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An Analysis of The Validity of Absolute Purchasing Power Parity: The Case of Turkish Lira and British Pound

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Mutlak Satın Alma Gücü Paritesinin Geçerliliğine İlişkin Bir Analiz: Türk Lirası ve İngiliz Sterlini Örneği

Abstract

This study aims to determine the validity of the absolute purchasing power parity between the Turkish lira and the British pound for March 2001-November 2020. Traditional unit root tests (and stationarity test) that do not take structural breaks into account and unit root tests that take structural breaks into account were used in the study. According to the results of all tests, it was found that the absolute purchasing power parity between the Turkish lira and the British pound was not valid.

Keywords : Absolute Purchasing Power Parity, Turkish Lira, British Pound.

JEL Classification Codes : F31.

Öz

Bu çalışmanın amacı, Mart 2001-Kasım 2020 dönemi için Türk lirası ile İngiliz sterlini arasında mutlak satın alma gücü paritesinin geçerliliğini belirlemektir. Çalışmada yapısal kırılmaları dikkate almayan geleneksel birim kök testleri (ve durağanlık testi) ve yapısal kırılmaları dikkate alan birim kök testleri kullanılmıştır. Tüm testlerin sonuçlarına göre Türk lirası ile İngiliz sterlini arasında mutlak satın alma gücü paritesinin geçerli olmadığı tespit edilmiştir.

Anahtar Sözcükler : Mutlak Satın Alma Gücü Paritesi, Türk Lirası, İngiliz Sterlini.

1. Introduction

As it is known, the rates at which different currencies are converted to each other are called the exchange rates. Unlike the fixed exchange rate or managed fluctuation system, in the flexible or floating exchange rate system, the monetary authority has little or no intervention in exchange rates. Although monetary authorities try to keep exchange rates at target levels in a fixed exchange rate system, this is unsustainable, especially for economies in a foreign currency bottleneck and with high current account deficits. On the other hand, exchange rates can appreciate significantly if economies that allow their national currency to float against foreign currencies are in foreign currency bottlenecks and have high current account deficits. Severe exchange rate increases can cause various economic problems. For instance, due to an unexpectedly significant increase in the exchange rate, the external debt, expressed in national currency, will increase.

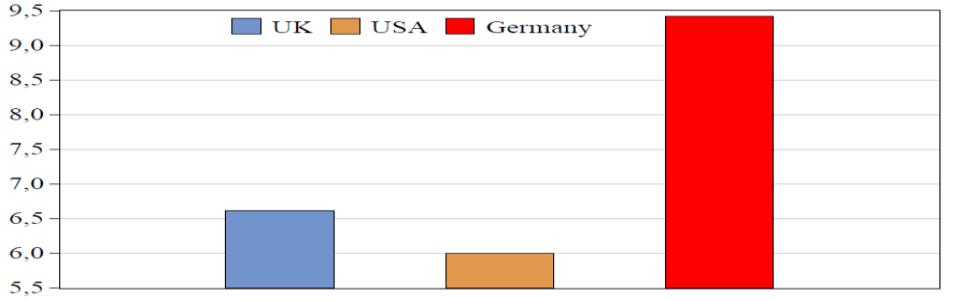
On the other hand, in economies with high import dependency, serious inflation may arise as serious increases in exchange rates will increase the costs of imported products (imported inputs, final goods, and services) in the national currency. It is extremely important to know at which level the exchange rates will stabilize to combat problems that may arise due to the increase in exchange rates. Suppose the level of exchange rates can be correctly predicted. In that case, economic actors will not face foreign currency risk, and the monetary authorities will be able to carry out a healthier monetary policy.

In this study, the absolute purchasing power parity (PPP), which is one of the theories trying to explain the development of exchange rates (Sperber & Sprink, 2012: 152), is investigated whether it is valid for the Turkish lira and the British pound. Since the United Kingdom is very substantial for Turkey's exports, the exchange rate between the Turkish lira and the British pound is significant for Turkey. Figure 1 shows the shares of exports on Turkey's total exports of the first three countries to which Turkey exports the most in 2020 [calculated according to Turkish Statistical Institute (TSI) data]. The country with the highest share is Germany. The UK is in second place, and the USA is in third place. Germany was not included in the analysis in this study because Germany uses the common currency, the euro. The exchange rate between the euro and the Turkish lira cannot be expected to depend only on the price level in Germany and Turkey. Therefore, the absolute PPP between the British pound and the Turkish lira was investigated in this study.

Most of the studies on the validity of PPP have investigated either the stationarity of the real exchange rate or/and the relationship between the nominal exchange rate and the price level of the two countries. Studies such as Taylor (1988), MacDonald (1993), Enders and Chumrusphonlert (2004), and Doğanlar et al. (2009) can be given as examples of empirical studies that try to test the validity of PPP by examining the relationship between nominal exchange rates and price levels. Studies such as Papell (1997), Baum et al. (1999), Narayan (2005), Kalyoncu and Kalyoncu (2008), Acaravci and Ozturk (2010), Chang et al. (2012), Pan et al. (2012), He and Chang (2013), Bahmani-Oskooee et al. (2014), Karagöz and Saraç (2016), Bahmani-Oskooee et al. (2018), Mike and Kızılkaya (2019), Bahramian

and Saliminezhad (2020) and Doğanlar et al. (2020) can be given as examples of empirical studies trying to reveal the validity of PPP by testing the stationarity of the real exchange rate. In this study, to test the validity of absolute PPP, it is investigated whether the real exchange rate is stationary or not.

Figure: 1
Shares of Turkey's Exports by Countries in Total Exports (in 2020)



Source: Created by the author using TSI data.

In an analysis aimed at estimating the parameters between the nominal exchange rate and price levels (such as OLS), if only price levels are included as an independent variable in the equation, the problem of endogeneity may be encountered. Due to such problems that may arise, methods for estimating the parameters between the nominal exchange rate and price levels were not preferred in this study. Instead, the real exchange rate stationarity was analysed in this study to examine the validity of the absolute PPP. To determine whether the real exchange rate is stationary, traditional tests that do not take structural breaks into account [the Augmented Dickey-Fuller-ADF (1981), the PP (1988), the DF-GLS (1996), the ERS-Point Optimal (1996), the KPSS (1992), the Ng and Perron (2001)] and tests that take structural breaks into account [the Lee and Strazicich-LS (2003), the Güriş (2019), the Otto (2021)] have been used.

There have been a lot of empirical studies on absolute PPP before. However, the fixed-b unit root test, which was not used in previous studies, was employed in this study. This test proposed by Otto (2021) has many advantages. The number of breaks in a trend of a series is not limited. This test can be used to make a robust estimate against autocorrelation and heteroscedasticity. This test can also be used for smooth and sharp breaks. This study aims to contribute to the literature by applying the fixed-b test, which has not previously been used for PPP, to absolute PPP and determine whether the absolute PPP is a valid theory between the British pound and the Turkish lira.

After the introductory part, the second part of the study presents the theoretical framework for the PPP theory. In the third part of the study, some examples of empirical literature of the PPP theory are presented. In the fourth part of the study, information about the data and methods used in the study's empirical analysis is presented. The results of the

empirical analysis are contained in the fifth part of the study. In the conclusion part of the study, a general evaluation was made, and recommendations were made.

2. Theoretical Framework for Purchasing Power Parity

Different theories have been developed to reveal the factors that determine the development of exchange rates. These theories are divided into two groups as *traditional exchange rate theories* and *new exchange rate theories*. Traditional exchange rate theories try to explain the development of exchange rates with the values of macroeconomic variables in the past and current periods. New exchange rate theories emphasize the expectations of market actors in explaining the development of exchange rates. Traditional exchange rate theories are divided into three groups. These are theories based only on goods markets, on financial markets, and both goods markets and financial markets. New exchange rate theories are divided into two groups. These are theories that assume market actors have irrational expectations and theories that assume they have rational expectations. The PPP theory is one of the theories based on goods markets (Sperber & Sprink, 2012: 152). PPP was systematically introduced by the famous Swedish economist Gustav Cassel (1916). However, Cassel (1918: 413) coined the term PPP for the first time in his 1918 work.

According to the PPP theory, the exchange rate between the currencies of two countries reflects the relationship between the price levels of the two countries (Krugman et al., 2015: 538). The PPP theory has two different approaches as absolute and relative. According to the absolute PPP theory, the price of a basket of goods will be the same in different countries if expressed in a common currency (Feenstra & Taylor, 2008: 506). According to the absolute PPP theory, it is possible to purchase the same goods at home and abroad with a specific currency. Suppose that in country *A* product *x* is *P* euro, in country *B* product *x* is *P** US dollar, and country *A* is the domestic country. In this case, the foreign country (country *B*) price multiplied by the exchange rate (in the form of direct quotation) must be the same as the domestic country (country *A*) price so that the absolute PPP is valid [Equation (1)]. In Equation (1), *W* indicates the exchange rate in direct quotation according to the absolute PPP. If *W* is left on one side alone, Equation (2) is obtained. It can be understood from Equation (2), according to absolute PPP, the exchange rate will be equal to the ratio of domestic and foreign prices to each other. For the absolute PPP to be valid, the real exchange rate must always be equal to one. In this case, since the real exchange rate (W_{real}) is calculated in the form of $[(P)]/[(P^*)(W)]$, $[(P)]/[(P^*)(W)]$ is equal to 1. If $W < (P)/(P^*)$, the real exchange rate will be greater than one and the national currency will become overvalued against foreign currency. In other words, more of the same good can be purchased abroad than in the domestic country with a certain amount of national currency. On the other hand, if $W > (P)/(P^*)$, the real exchange rate will be less than 1, and the national currency will be undervalued against foreign currency. In this case, less of the same good can be purchased abroad than in the domestic country with a certain amount of national currency (Moritz & Stadtmann, 2010: 127-129).

$$P = (P^*)(W) \tag{1}$$

$$W = \frac{(P)}{(P^*)} \tag{2}$$

$$(W)\% = (P)\% - (P^*)\% \tag{3}$$

$$(W_{real}) = \frac{(P^*)(W)}{(P)} \tag{4}$$

$$(W_{real})\% = (W)\% + (P^*)\% - (P)\% \tag{5}$$

Equation (2) can also be expressed in percent as in Equation (3). If the necessary adjustments are made, the real exchange rate is equal to Equation (4). In this case, the percentage change in real exchange rate will be as in Equation (5)[1]. If Equation (3) and Equation (5) are taken together, it is understood that the percentage change in real exchange rate should be zero according to the absolute PPP. For instance, if foreign prices increase by *a*% while domestic prices are stable and the nominal exchange rate decrease by *a*% then, absolute PPP will be valid. In such a case, the competitive advantage gained domestically due to the price increase abroad will be eliminated by the appreciation of the national currency against foreign currency (Rübel, 2013: 271-272). The PPP theory, in its absolute or powerful form, based on the *law of one price* (Dornbusch, 1985: 2). According to the law of one price, the prices of homogeneous goods purchased and sold in perfect competition markets- where there are no transportation costs and public restrictions (such as customs duties) on trade- will be the same in different countries if expressed in the same currency (Krugman et al., 2015: 537). According to the law of one price, if expressed in the same currency, the price difference between countries can only be short-lived due to arbitrage activities. As a result of arbitrage activities, goods will be bought from the country where they are cheap and sold to the country where they are expensive. The increase in demand seen as a result of arbitrage activities in the country where the goods are cheap will increase the prices in the relevant country. On the other hand, prices will decrease as the supply increases due to arbitrage in a country where goods are expensive. As a result, prices between countries will begin to equalize (Jarchow & Rühmann, 2000: 265).

$$\frac{\partial(W)}{(W)} = \frac{\partial(P)}{(P)} - \frac{\partial(P^*)}{(P^*)} \tag{6}$$

[1] *If the natural logarithmic transformation is made,* $\ln(W_{real}) = \ln(W) + \ln(P^*) - \ln(P)$ *Equality is obtained (Abuaf & Jorion, 1990: 158). If the absolute PPP is valid, the natural logarithm of the real exchange rate will be zero, so* $\ln(W_{real}) = \ln(W) + \ln(P^*) - \ln(P) = 0$ *Equality will be valid (MacDonald, 2007: 41).*

$$\partial\left[ln(W)\right] = \partial\left[ln(P)\right] - \partial\left[ln(P^*)\right] \tag{7}$$

$$\frac{\Delta(W)}{(W)} = \frac{\Delta(P)}{(P)} - \frac{\Delta(P^*)}{(P^*)} \tag{8}$$

$$\Delta\left[ln(W)\right] = \Delta\left[ln(P)\right] - \Delta\left[ln(P^*)\right] \tag{9}$$

$$\Delta\left[\ln(W_{real})\right] = \Delta\left[\ln(W)\right] + \Delta\left[\ln(P^*)\right] - \Delta\left[\ln(P)\right] \tag{10}$$

According to the relative PPP theory, changes in the nominal exchange rate (provided that the rate is in the form of direct quotation) between the currencies of two countries for a given period is equal to the difference between the domestic inflation rate and the foreign inflation rate (Shim et al., 2016: 2386). According to the relative PPP theory, the higher the domestic inflation rate than the foreign inflation rate is, the more the national currency will depreciate against the foreign currency (Moritz & Stadtmann, 2010: 134). It is possible to show the relative PPP equation as Equation (6). ∂ is the first-order derivative operator. Equation (6) is equal to Equation (7). In Equation (7) *ln* denotes the natural logarithm operator (Clements et al., 2007: 4). It is also possible to express the relative PPP as in Equation (8). Where Δ is the first difference operator, $\Delta(W)/(W)$ represents the relative change in the nominal exchange rate, $\Delta(P)/(P)$ indicates the domestic inflation rate and $\Delta(P^*)/(P^*)$ indicates the foreign inflation rate (Krugman et al., 2015: 540; Feenstra & Taylor, 2008: 507). Since the relative change in numbers algebraically is approximately equal to the first difference of the natural logarithmic transformed numbers, it is possible to show the relative PPP with Equation (9). Equation (10) is obtained if $\Delta[ln(P)]$ and $\Delta[ln(P^*)]$ in Equation (9) are taken to the left. If the relative PPP is valid, $\Delta[ln(W_{real})]$ must be equal to zero (Patterson, 2000: 558).

There are several factors that limit the validity of the PPP theory. For instance, the existence of heterogeneous goods between countries, the existence of non-tradable goods, government intervention, and the existence of transportation costs limit the validity of the absolute PPP theory (Rübel, 2013: 273). Apart from price changes, the exchange rate is also affected by the changes in some variables important for international trade, which limits the validity of the relative PPP theory. For instance, if the national income increases while other conditions are constant, the demand for imported goods will also increase. In this case, if the supply elasticity of imported goods is perfect, the price of imported goods will not increase. However, the demand for foreign currency and the value of imported goods in a foreign currency will increase (Rose, 1974: 97). The exchange rate system implemented by the countries is also important. A fixed exchange rate system can adversely affect the validity of the PPP theory because exchange rates cannot reflect relative price changes (Patterson, 2000: 556). Monetary problems also cause exchange rates to deviate from PPP, at least temporarily, that is, changes in real exchange rates. Apart from these, differences in productivity growth between countries cause real exchange rates to change trend

(Dornbusch, 1985:2). In this respect, in order for the exchange rate estimates based on PPP to be healthy, it must first be revealed whether the PPP theory is valid or not.

3. Empirical Literature

While some economic views consider the PPP theory a reality, some economic views consider the PPP theory unrealistic (Dornbusch, 1985: 1). According to the relationship between the absolute and relative PPP, if the absolute PPP is valid, the relative PPP is valid. However, if the absolute PPP theory is not valid, the relative PPP may be valid (Feenstra & Taylor, 2008: 508; Taylor & Taylor, 2004: 4). In this study, the validity of the relative PPP was not tested, as it was intended to test only the validity of absolute PPP (in terms of the Turkish lira and British pound). Most of the empirical studies on PPP use unit root tests, stationarity tests, or cointegration tests. A limited number of examples of empirical studies of PPP are presented in Table 1.

Table: 1
Empirical Studies Examples on Purchasing Power Parity

Author	Period/Region	Method	Main Finding
Frenkel (1978)	1921M02-1925M05/France, UK, USA	Regression Analysis / Causality Analysis	It has been determined that absolute PPP is not valid. It has been observed that the relative PPP is only invalid between the pound and the US dollar. According to the causality test, a general one-way causality was determined from exchange rates to prices.
Dornbusch (1979)	1974M03-1978M05/Germany and the USA	Regression Analysis	It has been observed that PPP is not valid.
Taylor (1988)	1973M06-1985M12/USA, UK, West Germany, France, Canada, Japan	Cointegration Analysis	It has been determined that PPP is not valid.
MacDonald (1993)	1974M01-1990M06/Canada, France, Germany, Japan, UK, USA	Cointegration Analysis	In general, it has been determined that absolute PPP is not valid, and relative PPP is valid.
Frankel & Rose (1996)	1948-1992 (A)/150 Countries	Regression Analysis	It has been observed that PPP is valid.
Papell (1997)	1973M01-1994M09; 1973Q1-1994Q3/Monthly Data for 18 Countries, Quarterly Data for 21 Countries	Unit Root Analysis	As the base currency, it has been observed that the German mark supports PPP more than the US dollar. It was observed that the validity of PPP increased with the increase in the number of countries. It has been determined that monthly data support PPP more than quarterly data.
Baum et al. (1999)	1973M08-1995M12/For CPI Based Real Exchange Rate 17 Countries; For Wholesale Price Index Based Real Exchange Rate 12 Countries	ARFIMA/ Unit Root Analysis	It was found that absolute PPP is not valid.
Enders & Chumrusphonlert (2004)	1973M01-2001M07/USA, Korea, Singapore, Thailand;1973M01-2001M06/ Philippines;1973M01-2001M04/Malaysia;1973M01-2000M12/Indonesia;1990M01-2001M06/Hong Kong; Japan	Cointegration Analysis	It has been determined that the long-run PPP is valid for Indonesia, Korea, Malaysia, the Philippines, and Thailand in case the base currency is as Japanese yen. If the base currency is the US dollar, it was seen that the long-run PPP was valid for the analysed countries except for Japan.
Narayan (2005)	1973M01-2002M12 (For United Kingdom); 1973M01-2003M09/17 OECD Countries	Unit Root Analysis	It has been observed that the PPP is valid for only three countries if the base currency is the US dollar, and that the PPP is valid for seven countries if the base currency is the German mark.
Doğanlar (2006)	1995M01-2002M12/Azerbaijan, Kazakhstan, Kyrgyzstan, USA	Unit Root- Stationarity Analysis/ Cointegration Analysis / Bound Test Analysis/ Regression Analysis	It has been determined that PPP is not valid.
Bahmani-Oskooee & Kandil (2007)	1970-2004 (A)/14 MENA Countries (EF)	Unit Root - Stationarity Analysis /Bound Test Analysis	It has been determined that the PPP theory is valid for almost half of the countries analysed according to the KPSS test.

Baharumshah et al. (2008)	1976M01-1997M06; 1997M07-2002M09/South Korea, Thailand, Indonesia, Malaysia, Singapore, Philippines, USA, Japan	Bound Test Analysis /Half-Life Measure	It was determined that the relative PPP was not valid before the Asian financial crisis. After the Asian financial crisis, findings regarding the validity of relative PPP have been reached. It was found that the absolute PPP was not valid.
Dal Bianco (2008)	2006-1900 (A)/Argentina, USA	Unit Root - Stationarity Analysis /Cointegration Analysis	It has been determined that PPP is not valid.
Kalyoncu & Kalyoncu (2008)	1980Q1-2005Q4/25 OECD Countries, USA	Unit Root Analysis	It has been determined that PPP is valid.
Doğanlar et al. (2009)	1995M01-2005M12/Brazil, India, Indonesia, South Korea, Mexico, Pakistan, Peru, Philippines, South Africa, Turkey, USA	Cointegration Analysis	It was concluded that the PPP theory was valid only in Mexico and Peru among the analysed countries.
Acaravci & Ozturk (2010)	1992M01-2009M01/Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia (EF)	Unit Root - Stationarity Analysis	According to the unit root tests without a structural break, it has been observed that the PPP theory is not valid. According to the unit root tests with structural break(s), it was determined that the PPP theory is valid only for Bulgaria and Romania.
Chang et al. (2012)	1994M10-2008M09/ Cambodia; 1995M01-2008M06/ Vietnam; 1987M12-2008M06/ Laos; 1980M01-2008M09/ Indonesia, Malaysia, Philippines, Singapore, Thailand; USA	Unit Root Analysis	It was found that only in 3 out of 8 countries (Thailand, Malaysia, Indonesia) was the PPP valid.
Pan et al. (2012)	1985M01-2008M09/18 African Country, USA	Unit Root - Stationarity Analysis	PPP was valid in only four (Sierra Leone, Tanzania, Madagascar and Morocco) countries.
He & Chang (2013)	1994-2012 (Monthly and Quarterly Data)/14 Transition Countries (EF)	Unit Root - Stationarity Analysis	The PPP theory was determined to be valid in half of the countries analysed with the quarterly data. In terms of monthly data, it is found that the PPP theory is valid in most of the analysed countries. Countries in which the PPP theory is not valid according to monthly data are Bulgaria, Slovakia, Austria, and Romania.
Bahmani-Oskooee et al. (2014)	1971Q1-2012Q4/20 African Countries (EF)	Stationarity Analysis	It has been found that the PPP theory is valid in half of 20 African countries.
Karagöz & Saraç (2016)	2003M01-2014M06/Turkey (EF)	Unit Root Analysis	It has been found that the PPP theory is not valid.
Bahmani-Oskooee et al. (2018)	1971Q1-2015Q4 (For 22 Countries); 1980Q1-2015Q4 (For 7 Countries)/29 African Countries (EF)	Unit Root Analysis	It was concluded that the PPP theory is valid for 15 African countries.
Murad & Hossain (2018)	1973-2015 (A)/ ASEAN Member Countries, USA	Unit Root Analysis / Cointegration Analysis	It has been observed that the relative PPP is generally valid.
Mike & Kızılkaya (2019)	2001Q1-2016Q4/12 Emerging Market Economy, USA	Unit Root Analysis / Cointegration Analysis	According to the Fourier quantile unit root test results the PPP theory is valid for Colombia, India, the Philippines, Poland, South Africa, and Turkey. However, according to the KPSS Fourier cointegration analysis, the PPP theory is valid for Brazil, Colombia, India, Mexico, South Africa, Thailand, and Turkey.
Bahramian & Saliminezhad (2020)	1994M01-2018M09/Indonesia, Malaysia, Philippines, Thailand, Singapore (EF)	Unit Root Analysis	It was seen that PPP is only not valid for Malaysia.
Doğanlar et al. (2020)	2002M01-2018M10/Turkey, China, Euro Area, Russia, UK, USA	Unit Root Analysis	The PPP theory was found to be valid.
She et al. (2020)	1983Q1-2014Q4/Pakistan, 21 Countries	Unit Root - Stationarity Analysis / Regression Analysis	The PPP theory was found to be partially valid.

Note: A, Q, and M, denote annual, quarterly, and monthly data, respectively. EF denotes effective exchange rate.

4. Data and Methodology

In this study, the validity of the absolute PPP (in terms of the Turkish lira and British pound) was analysed between March 2001-and November 2020. The data used in the analysis are monthly frequency data. Since Turkey switched to the flexible exchange rate system at the end of February 2001 (February 22, 2001), February 2001 was not considered. To test the validity of the absolute PPP theory in relation to the Turkish Lira and British pound, the stationarity of the real exchange rate (*REXR*) was used. If the real exchange rate

is stationary, the real exchange rate will return to its previous parity in the face of a shock. This will mean that the absolute PPP is valid. In Baum et al. (1999: 365), consumer and wholesale price indexes were used to represent the price level. Similarly, in this study the nominal exchange rate and harmonized consumer price index (HCPI) (base year 2015) are used to calculate the real exchange rate between the British pound and the Turkish lira. The time path graph of the *REXR* series is as in Figure 2. Nominal exchange rate data were obtained from the Electronic Data Delivery System of the Central Bank of the Republic of Turkey (EDS). HCPI data for both countries were obtained from Eurostat. Descriptive statistics for the variable *REXR* are given in Table 2.

Table: 2
Descriptive Statistics Regarding the Variable

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
REXR	237	1,423	0,199	1,063	1,953

Figure: 2
The Time Path Graph of *REXR* Variable

Source: It was created by the author.

To analyse the stationarity of the *REXR* variable, some traditional tests that do not take into account the structural breaks were applied. These applied tests are the ADF (1981), the PP (1988), the DF-GLS (1996), the ERS-Point Optimal (1996), the KPSS (1992), and the Ng and Perron (2001). The ADF (1981) test is an extended version of the Dickey-Fuller [DF (1979)] unit root test. In the ADF (1981) unit root test, unlike the DF (1979) unit root test, the lagged values of the dependent variable are also included in the regression that tests the unit root (Hackl, 2013: 257-259). In the ADF (1981) unit root test proposed by Dickey and Fuller (1981), there are models with no deterministic term, with a constant term and a constant term and a trend term. The null hypothesis of this test states that the series contains a unit root (Greene, 2016: 954). The PP (1988) test, another traditional unit root test proposed by Phillips and Perron (1988), can also be examined in terms of three models (model with no deterministic term, constant model, constant and trend model). The null hypothesis of this unit root test states that the series contains a unit root. However, the PP (1988) test is non-parametric in terms of nuisance parameters (Phillips & Perron, 1988: 335). Unlike the ADF (1981) unit root test, the PP (1988) unit root test does not include the lags of the

dependent variable as an independent variable in the analysis to eliminate the autocorrelation seen in the residues. Against the potential problems, a correction factor is added to the test statistic of the DF (1979) unit root test in the PP (1988) unit root test (Patterson, 2000: 264). However, the test statistic of the PP (1988) unit root test has the same asymptotic distribution as the test statistic of the DF (1979) unit root test (Hackl, 2013: 261). Elliott et al. (1996) suggested the DF-GLS (1996) and ERS-Point Optimal (1996) tests to determine the stationarity of a series. The null hypothesis of both tests states that the series contains a unit root. The DF-GLS (1996) unit root test and ERS-Point Optimal (1996) tests can be applied for the constant model and the constant and trend model. In the DF-GLS (1996) unit root test, the ADF (1981) model without exogenous components is applied to the series after removing the series from their deterministic components using the appropriate method. In the ERS-Point Optimal (1996) test, the test statistic is based on residuals from quasi-difference regression (Elliott et al., 1996: 817, 819, 824-825). The KPSS (1992) stationarity test proposed by Kwiatkowski et al. (1992: 160-161, 166) can be applied for the constant model and the constant and trend model. The null hypothesis of the test states that the series is stationary. The null hypothesis of the Ng and Perron (2001) unit root test states that the series contains a unit root. This test can be applied for the constant model and the constant and trend model. In the Ng and Perron (2001) unit root test, four new test statistics (MZ_{α}^{GLS}, MZ_{t}^{GLS}, MSB^{GLS} and MP_{T}^{GLS}) are calculated by applying some modifications to the test statistics in Perron and Ng (1996) [MZ_{α} , MZ_{t} , MSB] and the ERS-Point Optimal (1996) test statistic (Ng & Perron, 2001: 1520, 1522-1524).

In the study, Bai and Perron (1998, 2003a) structural break test was applied to determine the number of structural breaks and regimes. Bai and Perron developed this test in 1998 and applied it in another study in 2003 (Bai & Perron, 2003a: 1). Bai and Perron (1998, 2003a) structural break test is used to determine the number of structural breaks internally in the linear regression model estimated using the least-squares method. In this test, the minimum sum of the squared residuals of the linear regression model is taken into account to predict various structural changes. The Bai and Perron (1998, 2003a) structure break test can take into account the general autocorrelation and heteroscedasticity of error terms, different error distributions, and independent variable distributions for different regimes. Assume that there is a multiple regression such as in Equation (11) and m + 1 (m represents the number of breaks) different regimes ($t = T_{j-1} + 1,\ldots,T_j$; $j = 1,\ldots, m+1$). In Equation (11), y_t is the dependent variable, x_t' ($x_t = px1$) and z_t' ($z_t = qx1$) are the independent variable vectors, and u_t is the error term. The aim is to estimate both the unknown regression parameters and the unknown break time(s) ($T_1,\ldots,T_m$) using the variables y_t, x_t, and z_t. The β parameter (as it can be understood that there is no subscript) is a parameter that does not vary according to different regimes. In this respect, models with β parameter are known as partial structural change models. However, models without the β parameter are pure structural change models (Bai & Perron, 1998: 47-49). In the Bai and Perron (1998, 2003a) structural break test, different test strategies determine the number of structural breaks and regimes in a series. In this study, the sequential break strategy was applied. In this strategy, the null hypothesis states that the number of breaks of a series is *l*,

and the alternative hypothesis states that the number of breaks of a series is l+1 (Bai & Perron, 2003a: 11-15, 18).

$$y_t = x_t'\beta + z_t'\delta_j + u_t \tag{11}$$

One of the unit root tests used in the study is the LS (2003) unit root test suggested by Lee and Strazicich (2003). The LS (2003) unit root test is similar to the Lee and Strazicich (2004) unit root test. However, unlike this test, the LS (2003) unit root test considers two structural breaks and not only one. Let it be assumed that the data generation process is as in Equation (12). In Equation (12), y_t is the analysed series, Z_t is the vector of exogenous variables and e_t is the error term [$e_t \sim$ iid $N(0,\sigma^2)$]. There are two types of models (model A and model C) in this unit root test. Model A examines structural breaks only at the level, while model C examines structural breaks at both the level and the trend. Considering Equation (12), [1, t, D_{1t}, D_{2t}]′ (D_{jt} = 1 for t ≥ T_{Bj} + 1 otherwise 0; j =1,2; T_{Bj} indicates the time when a structural break occurs) will be substituted for Z_t for model A and [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]′ (DT_{jt} = t - T_B for t ≥ T_B + 1 otherwise 0; j = 1, 2) will be substituted for Z_t for model C. In this unit root test, structural breaks are determined internally based on the LM statistic. The equation to be estimated to calculate the LM statistic in this unit root test is as in Equation (13). $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\tilde{\delta}$, ($t$ = 2,…, T). $\tilde{\psi}_x$ is obtained with $y_1 - Z_1\tilde{\delta}$. The null hypothesis of this unit root test states that the series has unit root under structural breaks (Lee & Strazicich, 2003: 1082-1083).

$$y_t = \delta' Z_t + e_t, \quad [e_t = \beta e_{t-1} + \varepsilon_t]' \tag{12}$$

$$\Delta y_t = \delta' \Delta Z_t + \phi\tilde{S}_{t-1} + u_t \tag{13}$$

The other unit root test used in the study is the nonlinear unit root test with the Fourier function proposed by Güriş (2019). In terms of structural break and nonlinearity, traditional unit root tests may incorrectly show that the stationary series is non-stationary. The Güriş (2019) test is proposed against such problems that may arise. According to the simulation results, it has been determined that the Güriş (2019) test has more power than the Kruse (2011) and Kapetanios et al. (2003) tests. The Güriş (2019) test has a two-stage estimation process. In the first step, if the constant model is used, Equation (14) is estimated by OLS, and if the constant and trend model is used, Equation (15) is estimated by OLS. In the second stage of the test, the unit root test is performed with Equation (16), assuming that the residuals ($\hat{v}_t$) estimated from Equation (14) and (15) follow the ESTAR process. This Equation tests the unit root null hypothesis ($\delta_1 = \delta_2 = 0$) against the alternative hypothesis ($\delta_1 < 0, \delta_2 \neq 0$). In Equation (14) and (15), *sin* represents the sine function, *cos* is the cosine function, t is the linear trend term, k^* is the optimal frequency, α_0 is the constant term, T is the number of observations, and v_t represents the error term (Güriş, 2019: 3056-3058).

$$y_t = \alpha_0 + \alpha_1 \sin\left(\frac{2\pi k^* t}{T}\right) + \alpha_2 \cos\left(\frac{2\pi k^* t}{T}\right) + v_t \tag{14}$$

$$y_t = \alpha_0 + \gamma t + \alpha_1 \sin\left(\frac{2\pi k^* t}{T}\right) + \alpha_2 \cos\left(\frac{2\pi k^* t}{T}\right) + v_t \tag{15}$$

$$\Delta\hat{v}_t = \delta_1 \hat{v}_{t-1}^3 + \delta_2 \hat{v}_{t-1}^2 + \sum_{j=1}^{p} \varphi_j \Delta\hat{v}_{t-j} + \varepsilon_t \tag{16}$$

The fixed-b test was proposed by Otto (2021) to determine the stationarity of a series. This test can be used to determine the stationarity of time series without linear trend components. This test can be applied in the case of multiple breaks and different types of breaks (smooth or sharp). Another benefit of this test is that it can handle heteroscedasticity and autocorrelation. Corrections to the nuisance parameters provide results that are robust to heteroscedasticity. By using the pre-whitening process, autocorrelation is taken into account. The fixed-b statistic does not have the standard normal distribution. The null hypothesis of this test states that the series contains a unit root. To apply the fixed-b test, firstly, the series is divided into *T-B* overlapping blocks of length *B* [*B* is the block length; *T* is the number of observations. In fixed-b test *B* equals to $(b)\times(T)$]. The obtained blocks are treated as cross-section units in panel data, and pooled OLS is applied. The variable Δy_{j+t} is regressed on $(y_{j+t-1} - y_j)$ [here $2 \le t \le T$ and $1 \le j \le T - B$]. Then, the test statistic is obtained. The test statistic of the fixed-b test is as in Equation (17). The $\tilde{y}$ in Equation (17) and (18) shows the time-transformed series. $\tilde{y}_{1,T}$ and $\tilde{y}_{2,T}$ in Equation (17) are calculated with the related formulas in Equation (18). It should be noted that the trend of the series analysed must meet the partial Lipschitz condition for these tests to be used (Otto, 2021: 86-88, 90, 94).

$$\tau\text{-Fixed-b} = \frac{\tilde{y}_{1,T}}{\hat{\sigma}\sqrt{\tilde{y}_{2,T}}} = \frac{\sum_{j=1}^{T-B}\sum_{t=2}^{B} \Delta\tilde{y}_{t+j}\left(\tilde{y}_{t+j-1} - \tilde{y}_j\right)}{\hat{\sigma}\sqrt{B\sum_{j=1}^{T-B}\sum_{t=2}^{B}\left(\tilde{y}_{t+j-1} - \tilde{y}_j\right)^2}} \tag{17}$$

$$\tilde{y}_{1,T} = \frac{1}{B^{3/2}T^{1/2}} \sum_{j=1}^{T-B}\sum_{t=2}^{B} \Delta\tilde{y}_{t+j}(\tilde{y}_{t+j-1} - \tilde{y}_j); \quad \tilde{y}_{2,T} = \frac{1}{B^2 T} \sum_{j=1}^{T-B}\sum_{t=2}^{B} (\tilde{y}_{t+j-1} - \tilde{y}_j)^2 \tag{18}$$

5. Results of the Empirical Analysis

First of all, Bai and Perron (1998, 2003a) test was applied to determine whether there is a structural break in the *REXR* series. According to the Bai and Perron (1998, 2003a) test results in Table 3, two sharp structural breaks (in December 2010 and March 2016) were detected in the *REXR* series. Figure 3 shows the predicted structural breaks and different

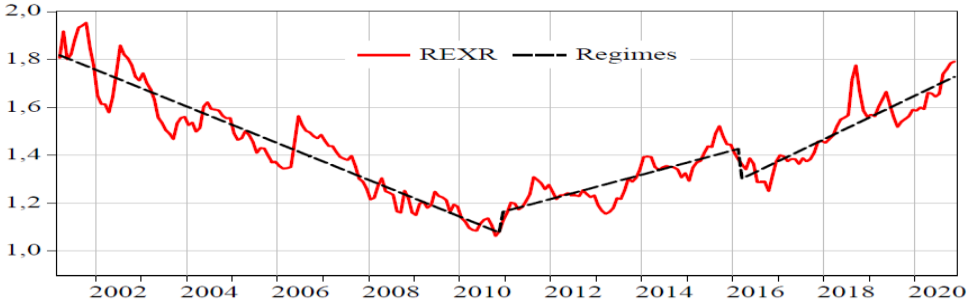
regimes according to the Bai and Perron (1998, 2003a) test. Since structural breaks were found in the *REXR* variable according to Bai and Perron (1998, 2003a) structural break analysis, it would be more appropriate to use unit root tests that take structural breaks into account. As Perron (1989: 1361) stated, unit root tests that do not take into account the structural break in case of structural break can perceive the series that is stationary as non-stationary.

Table: 3
Structural Break Analysis Results For *REXR*

Test for Break in Level and Trend	
$SubF_T(l+1\|l)$- Statistics	**Critical Values (5% Significance Level)**
$SubF_T(1\|0)$ = 359,990**	10,980
$SubF_T(2\|1)$ = 13,906**	12,550
$SubF_T(3\|2)$ = 10,863	13,460
Break Dates= December 2010, March 2016	

*Note: The maximum number of breaks has been chosen as three. ** indicates statistical significance at 5% significance level. The critical values are obtained from Bai and Perron (2003b).*

Figure: 3
Structural Breaks According to the Bai and Perron (1998, 2003a) Test



Source: It was created by the author.

Although structural breaks were found, the results of the traditional unit root tests are shown in Table 4 to compare the results of the traditional unit root tests with the results of the unit root tests that take structural breaks into account. According to all the traditional tests given in Table 4, the *REXR* variable is not stationary at the level. Therefore, it can be concluded that the absolute PPP between the British pound and the Turkish lira is not valid in the analysed period.

Table: 4
Results of Traditional Tests

Test Name	Constant and Trend Model			
	Test Statistics			
ADF[2]	-1,357 (16)			
DF-GLS[3]	-0,238 (16)			
ERS-Point Optimal[4]	36,118 [5]			
PP[2]	-1,278 [5]			
KPSS[5]	0,491** [11]			
Ng-Perron[6]	MZ_{α}^{GLS}	MZ_{t}^{GLS}	MSB^{GLS}	MP_{T}^{GLS}
	-1,637 [5]	-0,622 [5]	0,380 [5]	33,943 [5]

*Note: ** indicates significance at 5% level. Values in round brackets indicate the lag length, values in square brackets indicate the bandwidth length.*

As two structural breaks were found according to the Bai & Perron (1998, 2003a) test, the LS (2003) unit root test, which takes two structural breaks into account, was also used. The result of this unit root test is given in Table 5. According to the results in the Table, it is seen that the null hypothesis stating that the series contains a unit root under two structural breaks cannot be rejected. In this respect, the absolute PPP between the British pound and the Turkish lira is not valid in the period analysed according to the LS (2003) test results. The structural break dates predicted by the LS (2003) [September 2010, April 2016] test is very close to the break dates predicted by the Bai and Perron (1998, 2003a) [December 2010, March 2016] test. Although there are slight differences between months, the first structural break was predicted in 2010 and the second structural break in 2016, according to the results of the two tests. The European Debt Crisis may have been effective in the structural break seen in 2010. The European Debt Crisis first appeared in Greece in 2010 (Moeller, 2011: 3). Since the Debt Crisis in the European Union had a negative impact on economic relations between European countries, the European Debt Crisis also had a negative impact on the British economy.

On the other hand, it should be noted that there are important foreign trade partners for Turkey in the European Union and that Turkey was also negatively affected by the European Debt Crisis. The Brexit event may have caused the reason for the structural break in 2016. The Brexit referendum took place on June 23, 2016. However, the Brexit date was announced on February 20, 2016 (Cucinelli et al., 2020: 66). For this reason, the announcement of the Brexit referendum could be a cause of the structural break found in March 2016 or April 2016.

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2 *The critical value is -3,450 for the 5% significance level. The critical value is obtained from Fuller (1996).*

3 *The critical value is -2,890 for the 5% significance level. The critical value is obtained from Elliot et al. (1996).*

4 *The critical value is 5,620 for the 5% significance level. The critical value is obtained from Elliot et al. (1996).*

5 *The critical value is 0,146 for the 5% significance level. The critical value is obtained from Kwiatkowski et al. (1992).*

6 *The critical values for MZ_{α}^{GLS}, MZ_{t}^{GLS}, MSB^{GLS} and MP_{T}^{GLS} according to 5% significance level are -17,300; -2,910; 0,168; 5,480; respectively. The critical values are obtained from Ng and Perron (2001).*

Table: 5
Results of Unit Root Test with Two Breaks

Break-in Level and Trend Model			
Test Statistics	***L***	**Critical Value (5% Significance Level)**	**Break Dates**
-5,276	12	-5,650	September 2010; April 2016

Note: The critical value is obtained from Lee and Strazicich (2003). L indicates the lag length.

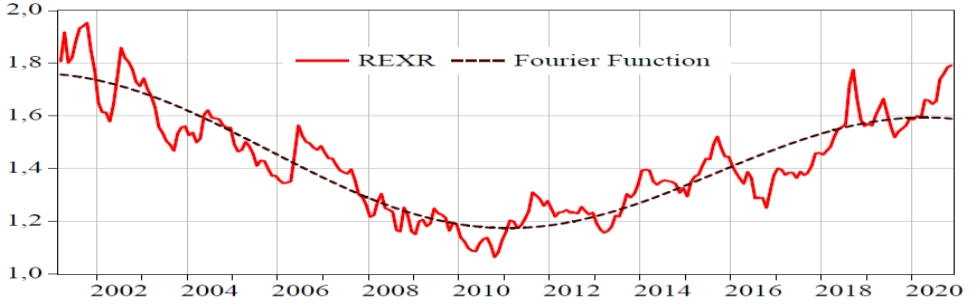
The results of the Güriş (2019) test, which takes into account smooth breaks and nonlinearity, are given in Table 6. According to the test, the optimal frequency was estimated as one. According to the results in the Table, since the test statistic is smaller than the 5% critical value, the null hypothesis of unit root cannot be rejected. In this respect, according to the results of the Güriş (2019) test, the *REXR* series is non-stationary at the level. Therefore, it can be said that the absolute PPP between the pound and the Turkish lira is not valid in the analysed period. Figure 4 shows the *REXR* series and the Fourier function (according to frequency one) for this series.

Table: 6
Results of Nonlinear Unit Root Test with Fourier Function

Constant and Trend Model			
Test Statistic	***k****	***L***	**Critical Value (5% Significance Level)**
9,559	1	12	18,400

Note: The critical value is obtained from Güriş (2019). k and L indicate the optimal frequency and lag length, respectively.*

Figure: 4
Fourier Function and *REXR* Series



Source: It was created by the author.

Table 7 shows the results of the fixed-b unit root test proposed by Otto (2021). For all block lengths in the Table, the *REXR* series is found to be non-stationary. In this respect, according to the fixed-b unit root test result, it was seen that the absolute PPP between the Turkish lira and the British pound was not a valid parity in the analysed period.

Table: 7
Fixed-b Unit Root Test Results

Test Statistic	L_B	Critical Values (5% Significance Level)
-0,103	135	-1,067
-0,171	157,500	-0,939
-0,213	180	-0,781
-0,155	202,500	-0,573

Note: The critical values are obtained from Otto (2021). L_B indicates block length.

According to the results of the unit root tests, which do not take into account structural breaks and take structural breaks into account, it is understood that the absolute PPP between the Turkish lira and the British pound is not a valid theory in the analysed period. The absolute PPP theory argues that the same basket at home and abroad can be purchased with a particular currency (Moritz & Stadtmann, 2010: 127). However, certain factors are necessary for absolute PPP to be valid. First of all, a period in which there was no fixed exchange rate system was selected (March 2001-November 2020). In a fixed exchange rate system, the nominal exchange rate cannot be expected to adapt to the price level. This may adversely affect the validity of the PPP theory (Patterson, 2000: 556). If the country data used are calculated with different techniques, it would not be correct to compare them. Considering this fact, the harmonized consumer price index (HCPI) data of Eurostat, which takes into account the same base year (2015), were used in the study. HCPI data are calculated according to harmonized and jointly determined methods[7]. The heterogeneity of foreign trade goods can cause the absolute PPP to be invalid (Rübel, 2013: 273).

The difference in quality (heterogeneity) of the same goods will be more pronounced, especially between developing and developed countries. Since the currency of a developing country (Turkish lira) and the developed country (British pound) are analysed in the study, it is expected that the quality will differ between the same goods. Therefore, the difference in the quality of the same kind of goods may have caused the absolute PPP between the Turkish Lira and British Pounds to be invalid. Another factor that can prevent absolute PPP from being valid is the presence of non-tradable goods (Rübel, 2013: 273). Goods produced in one country are considered non-tradable if they cannot or are not consumed in another country (Siebert, 1988: 2). There may be goods that Turkey and the United Kingdom have never bought from each other. This situation may cause the absolute PPP not to be valid. More or less, every state intervenes in the economy for different reasons.

Various interventions by governments make it difficult for absolute PPP to be valid (Rübel, 2013: 273). New public regulations have been introduced for the commercial relationship between Turkey and the United Kingdom. A new trade agreement was signed with the EU and the United Kingdom, following the final realization of Brexit on January 31, 2021. In parallel with this process, as a result of the negotiations between Turkey and the United Kingdom, a new Trade Agreement was signed on December 29, 2020. The signed

[7] *<https://ec.europa.eu/eurostat/de/web/hicp/>, June 30, 2021.*

treaty entered into force on 20 April 2021[8]. Apart from these, another factor limiting the validity of absolute PPP is the transportation costs in trade (Rübel, 2013: 273). High transportation costs will negatively affect foreign trade. High transport costs may result in some goods not being tradable at all. According to TSI data in 2020, Turkey's most used transportation channel in foreign trade was the sea route (share of maritime transport in exports is ~59,48%, and its share in imports is ~52,31%)[9].

Some previous empirical studies support the finding that the absolute PPP between the British pound and the Turkish lira is not valid. For example, according to the results of the regression analysis of Vergil and Özkan (2007), it can be seen that there is no absolute PPP between the Turkish lira and the British pound. According to the study of Aloy et al. (2011), the real exchange rate between the Turkish lira and the British pound was not stationary in either the linear stationarity test or the nonlinear unit root test. Therefore, according to the results of this study, it can be said that absolute PPP is not valid.

6. Conclusion

It is important to follow the development of exchange rates, especially for developing countries such as Turkey that need foreign exchange. If the absolute PPP is valid, the development of the exchange rates can be estimated considering the absolute PPP. On the other hand, the United Kingdom has an important place in Turkey's exports. Therefore, this study investigated the validity of the absolute PPP between the Turkish lira and the British pound. The research period is between March 2001 and- November 2020. Since Turkey switched to a flexible exchange rate system towards the end of February 2001 (on February 22, 2001), the period starts in March 2001. In the study, monthly British pound and Turkish lira real exchange rate data calculated by the author were used to test the absolute PPP. In calculating the real exchange rate, the nominal exchange rate between the Turkish lira and the British pound and the HCPI data for Turkey and the United Kingdom were used. Nominal exchange rate data were obtained from the EDS, and HCPI data were obtained from Eurostat.

In the study, the stationarity of the real exchange rate was analysed to test the absolute PPP. To determine the stationarity of the real exchange rate, both traditional unit root tests, which do not take structural breaks into account [ADF (1981), PP (1988), DF-GLS (1996), ERS-Point Optimal (1996), KPSS (1992), Ng and Perron (2001)], and unit root tests, which take structural breaks into account [LS (2003), Güriş (2019), Otto (2021)], were used. It is also possible to determine the validity of the absolute PPP by testing the relationship between the nominal exchange rate and the countries' price levels. However, such methods were not preferred due to the possible endogeneity problem. There are many previous studies on absolute PPP. However, the newly developed fixed-b test was applied for the first time in this study. It aims to contribute to the literature by comparing the new test results with the

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[8] *<https://ticaret.gov.tr/dis-iliskiler/brexit-ve-birlesik-krallik-sta>, June 30, 2021.*

[9] *<https://data.tuik.gov.tr/Bulten/Index?p=Dis-Ticaret-Istatistikleri-Eylul-2020-33857>, June 30, 2021.*

existing tests' results. In this test proposed by Otto (2021), the fact that there is no limitation in the number of structural breaks and that it can be applied in smooth and sharp breaks provides an advantage over many unit-root tests. According to the findings, the real exchange rate variable between the British pound and the Turkish lira was found to be non-stationary, both according to the results of the traditional unit-root tests which do not take into account structural breaks, and according to the results of the unit-root tests which take into account structural breaks. For this reason, it has been determined that the absolute PPP between the Turkish lira and the British pound is not valid in the analysed period. For this reason, it is recommended not to estimate the Turkish lira/British pound exchange rate based on absolute PPP.

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