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Frequency domain approach and short run and long run causality test: Evidence from Turkey for interest rate and exchange rate relationship

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Abstract

Relationship between short term nominal interest rates and nominal exchange rates that the Central Bank in Turkey used as a means of monetary policy tool during the period of 1987:1-2008:1 was analysed by using frequency domain approach within the framework of spectral analysis. According to the findings, the causal relationship from the exchange rate to the interest rate was valid only for the short run, whereas this relationship was effective for totally 45 months before, during and after the crisis. The causal relationship was seen between the $\omega \in (1.49, 1.94)$ frequencies However, in the long run this effect left its place to interest rates.

Key words: Causality, spectral analysis, frequency domain, exchange rate, interest rate.

Jel classification: E52.

1. Introduction

This study, investigating the relationship between the monetary policy and exchange rate applied during the period of 1987:1-2008:1 in Turkey within the framework of spectral analysis, has been organized under five headings: in the second part of the study, the literature has been given and in the third part the method applied has been defined in detail. In the fourth part, estimation results have been explained. In the last part, a general evaluation of the study and suggestions has been presented. In addition importance of this study a new causality test based on frequency domain is introduced and determining of timing causality between interest and exchange rate variables.

The approaches to determine exchange rates were put forward in the early 1970s in the modern sense and can be presented under two main headings as contemporary approaches. The first one is monetary approach and the next one is portfolio balance approach. Monetary approach is divided within itself as flexible-price monetary approach, inflexible-price monetary approach and real interest rate differences monetary approach (Macdonald ve Taylor; 1992:2).

The interest-exchange rate relationship usually changes according to whether the level of prices is flexible or not. Under the Chicago Approach the studies related to the announcement of exchange rates have been carried out assuming that the level of prices is completely flexible. As a result of the assumption that prices are perfect flexible, the changes in the nominal interest rates will reflect the changes in the expected inflation rates (Frankel; 1979:610). If domestic interest rates are relatively higher than international interest rates, depending on the size of the reaction that demand for money shows to interest rates, demand for money decreases and national currency depreciates, so exchange rate appreciates. According to the Keynesian Approach, since the prices are not flexible, the change in the nominal interest rates will show the expansionary or contractionary change in the monetary policy. An increase in the interest rates will cause the foreign capital to enter the country and therefore, a decrease will be observed in the exchange rate. According to the Chicago approach, while the correlationship between the interest and the exchange rates is positive, it is negative in the Keynesian approach. Macroeconomic indicators affecting the exchange rate also determine the level of interest. Income effect can be listed as the effect of the level of prices and effect of the expected inflation (Mishkin; 2004:113). Particularly, it is quite difficult to determine the direction of the relationship between the interest and exchange rate during the periods of crisis[1].

The longstanding relationship between the interest rates and inflation rates enables interest and exchange rate interaction. That the changes in the interest rates have been determined as the source of the expected change in the interest rates brings the Fisher hypothesis to the mind (Strauss and Terrell; 1995:1047). According to this hypothesis, nominal interest rates consist of the sum of the expected inflation rates and the real interest rates and it is accepted that nominal interest rates have a direct relationship with inflation. In other words, since long term growth in the money supply will exactly cause an adaptation in inflation and nominal interest rates, real interest rates will remain constant in the long run (Çakmak ve Aksu; 2002:32). Such a result arises since there is no relationship between real interests and the inflation rate. A close relationship is observed between the

[1] See Furman *et al*. (1998) for detailed information.

Fisher hypothesis and exchange rates. When the domestic real interest rate is inclined to increase, national currency will appreciate and the exchange rate will depreciate. Similarly, due to the increase in the expected inflation, increasing interest rates will cause national currency to depreciate and the exchange rate to appreciate. The phenomenon to be paid attention here is the computation of the interest rate to as nominal or real term. Taylor hypothesis, which brought a different approach to the interest-exchange rate relationship and its modified extensions, can also be considered. The Taylor Rule (modified) consists of the applications used to eliminate the balance problem arising due to the deviation of the production or inflation rates from the long term balance values by means of the optimal short term interest rate determined by the monetary authority. This rule requires the adaptation of the interest rates resulting from the deviation of the exchange rates from the target values (Erdoğan ve Abasız, 2008:1). Within the scope of the rule-based monetary policy, the existence of a causality relationship from the exchange rate to the interest rate is expected.

2. Literature survey

It is remarkable that the studies to determine the direction of the relationship between the interest and exchange rate have generally been carried out for the periods of crisis depending on the price elasticity. The other studies cover the pre-, during- and post-crisis periods depending on the quality of the monetary policy applied.

Karaca (2005), in his study, investigated the relationship between interest and exchange rate in the short and long run with the monthly data belonging to the period of 1990:1-2005:7 for the Turkish economy by using the ARDL method. During the related period, since no significant relationship was found between the interest and exchange rate, the period of analysis was limited with the period of 2001:3-2005:7 in which floating exchange rate system was applied, and positive and statistically significant relationships were found between the variables in the short and long run.

Gould and Kamin (2000), in their study, examined the effects of monetary policy during the financial crisis period on the exchange rate by using monthly data with the Granger causality test by comparing five countries[2] which were affected by the Asia crisis with Mexico. According to the findings, it was determined that the interest rate had no effect on the exchange rate. Also, that the exchange rate affected the interest rate in a single way and positively for Mexico is among the other findings of the study.

Akçağlayan (2007), by using daily data for Turkish economy, tested the effect of monetary policy for the 2001 crisis and the aftermath on the exchange rate by using error correction model. According to the test results,

[2] Indonesia, Korea, Malesia, Phillippines, and Tailand.

a one way causality relationship was obtained from the interest rate to the exchange rate during the period of the crisis and revisionist view was supported.

Gül *et al*. (2007), in their study, investigated the relationship between the nominal exchange rate and interest rates for the Turkish economy by using Granger causality test. The main result was that there was a one way causality relationship from the exchange rate to the interest rate. Also, Gümüş (2002) in his study determined that an increase in the interest rate during the 1994 crisis would increase the exchange rate by using VECM method.

Narayan and Smyth (2006), in their study, tested the short and long run interest rate[3] – exchange rate relationship for the periods of 1980-2002 for the Chinese economy by using monthly data under the ARDL method. In the long run, real exchange rate had positive and significant effect on the foreign exchange reserves, but the variable for the interest rates difference was not statistically found significant. Additionally, the other findings in the study showed that real interest rate, interest rate differences and reserves had a flat (monotonous) relationship.

3. Theoretical model: Short and long-run causality test: Frequency domain approach

Geweke (1982) and Hosoya (1991) suggested a causality measurement for the frequencies having a characteristic based on the decomposition of the spectral density functions.Yao and Hosoya (2000) developed Wald-type causality test when data was a specific frequency level that envisaged the nonlinear limitations based on autoregressive parameters in order to measure causality. They stated the procedure by using bivariant vector autoregressive (VAR) model and linear limitations on the autoregressive coefficients. The stated procedure, as expressed in Yao and Hosoya (2000), is the Delta method. This test process can be generalized as high dimension systems that allow the cointegration relationship. First, let's define $z_t = [x_t, y_t]$ vector till t=1,…,T, where z_t shows an infinite VAR system.

$$\Theta(L) z_t = \varepsilon_t \qquad (1)$$

where $\Theta(L) = I - \Theta_1 L - ... - \Theta_p L^p$, $L^k z_t = z_{t-k}$ and 2x2 sized lagged polynom equation. Error vector is ε_t white noise is E(ε_t)=0 and $\mathrm{E}(\varepsilon\varepsilon') = \sum$. Here, $\sum$ is a positively defined value. With Cholesky decomposition, G low triangular matrix is $\mathrm{G}'\mathrm{G} = \sum^{-1}$ and its expected value is $\mathrm{E}(\eta_t \eta_t') = I$, where $\eta_t = \mathrm{G}\varepsilon_t$. Under the assumption that the system is stationary, MA process can be shown as follows.

[3] Interest rate differences of the American and Chinese economies were considered…

$$z_t = \Phi(L)\varepsilon_t = \begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} =$$

$$\Psi(L)\eta_t = \begin{bmatrix} \Psi_{11}(L) & \Psi_{12}(L) \\ \Psi_{21}(L) & \Psi_{22}(L) \end{bmatrix} \begin{bmatrix} \eta_{1t} \\ \eta_{2t} \end{bmatrix} \qquad (2)$$

where $\Phi(L) = \Theta(L)^{-1}$ and $\Psi(L) = \Phi(L)\mathrm{G}^{-1}$. By using these equations, spectral density function can be written as follows:

$$f_x(\omega) = \frac{1}{2\pi}\{|\Psi_{11}(\mathrm{e}^{-i\omega})|^2 + |\Psi_{12}(\mathrm{e}^{-i\omega})|^2\}$$

If the measurement of causality as determined in Geweke (1982) is $|\Psi_{12}(\mathrm{e}^{-i\omega})|=0$ in any ω frequency according to the equation

$$\mathrm{M}_{y \to x}(\omega) = \log\left[\frac{2\pi f_x(\omega)}{|\Psi_{11}(\mathrm{e}^{-i\omega})|^2}\right] \qquad (3)$$

$$= \log\left[1 + \frac{|\Psi_{12}(\mathrm{e}^{-i\omega})|^2}{|\Psi_{11}(\mathrm{e}^{-i\omega})|^2}\right] \qquad (4)$$

no causality relationship from the variable y to the variable x will be found since log(1)=0. If the elements of z_t are I(1) and cointegrated, autoregressive polynom will have $\Theta(L)$ unit root and the roots of the polynom will remain outside the unit circle. For this, if z_{t-1} is taken out of both sides of the equation 1,

$$\Delta z_t = (\Theta_1 - I)z_{t-1} + \Theta_2 z_{t-2} + \ldots + \Theta_p z_{t-p} + \varepsilon_t$$

$= \tilde{\Theta}(L)z_{t-1} + \varepsilon_t$, where $\tilde{\Theta}(L) = \Theta_1 - I + \Theta_2 L + \ldots + \Theta_p L^p$. If y is not the cause of x according to Granger, the elements of $\Theta(L)$ or $\tilde{\Theta}(L)$ are equal to zero. By orthogonalizing causality measurement MA[4] process by means of frequency domain approach,

$$\Delta z_t = \tilde{\Phi}(L)\varepsilon_t$$

$= \tilde{\Psi}(L)\eta_t$, where $\tilde{\Psi}(L) = \tilde{\Phi}(L)\mathrm{G}^{-1}$, $\eta_t = \mathrm{G}\varepsilon_t$ and G is low triangular matrix and $\mathrm{E}(\eta_t\eta_t') = I$. It should be noted here that in the cointegrative bivariant systems $\beta'\tilde{\Psi}(1) = 0$, where β is cointegrative vector and $\beta' z_t$ has a stationary process. In the stationary process, causality measurement is possible with the equation 7.

[4] Coefficients are computed with Fourier transformation.

$$\mathrm{M}_{\mathrm{y}\to\mathrm{x}}(\omega)=\log\left[1+\frac{|\tilde{\Psi}_{12}(\mathrm{e}^{-\mathrm{i}\omega})|^2}{|\tilde{\Psi}_{11}(\mathrm{e}^{-\mathrm{i}\omega})|^2}\right] \tag{7}$$

In his study, Hosoya (2001) tested causality relationship by Hilbert Space Approach after the addition of different variables in the higher systems to the model. Let's measure the causality relationship of the variable $y_t=[y_{1t},y_{2t},y_{3t}]'$ y_1 on y_2 variable on a three dimensional system. For this, in the Hilbert space $H(y_{1t},y_{2t},y_{t-1},y_{t-2},...)$, let w_t be the vector covering the errors obtained from the projection or projection matrix. If in the $H(w_t,w_{t-1},....)$ space, $u_t(v_t)$ projection error terms obtained from $y_{1t}(y_{2t})$ projection are shown in the matrix format,

$$\begin{bmatrix}\Delta y_{1t}\\ \Delta y_{2t}\\ \Delta y_{3t}\end{bmatrix}=\begin{bmatrix}\Psi_{11}(L) & \Psi_{12}(L) & \Psi_{13}(L)\\ \Psi_{21}(L) & \Psi_{22}(L) & \Psi_{23}(L)\\ \Psi_{31}(L) & \Psi_{32}(L) & \Psi_{33}(L)\end{bmatrix}\begin{bmatrix}\eta_{1t}\\ \eta_{2t}\\ \eta_{3t}\end{bmatrix}$$

then $u_t=\Psi_{11}(L)\eta_{1t}+\Psi_{12}(L)\eta_{2t}$ and $v_t=\Psi_{21}(L)\eta_{1t}+\Psi_{22}(L)\eta_{2t}$. Hosoya (2001) showed the measurement of causality between the vectors u_t ve v_t as it was tested in the two dimension system. $\mathrm{M}_{y_1\to y_2|y_3}(\omega)=\mathrm{M}_{u\to v}(\omega)$. Causality relationship can be tested as in the dual system by subjecting such high degree systems to such a transformation. When $|\tilde{\Psi}_{11}(\mathrm{e}^{-\mathrm{i}\omega})|$ and $|\tilde{\Psi}_{12}(\mathrm{e}^{-\mathrm{i}\omega})|$ parameters are tried to be estimated by means of delta method which was developed by Yao ve Hosoya (2000), nonlinear VAR parameter and coefficients will be seen. In order to overcome this difficulty, Breitung and Candelon (2006) eliminated this problem by putting lineer limitations in their works (frequency domain approach). $\mathrm{M}_{\mathrm{y}\to\mathrm{x}}(\omega)$=0, that is, if there is no causality relation from y to x in the ω frequency, $|\Psi_{12}(\mathrm{e}^{-\mathrm{i}\omega})|$ value is zero. By using $\Psi(L)=\Theta(L)^{-1}G^{-1}$, $\Psi_{12}(L)=-\dfrac{g^{22}\Theta_{12}(L)}{|\Theta(L)|}$ is obtained, where g^{22} is low diagonal elements of G^{-1} matrix, $|\Theta(L)|$ is the determinant value of $\Theta(L)$. The hypothesis questioning whether y is the cause of x when $\theta_{12,k}$ shows the (1,2) elements of Θ_k matrix is tested as follows.

$|\Theta_{12}(\mathrm{e}^{-iw})|=\left|\sum_{k=1}^{p}\theta_{12,k}\cos(k\omega)-\sum_{k=1}^{p}\theta_{12,k}\sin(k\omega)i\right|=0$. This equation is a sufficient condition to have $|\Theta_{12}(\mathrm{e}^{-iw})|=0$

$$\sum_{k=1}^{p}\theta_{12,k}\cos(k\omega)=0 \tag{10}$$

$$\sum_{k=1}^{p} \theta_{12,k} \sin(k\omega) = 0 \quad (11)$$

In the constraint function numbered 11, this can be excluded since $\sin(k\omega) = 0$ in each frequency of zero and π value.

4. Data source and empirical results

The concepts of feedback and dependency are often referred in the discussion focus of the relationship between the time series. In the determination of these concepts underlies the process of obtaining information related to the definition of the characteristics of an estimated econometric model or the definition and use of the relationship between the two series.

The data used in this study is quarterly data and covers the period of 1987:1-2008:1. In addition, in the study, it was aimed to examine the direction and dimension of the relationship between short term nominal interest rates and nominal exchange rates within the scope of the monetary policy tool that the Central Bank applied as a means of politicy in Turkey during the related period within the framework of spectral analysis. In this stage, overnight interest rate (ON=i) and exchange rate (KUR= μ) variables were used in the model. The data were compiled from IMF-IFS, Central Bank of the Republic of Turkey EVDS and the other statistical resources. Unlike the other tests, with the frequency domain approach which has brought a different point of view, the short and long run causal relationship can be seen simultaneously without a need for a different test. In order for the test to be applied, the variables used in the model must be stationary. Single-break and multiple-break tests were used for stationarity.

4.1. Testing stationarity

During the analysis period, structural changes take place because of economic crises, technological shocks, changes in the nominal exchange rate by devaluation, policy and regime changes. As a result of this changes observed in Turkish economy, it is quite difficult to eliminate and show the effects of the shocks the series were exposed to by means of unit root tests. In case of structural change in the variables, classical unit root tests lose their validity and the possibility to accept the null hypothesis increases. In this respect, Zivot-Andrews single break, Lumsdaine-Papell double break, Bai-Perron multiple break test results that determine the breaking time endogenously and make an estimated break in the trend function possible have been shown below. Because it is not appropriate to research the cointegration relationship for structural break trend stationary series. Instead, application of causality test will provide more realistic results after the series are cleared of from the trend by taking into consideration the breaking period in which structural change occurs.[5] Unit root tests have been used as follows. Zivot and Andrew (1992:253 ve 254) was obtained by using the equations 1, 2, 3 for which Perron determined the break exogenously together with the equations number $1'$, $2'$ and $3'$ for which the break was determined endogenous.

Tablo 1

Zivot-Andrews Single-Break Test Results

Variable	Model	μ	β_t	DU_t	$D(TB)_t$	$D(T)_t$	α	TB	delay	Critical values 1%	Critical values 5%
Interest	**Fixed**	54.4765	-1.1167	46.6333	-	-20.9703	-0.6987	1994:1	1	-4.39	-3.76
	t-statistics	**5.6559**	**-4.6621**	**4.0274**	-	-0.8749	**-6.4648**				
	Trend	33.7213	0.7975	28.1764	-1.9971		-0.7619	1993:3	1	-4.51	-3.87
	t-statistics	**3.1718**	**1.1186**	**2.4681**	**-2.5631**		**-6.8722**				
	Fixed trend	28.5996	1.6087	-0.1462	-2.8097	48.4539	-0.8108	1995:3	1	-4.78	-4.17
	t-statistics	**3.123**	**2.8755**	-0.0141	**-4.1117**	1.7875	**-7.0391**				
	Fixed*						-4.712	1994:2	2	-5.34	-4.80
	trend*						-4.821	1994:4	2	-4.93	-4.42
	Fixed trend*						**-5.721**	1994:2	2	-5.57	-5.08
Exchange Rate	**Fixed**	42.9063	0.7487	-20.267		21.2566	-0.496	1994:2	1	-4.39	-3.76
	t-statistics	**5.55**	**5.6274**	**-4.5916**		**2.3825**	**-5.7092**				
	trend	43.8526	0.6931	-19.801	0.0642		-0.4972	1994:2	1	-4.51	-3.87
	t-statistics	**5.2851**	**3.0214**	**-4.1967**	0.3019		**-5.7209**				
	Fixed trend	44.0092	0.6776	-19.608	0.0799	21.5021	-0.4974	1994:1	1	-4.78	-4.17
	t-statistics	**5.2534**	**2.8104**	**-4.0753**	0.3546	**2.3896**	**-5.6876**				
	Fixed*						**-5.746**	1994:3	1	-5.34	-4.80
	trend*						-4.416	2002:2	1	-4.93	-4.42
	Fixed trend*						**-5.721**	1994:3	1	-5.57	-5.08

Note: Coefficients in bold show that the related variable is statistically different from zero. Those marked with * were computed by using the equations $1'$, $2'$ and $3'$ that Zivot and Andrews (1992:253 ve 254) determined the breaking endogenously contrary to Perron. The others were computed by taking the break into account externally in the equations 1, 2, and 3 of the same study.

Source: All results reported in this table were computed by authors.

Table 1 shows the single-break test results. According to the results, by using the equations 1, 2 and 3 for which the break is accepted as external, it shows that the possible break for the interest variable both in the constant and trend occured during the period of 1995:3. When the critical values for the interest variable was compared to the statistical values of the test by using the equations $1'$, $2'$ and $3'$ for which the break is accepted as internal, it shows that the possible breaking period in the constant and trend of the series occurred in the 1994:2 period. Similarly, the break is the same as it is for the interest rate in the models for which the break is determined as

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[5] For this, by using Gregory-Hansen and Bruce-Hansen cointegrative techniques that take the structural breaking into consideration in the literature, causality relationships can be investigated by the limitations put on the long term parameters.

exogenously and endogenously for the exchange rate. However, the breaking period was seen in the 1994:1 period for the exogenously model and in the 1994:3 period for the endogenous model. The series are trend stationary according to the single-break test results.

Multiple-break Lumsdaine- Papell[6] (LP) test was also used in order to satisfy the validity of the results obtained. Modified ADF test was used for this test. Test procedure can be written for the main model (Model CC) as follows.

$$\Delta y_t = \mu + \beta_t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t$$

DU1 and DU2 are dummy variables that show the break in the mean and DT1 and DT2 are those that show the breaks during the period of TB1 and TB2 in the trend. If $t \rangle TB1$, DU1=1, otherwise it equals to 0. In another case, when $t \rangle TB2$, DU2=1, otherwise it again equals to 0. In another case, if $t \rangle TB1$, DT1=(t-TB1), otherwise it equals to 0. When $t \rangle TB2$, DT2=(t-TB2), otherwise it equals to 0. The results obtained from the LP test were shown in Table 2.

According to the analysis results, when the critical values for the interest variable were compared to the test statistics values by using Model AA, a double break was observed in the periods of 1990:2 and 1994:1 in the constant of the series. For the exchange rate, structural changes occurred during the periods of 1994:2 and 2001:3. Break was found both in the constant and trend in 1994:2 and 1995:4 for the interest variable and in 1994:2 and 2001:3 for the exchange rate variable by using the main model (Model CC). Finally, according to the results obtained by using the Model CA, double break was found in the constant coefficient in 1994:1 and 1995:4 for the interst variable and in 1994:2 and 2001:1 for the exchange rate variable. In the trend, the existence of the break was rejected since critical values were not exceeded while break existed in the same period. The results obtained exhibit a great harmony with those in Table 1.

Finally, in the Bai-Perron (BP) test, all the series M=5 were tested for five breaks and BP (2003:14) trimming value was taken as 0.15. Therefore, the series were subjected to cutting procedure with at least 15 observations based on the trimming value. Additionally, in order for the sum of the global estimators' square errors to be minimum, each part of the series composing all the trimming values of the computed algorithms have to be higher than $h = [\varepsilon T]$ value. For the present break or breaks, firstly, $SupF_t(k)$, $UD_{\max}$ and $WD_{\max}$ values were computed. These tests tested the null hypothesis where there is no structural break for an unknown break. These tests are also used to determine whether there is at least one break. Table 3 shows the results of

6 The test results and the process of investigating the break is the same as it is in the single-break. Only critical values change.

Tablo 2

Lumsdaine-Papell Multiple-Break Test Results

$$\Delta y_t = \mu + \beta_t + \theta DU1_t + \omega DU2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \text{ (Model AA)}$$

Variable	TB1 / TB2	α	Θ	ψ	ω	γ	μ	β_τ	k
Interest	1990:2	-0.7866	28.0142	-	44.034	-	45.3	-1.328	**1**
t-statistics	1994:1	**-7.3017**	**2.8879**	-	**4.154**	-	**4.85**	**-5.570**	
Exchange Rate	1994:2	-0.614	-31.9178	-	-15.520	-	47.9	1.277	**0**
t-statistics	2001:3	**-7.3816**	**-6.6529**	-	**-4.244**	-	**6.77**	**7.394**	

$$\Delta y_t = \mu + \beta_t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \text{ (Model CC)}$$

Variable	TB1 / TB2	α	Θ	ψ	ω	γ	μ	β_τ	k
Interest	1994:2	-0.9662	129.4684	23.0668	40.1787	-25.4681	43.747	0.8723	1
t-statistics	1995:4	**-9.609**	**6.3761**	**5.0094**	**2.7529**	**-5.4648**	**5.0914**	1.7762	
Exchange Rate	1994:2	-0.8051	-31.1136	0.5573	-23.4529	0.3968	71.653	1.0853	1
t-statistics	2001:3	**-8.7592**	**-6.7743**	**2.3881**	**-5.9073**	1.6602	**8.3807**	**5.0946**	

$$\Delta y_t = \mu + \beta_t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \text{ (Model CA)}$$

Variable	TB1 / TB2	α	Θ	ψ	ω	γ	μ	β_τ	k
Interest	1994:1	-0.9837	-29.876	-	42.5523	-25.6513	44.527	0.8871	1
t-statistics	1995:4	**-9.7355**	-1.5558	-	**2.9078**	**-5.5114**	**5.1299**	1.7057	
Exchange Rate	1994:2	-1.0152	36.2044	-	-24.5082	0.2622	92.267	1.3549	3
t-statistics	2001:1	**-8.1723**	**4.6963**	-	**-5.7647**	0.9821	**8.0359**	**5.3541**	

Note: Critical values for Model AA are 1%, 5% and 10% and their signifancy levels are -6.94, -6.24 and -5.96, respectively. Critical values for Model CC are 1%, 5% and 10% and their signifancy levels are -7.34, -6.82 and -6.49 respectively. Critical values for Model CA are 1%, 5% and 10% and their signifancy levels are -7.24, -6.65 and -6.33, respectively.

Source: All results reported in this table were computed by authors.

the BP test. According to this, SupFT(k) and Double Max tests computed for the interest and exchange rate variables are statistically significant in the importance level of 1%. These results indicate that there is at least one break in the series. Then, to search for more than one break in the series, SupF(l+1|l) tests were applied and two breaks were found for the interest rate in 1994:2 during the period of 1992:3-1994:3 with a possibility rate of 5%, and again, in 2001:4 during the period of 1998:2-2002:3 with the possibility rate of 5%. In addition, according to the information criteria, sequential and LWZ indicated one break, BIC indicate two breaks. Two breaks were found for the exchange rate variable in 1994:2 and 2002:2.

According to the results obtained from these tests in which the break was determined internally, both series were stationary and the series were cleared of from the trend by taking the LP test main model results into consideration.

Tablo 3
Bai-Perron Multiple-Break Test Results

zt{1}	**q=1**	**p=0**	**h=12**	**M=5**	**Double Max Tests**	
For Nominal Interest Rate						
SupFt(1)	SupFt(2)	SupFt(3)	SupFt(4)	SupFt(5)	UDmax	WDmax
25.4943*	8.8607*	12.4209*	13.5664*	51.0028*	51.0028*	127.6628*
SupF(2|1)	SupF(3|2)	SupF(4|3)	SupF(5|4)			
7.5126 ***	0.1393	7.6592***	0			
Number of Breaks according to Information Criteria						
Sequential	1					
LWZ	1					
BIC	2					
Estimation with two-breaks (BIC)						
δ1	δ2	δ3	T1	T2		
			1994:2			
48.252281	77.102362	24.024158	(28.observation)	2001:4 (58.observation)		
5.6226	5.7329	9.4877				
(Std. Error)	(Std. Error)	(Std. Error)	1992:3-1994:3	1998:2-2002:3		
Nominal Exchange Rate						
SupFt(1)	SupFt(2)	SupFt(3)	SupFt(4)	SupFt(5)	UDmax	WDmax
25.0636*	25.1922*	18.0513*	8.5075***	15.5975*	25.1922*	39.0413*
SupF(2|1)	SupF(3|2)	SupF(4|3)	SupF(5|4)			
7.9655***	1.6084	1.6084	0			
Nember of Breaks according to Information Criteria						
Sequential	1					
LWZ	2					
BIC	5					
Estimation with two-breaks (LWZ)						
δ1	δ2	δ3	T1	T2		
			1994:2	2002:2		
94.425	114.91875	99.271429	(28. observation)	(60.observation)		
17.0517	3.848	4.9652				
(Std. Error)	(Std. Error)	(Std. Error)				

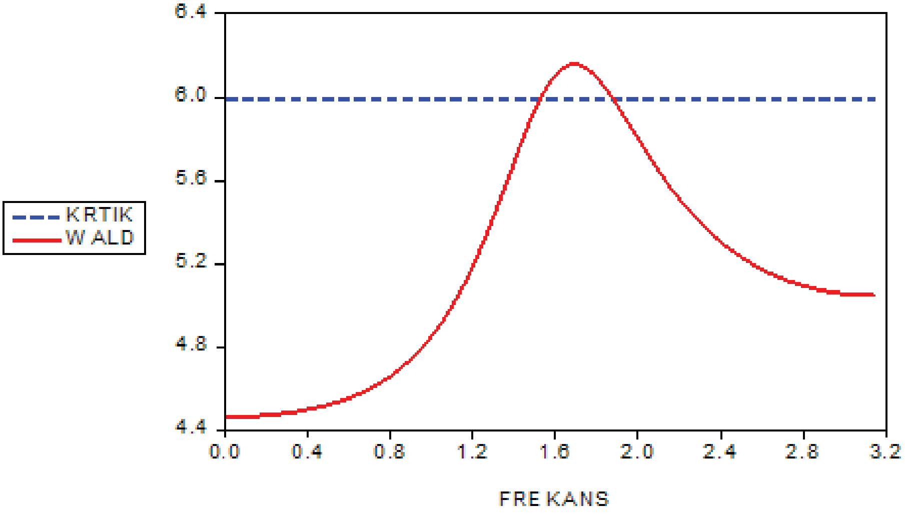
Note: * and *** inidicate that the related variables are higher than the critical values in the importance levels of 1% and 10%, respectively.
Source: All results reported in this table were computed by authors.

4.2. Estimation results

In this part, the results obtained by frequency domain approach explained in detail in the third part will be mentioned and causality relation for each of the ω frequency will be sought. For this, $\lambda^2_{estimation}$ values were investigated by using equations 7 and 10 in the gap of $\omega \in (0,\pi)$ in which it is the element of each frequency value and in the significancy level of 5%, λ^2_2 table value were compared to 5.99. In the related analysis period, in order to better express the causality relation, π value was determined to be 3.14. Therefore, 314 unit frequency and Wald statistics values were given in the annex. Figure 1 and 2 shows the causality relationship $\mathrm{M}_{\mu\to \mathrm{i}}(\omega)$, $\mathrm{M}_{\mathrm{i}\to\mu}(\omega)$ between the frequency thresholds of $(0,\pi)$ respectively. In addition, broken lines were drawn according to λ^2_2 table value 5.99 in the

Figure 1

Causality from Exchange Rate to Interest Rate ($M_{\mu\rightarrow i}(\omega)$)



Source: All results reported in this figure were computed by authors.

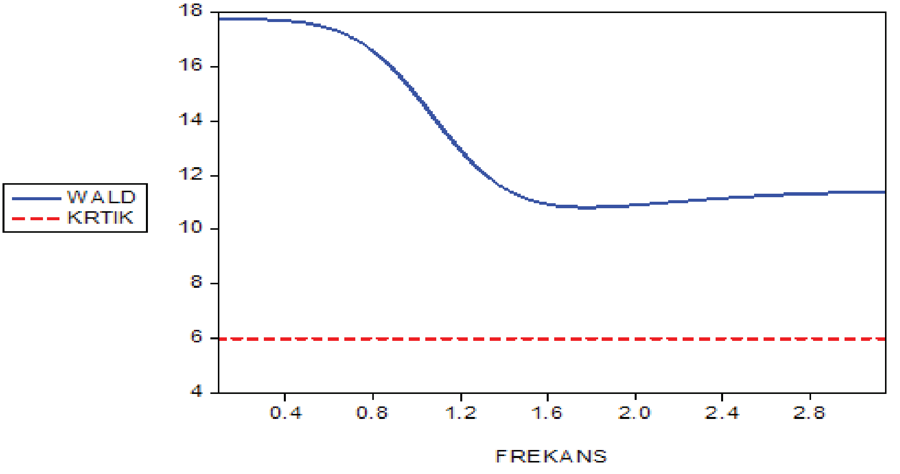
importance level of 5%. Causality relationship from exchange rate to interest was only seen in the short run in the frequency of $\omega \in (1.49, 1.94)$.

These periods cover the 2000 November and 2001 February crisis. With the stabilization program put into effect before the November crisis, reducing the increasing speed of inflation was aimed; exchange rates were used as anchors. Since the decreases observed in the inflation rates could not be satisfied sufficiently within the framework of the programme, domestic currency appreciates and foreign deficit grows. Although the Central Bank increased the interest rates, foreign currency reserves of the Central Bank constantly decreased due to the increasing demand for the exchange rate. The February Crisis occurred because of the political instability, negative perception of the expectations by the markets and for the domestic currency began to depreciate. In order to prevent national currency to depreciate, interest rates were increased incredibly. Therefore, there was a short run causality relationship from the exchange rate to the interest rate during the crisis period in Turkey. In the long run no relationship could be observed.

According to Figure 2, a causal relationship was found between the frequency gaps $(0, \pi)$ from the interest variable to the exchange rate variable in the long run. In conclusion, according to the findings obtained by frequency domain approach, during the period of 1987:1-2008:1 in Turkey only in the short run exchange rates determined the interest rates whereas in the long run this relationship was from the interest rates to the exchange rates.

Figure 2

Causality from Interest Rate to Exchange Rate ($M_{i \to \mu}(\omega)$)



Source: All results reported in this figure were computed by authors.

According to this findings, causal relationship from the exchange rate to the interest rate is valid only for the short run especially in crisis period so it is supported by Gould and Kamin (2000), Gül et al (2007)'s papers.

5. Summary and conclusion

There is no certain consensus in the literature about the direction of the relationship between the interest rate and exchange rate variables. Since the methods applied have different characteristics, different results have been found.

In this study, by using frequency domain approach within the framework of spectral analysis, interest rate relations have been analyzed for the Turkish economy during the period of 1987:1-2008:1. According to the results, while the causality relationship from the exchange rate to the interest variable is valid only for the short run, this relationship continued its effect totally for 45 months, before, during and after the crisis. Causality relationship is seen between $\omega \in (1.49, 1.94)$ frequencies or the period of 1998:1-2001:3.

After the February Crisis, with letting the exchange rate fluctuate, causality relationship towards interest was eliminated. In the long run this effect left its place from exchange rate to interest rate. While this effect had been quite significant since crisis began to be felt, it reduced after this period and the effect has remained constant till today. When considered in this respect, monetary authority needs to keep track of the exchange rate movements within the crisis periods and produce related policies under the inflation targeting regime to make effectiveness of the monetary policy and cope with the exchange rate risk over time by reason of credibility of inflation targeting regime has decreased inflation and pass-through from exchange rate to the inflation.

ANNEX 1

Causality Relationship From Exchange Rate to Interest Rate-Frequency and Values of Wald Statistics ($M_{\mu \to i}(\omega)$)

Frequency (ω)	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
Wald Statistics	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.47	4.47	4.47	4.47	4.47	4.47	4.47	4.47	4.47	4.47	4.47
Frequency (ω)	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40
Wald Statistics	4.47	4.47	4.47	4.48	4.48	4.48	4.48	4.48	4.48	4.48	4.48	4.49	4.49	4.49	4.49	4.49	4.49	4.50	4.50	4.50
Frequency (ω)	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60
Wald Statistics	4.50	4.50	4.51	4.51	4.51	4.51	4.52	4.52	4.52	4.52	4.53	4.53	4.53	4.54	4.54	4.54	4.54	4.55	4.55	4.56
Frequency (ω)	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80
Wald Statistics	4.56	4.56	4.57	4.57	4.58	4.58	4.59	4.59	4.60	4.60	4.61	4.61	4.62	4.62	4.63	4.63	4.64	4.65	4.65	4.66
Frequency (ω)	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
Wald Statistics	4.67	4.68	4.68	4.69	4.70	4.71	4.72	4.72	4.73	4.74	4.75	4.76	4.77	4.78	4.79	4.80	4.82	4.83	4.84	4.85
Frequency (ω)	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20
Wald Statistics	4.87	4.88	4.89	4.91	4.92	4.94	4.95	4.97	4.98	5.00	5.02	5.03	5.05	5.07	5.09	5.11	5.13	5.15	5.17	5.19
Frequency (ω)	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40
Wald Statistics	5.21	5.23	5.26	5.28	5.30	5.33	5.35	5.38	5.40	5.43	5.45	5.48	5.50	5.53	5.56	5.58	5.61	5.64	5.66	5.69
Frequency (ω)	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.58	1.59	1.60
Wald Statistics	5.72	5.74	5.77	5.79	5.82	5.84	5.87	5.89	5.92	5.94	5.96	5.98	6.00	6.02	6.04	6.05	6.07	6.08	6.10	6.11
Frequency (ω)	1.61	1.62	1.63	1.64	1.65	1.66	1.67	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.75	1.76	1.77	1.78	1.79	1.80
Wald Statistics	6.12	6.13	6.14	6.14	6.15	6.15	6.16	6.16	6.16	6.16	6.15	6.15	6.15	6.14	6.14	6.13	6.12	6.11	6.10	6.09
Frequency (ω)	1.81	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.89	1.90	1.91	1.92	1.93	1.94	1.95	1.96	1.97	1.98	1.99	2.00
Wald Statistics	6.08	6.07	6.06	6.04	6.03	6.02	6.00	5.99	5.97	5.96	5.94	5.93	5.91	5.89	5.88	5.86	5.85	5.83	5.81	5.80
Frequency (ω)	2.01	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.14	2.15	2.16	2.17	2.18	2.19	2.20
Wald Statistics	5.78	5.77	5.75	5.74	5.72	5.70	5.69	5.67	5.66	5.64	5.63	5.62	5.60	5.59	5.57	5.56	5.55	5.53	5.52	5.51
Frequency (ω)	2.21	2.22	2.23	2.24	2.25	2.26	2.27	2.28	2.29	2.30	2.31	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40
Wald Statistics	5.50	5.49	5.47	5.46	5.45	5.44	5.43	5.42	5.41	5.40	5.39	5.38	5.37	5.36	5.35	5.34	5.33	5.32	5.31	5.30
Frequency (ω)	2.41	2.42	2.43	2.44	2.45	2.46	2.47	2.48	2.49	2.50	2.51	2.52	2.53	2.54	2.55	2.56	2.57	2.58	2.59	2.60
Wald Statistics	5.30	5.29	5.28	5.27	5.27	5.26	5.25	5.24	5.24	5.23	5.22	5.22	5.21	5.21	5.20	5.19	5.19	5.18	5.18	5.17
Frequency (ω)	2.61	2.62	2.63	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.79	2.80
Wald Statistics	5.17	5.16	5.16	5.15	5.15	5.14	5.14	5.14	5.13	5.13	5.12	5.12	5.12	5.11	5.11	5.11	5.10	5.10	5.10	5.09
Frequency (ω)	2.81	2.82	2.83	2.84	2.85	2.86	2.87	2.88	2.89	2.90	2.91	2.92	2.93	2.94	2.95	2.96	2.97	2.98	2.99	3.00
Wald Statistics	5.09	5.09	5.09	5.08	5.08	5.08	5.08	5.07	5.07	5.07	5.07	5.07	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Frequency (ω)	3.01	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.09	3.10	3.11	3.12	3.13	3.14						
Wald Statistics	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05						

Source: All results reported in this table were computed by authors.

ANNEX 2

Causality Relationship from Interest Rate to Exchange Rate -Frequency and Values of Wald Statistics ($M_{i \to \mu}(\omega)$)

Frequency (ω)	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
Wald Statistics	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.74	17.73	17.73	17.73
Frequency (ω)	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40
Wald Statistics	17.73	17.73	17.73	17.73	17.73	17.73	17.73	17.72	17.72	17.72	17.72	17.71	17.71	17.71	17.70	17.70	17.69	17.69	17.68	17.68
Frequency (ω)	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60
Wald Statistics	17.67	17.66	17.66	17.65	17.64	17.63	17.62	17.61	17.60	17.58	17.57	17.56	17.54	17.52	17.51	17.49	17.47	17.45	17.42	17.40
Frequency (ω)	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80
Wald Statistics	17.37	17.35	17.32	17.29	17.26	17.23	17.19	17.15	17.12	17.08	17.03	16.99	16.94	16.90	16.85	16.80	16.74	16.68	16.63	16.57
Frequency (ω)	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
Wald Statistics	16.50	16.44	16.37	16.30	16.23	16.16	16.08	16.00	15.92	15.84	15.75	15.67	15.58	15.49	15.40	15.31	15.21	15.12	15.02	14.92
Frequency (ω)	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20
Wald Statistics	14.82	14.72	14.62	14.52	14.42	14.31	14.21	14.11	14.01	13.90	13.80	13.70	13.60	13.50	13.40	13.30	13.21	13.11	13.02	12.93
Frequency (ω)	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40
Wald Statistics	12.84	12.75	12.66	12.58	12.50	12.42	12.34	12.26	12.19	12.12	12.05	11.98	11.92	11.85	11.79	11.74	11.68	11.63	11.58	11.53
Frequency (ω)	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.58	1.59	1.60
Wald Statistics	11.48	11.43	11.39	11.35	11.31	11.28	11.24	11.21	11.18	11.15	11.12	11.09	11.07	11.04	11.02	11.00	10.98	10.97	10.95	10.94
Frequency (ω)	1.61	1.62	1.63	1.64	1.65	1.66	1.67	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.75	1.76	1.77	1.78	1.79	1.80
Wald Statistics	10.92	10.91	10.90	10.89	10.88	10.87	10.86	10.85	10.85	10.84	10.84	10.83	10.83	10.83	10.83	10.82	10.82	10.82	10.82	10.82
Frequency (ω)	1.81	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.89	1.90	1.91	1.92	1.93	1.94	1.95	1.96	1.97	1.98	1.99	2.00
Wald Statistics	10.83	10.83	10.83	10.83	10.83	10.84	10.84	10.84	10.85	10.85	10.86	10.86	10.87	10.87	10.88	10.88	10.89	10.89	10.90	10.91
Frequency (ω)	2.01	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.14	2.15	2.16	2.17	2.18	2.19	2.20
Wald Statistics	10.91	10.92	10.92	10.93	10.94	10.94	10.95	10.96	10.96	10.97	10.98	10.98	10.99	11.00	11.00	11.01	11.02	11.02	11.03	11.04
Frequency (ω)	2.21	2.22	2.23	2.24	2.25	2.26	2.27	2.28	2.29	2.30	2.31	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40
Wald Statistics	11.04	11.05	11.05	11.06	11.07	11.07	11.08	11.09	11.09	11.10	11.11	11.11	11.12	11.12	11.13	11.14	11.14	11.15	11.15	11.16
Frequency (ω)	2.41	2.42	2.43	2.44	2.45	2.46	2.47	2.48	2.49	2.50	2.51	2.52	2.53	2.54	2.55	2.56	2.57	2.58	2.59	2.60
Wald Statistics	11.16	11.17	11.18	11.18	11.19	11.19	11.20	11.20	11.21	11.21	11.22	11.22	11.23	11.23	11.24	11.24	11.24	11.25	11.25	11.26
Frequency (ω)	2.61	2.62	2.63	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.79	2.80
Wald Statistics	11.26	11.27	11.27	11.27	11.28	11.28	11.29	11.29	11.29	11.30	11.30	11.30	11.31	11.31	11.31	11.31	11.32	11.32	11.32	11.33
Frequency (ω)	2.81	2.82	2.83	2.84	2.85	2.86	2.87	2.88	2.89	2.90	2.91	2.92	2.93	2.94	2.95	2.96	2.97	2.98	2.99	3.00
Wald Statistics	11.33	11.33	11.33	11.34	11.34	11.34	11.34	11.34	11.35	11.35	11.35	11.35	11.35	11.36	11.36	11.36	11.36	11.36	11.36	11.36
Frequency (ω)	3.01	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.09	3.10	3.11	3.12	3.13	3.14						
Wald Statistics	11.36	11.37	11.37	11.37	11.37	11.37	11.37	11.37	11.37	11.37	11.37	11.37	11.37	11.37						

Source: All results reported in this table were computed by authors.

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Özet

Frekans alanı yaklaşımı ile kısa ve uzun dönemli nedensellik testi: Faiz-kur ilişkisi ve Türkiye örneği

Bu çalışmada spektral analiz çerçevesinde frekans alanı yaklaşımı kullanılarak 1987:1-2008:1 periyodunda Türkiye'de Merkez Bankası'nın para politikası aracı olarak kullandığı kısa vadeli nominal faiz oranları ile nominal döviz kurları arasında ilişkinin yönü ve boyutu analiz edilmiştir. Elde edilen bulgulara göre döviz kurundan faiz değişkenine doğru nedensellik ilişkisi sadece kısa dönemde geçerliyken bu ilişki; kriz öncesi, kriz dönemi ve sonrasında toplam 45 ay etkisini sürdürmüştür. Nedensellik ilişkisi $\omega \in (1.49, 1.94)$ frekansları arasında ya da 1998:1-2001:3 periyodunda gözükmektedir. Uzun dönemde ise bu etki yerini döviz kurundan faiz oranlarına bırakmıştır.

Anahtar kelimeler: Nedensellik, spektral analiz, frekans alanı, döviz kuru, faiz oranı.

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