken in scale and position. Multiplying each coefficient by the fittingly scaled (dilated) and shifted wavelet produces the constituent wavelets of the authentic signal. There are several types of wavelets, which have various properties for different applications. In the analysis of both the amplitude and phase information. since we are interested in the most popular wavelet which is Morlet wavelet which is define as

$$\psi_\eta(t) = \pi^{-\frac{1}{4}}\, e^{iw0\eta} - e^{-\frac{\eta^2}{2}}$$

Where is w the frequency of the angle (rotation rate per time unit). which is assigned value to 6 as indicated in the literature, the normalization term is -1/4 is the dimensionless time parameter represented by, $\eta = t/\lambda$, t is the time parameter, λ is the scale of the wavelet. The process of scaling and shifting is described in equation xxx (Gençay et al., 2001; In & Kim, 2013; Loh, 2013).

Cross wavelet analysis and wavelet coherence are considered as powerful techniques for testing suggested linkages between two-time series. The continuous wavelet transform can be extended to include to time series and construct a cross wavelet transformation, which identifies areas with high joint influence and provides more detail on the phase association (Grinsted et al., 2004). When the two wavelet transformations being performed are in reference to the same mother wavelet, then the transformation of the cross wavelet shows the degree of the commonality between the two initial wavelet transforms or signal. To deduce the existence of a mutual signal or to locate the source of these common signals can be used by the magnitude' of the cross wavelet transform. Similarity may occur for various reasons and each implementation may give different justifications for this commonality. The magnitude of the cross wavelet transform will have a peak showing this similarity.(Randy & Young, 1993)

In this paper, to avoid biased results and the production of any incorrect distortions or deviation by giving more weight to the large-scale linking phenomena than to the small-scale phenomena, the study uses the corrected wavelet transformation by normalizing the scale as follows:

$$wxy\ (t,s) = \frac{1}{s}.wx(t,s).\overline{w}y(t,s)$$

For more information about the suggested cross-wavelet bias corrected by normalizing scales, see Veleda et al. (2012)

For the phase differences, we follow Rösch & Schmidbauer (2016) and write:

$$Angle(\mathcal{T},\mathcal{S}) = Arg(Wave.xy(\mathcal{T},\mathcal{S}))$$

This so-called x-over-y phase difference at each time and scale is equal to the difference between the individual local phase separations when transformed into an interval angle$[-\pi, \pi]$. The two series are considered in phase (anti-phase) if the absolute value is less or greater than $\pi/2$ respectively at the scale. Appendix 1 presents an interpretation of phase differences.

Wavelet coherence is another useful measure used to determine how coherent the cross wavelet transform is in time-frequency space (Grinsted, Moore, & Jevrejeva, 2004, p. 564) and demonstrates how powerful the co-movement between two series is over time and frequency and it locate between zero and one, as we closer to one as we have more powerful association. In addition to the degree of the relation, the wavelet coherency plot indicates the frequencies at which the association is located (Özmen & Yılmaz, 2017). To analyze the wavelet coherence between two time series, we follow Torrence and Webster (1998) and write:

$$R_n^2(s) = \frac{\left|s(s^{-1}w_n^{xy}(s))\right|^2}{s(s^{-1}|w_n^x(s)|^2)\; s(s^{-1}|w_n^Y(s)|^2)}$$

The smoothing operator is S a suitable smoothing operator for the Morlet wavelet and is given by:

$$s_{time}(w)|_s = (w_n(s) * c_1{}^{\frac{-t2}{s^2}})|,$$

$$s_{time}(w)|_s = (w_n(s) * c_2\prod(0.6s))|,$$

where the normalization constants are c1 and c2 and $\prod$ is the rectangle function. The factor of 0.6 is the empirically determined scale decorrelation length for the Morlet wavelet.

For the phase differences, we follow Rösch and Schmidbauer (2016) and write:

$$Angle(\mathcal{T}, \mathcal{S}) = Arg(Wave.xy(\mathcal{T}, \mathcal{S}))$$

This so-called x-over-y phase difference at each time and scale is equal to the difference between individual local phase separations when transformed into an interval angle$[-\pi, \pi]$. The two series are considered in phase (anti-phase) if the absolute value is less or greater than $\pi/2$ respectively at the scale. Appendix 1 presents an interpretation of the phase differences.

4. Data and results

For the purpose of analysing the nexus and lead lag relationship between growth inflation (IN) and money growth (Narrow Measure (M1), Intermediate Measure (M2), Broad Measure (M3)), monthly data was obtained from the Turkish Central Bank. The data covered the period between February 1987 till October 2019, the data monthly percent change. No adjustment was made to the original data since the study data is growth and the wavelet transform can handle non stationary data so it is not necessary to check for a unit root or take any difference. Appendix B shows the plots for all variables A large deviation in inflation can be observed in 1994, which was caused by the currency crisis in Turkey, while another large deviation occurred in 2005 in M1 and M2, which was the year that the Turkish currency converted to the New Turkish Lira.

Appendix C shows the descriptive statistics of the variables. It can be observed the inflation fluctuated between -1% and 23% with a mean of 0.03 and a standard deviation of 0.03. The growth in money supply rates also showed a very wide range of fluctuation. For instance, M1 had a minimum of -20.19% and a maximum of 68.2%, with a mean of 3.39 and standard deviation of 7.98. These fluctuations can be explained by the major successive crises that impacted Turkey during the period of the study.

Before analysing the correlation relationship between money inflation and money supply, we start by conducting the continuous wavelet transform to capture the important information that occurred in frequency. Fig. 1 shows the results of continuous wavelet transform for both inflation and money supply at different time horizons. The INF plot has many large significant plots at different times and frequencies. One interesting significant region is located around 1994, which is the year of the Turkish currency crisis.

We can see the effect of the crisis in high frequency and extended to reach more than 32 periods.

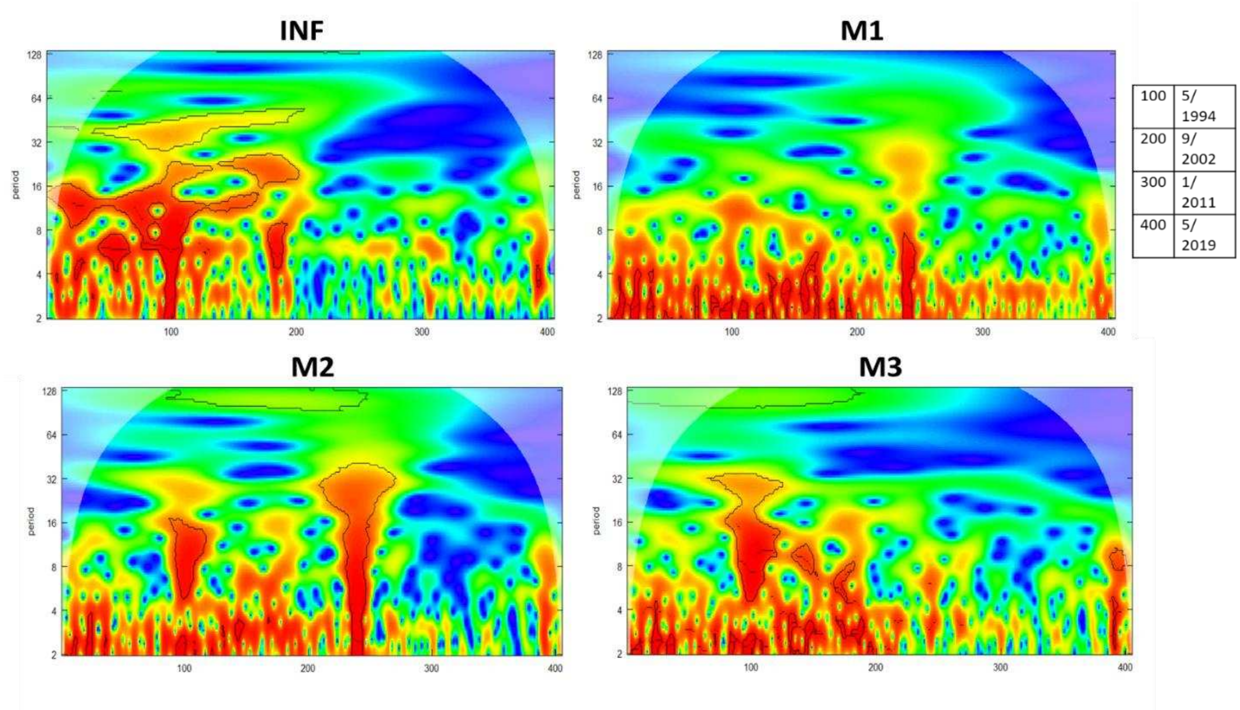


Fig. 1. Continuous wavelet transforms for the study variables. Note: 5% significance level against red noise designates by the contour, the lighter shade shows the cone of influence. Power color code ranges from blue (low power) to red (high power).

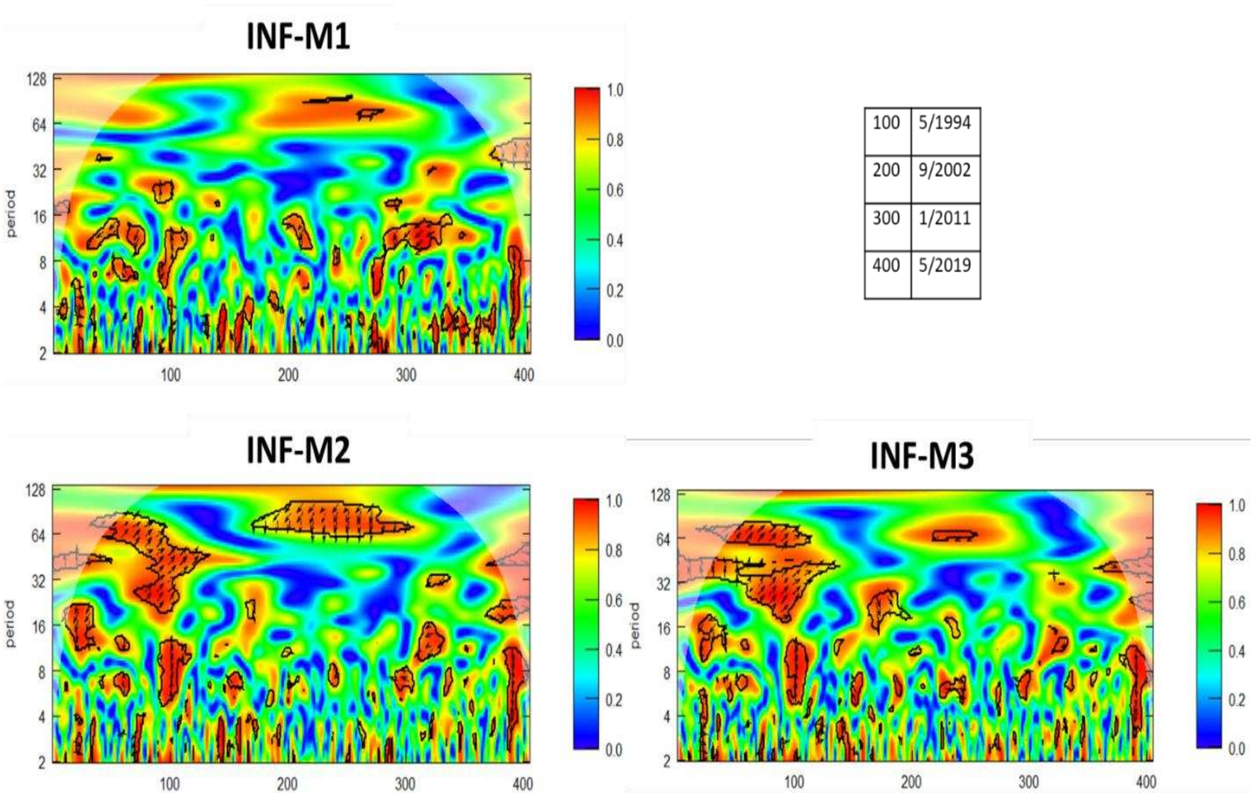
As a result of the currency crisis that occurred in 1994, the output fell by 6 percent, inflation increased to three-digit levels, the central bank lost half of its reserves, and in the first quarter of the year, the exchange rate (against the US dollar) depreciated by more than half (Celasun, 1999). Another significant plot region can be observed around 2001, which was the year that the Turkish government was close to announcing bankruptcy as a result of its deficit (Tursoy, 2019)

The effect of the crisis of 2001 was not as large as the crisis of 1994, which clear from the plot xx that extended for years at low frequency (around 16 month and 32 month). The last significant region located at high frequency is around 2018, which represents the fall of the Turkish lira against US dollar by 40% from the start of the currency crisis in 2018.

Regarding money supply, it is clear from Fig 1. that M3 was the most effected by the currency crisis in 1994, the effect of which appears from month 4 to month 32, while M2 was the most effected by the mortgage crisis in 2008. We can see a significant plot region extending from high frequency (2 month) and extended to low frequency (32 month). M1 shows many significant regions from 1987 to around 2008, where the greatest effect on money supply was caused by the global crisis in 2008.

For the correlation analysis between the study variables, we employ wavelet coherence with phase difference to capture the nature of the relationship between inflation and money supply. Fig. 2 presents the wavelet coherence for the variable of the study. In terms of the relationship between the IN-M1 pair, we can see in Fig. 2 many plot regions for the significant relationship between inflation and money supply. From 1987 until 1994 (up to frequency 7), there is generally a positive relationship between inflation and money supply, while from cycle 8 to cycle 6, there is largely a negative relationship (the arrows left). From 1995 to 2019, it can be seen from Fig. 2 that there is a negative relationship between inflation and M1 at either high or low frequency.

It is clear from the IN-M1 pair results that it agrees with the modern quantity theory of existing the existence of a relationship between money supply and inflation. These results (from 1987 until 1994) confirm those of Abdullah et al. (2020) and Jiang et al. (2015) who found a positive relationship between money supply and inflation in the short run while, but conflict with them after 1995, where the change in the positive relationship may reflect the different policy that was followed after the currency crisis in 1994.



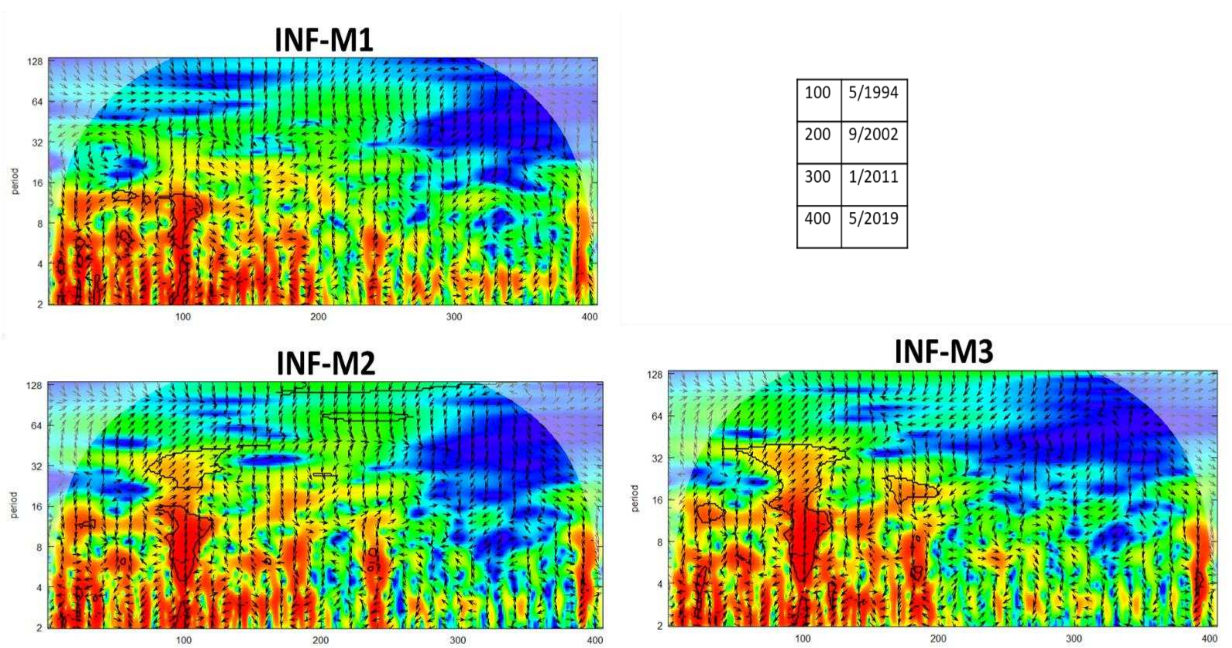
100	5/1994
200	9/2002
300	1/2011
400	5/2019

Fig. 2. Wavelet coherence between money growth and selected inflation. Note:5% significance level against red noise is designated by the contour, the lighter shade shows the cone of influence, by using phase randomized surrogate series is estimated from Monte Carlo simulations. Power colour code ranges from blue (low power) to red (high power). Arrows represent phase differences.

For the IN-M2 and IN-M3 pairs, it can be observed that the relationship quite similar together and almost similar to the IN-M1 pair, although the association between IN-M2 and IN-M3 is stronger at low frequency (around month 25 to month 120). The correlation between money supply growth and inflation almost up to 1, and there are two large significant region plots, where the first region plot shows a positive relationship while the second one shows a negative relationship.

In order to determine the similarity of change between two time series signals together as well as the causality, we employ cross wavelet analysis phase differences. Fig.3. shows cross the wavelet analysis, for the pair of IN-M1. We can observe significant plots from 1987 until around 1994 at different frequencies, around before 1990s we can notice significant plots for the pairs at high frequency (up to around 5 month),

For the IN-M2 pair and the IN-M3 pair, as shown in Fig. 3. it almost similar to the IN-M1 pair with minor differences. There is a significant plot region around 1994 at low frequency (around 25 to around 50) that did not appear for the IN-M1 pair. it's appears in this pair (IN-M1) that the leading inflation while M2, M3 lagging after neutral significant plot region in 1994 which it's not clear which variable was leading and which one lagging. The significant region plots in 1994 is larger for the IN-M3 pair than IN-M2. We can see another region plot during the study period, but it is not clear which is leading and which is lagging.



100	5/1994
200	9/2002
300	1/2011
400	5/2019

Fig. 3. Cross wavelet transforms between money growth and selected inflation. Note: 5% significance level against red noise designated by the contour, the lighter shade shows the cone of influence, by using phase randomized surrogate series is estimated from Monte Carlo simulations. power colour code ranges from blue (low power) to red (high power). Arrows represent phase differences.

In some frequencies and times, we notice that the inflation is leading while money supply growth is lagging. The explanation for this may come from Demand pull theory, which suggests that an increase in aggregate demand more than an economy's productive capacity leads to an increase in prices and wages and this pushes the central bank to increase the money supply.

The phase differences show that the causality is bidirectional and changeable between money supply and inflation. Although some researchers argue that the relationship between money supply and inflation is bidirectional, there is no exclusive result across countries about these relationships which different regarding country and methodology. The monetary policy Procedures have a primary role in controlling and directing this direction. The result confirms both the traditional and modern quantity of theory they agree on existing relationship on long run. Although there is no consensus regarding the relationship in the short-run, there is agreement between the traditional quantity theory of money and the modern quantity theory of money about the existence of a relationship between money supply and inflation in the long-run (Jiang et al., 2015, P 250). The results from the IN-M1 and IN-M2 pairs until the mid-1990s agree with both Abdullah et al. (2020) and Nguyen (2015) regarding the existence of a relationship in the short run. Our results also agree with Rua (2012), who argued that the relationship becomes stronger in the long run (low frequency) but the sign of the relationship differs in the long run compared to the short run. Also, after the mid-1990s our results still agree with Rua (2012) that the relationship becomes stronger in the long term. The results concur with both Vladova and Yanchev (2015) and Su et al. (2016) that there is a two-way relationship between inflation and money supply.

Conclusion

This paper has investigated the relationship between inflation and growth in money supply (M1, M2, M3) during the period from 1987 to 2019 and attempt to provide an insight regarding the nature and direction of this relation. The study employed continuous wavelet transform to capture important information in frequency and also used cross wavelet and different phases analysis to determine the lead lag relationship, while wavelet coherence was also adopted to describe the association between the study variables.

Generally, the results confirm the modern quantity theory of money about the existence of a relationship between inflation and money supply in the short run and long run, and also confirm the traditional quantity theory of money about the existence of a relationship in the long run. Also, the results are in complete agreement with Su et al. (2016) that money supply has a positive and negative impact on inflation in several sub-periods and vice versa.

The phase difference confirms the existence of a bidirectional relationship between money supply and inflation. Since the relation between money supply and inflation is changeable, the study shows that the lead lag is changeable between money supply and inflation. The changeable impact and changeable lead lag relationship between the variables appear to be connected with different policies implemented after each crisis that impacted Turkey.

The study recommends that sub-period analysis should be conducted to investigate money supply and inflation for each crisis and the polices subsequently implemented by the authorities to handle them. Also, we suggest that a review study should be performed focused on monetary and fiscal policies that followed these periods in order to obtain a better understanding on the nature of this relationship.

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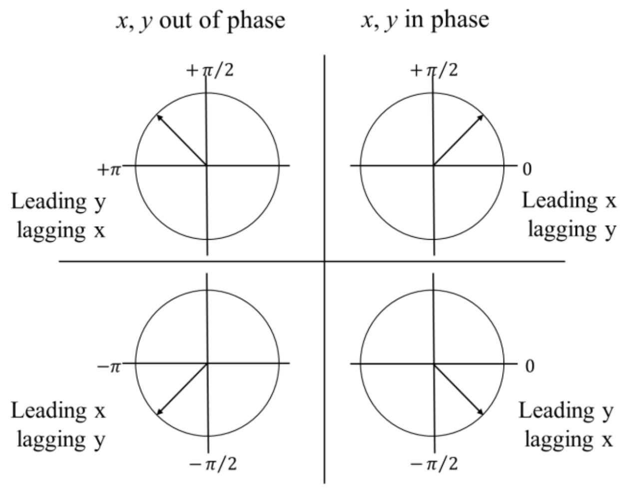
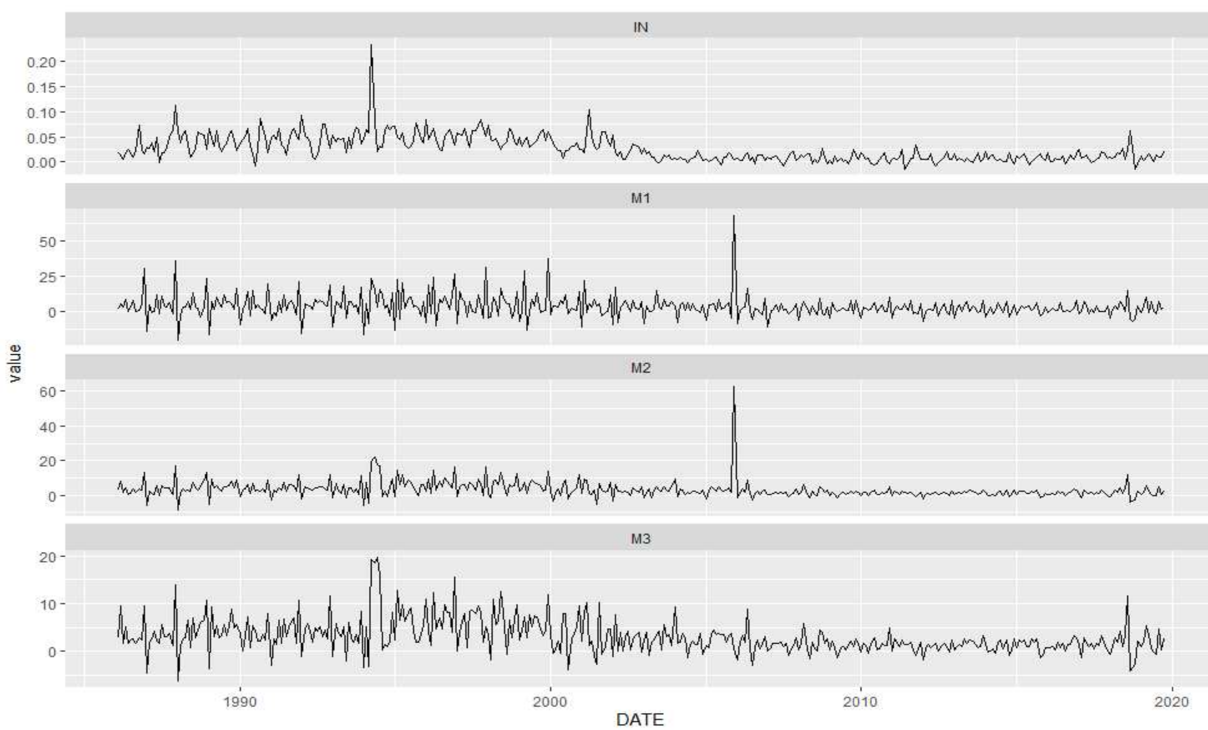
Appendix

Appendix A



Based on Rösch & Schmidbauer (2016)

Appendix B



Appendix C

variable	mean	sd	median	min	max	range	skew	kurtosis
INF	0.03	0.03	0.02	-0.01	0.23	0.25	1.93	9.94
M1	3.39	7.98	2.38	-20.19	68.2	88.39	2.03	12.38
M2	3.26	4.88	2.39	-8.75	62.94	71.69	5.14	54.68
M3	3.08	3.55	2.28	-624	19.79	26.3	1.34	3.29