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Co-movement of exchange rate and housing rental rate in Iranian economy: An econophysic analysis

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Abstract

The historical study of Iran's economy shows that one of the main problems that Iran's economy has always faced is exchange rate fluctuations and their effects. For this purpose, in the current research, wavelet coherence analysis has been used to investigate the relationship between the exchange rate and the rental rate (the price of money in the housing market) in different time scales between the spring of 1980 and the winter of 2021. The results show that in the short-term time scale, The real exchange rate and the rental rate have a high degree of coherence, and the two variables are in opposite phases in most intervals, which shows the confirmation of the monetary model with a sticky price. But in the medium-term and long-term time scale, this relationship is the same phase, which shows the approval of the monetary model with flexible prices. Also, the results show that in the long term, this relationship was significant only in years when the real exchange rate was negative and strictly controlled.

Keywords: Wavelet theory, rental rate, exchange rate, Wavelet coherence
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1 Introduction

Among the important variables that have attracted the attention of many economists and policymakers and have a very important role in the economic growth of societies, we can mention the exchange rate and interest rate variables. In recent years, special attention has been paid to the relationship between these two variables in different economies. However, they have not given an unambiguous answer to the data related to this issue. The studies conducted in different economies (advanced, emerging and developing) show contradictory results. This contradiction in the results of the studies of different economies has practically put the relationship between the exchange rate and the interest rate in an aura of uncertainty. Several studies that have examined the time series relationship between interest rate and exchange rate variables tend to find contradictory results that depend on the sample of countries and the period under study [1]. Considering that exchange rate fluctuations have important consequences for monetary policies, from the point of view of policymakers, it is important to analyze the transition paths between these markets to adopt

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appropriate policies and predict the full impact of their decisions [2]. Economic literature, empirical studies conducted in development economics, influence They show different variables in economic growth and development. Among these important variables that have attracted a lot of attention from economic thinkers and have a valuable role in improving the economic growth of societies, are interest rate and exchange rate variables. Therefore, examining the relationship between the exchange rate and the interest rate has been one of the favourite topics of economists and economic policy makers [9]. A study of the economies of developing countries shows that these countries face very high fluctuations in exchange rates. To prevent exchange rate fluctuations, many countries stabilize the value of their currency against foreign currencies that are of great importance. However, some other countries refuse to stabilize the exchange rate and accept a floating exchange rate [4]. The studies have shown problems such as negative effects on economic growth due to the rule of the floating exchange rate system for some countries, while negative effects are not observed in developed countries. This duality makes exchange rate fluctuations have an important effect on economic variables, including the rate have interest Considering that the interest rate is also one of the most important macroeconomic variables that affects investment and the real sector of the economy, it is very important to know the relationship between the exchange rate and the interest rate. It has attracted economists and policymakers [1]. The historical study of Iran's economy shows that one of the main problems that Iran's economy has always faced is exchange rate fluctuations and their effects. The exchange rate in Iran, as a key price variable in the economy, affects many government policies and decisions of economic actors. Any instability and turbulence in the price of the currency leave an adverse effect both at the micro and macro levels. Examining the developments of the foreign exchange market in the country indicates the existence of turbulence in this market and extreme fluctuations during recent years, so that since the middle of 2019 after the tightening of sanctions Disruption was created in the country's currency exchanges and transfers, and from then on, the exchange rate in the foreign exchange market deviated from the official rate, and a two-rate and even a multi-rate situation was formed in the currency market and continues. In the formation and continuation of the country's unfavourable currency situation, there are several factors with a high degree of influence. different and each of them has played a special role, among which economic sanctions, liquidity growth, the conditions of the structure of the foreign exchange market and the interest rate are more important. Since the adverse effects of exchange rate fluctuations on the Iranian economy are not hidden, this study aims to study the relationship between this variable and the housing rental rate (the price of money in the housing market). One of the alternatives to the interest rate in Iran's economy is the housing rental rate due to its mandatory nature. The reason for using it is because the natural interest rate is the same as the rental rate of physical capital, and in the Iranian economy, the most important item of physical capital is housing, the rental rate of which can be a reasonable substitute for the interest rate. Secondly, in Iran's economy, the calculation of the rental rate has been a function of the unofficial market interest rate. This study tries to explain the relationship between exchange rate and housing rental rate (price of money in the housing market) in the Iranian economy by using the available seasonal data in the form of a monetary model by presenting the wave theory method (econophysics analysis) to address the question that the exchange rate What is the relationship with the rental rate in Iran's economy, or how does the rental rate react to the impulses on the exchange rate, is the main question of the present study, which is examined in the form of a monetary model.

In this study, an attempt has been made by presenting the wavelet analysis method for the first time to establish the relationship between the real exchange rate and the housing rental rate (the price of money in the housing market) in Iran's economy using available seasonal data (spring 1980-winter 2021) extracted from the information banks of the department. The economic accounts and the national accounts of the central bank should be examined. The reason for using this method is the high ability to analyze the dynamics of the causality relationship between time series. Since in this method, the wavelength changes optimally in different time scales, it is possible to examine the causality at the same time. Short-term and long-term causality is provided between economic time series. Wavelet analysis is much different from other conventional mathematical methods. Unlike time-based methods (correlation analysis and Granger causality, etc.), which cannot identify the short-term and long-term relationship between time series, or frequency-based models (such as Fourier analysis) which cannot show how such a relationship changes over time, wavelet analysis expands the time series to the time-frequency space and shows local correlation and backwards-forward relationships between time series. Therefore, by using the wavelet approach, it is possible to simultaneously examine the short-term and long-term causality between the time series of the variables in question, and examine the intensity of the relationship between them in different time frames, according to different frequencies [5]. In this article, with a new approach and using wavelet transformation, the relationship between exchange rate and rental rate is investigated. In such a way that not only we will not have the limitations of econometric models, including the lack of data, but we can simultaneously observe the data of the exchange rate and the rental rate in different time scales and examine their relationship with each other. Also, the innovation of this research compared to other similar research that has investigated economic relationships with wavelet tools is the use of continuous wavelet transformation and the investigation of wavelet correlation and coherency between variables. In the current research, using cross-sectional continuous wavelet and coherence and phase difference, we will find out the intensity of the relationship between the exchange rate and the rental rate in different time horizons and over time. The main purpose of this research is to investigate and achieve the relationship between the exchange rate and the rental rate in different time scales. This article is written based on the hypothesis of the existence of a correlation between the exchange rate and the rental rate in the short-term and long-term time scales. From the introduction, in the Dubeh section, the review of the subject literature, the relationship between the exchange rate and the rental rate, and the background of the studies conducted inside. and outside the country, in the third part of the research method and the fourth part, while introducing the data, it depicts the power spectrum of the wavelet and presents the experimental results. The fifth section is also related to conclusions and suggestions.

2 Theoretical literature

Given that the most important variable that affects the housing rental rate is the housing price, therefore, to analyze the relationship between the exchange rate and the rental rate, the effects of currency market fluctuations on the housing market (housing price) should be investigated. The impact of currency fluctuations on the housing market is divided into short-term and long-term categories. In the short term, the effect of these price fluctuations will have an inverse relationship with the increase in housing prices, and in the long term, it will have a direct relationship with the increase in housing prices. In this way, in the short term, with the increase in the exchange rate, the prosperity of the housing market will decrease, and this recession will change the conditions for the improvement of this market in favour of tenants, that is, mortgage and rent applicants. This is because people are more inclined to allocate their capital to buy foreign currency and take advantage of short-term profits, and therefore they may sell their properties below the current common price. But in the long run, the result will be completely opposite because with The increase in the exchange rate of all the goods and equipment related to the building will be affected by the increase in the exchange rate, and as a result, the finished price of each residential unit will increase for the builders and will be offered to the applicants with a higher price [18]. Therefore, in this, The study of the relationship between the exchange rate and the rental rate (the price of money in the housing market) is based on the theory of purchasing power parity (as one of the famous theories in international finance, it is used to analyze the relationships between real variables and is based on the law of unit price) [30]. Money will be considered.

2.1 Paid model

The monetary approach has been used as the most important model for determining the exchange rate since 1970. The model developed by Dornbusch [11] is a combination of two diametrically opposed monetary models. This model includes price stickiness, which is a short-term feature, and a monetary model with a flexible price, which is a long-term feature. According to this model, interest rates and exchange rates have a negative relationship in the short term, which is the result of monetary shocks, and a positive relationship in the long term. They have that this requires variable prices. Therefore, the monetary model is divided into two parts: the monetary model with flexible prices and the monetary model of sticky balances [6].

2.1.1 The monetary model with flexible prices (FPM)

The monetary model with flexible prices (FPM) in which the price of goods is completely flexible and is used to explain the long-term behaviour of the exchange rate. The main form of the monetary approach to determining the exchange rate started with the Frankel model, which considers the flexibility of prices. The monetary model is usually called the two model. A two-poly country is presented in which all goods are tradable and the single price law is in place. The monetary model of flexible balances is based on two hypotheses purchasing power parity (PPP) and the existence of a stable money demand function for domestic and foreign economies [1]. Therefore, the demand function Standard money can be written as $\beta i_t - \alpha y_t + P_t = m_t$ and $\beta i_t^* - \alpha y_t^* + P_t^* = m_t^*$ [34]. m_t is the nominal demand for money, P_t is the general level of prices, y_t is the level of national income and i_t is the nominal interest rate. In this model, all the variables except the interest rate are logarithmic. In the above relationships, the sign $*$ indicates the values of the variables of the money demand function of the foreign country. α and β are constant parameters for two countries. It is assumed to be the same. If we denote the real exchange rate by e_t^r, $e_t^r = (1, \frac{P_t^*}{P_t} e_t \quad and \quad P_t^* e_t = P_t)$ and equally the unhedged interest rate will be $i_t^* - i_t = \Delta e_t$. If we take the natural logarithm from the relation $P_t^* e_t = P_t$ then $\ln(e_t) + \ln(P_t^*) = \ln(P_t)$ and assuming purchasing power $(PPP) e_t + P_t^* = P_t$ is obtained.

In the relationship $e_t + P_t^* = P_t$, e_t represents the logarithm of the nominal exchange rate, P_t is the domestic price and P_t^* is the foreign price. PPP is only used as a long-term equilibrium condition in this model. If the PPP

condition is continuously to be true, the logarithm of the real exchange rate,q_t, $P_t^* + P_t - e_t = q_t$ will be equal to zero, and as if the PPP model, foreign prices are exogenous to the domestic economy and are determined through the supply of foreign money, and the supply of domestic money also determines the general level of domestic prices. Therefore, The exchange rate is determined by the money supply. From placing the relations $\beta i_t - \alpha y_t + P_t = m_t$ and $\beta i_t^* - \alpha y_t^* + P_t^* = m_t^*$ in the relation:

$$e_t = (m_t - m_t^*) - \alpha(y_t - y_t^*) + \beta(i_t - i_t^*) \tag{2.1}$$

in relation (2.1), it is assumed for simplicity that the income elasticity (α) and interest rate elasticity (β) of money demand are the same for two countries. Finally, the monetary model considers the uncovered interest rate (UIP). According to UIP, The foreign interest rate plus the expected exchange rate change is equal to the domestic interest rate of the equation $i_t^* - i_t = \Delta e_t$.

Equation (2.1) is known as the Frenkel-Bilson model. Based on this relationship, the increase in liquidity, interest rate and decrease in national income causes the depreciation of the national currency of the ”domestic” country. Assuming that it is rational behavior in the long run and the relative level of prices and the exchange rate is proportional to the relative inflation of money, equation (2.1) can be written below:

$$e_t^L = ((y_t - y_t^*) + \beta(i_t - i_t^*)\alpha) - m_t^* - m_t. \tag{2.2}$$

Equation (2.2) gives the long-term equilibrium path of the monetary model. Equation (2.2) is the main monetary form of determining the exchange rate, which establishes a long-term relationship between a simple set of monetary variables. Mark and Sol emphasize that equation (2.2) represents a kind of long-term equilibrium exchange rate by applying new theories of exchange rate determination [26].

2.1.2 The monetary model of sticky balances (SPM)

The monetary model of sticky balances (SPM) in which the price of goods is completely sticky. It is used to explain the short-term behaviour of the exchange rate (the short-term equilibrium path of the exchange rate). Money demand in domestic and foreign countries follows the relations $\beta i_t - \alpha y_t + P_t = m_t$ and $\beta i_t^* - \alpha y_t^* + P_t^* = m_t^*$. And the equality of interest rate without coverage is also assumed to be $\Delta e_t = i_t - i_t^*$. In this model, it is assumed that the expected percentage of domestic currency depreciation is a positive function of the difference in the long-term expected inflation rate between two countries and the gap between the desired cash rate and its long-term equilibrium rate:

$$\Delta e_t = \theta(\acute{\bar{e}}_t - e_t) + (P^e - P^{e*}) \tag{2.3}$$

If we replace equation (3.6) in the equation $\Delta e_t = i_t - i_t^*$ and arrange it based on the long-term exchange rate difference, the relationship $(P^{e*} - i_t^* \left(\frac{1}{\theta}\right) = e_t - \acute{\bar{e}}_t)$ will be obtained.

Frankel [16] believes that this expression can be considered as the real interest rate difference. His visit, if the long-term exchange rate is equal to the cash rate of the currency in the long term, then it will be $\pi_t^* - \pi_t = \bar{i}_t^* - \bar{i}_t$. According to the theory of purchasing power parity, in the long run we will have:

$$\bar{e}_t = \overline{P}_t - \overline{P}_t^* = (\overline{m}_t - \overline{m}_t^*) - \beta(\bar{y}_t - \bar{y}_t^*) + \delta(\overline{\pi}_t - \overline{\pi}_t^*) \tag{2.4}$$

By placing equation (2.4) in the equation $(P^{e*} - i_t^* \left(\frac{1}{\theta}\right) - P^e - i_t \left(\frac{1}{\theta}\right) = e_t - \acute{\bar{e}}_t)$ and the assumption that the equilibrium amount of money supply and income levels through real levels If they are determined in the present tense, we will have the following relationship:

$$e_t = (m_t - m_t^*) - \beta(y_t - y_t^*) - \frac{1}{\theta}(i_t - i_t^*) + \left(\frac{1}{\theta} + \delta\right)(\pi_t - \pi_t^*). \tag{2.5}$$

In most of the studies based on monetary models, money supply and variables such as interest rate, production and inflation, which determine money demand, are affected by exchange rate fluctuations. Mark assumes that there is no difference between domestic and foreign interest rates. Unlike Mark, they believe that the difference in interest rates in different countries is very important in determining the exchange rate, and for this reason, the difference in domestic and foreign interest rates and expected inflation have been introduced into the monetary model and they have presented the monetary model as follows:

$$e_t = (m_t - m_t^*) - \beta(y_t - y_t^*) - \alpha(i_t - i_t^*) + \emptyset(\pi_t - \pi_t^*) + u_t. \tag{2.6}$$

We can write relation (2.6) as follows:

$$e_t = \alpha_0 + \alpha_1(m_t - m_t^*) - \alpha_2(y_t - y_t^*) \pm \alpha_3(i_t - i_t^*) + \alpha_4(\pi_t - \pi_t^*) + u_t \tag{2.7}$$

represents the exchange rate, m_t the money supply, y_t the gross domestic product, i_t the interest rate and π_t the inflation rate for the domestic country and the variables marked with $*$ represent the variables of the foreign country. Now, the impact of the explanatory variables on the exchange rate can be explained in this way.

With the establishment of PPP, an increase in the volume of money causes an increase in the exchange rate, which is expected to be a positive variable coefficient of the volume of liquidity (α_1). If we assume that the real income will increase. The increase in the real income will strengthen the domestic money and decrease the exchange rate, then the difference coefficient of the real income (α_2) will be negative. However, regarding the effect of the interest rate, monetarists believe that the increase in the domestic interest rate will increase the opportunity cost of holding money. and causes a decrease in the demand for money, and this decrease in the demand for money leads to an excess supply of money. To achieve equilibrium in the money market, prices increase, and this increase will lead to an increase in the exchange rate (a decrease in the value of the domestic currency). Therefore, the sign of the interest rate differential coefficient (α_3) will be positive. On the other hand, the model set by Dornbusch [11] is a combination of two completely opposite models. This model includes price stickiness in production markets as a short-term feature. Price adjustment, in the long run, to bring it to a new equilibrium is a characteristic feature of the flexible-price monetary model. In the short term, interest rate and exchange rate have a negative relationship (negative α_3) and this relationship is the result of monetary shocks; Interest rate and exchange rate have a positive relationship in the long run, which requires variable prices. The Mondel-Fleming model assumes international capital mobility and sticky (unchangeable) prices in the short term. This model also predicts a negative relationship between interest rate and exchange rate (negative α_3). However, since real inflation has a positive relationship with expected inflation, so that an increase in expected inflation causes an increase in real inflation, therefore, with the increase in the general level of domestic prices, the possibility of competitiveness of domestic goods and services will decrease. found and as a result, with the increase in the balance of payments deficit and the excess demand for foreign currency in the foreign exchange market, the value of the domestic currency will increase, and the depreciation of the foreign currency will increase, which will lead to an increase in the general level of domestic prices compared to foreign prices, and finally, we will face an increase in the exchange rate and (α_4) will be positive [29].

2.2 Research background

Wavelet analysis was introduced to economics by Ghaffari et al. [18], Ramsey and Lampart [31] in the mid-1990s. But it has been widely used in the economy in recent years. The branches of the wavelet method investigate the dependence of the wavelet and the phase difference based on the continuous wavelet transform (CWT). Other branches of this multiple resolution analysis method based on maximum overlap discrete wavelet transform (MODWT) deal with evaluating some connections in empirical economics. In the following, we refer to some of the studies that have studied the relationship between exchange rates and interest rates in the past.

2.2.1 Study records abroad

In most theoretical models, the exchange rate (currency exchange rate) is determined by economic fundamentals. The interest rate difference between inside (own country) and outside is one of the most important economic factors that affect the exchange rate. Theoretically, various models explain the various correlations between interest rates and exchange rates. Securities equilibrium models [4, 5, 6, 19, 22, 23, 27] suggest a negative relationship between exchange rates and interest rates. The Mondel-Fleming model assumes international capital mobility and sticky (unchangeable) prices in the short term. In this case, the lower interest rate of the main country determines capital outflow and causes a balance of payments deficit; This deficit is solved by the net increase in exports, through the decrease in the price of the domestic currency. This model predicts a negative relationship between interest rate and exchange rate.

Khajeh Mohammadlou and Khodaveisi [26] state: Any increase in expected inflation must correspond to an increase in the nominal interest rate of that country. Fisher's hypothesis is valid. On the other hand, the interest rate of the main country should increase exogenously, not due to disturbances in the money market. So an increase in price levels due to a decrease in demand for money can lead to a higher exchange rate. Therefore, the theory of purchasing power parity (PPP) predicts a positive relationship between the interest rate and the exchange rate [20]. This model relies on full-price flexibility in the long run. Another justification for the positive relationship between interest rates and exchange rates can be found in a Keynesian approach. A higher exchange rate leads to an increase in the country's trade balance. This problem can increase the interest rate of that country due to the increase in the total demand for the products of a country in the short term with sticky prices.

The model formulated by Dornbusch [11] is a combination of two completely opposite models. This model includes price stickiness in production markets as a short-term feature. Price adjustment, in the long run, to bring it to a new equilibrium is a characteristic feature of the flexible-price monetary model. Interest rates and exchange rates have a negative relationship in the short term, and this relationship is the result of monetary shocks; Interest rates and exchange rates have a positive relationship in the long run, which requires variable prices.

Eichanbaum and Evans [14] using data from a period of flexible exchange rates, have proved that expansionary shocks to monetary policy lead to sharp and persistent depreciations in nominal and real US exchange rates, as well as sharp increases and It is constant expanding between US domestic interest rates and foreign interest rates. One of the tools for measuring monetary policy shocks is orthogonal shocks to the federal funds rate. Drazen and Hubrich [13] found that during the 1992 European Exchange Rate Mechanism (ERM) crisis, currency forecasts reacted unevenly to interest rate increases, with increases in short-term prices accompanied by decreases in long-term prices of forecasted currency values. In the Eurozone, the exchange rate had a negative, albeit small, effect on the European Central Bank's interest rate between 1999 and 2010; This shows that the European Central Bank has not focused on exchange rates, although it has taken them into account during policy decisions [10].

Bautista [3] has investigated the "interest rate-exchange rate" interaction using a dynamic conditional correlation (DCC) analysis; This is a multivariate GARCH method with Philippine weekly data from 1988 to 2000. The results show that the correlation between these variables is not constant at all. Chinn and Meredith [8] found a positive relationship between the logarithm of the exchange rate and the interest rate differential using short-term bond data and long-term bond data. They found a positive relationship between these variables when using long-term data, but found contradictory results when using short-term data. Flood and Taylor [15] used medium-term bond data and estimated a positive relationship, but found a negative relationship when using medium-term bond data.

Hnatkovska and his colleagues [21] found that the relationship between interest rate and exchange rate is nonuniform. In particular, they observed that the reaction of the exchange rate depends on the size of the interest rate increase and on the initial level of the interest rate. Choi and Park [9] investigated the relationship between interest rates and exchange rates during the Asian crisis using the VAR model; They rejected the use of a recessionary monetary policy (high interest rates) to stabilize exchange rates. In Turkey, volatility shocks produced sudden changes in the dynamic correlations of interest rates and foreign exchange markets, but these changes only occurred in the short run. This behaviour was not sustainable in the long term [18].

Some articles have analyzed the relationship between exchange rates and interest rates using "wavelet-based analysis". Wavelet-based analysis has the advantage of being able to decompose time series into different time scales so that we can analyze the relationship between variables in the short-term, medium-term and long-term [7, 8]. Hacker et al. [20] use wavelet-based analysis to investigate the causality between spot exchange rates (day rate) and nominal interest rate differentials for seven pairs of countries. The interest rates used in this study are the monthly averages obtained from quarterly treasury bills, and the exchange rates are the average asking (seller) prices. They found from the tests that there is strong evidence that nominal interest rate differentials lead to exchange rate appreciation as the time scale of the wavelet increases. Also, when examining the immediate (shock) responses to how interest rate differentials affect exchange rates, there appears to be evidence for more negative relationships at shorter time scales, and more positive relationships at longer time scales. Walker [39] investigated the relationship between interest rate changes and Spanish stock returns on a wavelet basis for the period from January 1993 to December 2020. Econophysical analysis is a new and reliable approach, which can be referred to the studies by Nademi and Khochiany [28, 29], with the titles of co-movement of stock, currency and gold markets and the study of the relationship between the housing sector and some macroeconomic variables in the Iranian economy.

3 Methodology

In this research, we are trying to explain the relationship between the exchange rate and the rental rate in Iran's economy by presenting a wavelet analysis (economic and physical analysis) using the available seasonal data extracted from the information banks of the Economic Accounts Department, the national accounts of the Central Bank and the World Data Bank. One of the important features of wavelets is their high capability in dynamic analysis of the causal relationship between time series. Since the wavelength changes optimally in different time scales, it is possible to examine the short-term causality and long-term causality between economic time series simultaneously. The study method of this research is applied research in terms of purpose and analytical research in terms of analysis.

3.1 Wavelet analysis and methods

Wavelet transform is a very efficient tool to deal with the non-invariant properties of time series. Using the wavelet method in financial analysis has major advantages. In short, they can be categorized into three main parts. First, we can directly study the time series of Namana. Second, we can examine the local short-term properties of financial behavior. Thirdly, we can compare financial models and behaviors at different time scales.

In general, we can say that wavelet analysis is a modified and refined version of Fourier analysis. Before the advent of Fourier analysis, scientists investigated signals (time series) only by studying them in the time domain. Although this enables us to detect many recurring properties in time series, it fails to analyze complex signals with multiple components. Applying the autocorrelation function to time series enables us to obtain information about the frequencies present in the signal. However, these techniques provide us with a limited amount of information [8]. The need to obtain more information from time series led to a branch of mathematics in which each signal is represented using a series of orthogonal functions. The root of this problem goes back to the research of Joseph Fourier. The difference between a regular Fourier (sine wave) and a wavelet is the property of localization. A sine wave is localized only in the frequency domain, while a wavelet is localized in both the frequency domain and the time domain.

3.2 Continuous Wavelet Transform (CWT)

The extended versions of the parent wavelet, which are well localized in the time and frequency domains (the fluctuations of the desired variable at different time intervals). In this way, the time series can be transformed into spatial frequency expansion where fluctuations in time or frequency are observed intuitively and directly. There are often two classes of wavelet transforms. Discrete wavelet transform DWT and continuous wavelet transform DWT which are used to reduce noise and data compression, while CWT is useful for extracting features and discovering self-similarity of data [11]; therefore the CWT is widely used in economics and finance [2]; despite the time series $X(t) \in L^2(R)$ its CWT according to the mother wavelet $\psi\tau, S(t)$ as a scalar product of girls are defined as:

$$Wx, \psi(\tau, S) = (x(t), \psi\tau, S(t)) = \int_{-\infty}^{+\infty} x(t)\psi^* \tag{3.1}$$

in which the star sign $*$ indicates a complex combination, in other words, $\Psi^*\tau S$ is a complex combination of daughter wavelet functions $\Psi T, S(t)$. As mentioned above, $\Psi\tau, S(t)$ comes from the mother wavelet $\Psi(t)$ during decomposition, so that:

$$\Psi\tau, S(t) = |S|^{-1/2}\Psi\left(\frac{t-\tau}{S}\right), \quad \tau \in S. \tag{3.2}$$

The difference in the wavelet scale parameter s implies a compressed $(S < 1)$ or stretched $(S > 1)$ mother wavelet among the frequencies, while its restoration along the local time index τ implies the transition of the wavelet state $\psi\tau, S(t)$ in time has it. In this method, an image can be created that shows both the magnitude of each feature in $X(t)$ relative to different scales, and how this magnitude changes over time [38], that s and τ are real values that change continuously (with the adverb $S \neq 0$), so $Wx, \Psi(\tau, S)$ is named as a continuous wavelet. For the CWT mother wavelet, $\Psi, (t)$ must have two characteristics.

$$0 < C_\Psi = \int_{-\infty}^{+\infty} \frac{|\Psi(f)|^2}{|f|} df < +\infty \tag{3.3}$$

where $\Psi(f)$ is the Fourier transform of the mother wavelet $\Psi(t)$ and f is the Fourier frequency. Looking at the formula, it is clear that C_Ψ is independent of f and is only determined by the wavelet $\Psi(t)$, which means that C_Ψ is a constant value for any given mother wavelet function, also called acceptable constant. The importance of the admissibility condition is that it offers the possibility of improving the time series $x(t)$ of CWT, i.e. $Wx, \Psi(T, S)$ as follows:

$$x(t) = \frac{1}{C_\Psi}\int_{-\infty}^{+\infty}\left[\int_{-\infty}^{+\infty} W_{x,\Psi}(\tau, s)\Psi s_{s,\tau}(t)d\tau\right]\frac{ds}{S^2}, \quad S \neq 0 \tag{3.4}$$

In other words, in this method, we can go from $X(t)$ to CWT and return from CWT to $X(t)$, so we can accept that the same mathematical expression. More importantly, the original energy $X(t)$ can be preserved by wavelet transmission as follows.

$$X(t) = \frac{1}{C_\Psi}\int_{-\infty}^{+\infty}\left[\int_{-\infty}^{+\infty} |W_x(\tau, s)|^2\Psi s_{s,\tau}(t)d\tau\right]\frac{ds}{S^2}\|x\|^2 \tag{3.5}$$

where $\|x\|$ is defined as the energy of $X(t)$. There are different types of mother wavelets available for different purposes, such as Haar, Morelet, Dubchase, Mexican Hat, etc. The most widely used mother wavelet to achieve the goal of feature extraction is the Morelet wavelet, which was first introduced by Gapilad. Gençay et al. [17] was proposed. Its simplified version is presented below:

$$\Psi(t) = \pi^{-\frac{1}{4}} - e^{i\omega 0t} e^{\frac{-t^2}{2}} \tag{3.6}$$

where $\pi^{-\frac{1}{4}}$ guarantees the unit energy for the mother wavelet. In addition, the frequency $\omega 0$ is dimensionless and is generally equal to 1 in practice, because this value can ensure that the Morelet wavelet is almost an analytical wavelet and makes it easy to interpret the relationship between the scale s and the Fourier frequency f.

3.3 Wavelet power spectrum

In wavelet theory, the wavelet power spectrum of the time series $X(t)$ is given by $Wx, \Psi(\tau, S)$, which is called the automatic wavelet power spectrum. This spectrum can be interpreted as a measure of local variance for $X(t)$ at each frequency. Since the transfer between the wavelet of two time series $X(t)$ and $y(t)$, proposed for the first time by Hudgins et al. [24], the power spectrum between the wavelet is written as follows and the criterion correlation between x and y in each presents frequency [38].

$$|\Psi y, \Psi * (\tau, s)|^2 |Wx, \Psi(\tau, s)|^2 = |Wxy, \Psi(\tau, s)|^2 \tag{3.7}$$

Therefore, in the wavelet power spectrum graphs, the points marked with red color and black solid lines are the areas that have the most variance or fluctuations in their respective time scale, also the areas outside the curves conical are the points that are interpreted They are not easily achievable and should be interpreted with more caution.

3.4 Wave and phase difference correlation

When analyzing the dynamic relationship between exchange rate and interest rate, it is very important to pay attention to the correlation (consistency) of wavelet and phase difference. The wavelet correlation can be calculated using the inter-wave spectrum and the automatic wavelet spectrum as follows:

$$R^2_{xy}(\tau, s) = \frac{|s(S^{-1} w_{xy,\Psi}(\tau, s)|^2}{S|S^{-1}|w_{x,\Psi}(\tau, s)|^2 S|S^{-1}|w_{y,\Psi}(\tau, s)|^2|} \tag{3.8}$$

The correlation of the studied wavelet is presented as the second power. Although wavelet correlation shows the correlation in different time scales, it does not show the answer to the question of which variable caused the change in another variable. This answer is given by coherence diagrams and phase shift directions in these diagrams. According to the Fourier frequency spectrum transform method, wavelet coherence can be defined as the ratio of the cross-frequency spectrum of two-time series multiplied by the frequency spectrum of each of the time series (3.6), in simpler terms, autocorrelation in space A time series is defined, and consistency is the same as autocorrelation, but it is defined in the frequency space of the time series. Consistently, autocorrelation can be obtained at specific times and at the same time on specific time scales. In relation (3.5), the variable S is a smoothing operator. Thus, after smoothing, the correlation of the square signal takes a value between 0 and 1 in time-frequency space. In the wavelet correlation images, this problem is represented by colors, red indicates high correlation and blue indicates weak correlation. The wavelet correlation method leads to a three-dimensional analysis that can simultaneously show the time and frequency components as well as the degree of correlation, thereby helping us to differentiate the spatial correlation between the real exchange rate and the real interest rate and the structural changes in to identify duration and short- and long-term connections between frequencies. Since the wavelet correlation is in the form of the second power, we cannot distinguish between positive and negative correlations. Therefore, a phase difference tool is necessary to provide positive or negative suggestions about correlations and regressive relationships between time series. On the other hand, as the Morelet wavelet is a complex function, the CWT is also very complicated and divided into two parts, real and imaginary, according to this type of mother wavelet. Therefore, based on the work of Schleicher [32] and Sensoy et al. [33], the phase difference between x and y is defined as follows:

$$\Phi_{xy} = \tan^{-1}\left(\frac{\Im\{S(s-1Wxy, \Psi(\tau, s))\}}{\Re\{S(s-1Wxy, \Psi(\tau, s))\}}\right), \quad \text{with} \quad \varphi_{xy} \in [-\pi, \pi] \tag{3.9}$$

where $\Im$ and $\Re$ are respectively imaginary and real parts of the inter-wavelength transmission. Therefore, following the work of Aguiar-Conraria and Soares [2], we can easily convert the phase difference into a time interval between x and y, so that:

$$(\Delta t)_{xy} = \frac{\varphi_{xy}}{2\pi f} \tag{3.10}$$

where $2\pi f$ is the angular frequency along the time scale s, i.e. the usual frequency ω Fourier is such that $\omega_\Psi/2\pi s = f$. Note that ω_Ψ represents the frequency of the parent wavelet, or in other words, the dimensionless frequency $\omega 0$ of the Morelet wavelet. Using f by choosing $\omega 0 = 1, f$ is obtained. Therefore, the time interval (Δt) is:

$$(\Delta t)_{xy} = \frac{\varphi_{xy}, S}{2\pi} \tag{3.11}$$

In this study, an attempt is made to show the phase difference in the form of vectors in wavelet dependence diagrams. Vectors that are to the right (x) and y (are in phase) are positively related, while vectors that are to the left, i.e. x and y, are out of phase (or have a negative relationship). mean the progressive-regressive relationships between them, in other words, the difference can show the causal relationship between x and y.

4 Description of data and experimental results

In this study, to check the consistency between the real exchange rate (the data relating to the effective exchange rate linked to the study period were extracted from the World Bank website and after deduction of the inflation rate, they were converted into the real effective exchange rate) and the rental rate (the price of money in the housing market). In Iran, the analysis of the causal relationship between them was used based on the seasonal data of the real effective exchange rate (the first variable) and the rental rate. for the period from spring 1980 to winter 2021. First, the stationarity and co-accumulation of the variables are tested, and then the spectral causality test is used. The existence and direction of causality of the variables are discussed during different periods. Finally, using the wavelet analysis approach, the relationship between the real interest rate and the real exchange rate index is analyzed at different temporal frequencies.

4.1 Mana test of exchange rate and rent growth rate

In this section, due to the seasonal frequency of research data, the stationarity test specific to these data should be used. To this end, the test of Hylleberg et al. [25] known as HEGY was used. The significance level of this test was calculated by Monte Carlo simulation. The results of the Manay test of the variables studied are presented in Table 1.

Table 1: Manai test for monthly search data (Zero hypothesis, real exchange rate growth index, rental rate growth, critical value)

Zero hypothesis	**real exchange rate growth index**	**rental rate growth**	**critical value**
non-seasonal unit root	−5.31	−0.27	−1.93
Unit root (two chapters)	107.88	6.54	8.34
Unit root (three chapters)	−8.79	−7.29	−1.91
Unit root (four chapters)	139.29	23.60	5.99
All frequencies	108.73	17.73	4.99

The results of the Mana test of the variables show that the real exchange rate growth variable is Mana at all frequencies. The rental rate growth variable is unknown in certain frequencies; But considering all frequencies at the same time, this means; However, to ensure the long-term relationship between these two variables, the cointegration test is used. Results of the Engel-Granger cointegration test in Table 2. Provided. According to the results in Table 2, there is at least a long-run equilibrium relationship between the two variables.

Table 2: Investigation of the existence of the co-accumulation vector between the growth of the rental rate and the growth of the real exchange rate index

meaning threshold	**z statistic**	**meaning threshold**	**τ statistic**	**Dependent variable**
0.010	−26.62	0.372	−2.309	Rental rate growth
0.000	−101.06	0.000	−5.33	Growth of the real exchange rate index

4.2 Analysis of the Granger causality test according to frequency

As can be seen in Table 3, the hypothesis of causal relationship in all angular frequencies between two variables is rejected and there is no Granger causal relationship between them.

Table 3: The results of the Granger causality test in the range of different frequencies

Growth in the real exchange rate index is not the Granger cause of rent growth	**Rental rate growth is not the Granger cause of real exchange rate index growth**	**angular frequency**
0.685453	0.4811	0.038547
0.685711	0.484034	0.077094
0.686011	0.489081	0.115641
0.686114	0.496488	0.154189
0.685593	0.506617	0.192736
0.683761	0.519957	0.231283
0.679642	0.537128	0.26983
0.672142	0.55886	0.308377
0.660619	0.585915	0.346924
0.645757	0.618914	0.385471
0.629995	0.658018	0.424019
0.616681	0.702498	0.462566
0.608529	0.75033	0.501113
0.606863	0.798184	0.53966
0.611965	0.842108	0.578207
0.623673	0.878772	0.616754
0.641645	0.906559	0.655302
0.665253	0.925761	0.693849
0.69333	0.937873	0.732396

4.3 Correlation analysis between the exchange rate and the rental growth rate based on a continuous wavelet approach

The basic idea of wavelet correlation is similar to traditional linear correlation. The difference is that wavelet correlation examines the relationship between two time series based on time zone and time interval. Wavelet correlation calculations are based on the transformation of the transverse wavelets and wavelet power spectrum of each time series which is performed in MATLAB software.

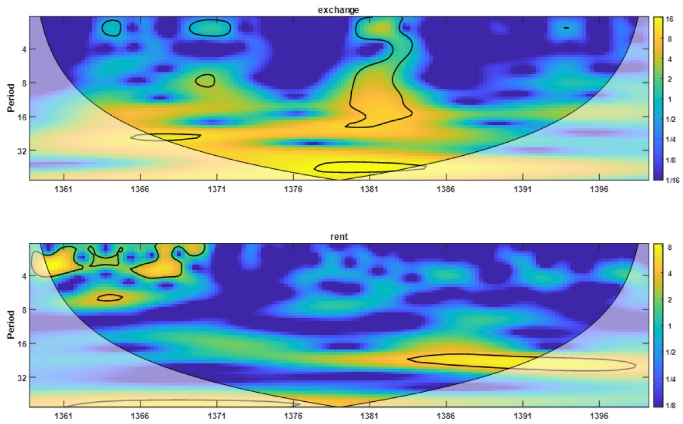

Figure 1: Real exchange rate growth and rental rate growth and their continuous wave power spectrum based on seasonal data

In diagram 1, the power spectrum of the growth wave of the real rate index and the growth of the rental rate is plotted. The thick black line indicates the 95% significance level, and the significant region where they may confound the significance is shown in a lighter shade. The wavelet power spectrum shows the local variance of the time series variable at the time scale and presents the fluctuations of the variance at different frequencies. In Figure 1, areas that are statistically significant at the 5% level are marked with bold black lines; Therefore, in the wavelet power spectrum plot, the points surrounded by bold red and black lines are the areas that have the highest variance or fluctuations in the specified time scale. Additionally, the areas outside the cone-shaped curves are the points whose interpretation is not easily possible and should be interpreted with more caution. As shown in Figure 1, the power spectrum of the rental rate growth wavelet and the growth of the real exchange rate index have similarities. So in the short-term and medium-term frequency, the variance of the two series has increased since the 1370s.

Cross-wavelet transform (XWT) allows detection of correlation strength, phase difference (delay), and non-stationarity. The approach presented here uses a continuous XWT technique with the Morlet wavelet as the parent function. The cross-wavelet power shown in Figure 2 shows areas of high joint power. Another useful measure is the correlation

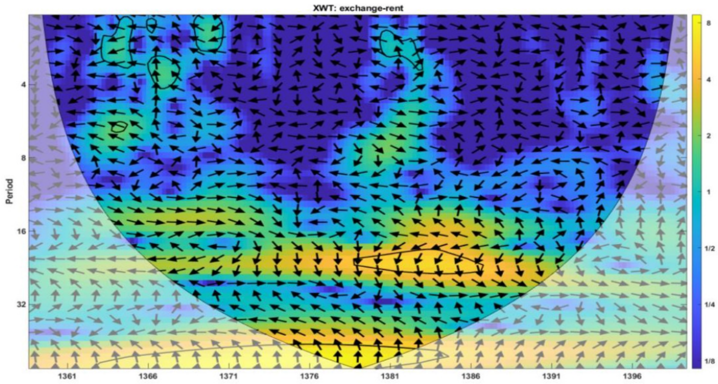

Figure 2: Common wavelet power between real exchange rate index growth and rental rate growth based on seasonal data

between cross-wavelet transforms in time-frequency space. The statistical significance level of wavelet coherence is estimated using the Monte Carlo method. To this end, a large set of alternative data pairs with the same first-order autoregressive coefficients as the input data set is produced. Then, the wavelet coherence is calculated for each pair. Next, we estimate the significance level for each scale using only the values outside the significance space.

Multiple wavelet correlation (coherence) is the same as traditional multiple correlation with the explanation that multiple wavelet correlation extends the traditional concept of correlation to the time interval region; This action results in the discovery of the correlation of time series for different times and intervals. The wavelet correlation of two-time series is defined by their local correlation coefficients in time-frequency space [38]. The wavelet correlation is defined as the square of the wavelet cross-spectrum value and normalized by the smoothed wavelet power for each of the time series. The square of the wavelet correlation is a number between zero and one in time-frequency space; As a result, the wavelet correlation diagram offers the possibility of analysis in three-dimensional space (correlation intensity, frequency and time). Considering that the correlation coefficient in wavelet analysis is between zero and one, using it alone it is not possible to determine the direction of the relationship between two variables, therefore the index called phase shift is proposed here. A zero phase difference indicates that two variables are moving in harmony with each other (opposite of phase difference).

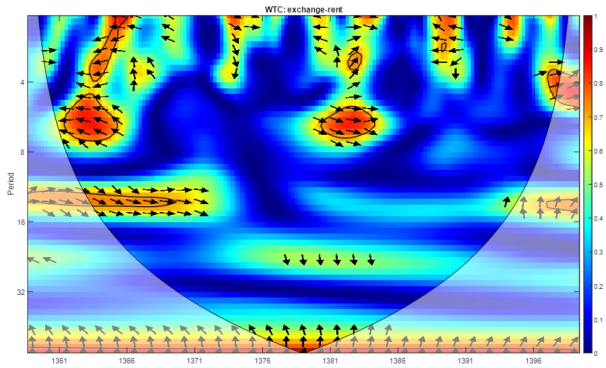

Figure 3: Correlation between real exchange rate index growth and rental rate growth using wavelet approach and seasonal data.

In order to be able to analyze the final diagram (graph 3) resulting from the examination of the compatibility of the exchange rate and rental rate variables, it is necessary to examine the direction of the arrows and how to determine the direction of causality between the variables.

If in the diagram (Figure 4) the arrowhead is vertical or to the right, then the second variable is in phase (direct relationship). Under in-phase conditions, if the arrowhead is upward (positive slope), the first variable is progressive and the second variable is backward (causation of the first variable), it will be the second variable. If the arrowheads are downward (negative slope) in the same phase condition, the second variable will be progressive and the first variable will be regressive. If the arrowhead is to the left, two variables are in phase opposition (opposite relationship). If the arrowhead is to the left and up, the second variable is progressive and the first variable is regressive. If the arrowhead is downward, the first variable will be progressive and the second variable will be regressive. In general, moving from

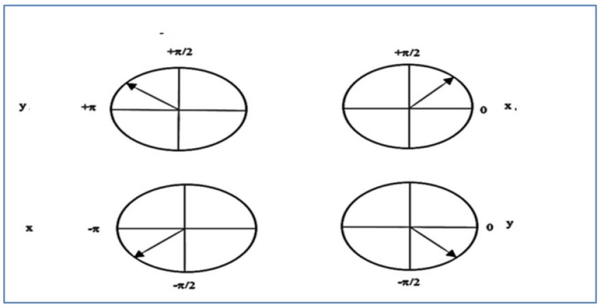

Figure 4: How to determine the direction of causality between variables in wavelet analysis [2]

horizontal to vertical, the impact interval increases [2].

The results of the wavelet correlation of the real exchange rate index growth index and rental rate growth on a seasonal basis are shown in Figure 3. The horizontal axis of this graph indicates the period. In this graph, the period extends from spring 1359 to winter 1400, and depending on the seasonal nature of the data, a total of 164 observations are included in this axis. The vertical axis of these graphs shows the frequency range of the scale (4 seasons at the highest scale of 32 seasons, 8 years). In wavelet analysis, scale and frequency have an opposite relationship, such that a smaller scale corresponds to a higher frequency. Using wavelet correlation analysis, it is possible to find out the relationship of time series in different time intervals. In diagram 3, the high correlation of the time series is marked by warmer colors (red color) and the arrows inside this color spectrum show the correlation of these time series. Additionally, significant correlation distances were specified with dividing lines. Unlike the situation above, areas outside significant distances are marked with a cooler color such as blue, indicating less correlation of the time series.

Based on the results presented in Figure 3- at the short term horizon, there is a strong correlation between the growth of the real exchange rate index and the growth of the rental rate in most periods. two variables are generally greater than 0.8 in the short term.

In the medium term, over the two periods 1362-1365 and 1379-1383, the degree of consistency between the two variables real exchange rate and real rental rate is significant. But the sense of harmony in these two scales is completely opposite to each other. In the time interval 1362-1365, two variables are not in the same phase; The reason for this may be the negative real exchange rate in the mentioned years, because until mid-1968 basic goods were imported at the rate of 7 tomans per dollar. The insistence on keeping the dollar rate low due to the war conditions imposed during these years led to a negative real exchange rate. However, in 1383-1379, following disorder in the currency market and widespread rents caused by multi-rate currency, the Central Bank increased the official exchange rate to 795 tomans. Then, from 1379 to 1389, it increased from 813 tomans to 1100 tomans. The exchange rate adjustment led to the synchronization of the exchange rate and the rental rate in these years.

Also, the results show that in the short term, in most periods, these two variables were not in the same phase, which shows that with the growth of the exchange rate, the rental rate did not necessarily increase in the same period, and its effect was intermittent. Moving from the short term to the medium and long term, the relationship between the growth rate of rents and the growth of the real exchange rate index was phased and a direct relationship was established between the two variables; Specifically, with the increase in the exchange rate, the rental rate has also increased almost proportionally. The main implication of the content of this section is that with an increase in the exchange rate, although in the short term, the rental rate can be controlled to some extent due to certain government policies; But in the medium and long term, policies to repress the rental market are doomed to failure and will not succeed; Because ultimately, the rental market will increase proportionally to the exchange rate.

In the following, for a more comprehensive analysis, the relationship between two variables was studied with the discrete wavelet analysis method.

In this part, the variance and correlation between variables are analyzed using the MODWT function at different frequencies. Diagram 5 shows the estimated variance of wavelets at different scales, the growth of the real exchange rate. As we see, the variances of the growth wave of the real exchange rate evolve over time; As a result, the intensity of changes in the growth of this variable is not constant and decreases after reaching the peak.

As shown in Figure 6, with the change of time, the variances of the growth wave of rental rates tend to decrease, and the frequency of 32 seasons has the lowest variance.

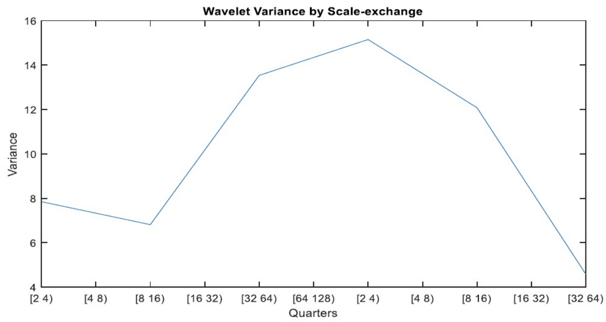

Figure 5: Analysis of the variance of real exchange rate growth at different frequencies

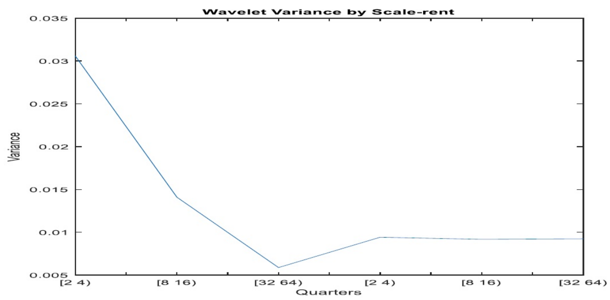

Figure 6: Analysis of the variance of the rental growth rate at different frequencies

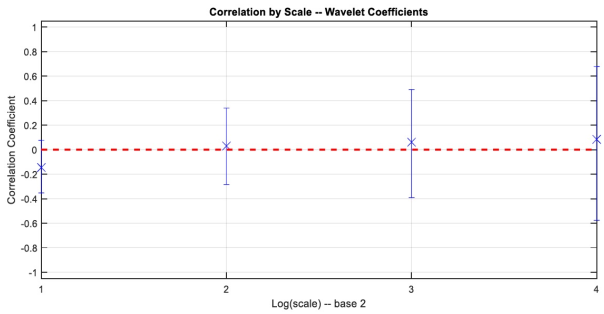

Figure 7: Correlation analysis between real exchange rate growth index and rental rate growth at different frequencies

The correlation between growth in the real exchange rate index and growth in the rental rate is shown in Figure 7. The midpoints of the indicated range of the correlation coefficient and the interval indicate the 95% confidence interval. As we can see, the correlation between two variables is negative in the short term; But by increasing the time scale and moving towards the long term, the correlation coefficient between the two variables changes its sign and there is a direct relationship between the two variables.

5 Conclusion and suggestions

In this study, to examine the relationship between the exchange rate and the rental rate from a wavelet analysis (economic and physical analysis) based on the theory of purchasing power parity in the form of two Completely opposite monetary models, namely the Flexible Price Monetary Model (FPM) to explain the long-term behavior of the exchange rate and the Sticky Residuals Monetary Model. SPM) in which the price of goods is completely sticky has been used to explain the short-run behavior of the exchange rate (the forward equilibrium path of the exchange rate). Wavelets are very capable in dynamic analysis of causal relationship between time series. Since the wavelet length changes optimally in different time scales, it is possible to study short-term causality and long-term causality between economic time series simultaneously. On the other hand, the wavelet transform is a very effective tool to deal with the non-identity properties of time series.

The variables used in this study are the real effective exchange rate and the rental growth rate. One of the alternatives to the interest rate in the Iranian economy is the housing rental rate due to its mandatory nature. The reason for its use is that the natural interest rate is the same as the rental rate of physical capital, and in the Iranian economy the most important element of physical capital is housing, whose rental rate can be a reasonable substitute for the interest rate. Second, in the Iranian economy, the calculation of the rental rate has been based on the unofficial market interest rate. The wavelet correlation results of the real exchange rate growth index and rental rate growth are seasonal for the period from spring 1359 to winter 1400, and according to the seasonality of the data, a total of 164 observations were placed in this axis.

Based on the results obtained in the short term between the growth of the real exchange rate index and the growth of the rental rate, it was observed that there is a high correlation in most of the periods studied, and the intensity of the correlation between the two variables over the short term horizon is generally greater than 0.8. In the medium and long term, in certain periods, the relationship between these two variables was only established during the years 1364 to 1372, and no significant relationship was observed in other years. In higher frequencies and long term, a significant relationship was observed for several years, and in some long term periods these two variables did not have much correlation.

Furthermore, the results indicate that the intensity and direction of the relationship between variables are not constant in the short term and have changed repeatedly. In the short term, in most periods, these two variables were not in the same phase, which shows that with the growth of the exchange rate, the rental rate did not necessarily increase during the same period and its effectiveness has been intermittent. Therefore, since the relationship between the two variables changed frequently in the short term, despite strong consistency. Moving from the short term to the medium and long term, the relationship between the growth rate of rents and the growth of the real exchange rate index was phased and a direct relationship was established between the two variables; Specifically, with the increase in the exchange rate, the rental rate also increased almost proportionally. Generally speaking, the results obtained from the analysis of the relationship between the variables (exchange rate and rental growth rate in Iran) indicate that the intensity and direction of the relationship between the two variables in the short term, over most periods, they were not in phase and had an inverse relationship (Dorenbusch analysis), which confirms the model monetary at sticky prices. In the medium term, the relationship between these two variables was established over several periods, and at higher frequencies and in the long term, a significant relationship was observed over several years, that over most periods, the relationship between the rental growth rate and the real exchange rate index are in sync, and in some periods, the rental growth rate variable is leading and the real exchange rate has declined; Thus, in the medium and long term, we observe to a certain extent a direct relationship between these two variables, which confirms monetary models with flexible prices (purchasing power parity theory).

The content of this section states that with the increase of the exchange rate, although in the short term, the rental rate can be controlled to a certain extent due to certain government policies; But in the medium and long term, policies to repress the rental market are doomed to failure and will not succeed; Because ultimately, the rental market will grow depending on the exchange rate. In the Iranian economy and in the medium and long term, the relationship between the real exchange rate and the rental rate shows that the flexible price monetary model is confirmed, there is adaptability to change. But in the short term, in most maturities, the relationship between the two variables shows that the sticky price monetary model is confirmed. Short-term timescales are those periods where the decision maker is waiting for the impact of the variable and there is not enough time to adjust other variables.

Comparison with previous studies shows that in the short term: the study Drazen and Hubrich [13] in Europe, like the Mundel-Fleming model, which in the short term assumes that there is a negative relationship between the exchange rate and the price of the currency, which confirms to some extent the results of the short-term time horizon of the present study. In the long term: Tafazzoli and et al. [35], Taghavi et al. [36], Tiwari and et al. [37] point out the exchange rate and the price of the currency, which confirms the results of the study in the long term. The study of Dornbusch [11] in the form of two monetary models, a monetary model with sticky prices (short term) and a monetary model with flexible prices (long term), Flood and Taylor [15], Chinn and Meredith [8] studied the relationship between the exchange rate and the price of currency, and the results of the studies show a negative relationship in the short term and a positive relationship in the long term, which confirms the results of the present study, especially in the long term.

The results of examining the relationships between the variables studied show that there are different behaviors in the relationships between the variables at different time horizons. The decision maker should pay attention to both the real exchange rate and the rental rate, while having long term plans to achieve this, he should not neglect the short and medium term plans, which are the main basis of long-term plans. In the Iranian economy and in the 1960s, due to the negative real exchange rate, there is a significant correlation between the exchange rate and the rental rate. But after that and with frequent adjustments, this consistency was lost over time. Therefore, it can be said that the relationship between the exchange rate and the rental rate exists in short-term time scales, but in the long-term time scale, the intensity of consistency will decrease. Policymakers are advised to monitor and control the short-term effects of exchange rate adjustments on rental rates.

Appendix

Table 4: The attachment Manu test for the growth variable of the real exchange rate index
Seasonal Unit Root Test for EXCHANGE
Method: Traditional HEGY
Null Hypothesis: Unit root at specified frequency
Periodicity (Seasons): 4
Non-Seasonal Deterministics: None
Seasonal Deterministics: None
Lag Selection: 0 (Automatic: SIC, maxlags=12)
Sample Size: 159

		Significance Level		
	Test Stat.	1%	5%	10%
Frequency 0	-5.315369			
n=140		-2.55	-1.93	-1.60
n=160		-2.55	-1.91	-1.60
n=159*		-2.55	-1.91	-1.60
Frequency 2PI/4 and 6PI/4	107.8827			
n=140		30.48	8.15	3.77
n=160		30.50	8.34	3.87
n=159*		30.49	8.33	3.86
Frequency PI	-8.791184			
n=140		-2.55	-1.93	-1.60
n=160		-2.55	-1.91	-1.60
n=159*		-2.55	-1.91	-1.60
All seasonal frequencies	139.2898			
n=140		21.05	5.90	2.94
n=160		21.05	5.99	3.07
n=159*		21.05	5.98	3.06
All frequencies	108.7315			
n=140		16.28	4.94	2.90
n=160		16.52	4.99	2.98
n=159*		16.51	4.99	2.97

*Note: Obtained using linear interpolation.

Dependent Variable: EXCHANGE-EXCHANGE(-4)
Method: Least Squares
Date: 07/04/22 Time: 22:14
Sample (adjusted): 1360Q2 1399Q4
Included observations: 159 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OMEGA(0)	-0.085448	0.016076	-5.315369	0.0000
OMEGA(2PI/4)	-0.796979	0.063342	-12.58217	0.0000
OMEGA(6PI/4)	-0.228442	0.063180	-3.615749	0.0004
OMEGA(PI)	-0.448790	0.051050	-8.791184	0.0000

R-squared	0.737101	Mean dependent var	0.243900
Adjusted R-squared	0.732012	S.D. dependent var	10.08993
S.E. of regression	5.223304	Akaike info criterion	6.168973
Sum squared resid	4228.850	Schwarz criterion	6.246178
Log likelihood	-486.4333	Hannan-Quinn criter.	6.200325
Durbin-Watson stat	1.880435		

Table 5: Manai test for the rent rate growth variable
Seasonal Unit Root Test for RENT
Method: Traditional HEGY
Null Hypothesis: Unit root at specified frequency
Periodicity (Seasons): 4
Non-Seasonal Deterministics: None
Seasonal Deterministics: None
Lag Selection: 9 (Automatic: SIC, maxlags=12)
Sample Size: 150

		Significance Level		
	Test Stat.	1%	5%	10%
Frequency 0	-0.275079			
n=140		-2.55	-1.93	-1.60
n=160		-2.55	-1.91	-1.60
n=150*		-2.55	-1.92	-1.60
Frequency 2PI/4 and 6PI/4	6.544247			
n=140		30.48	8.15	3.77
n=160		30.50	8.34	3.87
n=150*		30.49	8.24	3.82
Frequency PI	-7.293521			
n=140		-2.55	-1.93	-1.60
n=160		-2.55	-1.91	-1.60
n=150*		-2.55	-1.92	-1.60
All seasonal frequencies	23.59891			
n=140		21.05	5.90	2.94
n=160		21.05	5.99	3.07
n=150*		21.05	5.94	3.00
All frequencies	17.72976			
n=140		16.28	4.94	2.90
n=160		16.52	4.99	2.98
n=150*		16.40	4.97	2.94

*Note: Obtained using linear interpolation.

Dependent Variable: RENT-RENT(-4)
Method: Least Squares
Date: 07/04/22 Time: 22:17
Sample (adjusted): 1362Q3 1399Q4
Included observations: 150 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OMEGA(0)	-0.003568	0.012971	-0.275079	0.7837
OMEGA(2PI/4)	-0.351926	0.097327	-3.615903	0.0004
OMEGA(6PI/4)	-0.000301	0.101623	-0.002965	0.9976
OMEGA(PI)	-0.481871	0.066068	-7.293521	0.0000
DEP(-1)	-0.300709	0.116084	-2.590448	0.0106
DEP(-2)	0.247012	0.097849	2.524415	0.0127
DEP(-3)	-0.240658	0.087357	-2.754877	0.0067
DEP(-4)	0.085231	0.088294	0.965306	0.3361
DEP(-5)	-0.278429	0.087008	-3.200052	0.0017
DEP(-6)	0.262947	0.065969	3.985929	0.0001
DEP(-7)	-0.006893	0.065097	-0.105892	0.9158
DEP(-8)	0.031792	0.064830	0.490389	0.6246
DEP(-9)	-0.373857	0.064994	-5.752166	0.0000

R-squared	0.618807	Mean dependent var	0.082897
Adjusted R-squared	0.585418	SD dependent var	4.144902
SE of regression	2.668820	Akaike info criterion	4.883829
Sum squared reside	975.7965	Schwarz criterion	5.144751
Log likelihood	-353.2872	Hannan-Quinn critic.	4.989833
Durbin-Watson stat	1.956924		

Table 6: Cointegration test between rental rate growth and real exchange rate index growth
Date: 07/04/22 Time: 22:18
Series: RENT EXCHANGE
Sample (adjusted): 1359Q2 1399Q4
Included observations: 163 after adjustments
Null hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C
Automatic lags specification based on Schwarz criterion (maxlag=13)

Date: 07/04/22 Time: 22:18
Series: RENT EXCHANGE
Sample (adjusted): 1359Q2 1399Q4
Included observations: 163 after adjustments
Null hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C
Automatic lags specification based on Schwarz criterion (maxlag=13)

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
RENT	-2.309008	0.3722	-26.62584	0.0104
EXCHANGE	-5.332883	0.0001	-101.0568	0.0000

*MacKinnon (1996) p-values.

Intermediate Results:

	RENT	EXCHANGE
Rho - 1	-0.412150	-0.347337
Rho S.E.	0.178497	0.065131
Residual variance	6.874765	27.82909
Long-run residual variance	1.275177	93.18222
Number of lags	12	3
Number of observations	150	159
Number of stochastic trends**	2	2

**Number of stochastic trends in asymptotic distribution

Table 7: Granger Spectral Causality Test

0.038547	0.481100	0.685453
0.077094	0.484034	0.685711
0.115641	0.489081	0.686011
0.154189	0.496488	0.686114
0.192736	0.506617	0.685593
0.231283	0.519957	0.683761
0.269830	0.537128	0.679642
0.308377	0.558860	0.672142
0.346924	0.585915	0.660619
0.385471	0.618914	0.645757
0.424019	0.658018	0.629995
0.462566	0.702498	0.616681
0.501113	0.750330	0.608529
0.539660	0.798184	0.606863
0.578207	0.842108	0.611965
0.616754	0.878772	0.623673
0.655302	0.906559	0.641645
0.693849	0.925761	0.665253
0.732396	0.937873	0.693330
0.770943	0.944576	0.724064
0.809490	0.946958	0.755207
0.848037	0.945168	0.784573
0.886584	0.938441	0.810560
0.925132	0.925393	0.832422
0.963679	0.904526	0.850216
1.002226	0.874874	0.864535
1.040773	0.836581	0.876212
1.079320	0.791198	0.886093
1.117867	0.741467	0.894909
1.156414	0.690663	0.903218
1.194962	0.641790	0.911394
1.233509	0.596991	0.919639
1.272056	0.557329	0.928006
1.310603	0.522887	0.936430
1.349150	0.493023	0.944768
1.387697	0.466642	0.952840
1.426245	0.442423	0.960466
1.464792	0.419024	0.967499
1.503339	0.395284	0.973837
1.541886	0.370453	0.979423
1.580433	0.344406	0.984229
1.618980	0.317751	0.988228
1.657527	0.291745	0.991365
1.696075	0.268013	0.993519
1.734622	0.248203	0.994478
1.773169	0.233753	0.993906
1.811716	0.225870	0.991333
1.850263	0.225657	0.986163
1.888810	0.234212	0.977707
1.927357	0.252497	0.965287
1.965905	0.280837	0.948368
2.004452	0.318186	0.926738
2.042999	0.361785	0.900631
2.081546	0.407851	0.870732
2.120093	0.453086	0.838004
2.158640	0.495896	0.803373
2.197188	0.536541	0.767442
2.235735	0.576437	0.730398
2.274282	0.617241	0.692218
2.312829	0.660071	0.653155
2.351376	0.704927	0.614267
2.389923	0.750308	0.577599
2.428470	0.793162	0.545693
2.467018	0.829386	0.520620
2.505565	0.854922	0.503194
2.544112	0.867092	0.492894
2.582659	0.865488	0.488350
2.621206	0.851947	0.487951
2.659753	0.829722	0.490245
2.698300	0.802418	0.494101
2.736848	0.773190	0.498714
2.775395	0.744382	0.503546
2.813942	0.717514	0.508256
2.852489	0.693440	0.512634
2.891036	0.672549	0.516559
2.929583	0.654945	0.519963
2.968130	0.640573	0.522814
3.006678	0.629307	0.525096
3.045225	0.621008	0.526806
3.083772	0.615551	0.527944

References

[1] L. Aguiar-Conraria, N. Azevedo and M.J. Soares, *Using wavelets to decompose the time-frequency effects of monetary policy*, Phys. A: Stat. Mech. Appl. **387** (2008), 2863–2878.

[2] L. Aguiar-Conraria and M.J. Soares, *The Continuous Wavelet Transform: A Primer (No. 23/2010)*, NIPE-Universidade do Minho, 2010.

[3] C.C. Bautista, *Interest rate-exchange rate dynamics in the Philippines: A DCC analysis*, Appl. Econ. Lett. **10** (2003), 107–111.

[4] W.H. Branson, *Macroeconomic determinants of real exchange rates*, R.J. Herring (Ed.), Managing Foreign Exchange Risk, Cambridge University Press, Cambridge, 1983.

[5] W.H. Branson and H. Halttunen, *Asset-market determination of exchange rates: Initial empirical and policy results*, J.P. Martin and A. Smith (Eds.), Trade and payments adjustment under flexible exchange rates, Macmillan, London, 1979.

[6] W.H. Branson, H. Halttunen, and P. Masson, *Exchange rates in the short run: The Dollar-Deutschemark rate*, Eur. Econ. Rev. **10** (1977), 303–324.

[7] P. Caraiani, *Stylized facts of business cycles in a transition economy in time and frequency*, Econ. Model. **29** (2012), no. 6, 2163–2173.

[8] M.D. Chinn and G. Meredith, *Testing uncovered interest parity at short and long horizons during the post-Bretton Woods era*, National Bureau of Economic Research, working paper, 2005.

[9] I. Choi and D. Park, *Causal relation between interest and exchange rates in the Asian currency crisis*, Japan World Econ. **20** (2008), no. 3, 435–452.

[10] İ. Demir, *Monetary policy responses to the exchange rate: empirical evidence from the ECB*, Econ. Model. **39** (2014), 63–70.

[11] R. Dornbusch, *Expectations and exchange rate dynamics*, J. Politic. Econ. **84** (1976), 1161–1176.

[12] R. Dornbush, S. Fischer and R. Startz, *Macroeconomics*, McGraw-Hill, 2011.

[13] A. Drazen and S. Hubrich, *A simple test of the effect of interest rate defense*, J. Jpn. Int. Econ. **20** (2006), 612–636.

[14] E. Eichanbaum and C.L. Evans, *Some empirical evidence on the effects of shocks to monetary policy on exchange rates*, Q. J. Econ. **110** (1995), 975–1009.

[15] R.P. Flood and M.P. Taylor, *Exchange rate economics: what's wrong with the conventional macro approach?*, The microstructure of foreign exchange markets, University of Chicago Press, 1996.

[16] A. Frankel, *On the Mark: A theory of floating exchange rates based on real interest differentials*, Amer. Econ. Rev. **69** (1979), no. 4, 610–622.

[17] R. Gençay, F. Selçuk and B.J. Whitcher, *An Introduction to Wavelets and Other Filtering Methods in Finance and Economics*, Elsevier, 2001.

[18] H. Ghaffari, M. Saadat Mehr, M.R. Ranjbarfalah, and A. Souri, *Investigation on the effect of increasing the interest rate of banking facilities on the economic growth of Iran in the form of a new Keynesian stochastic dynamic model of general equilibrium*, Sci. Res. Quart. Econ. **10** (2013), no. 1, 1–31.

[19] B. Granville and S. Mallick, *Monetary policy in Russia: identifying exchange rate shocks*, Econ. Model. **27** (2010), 432–444.

[20] R.S. Hacker, H.K. Karlsson and K. Månsson, *An investigation of the causal relations between exchange rates and interest rate differentials using wavelets*, Int. Rev. Econ. Financ. 29 (2014), 321–329.

[21] V.V. Hnatkovska, A. Lahiri and C.A. Vegh, *The exchange rate response puzzle*, Available at SSRN 1996693, (2012).

[22] O. Holtemöller and S. Mallick, *Exchange rate regime, real misalignment and currency crises*, Econ. Model. **34** (2013), 5–14.

[23] O. Holtemöller and S. Mallick, *Global food prices and monetary policy in an emerging market economy: the case of India*, Asian J. Econ. **46** (2016), 56–70.

[24] L. Hudgins, A. Carl Friehe and E. Meinhard Mayer, *Wavelet transforms and atmopsheric turbulence*, Phys. Rev. Lett. **71** (1993), 3279.

[25] S. Hylleberg, R.F. Engle, C.W. Granger and B.S. Yoo, *Seasonal integration and cointegration*, J. Econ. **44** (1990), 215–238.

[26] A. Khajeh Mohammadlou and H. Khodavaisi, *The relationship between the exchange rate, inflation and interest rates under Fisher's theories approach for Iran*, Appl. Econ. Stud. Iran (Appl. Econ. Stud.) **6** (2017), no. 24, 199–221.

[27] S.K. Mallick and R.M. Sousa, *Real effects of monetary policy in large emerging economies*, Macroecon. Dyn. **16** (2012), 190–212.

[28] Y. Nademi and R. Khochiany, *Co-movement of stock, currency and gold markets in Iranian economy from coherence analysis and econophysical approach*, J. Financ. Eng. Secur. Manag. **8** (2016), no. 31, 149–166.

[29] Y. Nademi and R. Khochiany, *Considering the relationship between the housing sector and some macroeconomic variables of Iran: The Wavelet coherency approach*, J. Econ. Model. **2** (2018), no. 4, 85–106.

[30] S.J. Pourmoqim, *International economics (2)*, Tehran, Samt Publications, 2014. [In Persian]

[31] J.B. Ramsey and C. Lampart, *Decomposition of economic relationships by timescale using wavelets*, Macroecon. Dyn. **2** (1998), no. 1, 49–71.

[32] C. Schleicher, *An Introduction to Wavelets for Economists*, No. 2002-3. Bank of Canada, 2002.

[33] A. Sensoy and C. Sobaci, *Effects of volatility shocks on the dynamic linkages between exchange rate, interest rate and the stock market: the case of Turkey*, Econ. Model **43** (2014), 448–457.

[34] H. Shajari and K. Nasrallahi, *International Finance and the Course of Iran's Currency Developments*, Tehran, Shabak Publishing House, 2008. [In Persian]

[35] F. Tafazzoli, *Macroeconomics, Economic Theory and Policies*, Tehran, Nashr-e-Ney, 2016. [In Persian]

[36] M. Taghavi, A. Kahram, and P. Salatin, *Investigation of the contribution of exchange rate changes to exchange rate instability in Iran*, Econ. Res. J. **27** (2016), no. 7, 15–50.

[37] A.K. Tiwari, M. Mutascu, and A.M. Andrieș, *Decomposing time-frequency relationship between producer price and consumer price indices in Romania through wavelet analysis*, Econ. Model. **31** (2020), 151–159.

[38] C. Torrence and G.P. Compo, *A practical guide to wavelet analysis*, Bull. Amer. Meteorol. Soc. **79** (1998), 61–78.

[39] J.S. Walker, *A Primer on Wavelets and Their Scientific Applications*, CRC Press, 2020.