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Application of Discrete Wavelet Transform in Investigating the Relationship between Inflation and Exchange Rate in the Iranian Economy

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Abstract
The relationship between rate and inflation has a significant important for economies like Iran in two ways. On the one hand, policymakers by believing in a one-way relationship between the exchange rate and inflation try to control the general level of prices, which in practice has not been successful. On the other hand, activists of financial markets, considering the importance of exchange rate in other markets and also the lack of depth in financial markets, try to use the exchange rate as a shield against inflation and to maintain the value of their assets. In this regard, this study attempts to examine the causal relationship between inflation and exchange rate in the field of frequency and different time horizons using the discrete wavelet transform while eliminating the limitations of traditional econometric methods. For this purpose, the statistical population of Iranian economy and monthly data in the period 1991-2020 has been used. The results of the analysis show that in the long run, the causal relationship is from inflation to the exchange rate. This issue indicates that anchoring the exchange rate is not a proper policy to control inflation.

Key words; exchange rate, inflation, frequency range

1. Introduction

From a policy perspective in open economies, there are important reasons to study fluctuations of exchange rate. The most important of these is to be aware of the ability of exchange rate to influence macroeconomic variables. If the price of imported goods reacts strongly to the fluctuations of exchange rate, the expenditure-switching effect will act strongly and it can play a special role (Obstfeld & Rogoff, 1995 and Obstfeld, 2001). In other words, the devaluation of the national currency by increasing the price of imported goods and reducing the price of exported goods shifts consumer expenditure from the purchase of imported goods to the consumption of domestically produced goods. Another important variable affected by the exchange rate is the general level of domestic prices, which is known the exchange rate pass-through in the economic literature. Accordingly, in studies related to inflation, the exchange rate is considered an important factor and its role has been studied. On the other hand, in countries like Iran, the rate is affected by changes in inflation. Because inflation has a monetary root and following the devaluation of the domestic currency, the foreign currency acts as an inflation shield from the point of view of economic factors and protects assets against inflation. In other words, theoretically there is a bilateral relationship between inflation and the exchange rate. Nevertheless, policymakers consider the causality as the exchange rate to the inflation and try to prevent the exchange rate pass-through to the domestic price level by policies such as allocating foreign exchange at a price below the market price or temporarily prevent exchange rate jumps (despite money expansion) by suppressing currency and injecting resources into the market.

In this regard, the present study attempts to provide a new insight using discrete wavelet transform by empirically examining the relationship between the above two variables. In other words, the purpose of this article is to investigate the causal relationship between inflation and exchange rate in the Iranian economy during 1991-2020 using monthly data and discrete wavelet transform method. For this purpose, the article is organized as follows:

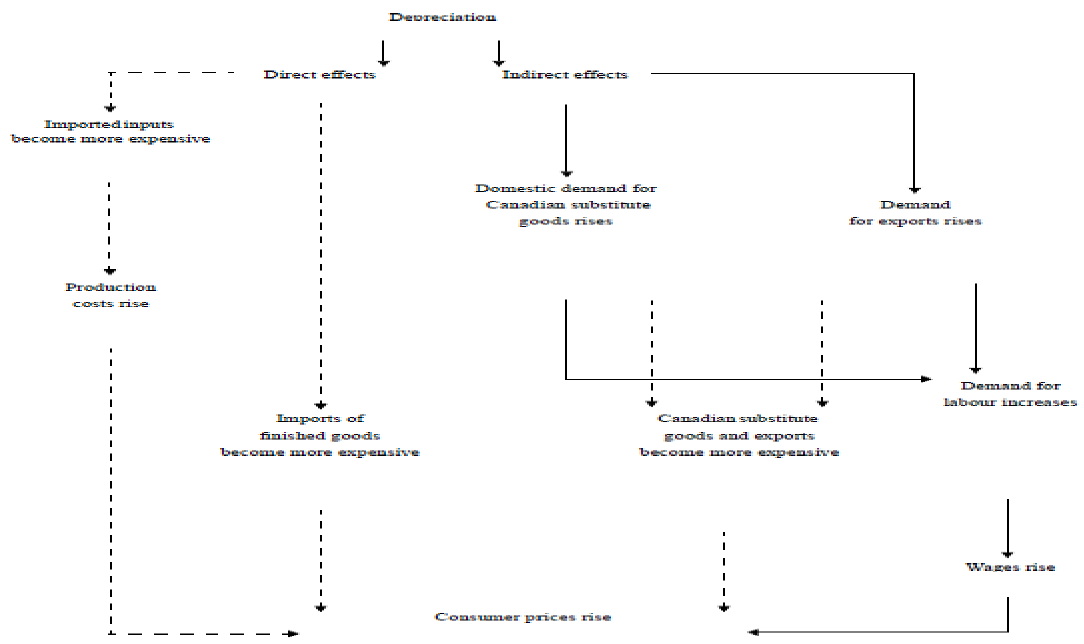
The second section reviews the most important theoretical foundations. The third section is dedicated to providing a summary of the wavelet method and in the fourth section, the research results are presented. The article concludes with a summary in the fifth section and presenting a policy recommendation.

2. Subject literature

The way of affecting exchange rate changes on the consumer price index is one of the interesting topics of economists. This interest intensified in the 1970s as increasing inflation coincided with the spread of flexible currency systems in many developed countries after the collapse of the Bretton Woods currency system. Accordingly, the relationship between exchange rate and changes in the general level of domestic prices has been the focus of studies on exchange rate pass-through in open and small economies. For example, Calvo and Reinhart (2002) state that the fear of a sharp exchange rate pass-through and the dollarization is the main reason for the monetary authorities' fear of floating exchange rate. Hausmann et al. (2006) believe that exchange rate pass-through is one of the reasons why central banks pay attention to exchange rate fluctuations. In addition, the main reason for the deviation of the exchange rate is the fear of devaluation of the domestic currency and its transfer to the general level of prices.

Lafleche (1996) describes the mechanism of affecting the exchange rate on the general level of domestic prices in the form of the following diagram:

Figure (1): Mechanism of the effect of exchange rate increase on the general level of domestic prices



منبع: لافلچ (1996)

According to the diagram above, exchange rate fluctuations affect domestic prices in two ways; Exchange rate fluctuations directly affect the price of intermediate and finished goods. In addition, by changing the level of demand, wages and the combination of demand components indirectly affect domestic prices.

In this section, the model presented by Jaffri (2010) is presented for the exchange rate pass-through. In this model, to maximize the profit of the foreign exporting company, Equation (1) is maximized relative to the price of imported goods in the domestic country (pm):

$$Max\ \pi = ER^{-1}.p_m.q - C(q) \quad (1)$$

π represents the profit in foreign currency, ER is the exchange rate, pm is the price of imported goods in the domestic country, C(q) is a function of cost in foreign currency and q is the amount of demand for goods. By solving equation (1) and entering the surplus, the value of pm is obtained as equation (2) (Jeffri, 2010; Bailliu and Fujii, 2004)

$$p_m = ER.C_q.\mu \quad (2)$$

Cq equals the final cost of the foreign company and μ represents the surplus. The amount of μ, in other words, the producer's pricing behavior depends on the degree of market competition and the prevailing demand conditions. The exchange rate and the gap between the prices of manufactured goods in the importing country (pd) and the production costs of the exporter will indicate the amount μ (Jeffri, 2010):

$$\mu = \left[\frac{p_d}{C_q ER}\right]^{\alpha} \quad (3)$$

By placing equation (3) in equation (2) and logarithmizing equation (4), we obtain:

$$ln\ ln\ P_m = \alpha\ ln\ ln\ P_d + (1-\alpha)\ ln\ ln\ C_q + (1-\alpha)\ ln\ ln\ ER$$
$$ln\ ln\ P_m = \alpha\ ln\ ln\ P_d + \beta\ ln\ ln\ C_q + \gamma\ ln\ ln\ ER \quad (4)$$

In the above equation, the coefficient γ represents the effect of exchange rate pass-through on import prices. In order to obtain the effect of exchange rate pass-through on the consumer price index from Equation (4), Equation (5) is defined. In Equation (5) Jeffri (2010) considers the consumer price index as a function of import prices and the gap between the prices of manufactured goods in the importing country:

$$ln\ ln\ P = \theta\ ln\ ln\ P_m + (1-\theta)\ ln\ ln\ P_d \quad (5)$$

θ represents the weight of imported goods. By placing equation (5) in equation (4) we will have:

$$ln\ ln\ P = \theta(\alpha\ ln\ ln\ P_d + \beta\ ln\ ln\ C_q + \gamma\ ln\ ln\ ER) + (1-\theta)\ ln\ ln\ P_d$$
$$ln\ ln\ P = \theta\alpha\ ln\ ln\ P_d + \theta\beta\ ln\ ln\ C_q + \theta\gamma\ ln\ ln\ ER + (1-\theta)\ ln\ ln\ P_d$$
$$ln\ ln\ P = [\theta\alpha + (1-\theta)]\ ln\ ln\ P_d + \theta\beta\ ln\ ln\ C_q + \theta\gamma\ ln\ ln\ ER \quad (6)$$

Therefore, in the recent equation, the consumer price index in the domestic country can be considered as an increasing function of the exchange rate.

The relationship between the two variables can be analyzed from another angle. In countries such as Iran, which are frequently exposed to monetary expansions and money creation to remove the imbalance of the banking system and government budget, the exchange rate is also affected by inflation. Lack of depth in financial markets strengthens this relationship, because economic factors use foreign currencies as a shield to protect their assets and financial reserves encountering with inflationary pressures. In addition, by tarnishing the macroeconomic environment and being the business environment unfavorable, economic factors became speculative in the markets, of which the foreign exchange market is one of the most important. So that with inflation fluctuations and following the small risk of the foreign exchange market compared to investing in productive sectors, the exchange rate will increase.

3. Research methodology

Granger causality test is one of the common methods of econometrics in which the causal relationship between time series is examined without relying on economic theories. This method provides one shot measure of causality test due to its nature, and it is incapable of analyzing the dynamics and reliability of causality. In addition, in Granger causality method, intermittent values of variables are used and as a result, there is the possibility of eliminating immediate effects. To solve this problem, spectral analysis is used. Fourier transform is one of the most widely used topics in spectral analysis, which is used to reveal the relationships between time series at different frequencies. This method, due to the oscillating nature of the correlation between some economic time series, can be used in the dynamic analysis of causal relationship (Wen, 2005). However, in the Fourier transform, in addition to discarding the local information of time, the reliability of the time series is essential (Aguiar-Conraria et al.., 2008).

However, many time series are unstable and most of their properties change over time. Given this limitation, wavelet transform is considered as a useful alternative to Fourier transform in the discovery of causal relationships. One of the important features of wavelet transform is its ability to decompose a time series into different frequencies at any point in time or the so-called time-frequency analysis of time series. In addition, wavelet transform, unlike Fourier transform is done in the frequency range by non-base on the reliability of time series, and it has the ability to detect frequencies in the data at any time point (Roueff and Sachs, 2011).

In wavelet theory, the power of the time series x (t) is defined by $|W_n^x|^2$ and allows the measurement of local variance and the amplitude of time series fluctuations. The statistical significance of wavelet power is tested with the null hypothesis of time series reliability (following an AR (0) or AR (1) process) with spectral power Pf (Grinsted et al., 2004). Torrance and Campo (1998), based on Monte Carlo simulations by calculating white noise and brownian (or red) noise of wavelet power, showed that the probability function of wavelet power distribution is obtained through equation (7).

$$D\left(\frac{|W_n^X(s)|^2}{\sigma_X^2} < p\right) \Rightarrow \frac{1}{2} P_f \chi_v^2 \tag{7}$$

n and s represent the time and scale of the wavelet power, respectively, and χ^2 andσ_X^2 represent the function of the wavelet power distribution and the time series variance. The significant probability of wavelet power is the large computational power of p table under test.

The time series decomposition operation can be adjusted from a continuous wavelet transform with place and time parameters to a transform with a more limited number of time scales with different numbers of wavelet coefficients in each scale. In fact, this is the same as discrete wavelet transform. Focusing on the continuous process, we find that the continuous wavelet transform moves on all points in the time series in two dimensions of time and frequency and extracts the information, while according to Equation (8), the discrete wavelet transform is applied only to limited points of the time series and extracts information:

$$\psi_{j,k}(t) = 2^{-j/2}\psi(2^{-j}t - k) \quad (8)$$

Similarly, for the father wavelet, the equation will be as follows:

$$\phi_{j,k}(t) = 2^{-j/2}\phi(2^{-j}t - k) \quad (9)$$

Here, k and j are integers representing a set of displacements (transitions) and discrete expansions (scale).

Discrete wavelet transform has two limitations: first, the sample size must be divisible by 2^j; Second, the wavelet and scale coefficients are not constant relative to the transfer. Maximum overlap eliminates discrete wavelet transform defects and allows decomposed data at different scales, including time series trends and details, together with the original time series to be extracted in an aligned way.

If the sampling method is such that a sequence of binary scales is still used for the scales but the correct transitions are used for the transitions instead of the binary transitions so that Where $s = 2^j$ and $u = k$, then we have actually used a discrete wavelet transform of maximum overlapping.

The approximation of any discrete function or time series using the wavelet functions is obtained as follows:

$$f(t) = \sum_{k=1}^{\infty} s_{j,k,j,k}(t) + \sum_{k=1}^{\infty} d_{j,k}\psi_{j,k}(t) + \sum_{k=1}^{\infty} d_{j-1,k}\psi_{j-1,k}(t) + \cdots + \sum_{k=1}^{\infty} d_{1,k}\psi_{1,k}(t) \quad (10)$$

In the above equation, $s_{j,k}$ are even j level and dj, k are called the details of the j level, which are calculated by equations (11) and (12):

$$s_{j,k} = \int \phi_{j,k} f(t)dt \quad (11)$$

$$d_{j,k} = \int \psi_{j,k} f(t)dt \quad (12)$$

Specifically, the particle coefficients of the wavelet, i.e $d_{j,k}$, are the same wavelet transform coefficients that are able to extract high-frequency oscillations and deviations from the time series smoothing process at any scale. On the other hand, $s_{j,k}$ represents those wavelet transform coefficients extracting the time series trend (Farzin Vash et al., 2013 and Rai et al., 2015).

4. Introducing variables and results

According to what was mentioned in the research methodology, the inflation of the consumer price index (growth of the consumer price index) and the growth of the exchange rate using the discrete wavelet transform method with maximum overlap and the D4 filter belonging to the Daubechies wavelet family were broken down to 6 levels. The first to sixth levels correspond to the time horizons of 2 to 4 months, 4 to 8 months, 8 to 16 months, 16 to 32 months, 32 to 64 months and more than 64 months. Accordingly, the first and second levels are divided into short-term scale, the third to fifth levels are divided into medium-term scale, and the sixth level is divided into long-term scale. In the following, the relationship between variables is analyzed using covariance, correlation and wavelet correlation.

Figure (1) shows the wave covariance between inflation of consumer price index and growth of exchange rate. In the figure below, the first point that attracts attention is the difference in results at different scales indicating the multi-scale relationship between business cycles and financial cycles.

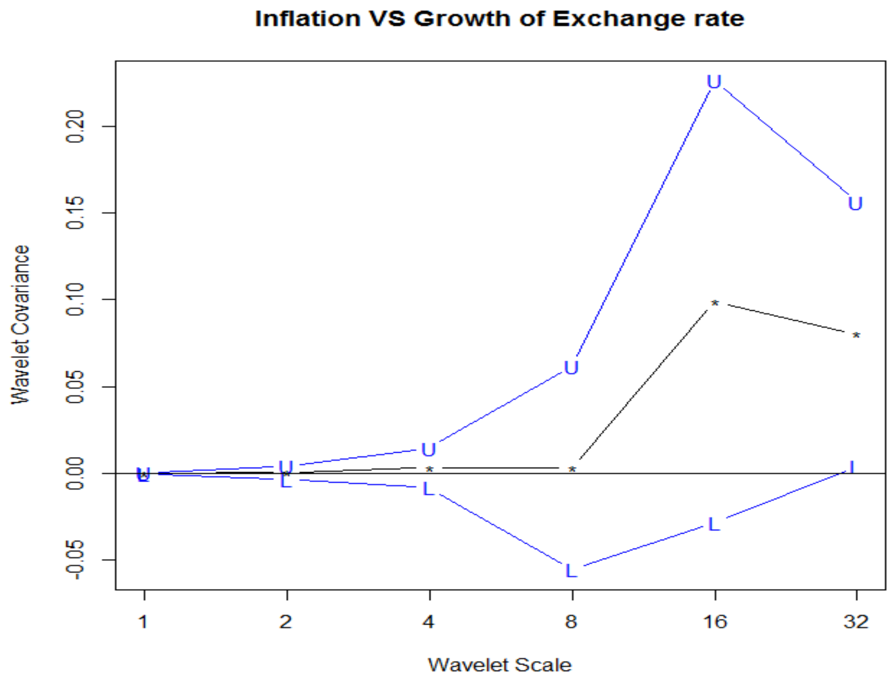


Figure 1). Wavelet covariance between inflation and growth of exchange rate

Source: Research Findings

The wavelet covariance shows how the two time series relate to each other. According to the figure, there is a strong relationship between the two variables used in all horizons and levels of analysis. Since covariance does not provide information about the intensity of the relationship between variables, wavelet correlation coefficient is presented in Figure (2). The correlation coefficient in different scales indicates the variability of intensity of the relationship between the variables in different time horizons.

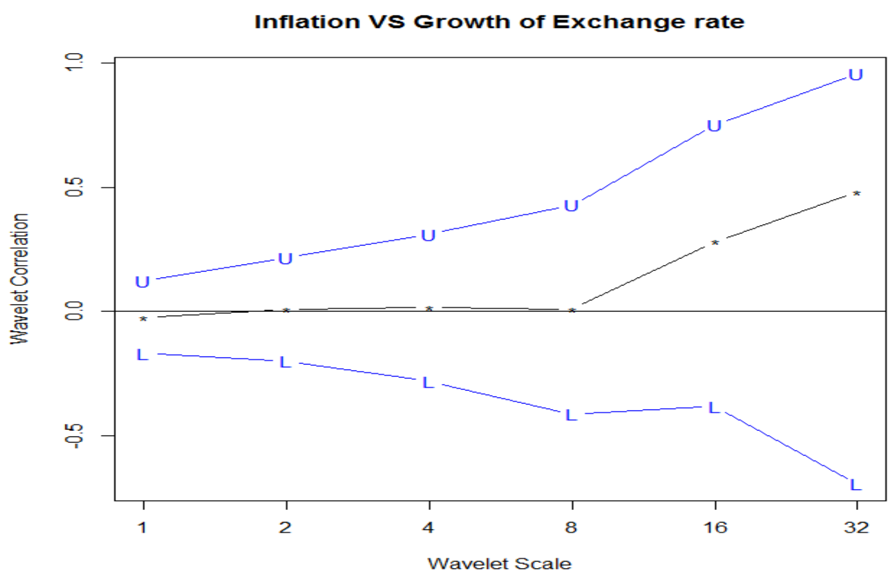


Figure 2). Wavelet correlation coefficient between inflation and growth of exchange rate

Source: Research Findings

In the short run, the inflation and growth of exchange rate are weakly correlated. As the time scale increases, the variables have a positive relationship and the intensity of this relationship increases. Thus, the mechanisms that correlate the two variables intensify at higher horizons, intensifying the relationship between the inflation and the exchange rate.

Using cross correlation in positive and negative intervals, it can judge the flow of causality by knowing the precedence relationship. For each time scale, the correlation between inflation and growth of exchange rate with 36 positive intervals (right half at each level) and 36 negative intervals (left half at each level) is presented in Figure (3).

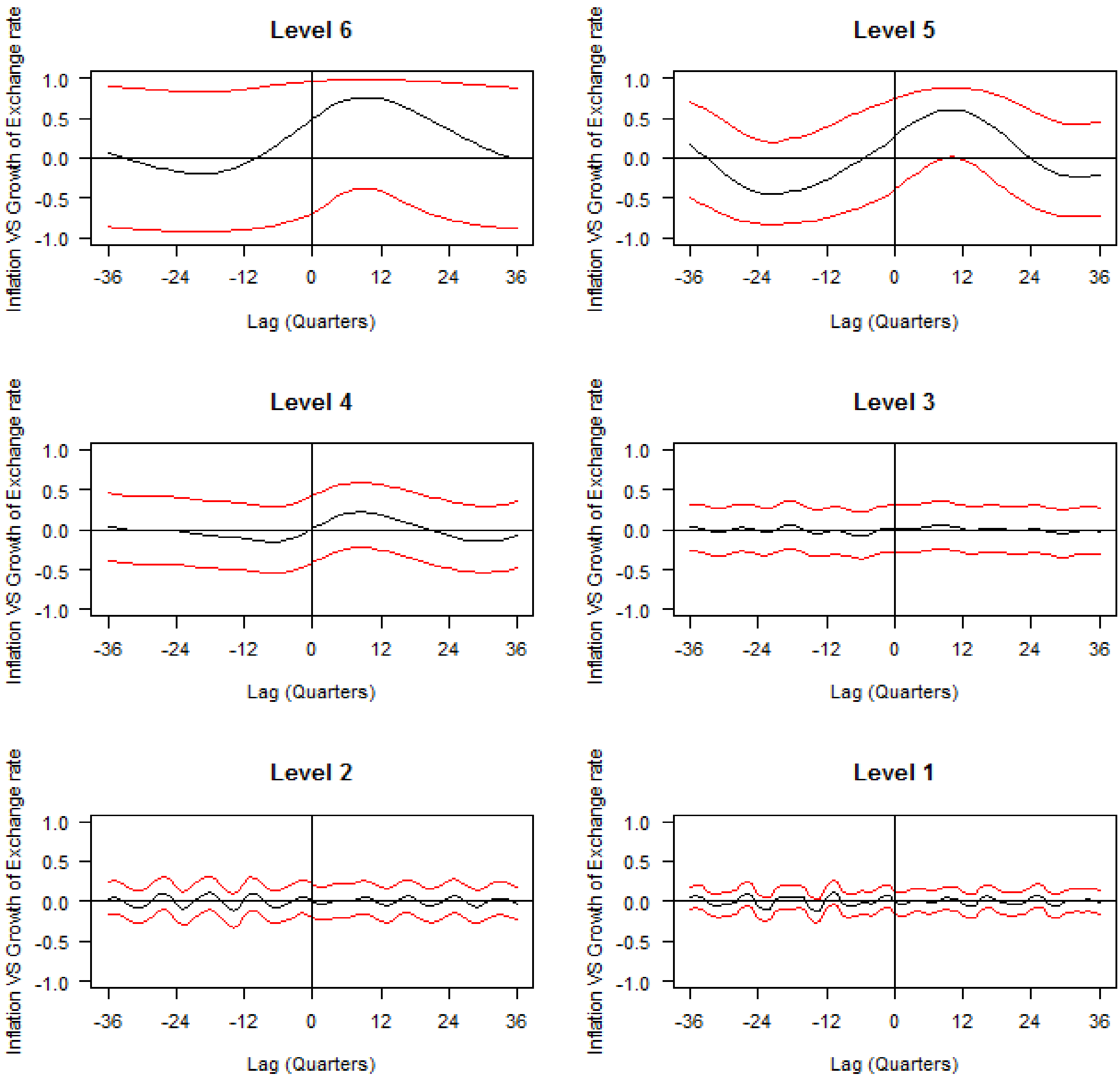


Figure (3): Cross correlation between inflation and growth of exchange rate

For each level, if the correlation between the positive (negative) intervals of business cycles and the current values of financial cycles is significantly different from zero, the figure is skewed to the right (left). In this case, inflation (growth of exchange rate) is considered the leading variable and growth of exchange rate (inflation) is considered the following variable. In other words, there is a one-way causality from inflation (growth of exchange rate) to the growth of exchange rate (inflation). If there is a significant difference with zero on both sides of the wavelet correlation coefficient, it can be stated that there is a two-way causality between the variables.

According to Figure (3), in the short-term horizon and up to the second level, there is no significant causal relationship between the variables. In the medium term and at the fourth level, inflation is the reason for the growth of the exchange rate. In other words, in the horizon of 8 to 16 months, rising inflation will increase the growth of the exchange rate. According to the monetary nature of inflation in the Iranian economy, the exchange rate increases at a higher rate encountering with monetary expansions and inflation. This indicates the asset aspect of the exchange rate in Iran. After this important issue and in the fifth level (16 to 32 months), a two-way causal relationship is established between the two variables. The increase in the exchange rate after the monetary expansions leads to the growth of prices and the phenomenon of exchange rate pass-through occurs. In other words, following the monetary expansion and the devaluation of the national currency, the household consumption basket will face with an increase in price by the increase in the price of foreign consumer goods as well as the increase in the price of imported capital and intermediate goods. If the analysis focuses on the long-term horizon (more than 64 months), the causal relationship will be from inflation to the growth of exchange rate, that is, in the long run, the inflation is the leading variable and the exchange rate is the following variable.

5. Summary and conclusion

The causal relationship between the variables is one of the issues challenged economies like Iran politically. In this regard, the way of interaction between the exchange rate and inflation is a controversial issue between policymakers and activists of financial markets. In the one hand, policymakers, believing in a one-way relationship from exchange rate to inflation, try to neutralize the effects of exchange rate pass-through, which in practice has no necessary effect depending on the requirements of the economy. On the other hand, activists of financial market due to the impact of this variable on the capital market always monitor this variable and use it as a shield against inflation. In this regard, the present study with a different method from economic and financial studies tried to examine the relationship between these two variables from another angle. For this purpose, the discrete wavelet transform method was used to investigate the relationship between inflation and growth of exchange rate on different horizons. The results showed that the two variables did not have a significant relationship with each other in the short run. Initially, inflation has a causal effect on the growth of exchange rate and the relationship between the two variables is two-way in the 32-month horizon. In the long run (more than 64 months), inflation is the leading variable and the rate is affected by changes in inflation.

Accordingly, the policies such as allocating the exchange rate at a price lower than the market price to firms and suppressing the exchange rate are not effective in the long run. Therefore, policymakers are advised to avoid using policies leading to money creation due to the imbalance between the government budget and the banking system. In addition, in the case of inflation, the injection of foreign exchange resources into the market is not effective and leads to the waste of national resources.

6. Resources

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