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Empirical Analysis on Stability of Real Effective Exchange Rate Based on PPP Theory

Jia-Hua Yang

Xiamen University Tan Kah Kee College, Xiamen 363105, China; lucy1871608@gmail.com

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Abstract: Purchasing power parity (PPP) has been one of the most enduring concepts in the global economy. However, its validity has been questioned around for a long time. In this study, annual data on real effective exchange rates for 64 countries or regions from 1994−2022 are used to conduct a unit root test without structural breaks, followed by the same test containing one or two structural breaks. The result shows that a unit root test with structural break leads to an increase in the number of countries with a steady state of the exchange rate, as this method reflects the effect of irresistible factors on smoothness. In general, 43 countries or regions have a steady series of the real effective exchange rate, which means that 67.19% of them follow mean reversion, confirming the validity of the PPP theory. Developed countries (regions) and emerging countries (regions) are steady overall, and the opposite is true for frontier countries (regions).

Keywords: Purchasing power parity, Real effective exchange rate, Unit root test, Structural break

1. Introduction

Purchasing power parity (PPP) is important in many macroeconomic models, and its effectiveness has important policy implications. PPP theory states that as the long-term real exchange rate is stable, the nominal exchange rates of goods and services converge to a constant long-term equilibrium level over time at domestic and foreign price levels. However, the validity of the PPP theory is easily affected by changes in the exchange rate and high-impact events such as wars or economic crises, in which case the real effective exchange rate (REER) sequence has a unit root. If the REER sequence does not contain a unit root, it returns to a certain mean over time, *i.e.* the REER sequence follows mean reversion, which also means that PPP is good in the long run. Conversely, if the REER sequence contains a unit root, it is randomly changed, the REER sequence becomes unpredictable and PPP theory is not supported.

The PPP theory presents the coefficient of equivalence between currencies based on the different price levels of various countries. The aim is to make a reasonable comparison of the gross domestic product of countries. There can be a significant gap between the PPP and real exchange rates of countries. In the case of foreign trade balance, the exchange rate between the two countries tends to converge towards purchasing power parity. PPPs are divided into absolute PPPs and relative PPPs. The former refers to the ratio between the equilibrium exchange rate between the national currency and the foreign currency equal to the purchasing power or price level of the domestic and foreign currencies. The latter refers to the relative change in the purchasing power of currencies of different countries and is the determining factor for exchange rate changes. Based on the characteristics of the PPP theory, a benchmark exchange rate has policy significance and practical significance for arbitrage.

In the 1980s, empirical studies generally did not support mean reversion, and studies by Adler and Lehmann (1983), Huizinga (1987), Edison (1987), and Corbae and Ouliaris (1988) showed that the real exchange rate is volatile and not stable, so the PPP theory was not supported. However, empirical analysis by later studies found that the real exchange rate conformed to mean reversion, supporting the PPP theory. With the development of econometrics, the structural breakpoint test and nonlinear unit root test have gradually gained favor from scholars, and the validity of PPP theory has been further proved, but still, the debate on its validity has not been resolved. Since 2000, the effectiveness of the PPP theory has been studied, and the results were varied with different research goals. Liu *et al.* (2006) conducted an Engel-Granger cointegration test analysis of PPP on the RMB exchange rate from January 1980 to August 2004 and concluded that the long-term PPP hypothesis of the RMB exchange rate is valid, but the RMB exchange rate still deviates from PPP in a relatively short period. Hao and Zhu (2008) used the Johansen cointegration analysis test and the ESTAR model to study the monthly price levels and nominal exchange rates in China and the United States from 1994 to 2006. They found that the PPP theory has a weak ability to explain RMB exchange rates, and the effectiveness of the PPP theory is insufficient. Vats and Kamaiah (2011) tested REER sequences in India with linear unit roots and found that they followed mean reversion, supporting the PPP theory. Kutan and Zhou (2015) categorized 23 countries into Euro and non-Euro zones, and using linear and nonlinear unit root testing, found that countries with highly integrated economies were more likely to exhibit linear

stationarity, *i.e*., such countries were more supportive of the validity of PPP theory. Wang (2012) used exchange rate and quarterly price level data from 1957 to 2011 to find through the unit root test and the cointegration test that the long-term equilibrium of the PPP theory does not hold in emerging Asian countries. Vasconcelos and Júnior (2016) studied the effectiveness of PPP in linear and nonlinear root tests for REERs in seven Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela) and found that linear roots indicate that the REERs of Chile and Peru were stable, while the nonlinear root test indicated that Mexico was stable. Glaus and Thoma (2018) categorized 96 countries into developed, emerging, and frontier countries and used linear and nonlinear two classes of unit root tests to understand the stationarity of these three types of countries. They showed that 60% of countries tended to have a plateau. Chen *et al.* (2018) studied data from 1996 to 2016 from Canada, the United States, and China to test the effectiveness of the PPP theory, and the results showed that the PPP theory was invalid between Canada and the United States as well as between China and the United States. Papell and Prodan (2020) narrowed the confidence interval to provide strong evidence for the validity of the long-term PPP theory. Doanlar *et al.* (2021) classified 45 countries into developed, emerging, and frontier markets and used the Fourier quantile unit root test to test the long-term effectiveness of PPP. They found that 26 countries supported the long-term effectiveness of PPP. Doroodian *et al*. (1999) showed that floating exchange rates are more likely to support the PPP theory than fixed exchange rate regimes. In conclusion, so far, the validity of the PPP theory has not been firmly confirmed.

REER is an important economic indicator in international economics. A country's nominal effective exchange rate equals its currency and all trading partner's currency as a bilateral nominal exchange rate weighted average, and the REER can be obtained if the impact of inflation on the purchasing power of countries' currencies is excluded. Before using the REER sequence to study the validity of the PPP theory, most scholars prefer to use the real exchange rate (RER) to verify whether the PPP theory is valid. This is mainly because fluctuations in the real exchange rate series can reflect the international competitiveness of domestic goods and therefore, are critical to the stability of trade flows. Thus, testing the effectiveness of PPP with real exchange rates is an important cornerstone of many macroeconomic models of open economies (Bahmani-Oskooee *et al*., 2007). However, one disadvantage of the real exchange rate is that it is influenced by many non-economic factors such as government intervention and market mechanism failure. Therefore, the REER can better reflect the real economic competitiveness of different countries, and studying the dynamic change and stability of the REER series is of great significance for understanding the evolution of international economic relations and the formulation of macroeconomic policies.

The common weighted average methods include arithmetic weighted average and geometric weighted average. When calculating the effective exchange rate, researchers often design the calculation method of the weighted average, the range of sample currencies, and relevant parameters such as trade weights according to their purposes, and the results may vary to some extent. The actual effective exchange rate used in this study was calculated by researchers on the official website of the Bank for International Settlements. The identity test is classified into linear and nonlinear types, which are widely used in the volatility of REER sequences. The traditional linear root of unity tests include ADF (1979), Phillips and Perron (1988), and KPSS (1993) tests, and almost all literature used the root of unity test with these standard root tests. Perron (1989) argued that in the presence of structural faults, traditional unit root tests such as ADF (1979) and Phillips and Perron (1988) tend not to reject the null hypothesis and that ADF (1979) detection errors may occur in the event of a currency crisis, oil shock, or other major policy change. Zivot and Andrews (1992), Perron and Vogelgang (1992), Perron (1997), and Lee and Strazicch (2004) proposed a unit root test that allows endogenous single structure breaks. However, one structural break is not enough because if there are multiple structural breakpoints, the results become inaccurate. Thus, Lumsdaine and Papell (1997), Clemente *et al*. (1998), and Lee and Strazicich (2003) proposed a multi-structural breakpoint unit root test. Wang (2012) used the standard linear unit root detection method, the ADF (1979) test. Vats and Kamaiah (2011) tested REER sequences in India using two major types of tests: the no-breakpoint unit root test and the structural breakpoint unit root test. Kutan and Zhou (2015), Vasconcelos and Júnior (2016), Glaus and Thoma (2018), and Doanlar *et al.* (2021) used both linear and nonlinear root tests.

Based on time series data, we studied whether the REER series in 64 countries or regions follow mean reversion to propose policy recommendations. In addition to the introduction, this article consists of three sections. The second section is to organize and analyze the original data of the REER, that is, the data from 1994 to 2022 from the official website of the Bank for International Settlements (BIS). The third section describes the data in this study and specific detection methods, summarizes the analysis results, and discusses them. The final section provides conclusions and policy recommendations.

2. Current Situation of Real Effective Exchange Rates

We classified 64 countries into developed countries (regions), emerging countries (regions), and frontier countries (regions) according to the UNCTAD STAT and FTSE annual country classifications.

2.1. Current Situation in Developed Countries (Regions)

Most of the REER sequences in developed countries (regions) are relatively stable as shown in Fig. 1. Ireland, Singapore, and the United States are selected as the main basis for the current status of REER sequences in developed countries (regions). Ireland and the United States were affected by the 2008 financial crisis at different times. Ireland's economy has plummeted since 2008 and the economy of the United States has been declining since 2007. Singapore, on the other hand, experienced a slight decline in 1997−1998 as a result of the Asian financial crisis. Appendix I presents that in general, the REER sequence of developed countries (regions) is relatively stable because the market's response to the economic development and monetary policy of these countries is relatively slow and stable due to the relatively solid economic foundation, mature monetary policy, and fiscal policy. Although there are also fluctuations in specific periods and specific circumstances, their fluctuations are mostly maintained in a small range.

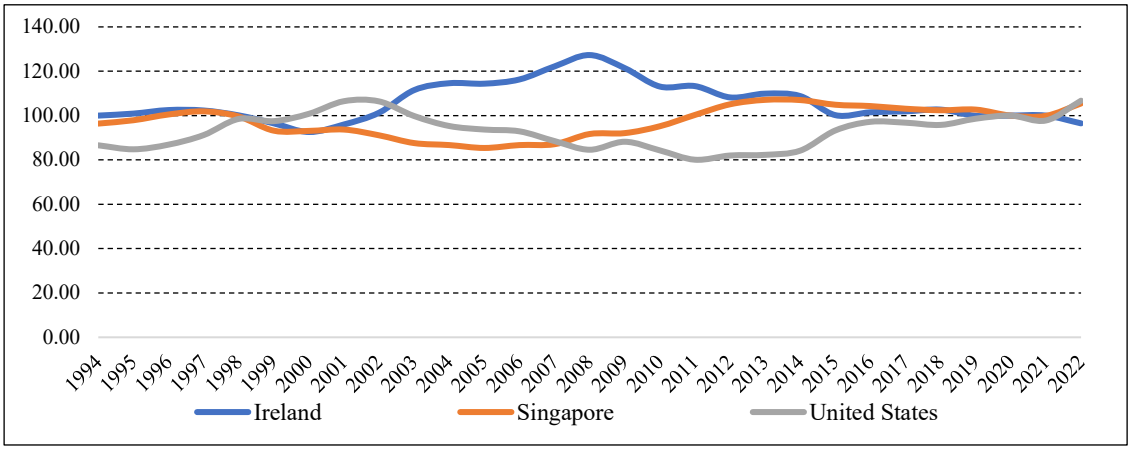

Fig. 1. Real effective exchange rates for Ireland, Singapore, and the United States.

Source: Bank for International Settlements (BIS) official website.

2.2. Current Situation in Emerging Countries (Regions)

Compared with developed countries (regions), the REER sequence of emerging countries (regions) is slightly scattered but still shows an upward trend in a certain range. China, Russia, and Thailand are selected as examples. Figure 2 shows that China has been less affected by crises and has maintained a stable upward trend although the RMB exchange rate has been less influenced by international financial market fluctuations and the depreciation of the US dollar in recent years. Russia experienced a small decline in 2008 due to the effects of the 2008 financial crisis. Thailand's REER sequence declined sharply from 1997 to 1998 and remained unchanged for many years. The sequence was then slowly recovered from about 2005 to 2006 and its stability was greatly affected by the Asian financial crisis of 1997−1998. The current status of REER sequences in emerging countries (regions) is affected by various internal and external factors, including macroeconomic factors, political and social factors, and changes in international trade and financial markets. The effect on each country is different in general. Appendix I shows that emerging countries (regions) are generally stable.

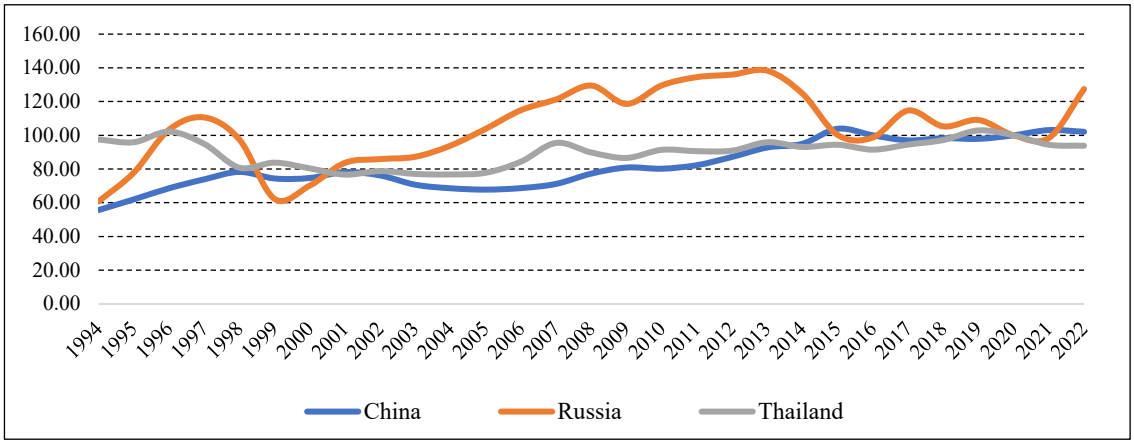

Fig. 2. Real effective exchange rates for China, Russia and Thailand.

Source: Bank for International Settlements (BIS) official website.

2.3. Current Situation in Frontier Countries (Regions)

The REER sequence of frontier countries is significantly less stable than that of developed countries (regions) and emerging countries (regions) (Fig. 3). Algeria and Slovakia have few complete fluctuations and generally operate in one direction. Algeria has generally shown a sustained downward trend, putting pressure on the REER due to factors such as its relatively lagging economic development, political instability, low levels of external trade and investment, and weak competitiveness in the international market. Saudi Arabia's REER sequence has been slowly declining since 2001, a result of the war in Afghanistan following the 911 terrorist events. The war in Afghanistan has had a greater impact on global oil markets and energy prices, and the impact has also spread to Saudi Arabia. The turmoil around Afghanistan has led to volatility and instability in oil prices, which impacted Saudi Arabia's economy as the world's largest oil exporter. Slovakia began in a completely upward trend with little change and only stabilized after 2009. It is presumably because it joined the Euro system on 1 January 2009. With the help and adjustment of the entire Eurozone, the REER of Slovakia did not grow rapidly. In general, as shown in Appendix I, there is no generally consistent trend in all frontier countries. The chaos is not only reflected in fluctuations within countries but also the correlation of trends between countries.

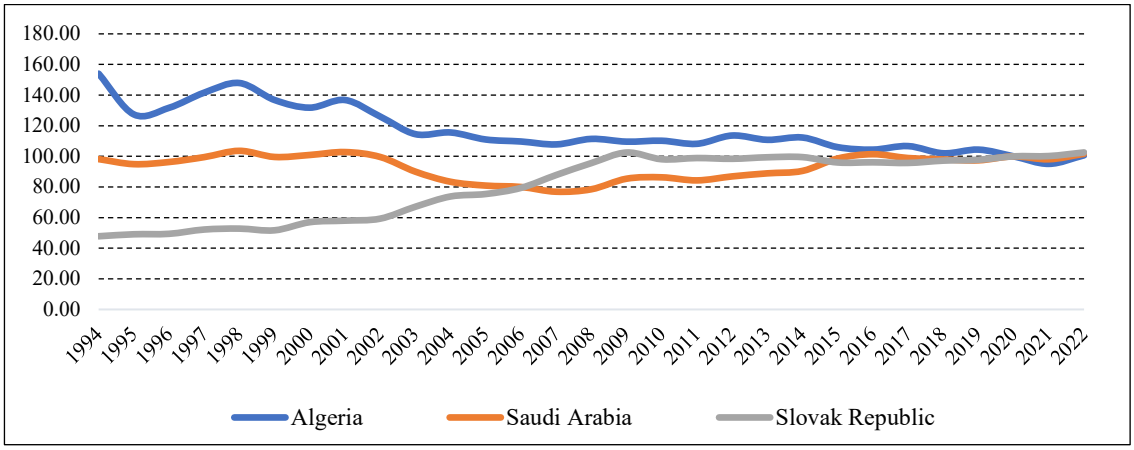

Fig. 3. Real effective exchange rates for Algeria, Saudi Arabia and Slovak Republic.

Source: Bank for International Settlements (BIS) official website.

3. Empirical Analysis on Stability of REER

We collected the annual REER data from 1994 to 2022 on the official website of BIS, including 64 countries or regions which were grouped into three categories: developed countries (regions), emerging countries (regions), and frontier countries (regions). Developed countries included Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom, the United States, and the Eurozone. Emerging countries included Argentina, Brazil, Chile, China, Taiwan, Colombia, Czech Republic, Greece, Hong Kong, Hungary, India, Indonesia, South Korea, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Thailand, Turkey, and the United Arab Emirates. Frontier countries include Algeria, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Estonia, Iceland, Latvia, Lithuania, Malta, Morocco, Republic of North Macedonia, Romania, Saudi Arabia, Serbia, Slovak Republic, and Slovenia. The sample span included the transition from the UK to the Chinese administration during the 1996 Hong Kong provisional legislative election, the Asian financial crisis of 1997−1998, the surge in oil prices in 2001, the war in Afghanistan that began in 2001 and ended in 2021, the SARS outbreak and the Iraq war in 2003, the US financial crisis in 2007−2008, and the coronavirus pandemic that began in December 2019 and ended now.

3.1. Unit Root Test without Breakpoint

In this study, three standard root-of-unit tests are used to examine the stationarity of REER sequences, namely the ADF (1979), Phillips and Perron (1988), and KPSS (1992) tests. The null hypothesis for the first two tests is the existence of a unit root, and the null hypothesis for KPSS (1992) is stationary. Dickey-Fuller GLS by Elliot *et al*. (1996) was used, followed by effective roots of Elliott-Rothenberg-Stock Point- Optimal (1996), and finally MZα and MZt and MSB and MPT tests of Ng-Perron (2001).

Table 1. Stationary number of 64 countries under unit root test without structural breakpoint.

Approach	ADF	PP	KPSS	DF-GLS	E-R-S P-O	Ng-Perron

						(MZα)	(MZt)	(MSB)	(MPT)
Developed countries	1	0	13	12	8	8	8	7	8
Emerging countries	5	2	13	10	6	7	8	7	7
Frontier countries	6	5	7	5	2	4	4	3	3

Note: ADF stands for Augmented Dickey-Fuller Unit Root Test; PP stands for Phillips-Perron Unit Root Test; KPSS stands for Kwiatkowski, Phillips, Schmidt, and Shin unit root test; DF-GLS stands for Dickey-Fuller vs. GLS removal trend unit root test; E-R-S P-O stands for Elliott-Rothenberg-Stock Point-Optimal Unit Root Detection; Ng-Perron, MZα, MZt, MSB and MPT represent Ng-Perron's MZα and MZt as well as MSB and MPT tests.

For 24 developed countries (regions), the ADF test result shows that only 1 country or region is stable. The PP test result shows no country or region is stable. The KPSS test result shows 13 countries or regions are stable. The DF-GLS test result shows 12 countries or regions are stable. The E-R-S P-O test result shows 8 countries are stable. The MZα detection in Ng-Perron shows 8 countries are stable. The MZt test result shows 8 countries are stable. The MSB test result shows 7 countries are stable. test result shows 8 countries are stable. According to the ADF test, in emerging countries (regions), 5 countries are stable. 2 countries or regions are stable in the PP test. 13, 10, 6, 7, 8, 7, and 7 countries or regions test in the KPSS, DF-GLS, E-R-S P-O, MZα detection in Ng-Perron, MZt, MSB, and MPT tests, respectively. Among frontier countries (regions), 6, 5, 7, 5, 2, 4, 4, 3, and 3 countries or regions are stable in the PP, KPSS, DF-GLS, E-R-S P-O, MZα detection in Ng-Perron, MZt, MSB, and MPT tests, respectively.

Overall, the ADF test result shows 12 of the 64 countries are stable, while the PP, KPSS, DF-GLS, E-R-S P-O, MZα detection in Ng-Perron, MZt, MSB, and MPT test results show 7, 33, 27, 16, 19, 20, 17, and 18 stable countries, respectively.

3.2. Unit Root Test with Breakpoint

We assume that in the structural breakpoint unit root test, the breakpoint is unknown, that is, endogenous. Zivot and Andrews (1992) proposed three models for testing unit roots (Eqs. (1)-(3)). The first is the intercept model, which allows the sequence to change in the intercept, called A. The second is the slope model, which allows the sequence to change in terms of slope, called B. The third is the intercept and slope model, which allows the sequence to change simultaneously in intercept and slope, called C. Eqs. (4) and (5) present the definitions of dummy variables in the first three equations. When $\rho = 0$, the null hypothesis is not rejected, and there is a unit root in the sequence. When $\rho < 0$, the sequence has structural breakpoints but is stable.

$$\Delta x_t = \alpha_0 + \alpha_1 DU_t + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-1} + \varepsilon_t \quad (1)$$

$$\Delta x_t = \alpha_0 + \gamma DT_t^* + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-1} + \varepsilon_t \quad (2)$$

$$\Delta x_t = \alpha_0 + \alpha_1 DU_t + \gamma DT_t + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-1} + \varepsilon_t \quad (3)$$

$$DU_t = 1 \ if \ t > TB, \ DU_t = 0 \ otherwise \quad (4)$$

$$DT_t^* = t - TB \ if \ t > TB, \ DT_t^* = 0 \ otherwise \quad (5)$$

We use Perron's structural breakpoint detection method (Peron, 1997), which is also extended with the assumption that the breakpoint is predictable and exogenous. Perron (1997) made the predetermined date unknown and contrasted it with the method of Zivot and Andrews (1992). We also use the single break unit root test of Lee and Strazicich (2003) and the double break detection. The least LM unit root test of Lee and Strazicich (2003; 2004) is used based on the Lagrange multiplier principle.

The 64 countries belong to the Eurozone and most of them are developed countries (regions) or frontier countries (regions). Only Greece is an emerging country. As shown in Appendix II, Belgium, Finland, France, Germany, Luxembourg, the Netherlands, Portugal, Spain, Greece, Cyprus, Slovakia, and Slovenia in the Eurozone are stable and support the validity of the PPP theory. When the Eurozone was unstable, Austria, Ireland, and Italy had breakpoints in 2002 possibly due to the official circulation of Euro banknotes and coins on January 1, 2002. Croatia, Estonia, Latvia, Lithuania, and Malta had breakpoints in 2008 or 2009, presumably

because of the 2008 U.S. subprime mortgage crisis. Singapore, Switzerland, Colombia, and Bulgaria had breakpoints in 2008. The Iraq War took place from March 2003 to December 2011 with Australia and Denmark as the participating countries. The United States, the United Kingdom, and Poland experienced breakpoints during this period. Thailand had a breakpoint in 1998 due to the Asian financial crisis that began on 2 July 1997, when Thailand was hit most seriously. Thailand implemented a floating exchange rate system in June 1997, and before then, Thailand had a fixed exchange rate system after World War II. The floating exchange rate system implemented at this time was not in line with Thailand's national conditions, which further deepened Thailand's losses.

The no-breakpoint unit root test results show that there are more stationary countries under the structural breakpoint unit root test. The ZA-A test result shows that 18 countries or regions are stable among developed countries (regions). The ZA-C, P-A, P-C, LS-A, LS-C, LS-AA, and LS-CC test results show that 16, 3, 4, 20, 22, 18, and 20 countries are stable in each test. Among emerging countries (regions), 19, 17, 5, 4, 20, 18, 18, and 22 countries are stable in the ZA-A, ZA-C, P-A, P-C, LS-A, LS-C, LS-AA, and LS-CC tests, respectively. Among frontier countries (regions), 14, 13, 4, 4, 10, 17, 10, and 15 countries are stable in the ZA-A, ZA-C, P-A, P-C, LS-A, LS-C, LS-AA, and LS-CC tests, respectively (Table 2).

Table 2. Stationary number of 64 countries under unit root test with structural breakpoint.

Approach	ZA-A	ZA-C	P-A	P-C	LS-A	LS-C	LS-AA	LS-CC
Developed countries	18	16	3	4	20	22	18	20
Emerging countries	19	17	5	4	20	18	18	22
Frontier countries	14	13	4	4	10	17	10	15

Note: ZA stands for Zivot-Andrews unit root test; P stands for Perron unit root test; LS means Lee Strazicich Unit Root Test; A indicates that interrupts on intercepts are allowed and are single breakpoints; C represents an interrupt that allows interception and slope and is a single breakpoint; AA represents an interrupt on the allowable intercept and is a double breakpoint; CC represents an interrupt that allows intercept and slope and is a double breakpoint.

Among 64 countries or regions, 51 (79.69%), 46 (71.88%), 12 (18.75%), 12 (18.75%), 50 (78.13%), 57 (89.06%), 46 (71.88%), and 57 (89.06%) countries are stable in the ZA-A, ZA-C, P-A, P-C, LS-A, LS-C, LS-AA, and LS-CC tests, respectively (Table 3).

Table 3. Stationary rates of 64 countries under unit root test with structural breakpoint.

Approach	ZA-A	ZA-C	P-A	P-C	LS-A	LS-C	LS-AA	LS-CC
Number of rejection	51	46	12	12	50	57	46	57
Percentage	79.69%	71.88%	18.75%	18.75%	78.13%	89.06%	71.88%	89.06%

Note: ZA stands for Zivot-Andrews unit root test; P stands for Perron unit root test; LS means Lee Strazicich Unit Root Test; A indicates that interrupts on intercepts are allowed and are single breakpoints; C represents an interrupt that allows interception and slope and is a single breakpoint; AA represents an interrupt on the allowable intercept and is a double breakpoint; CC represents an interrupt that allows intercept and slope and is a double breakpoint.

3.3. Comparative Analysis of Unit Root Tests with and without Structural Breakpoint

Compared with the linear unit root test without breakpoints, the results of the structural breakpoint unit root test show that there are more stationary countries, and the stationarity rate is relatively increased, which verifies that the structural breakpoint test considers the fluctation of the REER sequence when a sudden event occurs in the country. Although the REER sequence fluctuates suddenly, it also follows mean reversion after the breakpoint occurs. Since accidents are sudden or inevitable, the structural breakpoint unit root test becomes more flexible in a variety of possible situations. A more holistic view of the stability of countries is possible. The previous conclusion states that the rejection rate of the P-A and P-C tests is only 18.75%. That is, only 18.75% of countries or regions are stable under this method. In general, except for the P-A and P-C tests, the steady rate of other methods is high. The result of this study considering the 60% of steadiness of Glaus and Thoma (2018) shows that six tests are required to be stationary for the linear unit root test to be considered stable and five tests for the structural breakpoint unit root test to be considered stable.

For the unit root test without structural breakpoint, 7 developed countries (regions) showed stability, accounting for 29.17% of the total number of countries, 7 emerging countries (regions) showed a stable proportion of 30.43%, 2 frontier countries (regions) showed a stable proportion of 11.76% (Fig. 4). Under the unit root test with structural breakpoint, 15 developed countries (regions) showed that the proportion of stable was 62.5%. 18 emerging countries (regions) showed a stable proportion of 78.26%. The 10 frontier countries (regions) showed a stable proportion of 58.82%. In summary, the structural breakpoint unit root test has the

greatest impact on the growth of the stability rate in emerging countries (regions) (47.83%) followed by frontier countries (regions) (47.06%) and developed countries (regions) (33.33%). Overall, 64 countries or regions were stable, and 67.19% of countries or regions were stable for the unit root test without structural breakpoint. The REER sequence in China showed that it followed mean reversion. That is, it supports the validity of The PPP theory. Previously, Liu *et al*. (2006) also concluded that the long-term PPP hypothesis exists in the RMB exchange rate. In addition, the country-specific stability situation is shown in Appendix II.

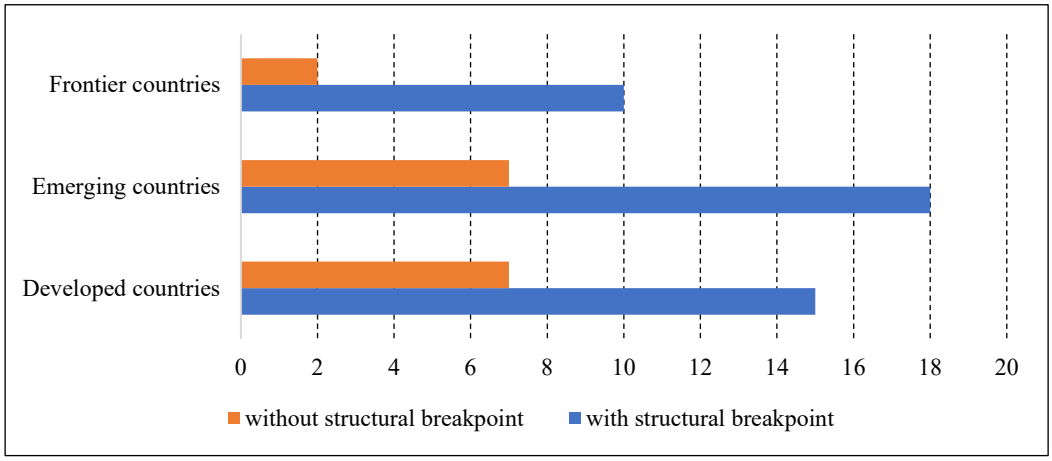

Fig. 4. Comparison of unit root test results with structural breakpoint versus without structural breakpoint.

The unit root test with structural breakpoint increases the stability rate the most in emerging countries (regions), followed by frontier countries (regions) and developed countries (regions). This reflects the fact that developed countries (regions) have more mature economic and financial systems and stronger technological advantages. Governments and enterprises need to pay more attention to risk management and preventive measures to more effectively deal with and correct imbalances and risks in the economic and financial fields. Compared with the unit root test without a structural breakpoint, in the unit root test with a structural breakpoint, the stability rate of developed countries (regions) increases by only 33.33%. Emerging countries (regions) are in a stage of rapid development, and their industrial and economic systems have greatly improved their development level in a relatively short period. However, China and India, for example, have fixed exchange rate systems, and the rise is relatively stable. Thus, the stabilization rate of emerging countries (regions) is the highest. Since emerging countries (regions) are more susceptible to external factors, the stability rate increases by as high as 47.83% in the unit root test with a structural breakpoint. As frontier countries (regions) do not have mature economic and social systems, the development speed is slower and relatively close. Due to a lack of sufficient resources and technical support, their stability rate is the lowest. Most of them do not support the effectiveness of the PPP theory, but they are also susceptible to external factors. The stability rate of frontier countries (regions) increases by 47.06% which is similar to that of emerging countries.

4. Conclusions and Recommendations

Taking the REER as the measurement index, we analyze the current situation of 64 countries or regions and propose targeted policy measures. Fewer countries' stability rates are higher in the unit root test without structural breakpoints than those in the test with structural breakpoints. This indicates that the former is not influenced by the impact of major catastrophes or events. The REER sequence may be stable. However, events break the balance at that moment, and the linear test cannot distinguish stability. Therefore, the stability rate of the unit root test with structural breaks becomes higher. Second, the unit root test with structural breakpoint better reflects the actual situation of economic phenomena. For example, economic policy adjustments and trade wars may cause the trend of the REER sequence to change. Therefore, the unit root test with structural breakpoints provides more accurate conclusions and practical references for detailed economic analysis and policy-making. Third, 25% of the countries or regions are stable in the unit root test without structural breakpoints, and 67.19% of countries or regions are stable in the test with structural breakpoints. In general, the REER sequence follows mean reversion, which supports the validity of The PPP theory. Fourth, under the unit root test without structural breakpoints, the stability rate of developed countries (regions) is 29.17%, the stabilization rate of emerging countries (regions) is 30.43%, and the stabilization rate of frontier countries (regions) is 11.76%. In the unit root test with structural breakpoint, the stationary rate of developed countries (regions) is 62.5%, the stability rate of emerging countries (regions) is 78.26%, and the stabilization rate of frontier countries (regions) is 58.82%. Developed countries (regions) and emerging countries (regions) are relatively stable compared to frontier countries (regions). Fifth, the unit root test with structural breakpoint

has the greatest impact on the growth of stability rate in emerging countries (regions) (47.83%), followed by frontier countries (regions) (47.06%), and developed countries (regions) the smallest (33.33%).

Compared with frontier countries (regions), developed and emerging countries (regions) have relatively stable development and have almost formed their systems. The REERs of frontier countries are often complex and affected by various factors as they face many challenges such as the level of poverty, the structure of their economies, and the scale of international trade. Therefore, for frontier countries (regions), these factors need to be considered more comprehensively and deeply to formulate more effective economic and trade policies. Under the increasingly complex and dynamically changing international situation, developed and emerging countries (regions) also need to continuously optimize their respective national policy systems to ensure their position in the international market and improve their competitive advantages and achieve sustainable economic and social development. The policy recommendations for this study are listed as follows.

4.1 Optimizing Fiscal Policies

Governments of frontier countries (regions) need to improve fiscal balances by increasing tax revenue and reducing wasteful spending to better manage the budget. These measures include increasing public investment, optimizing the debt structure, implementing fiscal incentives, establishing effective budgetary and financial supervision mechanisms, actively expanding imports of high-quality goods and services, and creating effective demand for the hard-hit world economy by playing the role of ultra-large markets, creating a favorable environment for building a new development pattern. Developed countries (regions) need a prudent monetary policy to control inflation, maintain the stability of prices and currency exchange rates to maintain stable economic growth, and at the same time, reduce tax burdens, strengthen social welfare protection, support innovation and scientific and technological development, and strengthen public investment and control debt. Emerging countries (regions) require the establishment of sustainable fiscal plans, economic development, and strengthening social protection and infrastructure. By achieving these goals, the overall competitiveness and livelihood of the country can be obtained.

4.2. Stabilizing Inflation Expectations

Governments of frontier countries (regions) need to adopt stricter monetary policies, including increasing interest rates, controlling the money supply, and adjusting exchange rates to curb inflation expectations, stabilize the economy and money market, and fundamentally solve the problem of inflation expectations. At the same time, it is necessary to strengthen regulatory mechanisms, including financial supervision, market supervision, and price supervision to maintain market stability and curb the further spread of inflation expectations. The main way for developed countries (regions) to stabilize inflation expectations is through adjustment and coordination of macroeconomic policies. In fiscal policy, government spending, tax revenues, and fiscal deficits need to be adjusted. In monetary policy, it is necessary to rationally adjust interest rates, adjust money supply, and other methods to control the price level. It is also required to stabilize inflation expectations, improve labor productivity and maintain the order of market competition. Emerging countries (regions) must strengthen market supervision, prevent the risk of inflation, and properly deal with the problem of currency liquidity. At the same time, it is needed to support moderate inflation targeting, increase productivity, further deepen financial marketization, and strengthen the soundness and transparency of the financial system to stimulate more market vitality.

4.3. Macro-policy Coordination

Frontier countries (regions) face special challenges in improving macroeconomic policy coordination, including poverty, unstable institutional environment, and weak institution-building. To improve macro-policy coordination, frontier countries (regions) need government measures such as strengthening institutions and capacity building, cooperation with other countries and international organizations, information collection and integration, establishing sound monitoring and evaluation mechanisms, and strengthening the participation of civil society organizations. Economic policies interact with each other among developed countries (regions). Thus, it is necessary to strengthen the coordination of macro policies to achieve balance and stability in the global economy. Developed countries (regions) can establish a global economic dialogue mechanism to coordinate the economic policies of various countries, share information and experience on time, and mitigate the impact and losses of the crisis on the economies and people of various countries in the event of a global economic crisis. For them, it is important to improve trade relations, promote a high degree of the industrial division of labor, strengthen innovation and scientific and technological cooperation, and jointly promote the research and development and application of new technologies. These are the responsibilities of developed countries (regions) to improve the overall production level, strengthen the complementarity of the economies of various countries, and achieve sustainable development. Emerging countries (regions) need an important driving force for global economic growth, and cooperation mechanisms are needed to strengthen innovation and technology cooperation, cultivate advantages in emerging scientific and technological fields, improve innovation capabilities, and promote economic structure optimization and industrial

upgrading. Emerging countries (regions) also need to strengthen regulatory cooperation, promote trade liberalization and promote regional economic integration to make greater contributions to the global economy.

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Conflicts of Interest: The authors declare no conflict of interest.

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Appendix I. Chart of real effective exchange rate fluctuations by country (region).

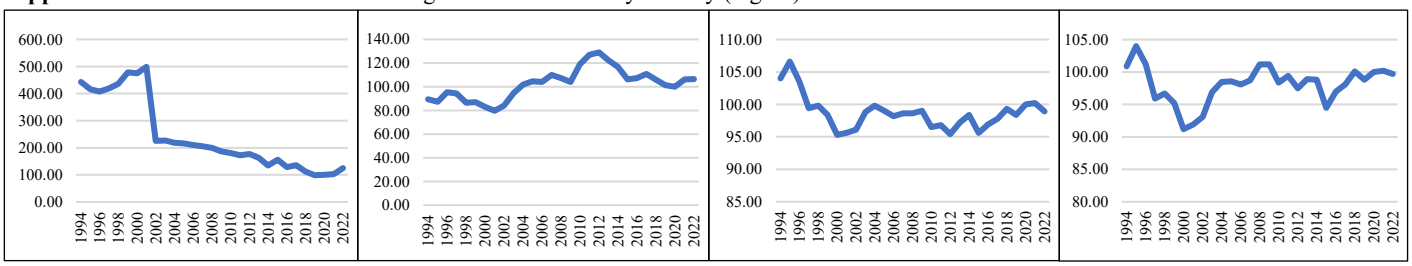

Figure A1. Argentina **Figure A2.** Australia **Figure A3.** Austria **Figure A4.** Belgium

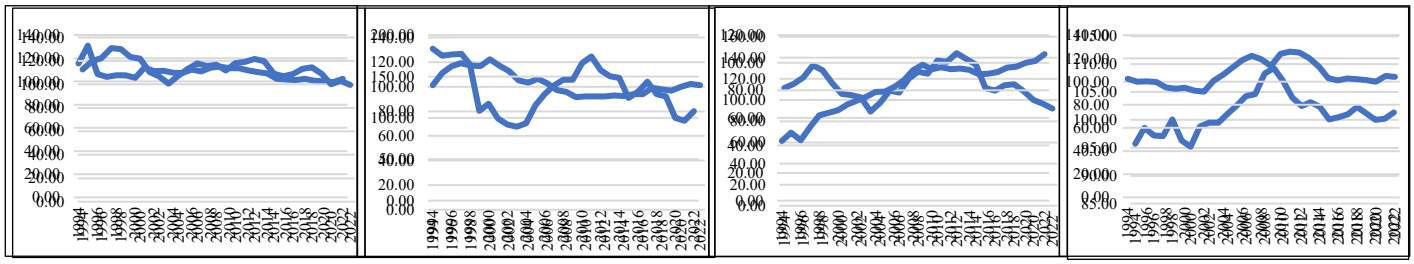

Figure A5. Bosnia & Herzegovina **Figure A6.** Brazil **Figure A7.** Bulgaria **Figure A8.** Canada

Figure A9. Chile **Figure A10.** Taiwan **Figure A11.** Colombia **Figure A12.** Croatia

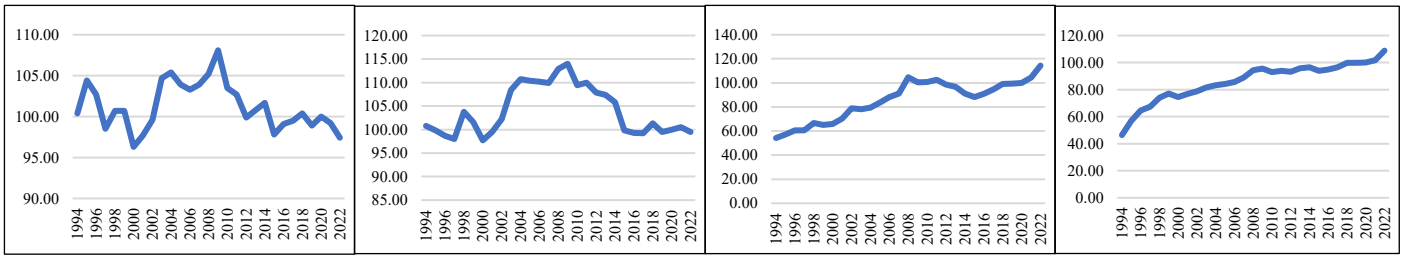

Figure A13. Cyprus **Figure A14.** Czechia **Figure A15.** Denmark **Figure A16.** Estonia

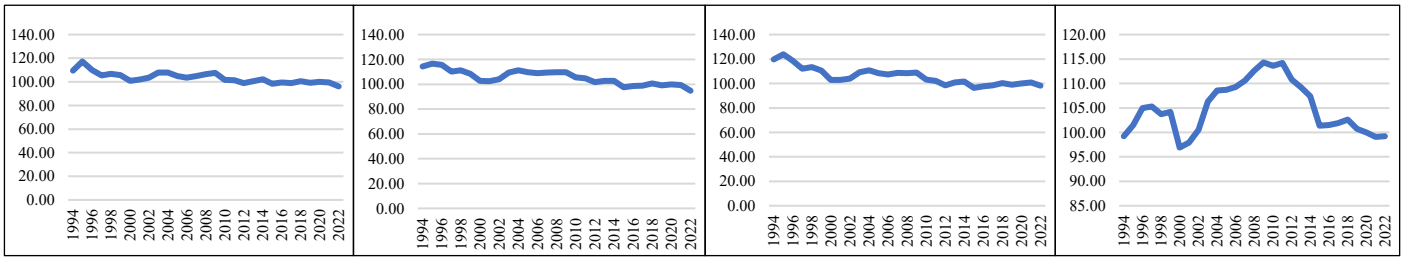

Figure A17. Finland **Figure A18.** France **Figure A19.** Germany **Figure A20.** Greece

Figure A21. Hong Kong SAR **Figure A22.** Hungary **Figure A23.** Iceland **Figure A24.** India

Figure A25. Indonesia **Figure A26.** Israel **Figure A27.** Italy **Figure A28.** Japan

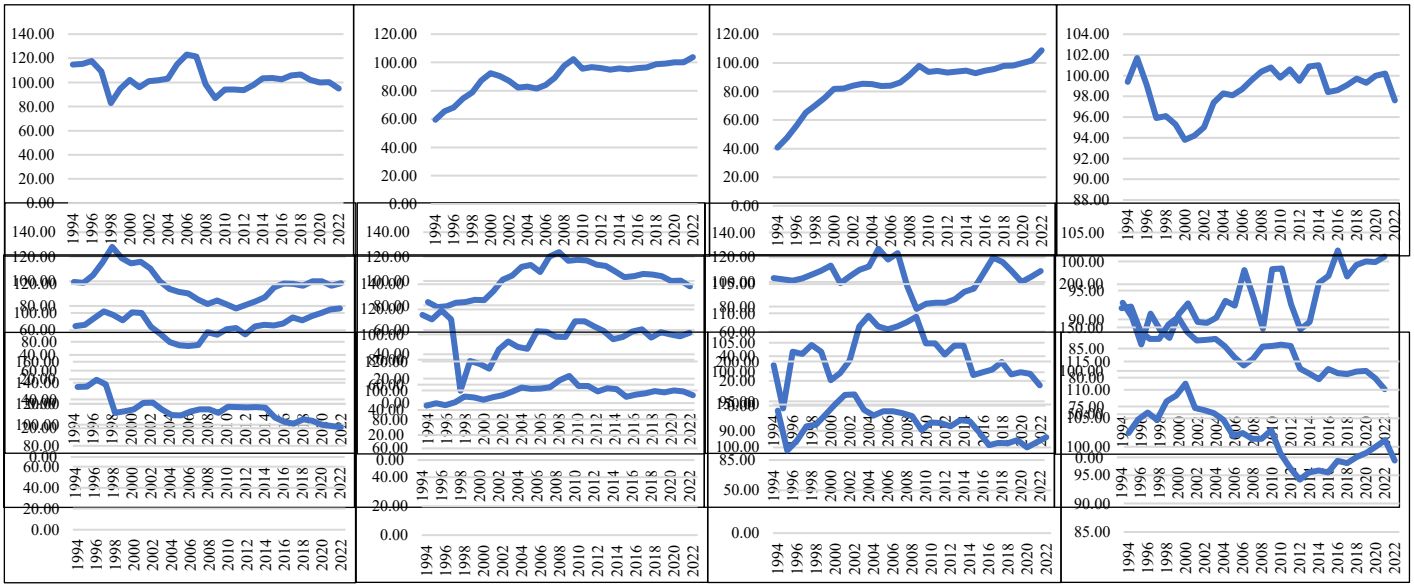

Figure A29. Korea **Figure A30.** Latvia **Figure A31.** Lithuania **Figure A32.** Luxembourg

Figure A33. Malaysia **Figure A34.** Malta **Figure A35.** Mexico **Figure A36.** Morocco

Figure A37. Netherlands **Figure A38.** New Zealand **Figure A39.** North Macedonia **Figure A40.** Norway

Figure A41. Peru **Figure A42.** Philippines **Figure A43.** Poland **Figure A44.** Portugal

Figure A45. Romania **Figure A46.** Serbia **Figure A47.** Slovenia **Figure A48.** South Africa

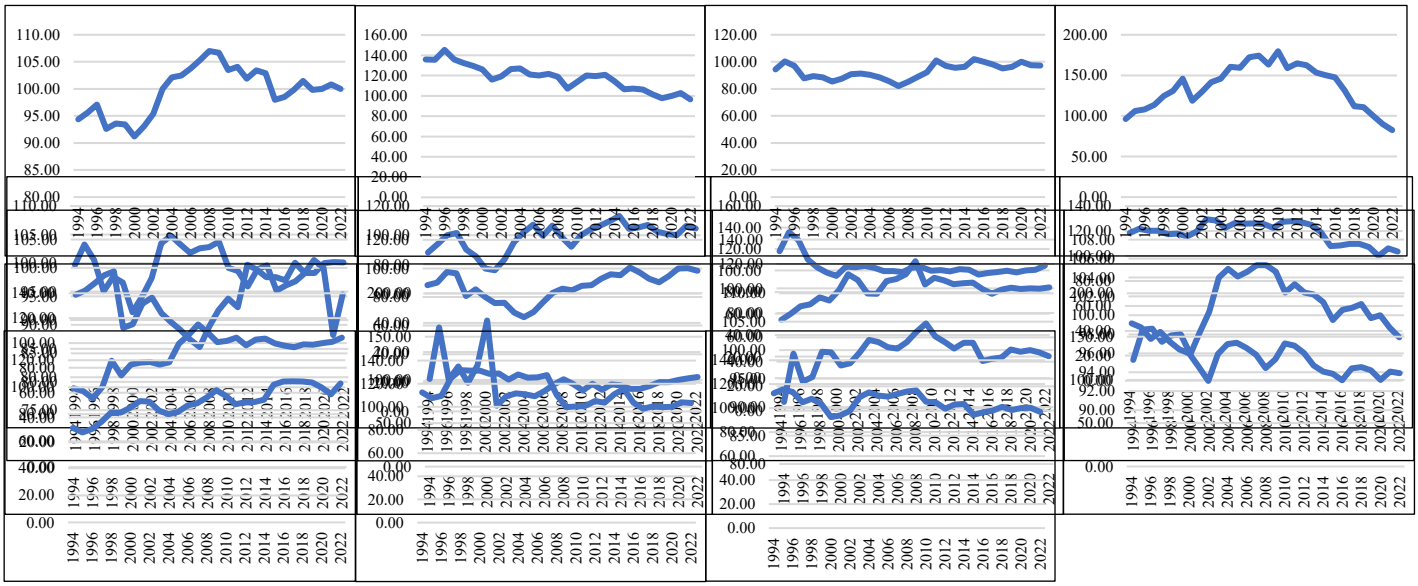

Figure A49. Spain **Figure A50.** Sweden **Figure A51.** Switzerland **Figure A52.** Turkey

Figure A53. United Arab Emirates **Figure A54.** United Kingdom **Figure A55.** Euro area

Appendix II. Tables of unit root test with and without structural breakpoint.

Table A1. Unit root test without structural breakpoint for developed countries (regions).

	ADF	PP	KPSS	DF-GLS	E-R-S P-O	Ng-Perron (MZα)	(MZt)	(MSB)	(MPT)

Australia	-1.8915	-1.5255	0.3960*	-1.6953*	5.6589	-5.3486	-1.6120	0.3014	4.6422
Austria	-2.6058	-2.5514	0.2594	-1.8390*	10.7582	-4.1308	-1.4211	0.3440	5.9495
Belgium	-2.2442	-2.3119	0.1258	-2.1014**	2.9914*	-6.4465*	-1.7918*	0.2780	3.8123*
Canada	-1.8293	-1.4757	0.1943	-1.8178	3.4970*	-6.7719*	-1.8394*	0.2716*	3.6202*
Denmark	-2.2164	-2.2897	0.1866	-2.2525**	3.2387*	-7.8823*	-1.9028*	0.2414*	3.4050*
Euro Area	-1.9584	-2.0386	0.3013	-1.7801*	6.2948	-5.2349	-1.4970	0.2860	4.9791
Finland	-1.2469	-1.4453	0.6222**	-0.0757	7.6796	-4.6763	-1.2921	0.2763	5.6737
France	-0.9584	-0.9599	0.5934**	-0.5600	19.8861	-0.6075	-0.2434	0.4007	13.3076
Germany	-1.8486	-1.8082	0.5992**	-1.0628	24.0724	-1.3306	-0.6111	0.4593	13.3017
Ireland	-2.4274	-1.3374	0.1478	-1.6287*	3.8046*	-6.6140*	-1.7767*	0.2686*	3.8430*
Israel	-0.9710	-1.3151	0.1642	-1.0555	7.8402	-2.8342	-1.0113	0.3568	8.1196
Italy	-2.1432	-2.1008	0.2135*	-2.1509**	3.4937*	-7.3549*	-1.8405*	0.2503*	3.6013*
Japan	-1.3415	-1.0212	0.6890**	0.5860	28.5389	0.2074	0.0923	0.4453	15.9194
Luxembourg	-1.7677	-1.8430	0.2580	-1.7764*	4.6088	-5.2710	-1.6021	0.3039	4.7032
Netherlands	-2.5182	-2.4794	0.0793*	-2.6149**	2.8522**	-8.0860*	-2.0074**	0.2483*	3.0422**
New Zealand	-1.8948	-1.8948	0.4325	-1.7025*	6.7697	-4.6152	-1.4571	0.3157	5.4245
Norway	-0.6952	-0.7451	0.3595*	-0.8240	9.1243	-2.1708	-0.8024	0.3696	9.4441
Portugal	-1.6839	-1.9534	0.1995	-1.3716	15.9391	-2.3042	-1.0572	0.4588	10.5171
Singapore	-1.3122	-1.1728	0.2849	-1.3743	3.3935*	-7.7214*	-1.8809*	0.2436*	3.4728*
Spain	-2.8447*	-1.6081	0.3104	-1.3043	11.7631	-2.5743	-1.1175	0.4341	9.4352
Sweden	-1.3241	-0.4180	0.6523**	-0.5936	20.3689	-0.6502	-0.2790	0.4291	14.1626
Switzerland	-1.7430	-1.8602	0.3287	-1.7776*	4.3589	-5.3799	-1.6128	0.2998	4.6269
United Kingdom	-1.2053	-1.2053	0.4388*	-1.2519	7.2395	-3.1384	-1.1989	0.3820	7.7186
United States	-1.9314	-1.3774	0.1017*	-1.9035*	0.3415***	-185.1650***	-9.5709***	0.0517***	0.2025***

Note: ADF stands for Augmented Dickey-Fuller Unit Root Test; PP stands for Phillips-Perron Unit Root Test; KPSS stands for Kwiatkowski, Phillips, Schmidt, and Shin unit root test; DF-GLS stands for Dickey-Fuller vs. GLS removal trend unit root test; E-R-S P-O stands for Elliott-Rothenberg-Stock Point-Optimal Unit Root Detection; Ng-Perron, MZα, MZt, MSB and MPT represent Ng-Perron's MZα and MZt as well as MSB and MPT tests.
*, **, ***indicate significance levels of 10%, 5% and 1% respectively.

Table A2. Unit root test without structural breakpoint for emerging countries (regions).

	ADF	PP	KPSS	DF-GLS	E-R-S P-O	Ng-Perron (MZα)	(MZt)	(MSB)	(MPT)
Argentina	-1.4238	-1.3498	0.6032**	-0.9551	21.5540	-1.3086	-0.6504	0.4970	14.4933
Brazil	-1.5790	-1.7960	0.0897	-1.6070	0.1635***	-272.9850***	-11.6734***	0.0428***	0.1007***
Chile	-2.6176	-1.7909	0.3652*	-2.7715***	0.6138***	-43.2758***	-4.5822***	0.1059***	0.7498***
China	-1.3585	-1.3888	0.6277**	-0.4417	67.4598	0.5781	0.3985	0.6892	33.7467
Chinese Taipei	-3.9328***	-2.4679	0.5294**	-2.2888**	61.2339	-0.0960	-0.4478	0.7513	29.8679
Colombia	-1.1439	-1.5135	0.0976	-1.2367	6.5551	-3.5321	-1.1726	0.3320	6.8970
Czechia	-0.9316	-0.9568	0.6141**	0.0681	72.3668	1.1321	0.7721	0.6821	36.6735
Greece	-1.6404	-1.5215	0.1506	-1.5577	4.9118	-5.5373	-1.6322*	0.2948	4.5128
Hong Kong	-2.4189	-1.4340	0.2719	-2.3750**	1.7077***	-13.7777**	-2.6246***	0.1905**	1.7784***
Hungary	-3.4470**	-1.4984	0.3304	-0.0499**	24.3890	-1.3408	-0.8187	0.6107	18.2725
India	-2.1518	-2.1620	0.5814**	-2.2239**	3.4115*	-7.9741*	-1.8679*	0.2342*	3.5330*
Indonesia	-2.5362	-2.9979**	0.1450	-1.9175*	3.9269	-6.6869*	-1.8276*	0.2733*	3.6670*
Korea	-3.4159**	-2.3740	0.2337	-2.8123***	0.0820***	-19.3320***	-3.0620***	0.1584***	1.4321***
Malaysia	-2.9466*	-1.4169	0.5814**	-0.9186	41.3408	-0.9522	-0.4197	0.4408	13.7783
Mexico	-1.9132	-2.0394	0.3394	-1.8156*	5.4255	-5.3933	-1.5709	0.2913	4.7308
Peru	-2.4329	-2.4207	0.1974	-2.4766**	2.7124**	-8.4460**	-2.0546**	0.2433*	2.9023**
Philippines	-1.3197	-1.2444	0.3178	-1.3735	5.0349	-4.7191	-1.4608	0.3096	5.3415
Poland	-3.0304**	-3.1361**	0.3056	1.7836*	16.4643	-3.3452	-1.2495	0.3735	7.2863
Russia	-2.3347	-2.3958	0.3845*	-1.5908	12.9174	-3.4445	-1.1501	0.3339	7.0306
South Africa	-2.5582	-2.1923	0.6146**	-1.5204	9.3719	-3.0759	-1.0804	0.3512	7.6743

Thailand	-1.8074	-1.8224	0.2631	-1.6927	6.0195	-4.5295	-1.5026	0.3317	5.4132
Turkey	-0.7728	-1.1442	0.1825	-0.7768	17.5490	-1.2159	-0.6105	0.5021	14.9680
United Arab Emirates	-0.5022	-1.3494	0.6351**	-0.2984	588.2117	-0.7872	-0.3840	0.4878	15.8868

Note: ADF stands for Augmented Dickey-Fuller Unit Root Test; PP stands for Phillips-Perron Unit Root Test; KPSS stands for Kwiatkowski, Phillips, Schmidt, and Shin unit root test; DF-GLS stands for Dickey-Fuller vs. GLS removal trend unit root test; E-R-S P-O stands for Elliott-Rothenberg-Stock Point-Optimal Unit Root Detection; Ng-Perron, MZα, MZt, MSB and MPT represent Ng-Perron's MZα and MZt as well as MSB and MPT tests.
*, **, ***indicate significance levels of 10%, 5% and 1% respectively.

Table A3. Unit root test without structural breakpoint for frontier countries (regions).

	ADF	PP	KPSS	DF-GLS	E-R-S P-O	Ng-Perron (MZα)	(MZt)	(MSB)	(MPT)
Algeria	-1.9700	-2.4522	0.6173**	1.1937	29.9351	-1.2761	-0.5883	0.4610	13.5074
Bosnia & Herzegovina	-2.9774**	-2.831*	0.4559*	-2.6930***	4.0846	-8.9824**	-2.0483**	0.2280**	2.9931**
Bulgaria	-2.0235	-2.1550	0.6368**	0.0725	158.4120	0.4145	0.2883	0.6956	33.1745
Croatia	-1.8919	-1.9606	0.2647	-1.4561	9.0845	-3.0874	-1.2213	0.3956	7.8958
Cyprus	-2.7858*	-1.2862	0.1588	-2.3719**	1.4705***	-3.0762	-1.2030	0.3911	7.8930
Estonia	-3.6529**	-3.4698**	0.6812**	-0.3355	229.8703	1.2289	1.0255	0.8345	52.4472
Iceland	-2.3878	-1.9200	0.1004	-2.4418**	3.7449	-6.1741*	-1.7443*	0.2825	4.0084
Latvia	-1.2586	-2.6029	0.6205**	-0.8143	76.4661	0.1593	0.1012	0.6355	27.4162
Lithuania	-4.2158***	-4.2158***	0.6343**	-0.4696	267.5966	0.0665	0.9238	0.8662	54.3349
Malta	-2.1569	-2.1104	0.3080	-1.5553	13.4883	-2.9470	-1.2111	0.4110	8.3064
Morocco	-0.9614	-0.9841	0.4878**	0.9953	10.0918	-2.1892	-0.9641	0.4404	10.5224
North Macedonia	-2.6934*	-2.0007	0.4136*	-0.4684	8.5050	-0.4904	-0.4138	1.0599	55.8761
Romania	-1.8049	-1.7873	0.5130**	-1.1367	21.5449	-1.5951	-0.7435	0.4661	12.7205
Saudi Arabia	-1.5053	-1.3637	0.1453	-1.5769	3.9390	-6.3250*	-1.7379*	0.2748*	4.0034*
Serbia	-11.5090***	-4.5462***	0.3276	-4.6180***	0.4656***	-13.8062***	-2.6262***	0.1902**	1.7792***
Slovak Republic	-1.3067	-1.2193	0.6128**	-0.4437	151.8305	0.4817	0.2846	0.5909	21.5943
Slovenia	-1.7776	-4.4036***	0.3005	-2.1954**	27.5144	-4.7637	-1.5220	0.3195	5.1874

Note: ADF stands for Augmented Dickey-Fuller Unit Root Test; PP stands for Phillips-Perron Unit Root Test; KPSS stands for Kwiatkowski, Phillips, Schmidt, and Shin unit root test; DF-GLS stands for Dickey-Fuller vs. GLS removal trend unit root test; E-R-S P-O stands for Elliott-Rothenberg-Stock Point-Optimal Unit Root Detection; Ng-Perron, MZα, MZt, MSB and MPT represent Ng-Perron's MZα and MZt as well as MSB and MPT tests.
*, **, ***indicate significance levels of 10%, 5% and 1% respectively.

Table A4. Unit root test with structural breakpoint for developed countries (regions).

	ZA-A	ZA-C	P-A	P-C	LS-A	LS-C	LS-AA	LS-CC
Australia	5%Reject p-v<0.05 2015	1%Reject p-v<0.01 2010	Accept 2017	Accept 2009	1%Reject 2011	1%Reject 2008	1%Reject 2011 2017	1%Reject 2008 2016
Austria	Accept p-v>0.1 2016		Accept 2016	Accept 2002	Accept 2012	1%Reject 2005	10%Reject 2005 2012	10%Reject 2008 2018
Belgium	1%Reject p-v<0.01 2003	1%Reject p-v<0.01 2003	Accept 2015	Accept 2002	1%Reject 2015	1%Reject 2015	5%Reject 2007 2015	1%Reject 2006 2014
Canada	1%Reject p-v<0.01 2003	Accept p-v>0.1 2010	Accept 2002	Accept 2002	1%Reject 2015	1%Reject 2008	1%Reject 2006 2015	1%Reject 2009 2017
Denmark	1%Reject p-v<0.01 2003	1%Reject p-v<0.01 2003	Accept 2002	10%Reject 2002	1%Reject 2011	1%Reject 2017	1%Reject 2011 2018	10%Reject 2007 2013
Euro Area	Accept p-v<0.01 2003	Accept p-v<0.05 2003	Accept 2002	Accept 2002	5%Reject 2014	1%Reject 2015	Accept 2008 2014	1%Reject 2006 2013
Finland	5%Reject p-v<0.05 2003	5%Reject p-v<0.05 2002	Accept 2000	5%Reject 2002	1%Reject 2015	1%Reject 2018	1%Reject 2004 2015	1%Reject 2005 2018
France	1%Reject p-v<0.01 2003	5%Reject p-v<0.05 2003	Accept 2002	Accept 2002	1%Reject 2015	1%Reject 2015	1%Reject 2010 2015	1%Reject 2006 2016
Germany	5%Reject p-v<0.05 2012	5%Reject p-v<0.05 2012	Accept 2015	Accept 2011	1%Reject 2008	1%Reject 2010	1%Reject 2007 2012	1%Reject 2006 2015
Ireland	Accept p-v<0.01 2003	Accept p-v<0.1 2006	Accept 2002	Accept 2002	1%Reject 2009	1%Reject 2016	5%Reject 2008 2016	1%Reject 2006 2013
Israel	1%Reject p-v<0.01 2002	1%Reject p-v<0.01 2002	10%Reject 2001	Accept 2001	1%Reject 2016	1%Reject 2015	1%Reject 2012 2014	5%Reject 2007 2017
Italy	1%Reject p-v<0.01 2003	1%Reject p-v<0.01 2003	Accept 2002	Accept 2006	1%Reject 2018		Accept 2009 2017	1%Reject 2007 2013
Japan	10%Reject p-v<0.1 2009	Accept p-v>0.1 2004	5%Reject 2015	10%Reject 2012	1%Reject 2008	1%Reject 2018	1%Reject 2008 2016	10%Reject 2005 2011
Luxembourg	1%Reject p-v<0.01 2003	5%Reject p-v<0.05 2003	Accept 2004	Accept 2002	1%Reject 2015	5%Reject 2018	1%Reject 2006 2015	Accept 2015 2019
Netherlands	5%Reject p-v<0.05 2003	5%Reject p-v<0.05 2002	Accept 2002	Accept 2002	1%Reject 2014		1%Reject 2014 2019	1%Reject 2014 2018
New Zealand	5%Reject p-v<0.05 2007	Accept p-v>0.1 2011	Accept 2017	Accept 2009	1%Reject 2017	1%Reject 2006	1%Reject 2006 2017	1%Reject 2006 2014
Norway	1%Reject p-v<0.01 2014	1%Reject p-v<0.01 2014	Accept 2014	Accept 2014	5%Reject 2011	5%Reject 2012	Accept 2011 2019	Accept 2004 2013
Portugal	1%Reject p-v<0.01 2002	1%Reject p-v<0.01 2003	1%Reject 2002	1%Reject 2002	Accept 2009	1%Reject 2005	Accept 2004 2006	1%Reject 2006 2015
Singapore	Accept p-v>0.1 2004	Accept p-v>0.1 2004	Accept 2010	Accept 2010	5%Reject 2010	1%Reject 2006	Accept 2008 2010	1%Reject 2005 2014
Spain	1%Reject p-v<0.01 2003	5%Reject p-v<0.05 2003	Accept 2002	Accept 2002	1%Reject 2016	1%Reject 2015	1%Reject 2013 2016	1%Reject 2006 2013
Sweden	1%Reject p-v<0.01 2010	1%Reject p-v<0.01 2012	Accept 2009	Accept 2009	1%Reject 2012	1%Reject 2011	1%Reject 2009 2014	1%Reject 2008 2012
Switzerland	Accept	Accept	Accept	Accept	Accept	1%Reject	1%Reject	Accept

	p-v<0.01 2011	p-v<0.01 2011	2010	2010	2008	2009	2007 2010	2009 2014
United Kingdom	1%Reject p-v<0.01 2008	1%Reject p-v<0.01 2008	Accept 2007	Accept 2007	Accept 2015	1%Reject 2006	Accept 2004 2007	10%Reject 2006 2013
United States	Accept p-v>0.1 2007	5%Reject p-v<0.05 2010	Accept 2018	Accept 2014	1%Reject 2007	1%Reject 2006	1%Reject 2007 2018	Accept 2006 2017

Note: ZA stands for Zivot-Andrews unit root test; P stands for Perron unit root test; LS means Lee Strazicich Unit Root Test; A indicates that interrupts on intercepts are allowed and are single breakpoints; C represents an interrupt that allows interception and slope and is a single breakpoint; AA represents an interrupt on the allowable intercept and is a double breakpoint; CC represents an interrupt that allows intercept and slope and is a double breakpoint.

Table A5. Unit root test with structural breakpoint for emerging countries (regions).

	ZA-A	ZA-C	P-A	P-C	LS-A	LS-C	LS-AA	LS-CC
Argentina	1%Reject p-v<0.01 2002	1%Reject p-v<0.01 2002	1%Reject 2001	1%Reject 2001	1%Reject 2014	1%Reject 2011	Accept 2008 2014	1%Reject 2011 2017
Brazil	1%Reject p-v<0.01 2006	5%Reject p-v<0.05 2005	Accept 2006	Accept 2005	5%Reject 2016	1%Reject 2009	10%Reject 2013 2016	5%Reject 2008 2019
Chile	5%Reject p-v<0.05 210	5%Reject p-v<0.05 2010	Accept 2006	Accept 2005	1%Reject 2019	1%Reject 2009	1%Reject 2012 2018	1%Reject 2011 2019
China	10%Reject p-v<0.1 2002	5%Reject p-v<0.05 2008	Accept 2011	Accept 2011	1%Reject 2017		1%Reject 2013 2017	1%Reject 2013 2019
Chinese Taipei	1%Reject p-v<0.01 2003	5%Reject p-v<0.05 2009	Accept 2002	Accept 2008	1%Reject 2017	1%Reject 2007	1%Reject 2015 2017	1%Reject 2011 2015
Colombia	1%Reject p-v<0.01 2007	10%Reject p-v<0.1 2007	Accept 2006	Accept 2006	Accept 2011	1%Reject 2008	Accept 2011 2014	1%Reject 2004 2010
Czech Republic	1%Reject p-v<0.01 2012	5%Reject p-v<0.05 2013	Accept 2013	Accept 2013	1%Reject 2007	1%Reject 2010	1%Reject 2007 2011	1%Reject 2006 2012
Greece	1%Reject p-v<0.01 2003	10%Reject p-v<0.1 2003	Accept 2002	Accept 2002	1%Reject 2012		1%Reject 2012 2017	1%Reject 2007 2013
Hong Kong	5%Reject p-v<0.05 2014	5%Reject p-v<0.05 2010	10%Reject 2013	Accept 2009	1%Reject 2018		1%Reject 2005 2014	Accept 2014 2017
Hungary	1%Reject p-v<0.01 2001	5%Reject p-v<0.05 2007	Accept 2001	Accept 2006	5%Reject 2008	1%Reject 2011	5%Reject 2008 2010	5%Reject 2005 2018
India	5%Reject p-v<0.05 2017	5%Reject p-v<0.05 2013	Accept 2013	Accept 2011	1%Reject 2016	1%Reject 2005	1%Reject 2004 2016	5%Reject 2011 2016
Indonesia	5%Reject p-v<0.05 2006	1%Reject p-v<0.01 2013	1%Reject 2005	1%Reject 2013	1%Reject 2013	1%Reject 2008	1%Reject 2009 2015	1%Reject 2008 2018
Korea	10%Reject p-v<0.1 2004	1%Reject p-v<0.01 2008	Accept 2007	Accept 2002	1%Reject 2009	1%Reject 2018	5%Reject 2004 2012	1%Reject 2006 2010
Malaysia	5%Reject p-v<0.05 2010	Accept p-v>0.1 2001	Accept 2009	Accept 2000	5%Reject 2005	1%Reject 2008	1%Reject 2005 2009	1%Reject 2008 2017
Mexico			10%Reject 1999	Accept 1999	1%Reject 2015	5%Reject 2012	5%Reject 2008 2019	1%Reject 2007 2014
Peru	5%Reject p-v<0.05 2012	5%Reject p-v<0.05 2012	Accept 2011	Accept 2009	1%Reject 2014	1%Reject 2011	1%Reject 2005 2018	1%Reject 2011 2019
Philippines		1%Reject p-v<0.01 2006	Accept 2000	Accept 2006	Accept 2018	1%Reject 2010	Accept 2007 2018	1%Reject 2013 2018

Poland	10%Reject p-v<0.1 2000	5%Reject p-v<0.05 2009	Accept 2000	Accept 2008	Accept 2007	1%Reject 2010	Accept 2004 2007	1%Reject 2008 2013
Russia	1%Reject p-v<0.01 2015	Accept p-v>0.1 2006	Accept 2005	Accept 2004	1%Reject 2016		1%Reject 2004 2016	5%Reject 2005 2013
South Africa	Accept p-v>0.1 2009	1%Reject p-v<0.01 2003	Accept 2002	10%Reject 2002	1%Reject 2009	1%Reject 2007	1%Reject 2009 2013	10%Reject 2008 2014
Thailand			Accept 1998	Accept 2005	10%Reject 2018		Accept 2014 2018	1%Reject 2013 2017
Turkey	1%Reject p-v<0.01 2003	Accept p-v>0.1 2010	Accept 2003	Accept 2011	1%Reject 2015	1%Reject 2009	1%Reject 2007 2015	5%Reject 2008 2016
United Arab Emirates	5%Reject p-v<0.05 2010		5%Reject 2006	10%Reject 2002	1%Reject 2013	1%Reject 2006	1%Reject 2015 2017	10%Reject 2007 2013

Note: ZA stands for Zivot-Andrews unit root test; P stands for Perron unit root test; LS means Lee Strazicich Unit Root Test; A indicates that interrupts on intercepts are allowed and are single breakpoints; C represents an interrupt that allows interception and slope and is a single breakpoint; AA represents an interrupt on the allowable intercept and is a double breakpoint; CC represents an interrupt that allows intercept and slope and is a double breakpoint.

Table A6. Unit root test with structural breakpoint for frontier countries (regions).

	ZA-A	ZA-C	P-A	P-C	LS-A	LS-C	LS-AA	LS-CC
Algeria	Accept p-v>0.1 2003		Accept 2001	Accept 2001	Accept 2010	1%Reject 2010	Accept 2004 2006	10%Reject 2006 2017
Bosnia & Herzegovina	10%Reject p-v<0.1 2006	5%Reject p-v<0.05 2001	Accept 2005	10%Reject 2000	1%Reject 2014	1%Reject 2006	5%Reject 2007 2014	1%Reject 2006 2017
Bulgaria	1%Reject p-v<0.01 2012	Accept p-v>0.1 2007	Accept 2013	Accept 2006	Accept 2009	1%Reject 2008	Accept 2009 2012	1%Reject 2008 2013
Croatia	5%Reject p-v<0.05 2004	Accept p-v>0.1 2005	Accept 2004	Accept 2005	10%Reject 2007	1%Reject 2009	Accept 2007 2018	1%Reject 2007 2014
Cyprus	1%Reject p-v<0.01 2003	1%Reject p-v<0.01 2003	Accept 2002	Accept 2002	1%Reject 2011	1%Reject 2011	1%Reject 2012 2017	1%Reject 2012 2017
Estonia	5%Reject p-v<0.05 2010	5%Reject p-v<0.05 2015	5%Reject 2008	Accept 2014	Accept 2004	5%Reject 2010	Accept 2009 2018	Accept 2006 2010
Iceland	1%Reject p-v<0.01 2008	1%Reject p-v<0.01 2008	10%Reject 2007	Accept 2007	10%Reject 2007	1%Reject 2006	1%Reject 2007 2016	1%Reject 2006 2019
Latvia	5%Reject p-v<0.05 2007	5%Reject p-v<0.05 2008	Accept 2011	Accept 1999	Accept 2007	1%Reject 2008	Accept 2004 2009	1%Reject 2008 2012
Lithuania	10%Reject p-v<0.1 2010	Accept p-v>0.1 2018	Accept 2018	Accept 2018	Accept 2008	1%Reject 2008	Accept 2009 2011	5%Reject 2008 2011
Malta	5%Reject p-v<0.05 2003	1%Reject p-v<0.01 2010	Accept 2002	Accept 2009	1%Reject 2016	1%Reject 2008	Accept 2008 2016	Accept 2006 2012
Morocco	1%Reject p-v<0.01 2016	1%Reject p-v<0.01 2010	Accept 2017	Accept 2009	5%Reject 2010	1%Reject 2008	5%Reject 2008 2010	1%Reject 2008 2014
North Macedonia	Accept p-v>0.1 2005	1%Reject p-v<0.01 2015	Accept 1998	1%Reject 2000	Accept 2012	1%Reject 2010	1%Reject 2007 2015	5%Reject 2009 2015
Romania		1%Reject p-v<0.01 2005	Accept 2004	Accept 2004	1%Reject 2006	1%Reject 2012	5%Reject 2006 2015	1%Reject 2004 2013
Saudi Arabia	1%Reject	1%Reject	Accept	Accept	1%Reject	1%Reject	1%Reject	10%Reject

	p-v<0.01 2003	p-v<0.01 2003	2002	2002	2008	2016	2013 2016	2008 2014
Serbia	1%Reject p-v<0.01 2001	1%Reject p-v<0.01 2001	1%Reject 2000	1%Reject 2000	1%Reject 2017	1%Reject 2012	1%Reject 2012 2017	1%Reject 2009 2017
Slovak Republic	5%Reject p-v<0.05 2003	1%Reject p-v<0.01 2007	Accept 2002	Accept 2006	1%Reject 2006	1%Reject 2006	1%Reject 2006 2014	1%Reject 2007 2012
Slovenia	10%Reject p-v<0.1 2003	5%Reject p-v<0.05 2012	5%Reject 2014	1%Reject 2011	Accept 2016	1%Reject 2006	10%Reject 2017 2011	5%Reject 2004 2011

Note: ZA stands for Zivot-Andrews unit root test; P stands for Perron unit root test; LS means Lee Strazicich Unit Root Test; A indicates that interrupts on intercepts are allowed and are single breakpoints; C represents an interrupt that allows interception and slope and is a single breakpoint; AA represents an interrupt on the allowable intercept and is a double breakpoint; CC represents an interrupt that allows intercept and slope and is a double breakpoint.

References

1. Adler, N. S., & Lehmann, B. (1983). Deviations from Purchasing Power Parity in the Long Run. *Journal of Finance*, *38*(5), 1471-1487.
2. Bahmani-Oskooee, M., Kutan, A. M., & Zhou, S. (2007). Testing PPP in the Non-linear STAR Framework. *Economics Letters*, *94*(1), 104-110.
3. Chen, C., Sun, X. J., & Chen, H. B. (2018). Research on the Validity of Purchasing Power Parity Theory. *Co-Operative Economy & Science*, *582*(7), 94-96.
4. Clemente, J., Montanes, A., & Reyes, M. (1998). Testing for A Unit Root in Variables with A Double Change in the Mean. *Economics Letters*, *59*(2), 175-182.
5. Corbae, D., & Ouliaris, S. (1988). Cointegration and Tests of Purchasing Power Parity. *Review of Economics and Statistics*, *70*, 508-511.
6. Dickey, D.A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with A Unit Root. *Journal of the American Statal Association*, *79*(366), 355-367.
7. Doanlar, M., Mike, F., & Kzlkaya, O. (2021). Testing the Validity of Purchasing Power Parity in Alternative Markets: Evidence from the Fourier Quantile Unit Root Test. *Borsa Istanbul Review*, *21*(4), 375-383.
8. Doroodian, K., Jung, C., & Boyd, R. (1999). Testing the Law of One Price under the Fixed and Flexible Exchange Rate Systems. *Applied Economics Letters*, *6*(9), 613-616.
9. Edison, H. (1987). Purchasing Power Parity in the Long Run: A Test of the Dollar/Pound Exchange Rate (1890-1978). *Journal of Money, Credit and Banking*, *19*(3), 376-387.
10. Elliot, G., Rothenberg, T., & Stock, J. (1996). Efficient Tests for An Autoregressive Unit Root. *Econometrica*, *64*(4), 813-836.
11. Glaus, T., & Thoma, A. (2018). Mean Reversion Properties in Real Effective Exchange Rates. SSRN Working Paper Series.
12. Hao, L. Y., & Zhu, H. M. (2008). Johansen Cointegration Test and Nonlinear Feature Study at Purchasing Power Parity. *Statistics and Decision*, *261*(9), 6-9.
13. Huizinga, J. (1987). An Empirical Investigation of the Long-Run Behavior of Real Exchange Rates. *Carnegie-Rochester Conference Series on Public Policy*, *27*, 149-214.
14. Kutan, A. M., & Zhou,S. (2015). PPP May Hold Better than You Think: Smooth Breaks and Non-linear Mean Reversion in Real Effective Exchange Rates. *Economic Systems*, *39*(2), 358-366.
15. Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the Null Hypothesis of Stationarity against the Alternative of A Unit Root. *Journal of Econometrics*, *54*(1-3), 159-178.
16. Lee, J., & Strazicich, M. C. (2003). Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks. *The Review of Economics and Statistics*, *85*(4), 1082-1089.
17. Lee, J., & Strazicich, M. C. (2004). Minimum LM Unit Root Test with One Structural Breaks. Department of Economics, Appalachain State University, Unpublished Manuscript.
18. Liu, J. Q., Yun, H., & Zheng, T. G. (2006). An Econometric Test of the RMB Exchange Rate Purchasing Power Parity Hypothesis: Engel-Granger Cointegration Analysis Based on Markov Zone System Transfer. *Management World*, *3*, 57-62.
19. Lumsdaine, R. L., & Papell, D. H. (1997). Multiple Trend Breaks and the Unit Root Hypothesis. *The Review of Economics and Statistics*, *79*(2), 212-218.
20. Ng, S., & Perron, P. (2001). Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power. *Econometrica*, *69*(6), 1519-1554.
21. Papell, D. H., & Prodan, R. (2020). Long-run Purchasing Power Parity Redux. *Journal of International Money and Finance*, *109*, 102260.
22. Perron, P. (1989). The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Econometrica*, *57*(6), 1361-1401.
23. Perron, P. (1997). Further Evidence on Breaking Trend Functions in Macroeconomic Variables. *Journal of Econometrics*, *80*(2), 355-385.

24. Perron, P., & Vogelsang, T. J. (1992). Nonstationarity and Level Shifts with An Application to Purchasing Power Parity. *Journal of Business and Economic Statistics*, *10*(3), 301-320.
25. Phillips, P., & Perron, P. (1988). Testing for A Unit Root in Time Series Regression. *Biometrika*, *75*(2), 335-346.
26. Vasconcelos, C. R. F., & Júnior, L. A. L. (2016). Validity of Purchasing Power Parity for Selected Latin American Countries: Linear and Non-linear Unit Root Tests. *Economia*, *17*(1), 114-125.
27. Vats, A., & Kamaiah, B. (2011). Is There a Unit Root in Real Effective Exchange Rate in India? Evidence from Structural Break Unit Root Tests. *Elixir Finance Management*, *34*, 2593-2597.
28. Wang, J. (2012). The Purchasing Power Parity Theory and Its Empirical Testing in Asia's Emerging Markets. *Statistical Research*, *29*(3), 41-46.
29. Zivot, E., & Andrews, D. W. K. (1992). Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Journal of Business & Economic Statistics*, *20*(1), 251-270.