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Does an Independent Central Bank Smooth Exchange Rate Volatility? Evidence from Time-Varying Panel Causality Analysis

Abstract: This paper empirically examines the effect of the central banks independence on exchange rate volatility by using a large dataset for the E7 (7 emerging countries) covering the period 1998-2017. This paper applies the time-varying panel causality analysis to obtain country-based results. The results show that the policy design, with relatively independent central banks, provides supportive results for macroeconomic stability. It is concluded that policies focusing on current problems by ignoring macroeconomic stability, such as the 2008 crisis, have eliminated the relationship between bank independence and stability.

Keywords: Time-varying panel causality analysis, E7 countries, Central Bank, Monetary Policy Strategy.

JEL Classification: C33, E58, F31.

1. Introduction

Following the abandonment of the Bretton Woods system in 1973, exchange rates have been left to fluctuate considerably. In this process, it is seen that the volatility in exchange rates has increased as globalization accelerated and economies became open to the outside both in real and financial terms. Exchange rate volatility plays a key role in the development of the macroeconomic performance of an open country. Increasing volatility is one of the most important

dynamics threatening macroeconomic stability. The most important risks faced by economic agents in the decision-making process stem from their inability to accurately predict forward exchange rate movements. Excessive volatility (fluctuation) in the exchange rate for an economy can have an impact on the production, consumption, investment and savings decisions of individuals. By assuming that higher volatility is equivalent to higher risk, the decision units may delay or abandon the investment and consumption decisions entirely as volatility increases. On the other hand, if companies operating in foreign trade are afraid that unexpected changes in the exchange rate will significantly affect their expected costs and profits, their risk aversion tendency may increase and thus they may be less willing to realize their long-term investment projects (Arize, Osang & Slottje, 2000; Devereux, 2004; Onafowora and Owoye, 2008; Aliyu, 2010; Sharma and Pal, 2018; Vo, Vo & Zhang, 2019). It is very difficult and risky to produce and trade with an ever-changing and unpredictable currency in terms of purchasing power. Therefore, changes in exchange rates may threaten a strand of macroeconomic balances such as price stability, balance of payments and economic growth by increasing the cost of many inputs used in the production and consumption process of the country's economy.

Another negative effect of exchange rate volatility is that they disrupt the wage and price-setting behavior in economies due to increasing uncertainty (Obstfeld and Rogoff, 1998; Pollard and Coughlin, 2004; Boug, Cappelen & Eika, 2013; Taylor, 2016; Yurdal and Demirel, 2021). The volatility in prices from the exchange rate makes it difficult for consumers to compare different goods and services with each other and, therefore, to choose products. This situation may lead consumers to limit their consumption by pushing them into indecision. Imbalances in prices may also adversely affect the distribution of income and wealth in the country relatively. In addition, uncertainties going forward in an economy where unpredictable fluctuations (high volatility) in foreign exchange markets may also erode the sense of confidence in the society (CBRT, 2013). From this point of view, since the changes in the exchange rate affect the functioning of the economic activities, a stable trend of the exchange rate movements contributes to the effective functioning of the markets, and this reflects positively on the economic stability. Nowadays, within the framework of modern central banking, the duty of price stability is widely given to central banks organized independently from governments. Most central banks focus primarily on smoothing volatility and stabilizing the trend path of the exchange rate rather than influencing the exchange rate level (Mohanty, 2013).

The deepening of financial markets and the integration of economies with international markets due to globalization and developing communication technolo-

gies make the policy implementations of central banks more complex. Therefore, in times of recession or crisis, central banks tend to pursue activist monetary policy strategies (Yıldırım and Turan, 2023; Yıldırım, Turan & Kantarcı, 2023)/ Check references as the third author in the latter reference is not listed. In order for central banks to choose effective monetary policy instruments and achieve the targets, it is critically important to determine the effects of monetary policy implementations on prices and the real sector. Therefore, the success of monetary policy is closely related to actively implementing the central bank independence. Many central banks around the world carry out duties within the framework of the price stability target, either explicitly or implicitly. The independence of central bank is one of the most important institutional reforms ever, designed to increase the efficiency and productivity of central banks whose primary objective is to ensure price stability. The independence is seen as a prerequisite that increases the efficiency and success of monetary policy by making central banks credible and thus enables them to more clearly achieve price stability target (Fischer, 1996; Güler, 2021; Haoudi and Touati, 2023). In this respect, central bank independence refers to the ability of monetary authorities to take their institutional, operational, financial, functional, legal or political steps independently from any pressure factor.

Ensuring and maintaining the exchange rate and ultimately price stability in open economies requires the implementation of policies created with a long-term perspective. There are findings in the literature that traditional and non-traditional policy practices do not have a significant effect on macroeconomic performance in developing countries, especially in the post-global crisis period. However, it is stated that unconventional policies have a strong impact on the real effective exchange rate (Yıldırım and Kırcı-Altınkeski, 2020). Same as when it comes to external shocks, policy makers' desire for high economic growth performance or their tendency to finance high public debts with central bank resources are among the factors that threaten price stability. Political authorities (governments) focusing on electoral processes may abandon previously announced policies and tend to implement policies that stimulate employment and economic growth by confusing economic units. In other words, electorally motivated governments may tend to deviate from the implementation of pre-announced and optimal economic policies to achieve economic growth in the short run. This situation, which is expressed as "time inconsistency" in the literature, arises from a series of attempts (political pressures) made by the political authority to discourage the monetary authority from pre-announced optimal monetary policies during the policy period (Walsh, 2010; Taylor, 2013). Although the activities of central banks involve a lot of technical information, they are ultimately political institutions (Fernández-Albertos, 2015). The elected political authority may find

it legitimate to intervene in the monetary policy, as they are held responsible for the economic crises by the voters, unlike the monetary authority. For this reason, central banks may be exposed to strong pressures to act in the way of governments' preferences. At this point, central banks' ability to stand up to risks that may threaten price stability and to make the necessary warnings constitutes the keystone of central bank independence. The existence of a central bank, which plans its long-term policies based on the price stability target and makes reliable commitments to its policies, may eliminate the problem of time inconsistency and reliability (Kydland and Prescott, 1977). At the same time, as the trust in the central bank and its monetary policies increases due to independence, expectations can be managed better and monetary policy targets can be achieved more easily. An independent central bank is seen as more credible by the public than other institutional structures. A credible central bank, on the other hand, can more easily persuade decision makers to reach its targets. In case of deviations from the target, it can prevent the public's hesitation about fulfilling the commitments, and in this way, the price stability target can be achieved with less cost.

Most empirical studies on estimating the possible impact of central bank independence (CBI) on macroeconomic balances have mainly focused on inflation or price stability (Grilli, Masciandaro & Tabellini, 1991; Cukierman, Web & Neyapti, 1992; Alesina and Summers, 1993; Loungani and Sheets, 1997; de Haan and Kooi, 2000; Bouwman, Jong-A-Pin & de Haan, 2005; Klomp and de Haan, 2010; Bodea and Hicks, 2015; Ftiti, Aguir & Smida, 2017; Iwasaki and Uegaki, 2017; Garriga and Rodriguez, 2020; Kokoszczyński and Mackiewicz-Łyziak, 2020), economic growth or output gap (Loungani and Sheets, 1997; de Haan and Kooi, 2000; Akinci, Akinci & Yilmaz, 2015; Harunogullari, 2019; Bogari, 2020; Ding and Vitenu-Sackey, 2021) and budget deficit or public debt (Beetsma and Bovenberg, 1997; Sikken and de Haan, 1998; Martin, 2015; Burdekin and Laney, 2016; Tufaner and Yavuz, 2019; Strong and Yayi, 2021). The CBI analysis has become a rapidly growing field of research, but less attention has been paid to its relationship to exchange rate uncertainty. Previous studies in the literature focus more on whether central bank's interventions (Dominguez, 1998; Kim, Kortian & Sheen, 2000; Beine, Laurent & Lecourt, 2003; Humala and Rodríguez, 2010; Das and Shimatani, 2013; Katusiime & Agbola, 2018), its transparency (Kuttner and Posen, 2005; Papadamou, Sidiropoulos & Spyromitros, 2016; Eichler and Littke, 2018; Weber, 2019; Candian, 2021; Aftab and Mehmood, 2023) or its communication (Jansen and de Haan, 2003; Égert, 2010; Fišer and Horvath, 2010) rather than central bank's independence have any effect on exchange rate level or volatility.

To sum up, the aim of this paper is to empirically examine the effect of the degree of independence of the central banks on exchange rate volatility by using

a large dataset for the E7 countries —Brazil, India, Turkiye, Indonesia, Mexico, Russia and China— covering the period 1998-2017. To examine the time-varying causality relationship between the variables, this paper employs the panel cointegration tests proposed by Pedroni (1999) and Westerlund (2007) and bootstrap panel causality test in a time-varying approach developed by Kónya (2006) and proposed by Yilanci and Özgür (2019).

More specifically, this paper makes two innovative contributions to ongoing debates in the literature regarding the long-run analysis of whether CBI produces macroeconomic stabilizing effects. Firstly, the current literature argues extensively and critically that the role of CBI needs to be addressed in a broader macroeconomic policy framework. The underlying reason for these discussions is that the signalling process required for CBI to produce anti-inflationary effects differs depending on the existence of some institutional and political variables that affect the wage and price formation processes (Bleaney, 1996; Hall and Franzese, 1998; Cukierman and Lippi, 1999; Iversen, 1999; Franzese and Hall, 2000; Franzese, 2001; Olivei and Tenreyro, 2010; Fernández-Albertos, 2015). Therefore, in studies on whether the independence of central bank produces anti-inflationary effects, it may be more meaningful to consider intermediate factors such as the exchange rate, which give important signals to the markets about the route of monetary policy on the way to the target, rather than the final targets such as inflation. In addition, the independence of the central bank can influence the expectations of foreign exchange market participants by providing information about the views and intentions of monetary authorities and indirectly put the exchange rate on a stable trend. Thus, the stabilizing effect of CBI on exchange rate volatility can signal economic units about the future trend of prices and contribute to achieving the inflation target. To the authors' knowledge, this paper is the first to examine the possible effects of CBI on exchange rate volatility. A recent strand of literature argues that the foreign exchange market is the market with the highest transaction volume among financial markets, and it also affects many macroeconomic variables such as inflation, interest, investment, production and foreign trade. From this point of view, the analysis of exchange rate volatility and its determinants, which has become a key indicator in investment decisions and portfolio selection, is of great importance.

A second set of contribution deals with the advantages of the empirical method adopted in the study, which led to more accurate results than previous empirical studies examining the effects of CBI on a set of macroeconomic stability variables. It is seen that previous studies generally examined the validity of the causal relationship among the variables by considering the entire observation range. However, it is likely that the causality relationship between the variables may

vary over time with the effect of economic and political events, that is, the relations may not be stable. To overcome such major econometric drawbacks found in previous literature, in this study, the relationship between CBI and exchange rate volatility is analysed separately for each sub-sample periods using the time-varying causality analysis, which is a novel approach in the field.

To this end, the rest of the paper proceeds as follows: Section 2 briefly describes the model and data used in the analysis. Section 3 presents the empirical method. Subsequently, Section 4 discusses the empirical results, while Section 5 provides some concluding remarks.

2. Model and Data

In this study, the relationship between central bank independence and exchange rate uncertainty for E7 countries (Brazil, India, Turkiye, Indonesia, Mexico, Russia and China) is investigated over the period 1998-2017. The estimation equation is shown in Eq.1.

$$\text{lneruit} = \alpha_0 + \alpha_1 \, \text{cbi}_{it} + \alpha_2 \, \text{inf}_{it} + \alpha_3 \, \text{lngdp}_{it} + \alpha_4 \, \text{lntrade}_{it} + u_{it} \qquad (1)$$

In Eq.1, eru: Exchange Rate Uncertainty, cbi; Central Bank Independence, inf: inflation, trade: trade openness, u_{it}: error terms, i: countries, t: time and l: logarithmic transformation.

In Eq.1, the main determinants of exchange rate volatility are included. In addition to these, central bank reserves are important for the exchange rate. A strong reserve can allow a strong stance against currency attacks. However, this situation may be related to the level of the exchange rate as well as the reserves. For this reason, the interaction variable is also included in the model in order to model the joint effect of reserves and exchange rate on exchange rate uncertainty. Description of variables can be seen in Table 1.

Table 1: Description of variables

Variables		Descriptions	Sources
Exchange Rate Uncertainty	eru	Derived in National Currency/US dollar	Authors
Central Bank Independence	cbi	Central bank independence index	Romelli (2022)
Inflation	inf	Annual consumer price index percentage	World Bank (2023)
Trade Openness	trade	Share of trade openness in GDP	World Bank (2023)
Gross Domestic Product	gdp	GDP per capita (constant 2015 US$)	World Bank (2023)

The central bank independence index was calculated by Romelli (2022) using the weighted average method over the main headings of institutional independence, independence of means and purpose, financial independence, financing of public deficits, transparency and accountability. Exchange rate uncertainty was determined by the authors using the exchange rate series by the moving average method of the standard deviation, which is the method used in many studies such as Cushman (1983), Akthar and Hilton (1984), Kenen and Rodrik (1986), Chowdhury (1993). This method is shown in equation (2) (Koray and Lastrapes, 1989).

$$V_t = \left[\left(\frac{1}{m}\right)\sum_{i=1}^{m}(exc_{t+i-1} - exc_{t+i-2})^2\right]^{\frac{1}{2}} \quad (2)$$

In Eq.2, exc: the ratio of the national currency to the US dollar, m: the number of moving average periods. Descriptive statistics of the variables are shown in Table 2.

Table 2: Summary Statistics

	lneru	cbi	inf	lngdp	lntrade
Mean	3.074	0.588	9.839	8.456	3.804
Median	2.394	0.553	6.365	8.822	3.879
Max.	9.471	0.862	85.746	9.378	4.566
Min.	-2.002	0.302	-1.401	6.543	2.799
Std. dev.	2.784	0.176	13.702	0.785	0.326
Skewness	1.167	0.256	3.795	-0.915	-0.804
Kurtosis	3.589	1.726	18.330	2.529	3.110
Obs.	140	140	140	140	140

In Table 2, mean of lneru is 3.07. The means of cbi, inf, lngdp and lntrade are 0.59, 9.8, 8.5 and 3.8, respectively. On the other hand, maximum values of lneur, cbi, inf, lngdp and lntrade are 9.5, 0.86, 85.7, 9.3 and 4.6, respectively.

3. Empirical Strategy

The study implemented a four-stage strategy for the methodology. In the first step, the cross-section dependence and stationarity levels of the series are tested. In the second stage, the slope homogeneity of the estimation equation is investigated and evidence of the existence of cointegration is sought. In the third step, long and short term coefficient estimation analysis is applied. Finally, the time-varying causality relationship between central bank independence and exchange rate uncertainty is examined.

Cross-Section Dependency

For panel unit root testing, first generation unit root tests may give misleading results in determining stationarity if the series contain cross-sectional dependence. For this reason, it is necessary to investigate the cross-sectional dependence in the series.

Tests developed by Breusch & Pagan (1980) and Pesaran (2004), which can be used for cases where the time dimension is more than the cross-sectional dimension, are shown in Eq.3 and Eq.4, respectively:

$$LM_{BP} = T \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \check{\rho}_{ij}^2 \tag{3}$$

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T\check{\rho}_{ij}^2 - 1) \tag{4}$$

The bias-corrected scaled LM test, which can be used for both cases where the time dimension is greater than or less than the cross-section dimension, was developed by Baltagi, Feng & Kao (2012). The estimation equation is seen in Eq.5:

$$LM_{BC} = \left[\sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T\check{\rho}_{ij}^2 - 1) \right] - \frac{N}{2(T-1)} \tag{5}$$

Here, T: time dimension, N: the number of cross-section units, $\check{\rho}_{ij}^2$: the estimate residuals obtained from the Least Squares technique.

The null hypothesis of all three tests indicates that there is no cross-section dependency, while the alternative hypothesis states that there is cross-section dependency. In case the null hypothesis is rejected, second generation unit root tests should be used in the analysis.

Unit Root Test

The unit root test developed by Pesaran (2007) allows the estimation of the ADF test statistic, which takes into account the cross-section dependency for all the units in the panel. Then, using the arithmetic mean of the CADF test statistics, the IPS test statistics, which takes into account the cross-sectional dependence, are determined. CADF and CIPS test statistics are shown in Eq.6 and Eq.7, respectively:

$$\Delta Y_{i,t} = \alpha_i + \rho_i Y_{i,t-1} + c_i\left[(1/N)\ \sum_{i=1}^{N} Y_{i,t-1}\right] + d_i\left[(1/N)\ \sum_{i=1}^{N} Y_{i,t}\right] + \varepsilon_{i,t} \quad (6)$$

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \quad (7)$$

The null hypothesis of the CIPS test in Eq.7 states that all cross-sections in the series contain a unit root, while the alternative hypothesis states that at least one cross-section in the series does not contain a unit root. If the null hypothesis is rejected, it is decided that the series is stationary.

Slope Homogeneity Test

In panel data analysis, when the panel is heterogeneous, it is necessary to check the cross-section heterogeneity, as the assumption of slope homogeneity may create a misleading estimation (Breitung, 2005). The advantages of the test are that the slope heterogeneity test developed by Pesaran and Yamagata (2008) is a more advanced test than the traditional heterogeneity tests that do not allow cross-sectional dependence, and that it can be used in cases where the time period is smaller than the number of observations (T>N). The tests can be seen in Eq.8 and Eq.9:

$$\bar{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right) \quad (8)$$

$$\bar{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(\bar{Z}_{it})}{\sqrt{var(\bar{Z}_{it})}}\right) \quad (9)$$

In Eq. 9, $E(\bar{Z}_{it}) = k$ and $var(\bar{Z}_{it}) = \frac{2k(T-k-1)}{T+1}$.

Cointegration Test

In the literature, there is some methodology to test the existence of a long-term relationship between the series. In this study, we preferred the tests developed by Pedroni (1999) and Westerlund (2007) which is frequently used in the literature.

In the cointegration analysis performed using the residuals obtained from the Pedroni (1999, 2004) OLS regression, there are a total of seven test statistics, four of which are within dimensions and three are between dimensions. These test statistics are obtained with the help of the following equation:

The Pedroni (1999, 2004) cointegration test, which is performed using the residuals obtained from the LCC regression, includes a total of seven test statistics, four of which are within dimensions and three are between dimensions. These test statistics are obtained with the help of the following equation:

$$Y_{it} = \acute{\alpha}_{\iota} + \theta_i t + \beta_i X_{it} + \varepsilon_{it} \quad , t = 1, \dots, T \quad ve \quad i = 1, \dots, N \tag{10}$$

Test statistics in Westerlund (2007) cointegration analysis, which has various features such as being sensitive to cross-section dependence and not including common factor constraints, are obtained with the help of Equation (11):

$$\Delta y_{it} = \delta_i^{'} d_t + \alpha_i (y_{i,t-1} - \beta_i^{'} x_{i,t-1}) + \sum_{j=1}^{P_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=q_i}^{P_i} y_{ij} \Delta x_{i,t-j} + u_{it} \tag{11}$$

In Eq.10, α_i: error correction parameter, d_t: deterministic components, p_i and q_i represent lag and lead numbers, respectively. A total of four statistics, group and panel, were developed based on the least squares estimation of the error correction parameter in this equation and its τ ratio. Group statistics do not use information from the error correlation mechanism. Panel statistics, on the other hand, are based on the collection of the information obtained from the error correction term together with the cross-section units in a pool. The calculation method of G_τ and G_α statistics, which are group statistics, is shown in Eq. 12 and Eq.13.

$$G_\tau = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\partial}_i}{Se(\hat{\partial}_i)} \tag{12}$$

$$G_\alpha = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\partial}_i}{1 - \sum_{j=1}^{k} \hat{\partial}_{ij}} \tag{13}$$

P_τ and P_α statistics are used to investigate whether there is cointegration in the whole panel and their statistics are seen in Eq. 14 and Eq.15:

$$P_\tau = \frac{\hat{\partial}}{Se(\hat{\partial}_i)} \tag{14}$$

$$P_\alpha = T\hat{\partial} \tag{15}$$

The null hypothesis indicates that there is no cointegration in at least one cross-section unit for group tests, while panel tests indicate that there is no cointegration relationship for all cross-section units.

Long Run Estimation

After confirming the cointegration, the next step is to determine the long-run effects of exogenous variables on exchange rate uncertainty. For this purpose, PMG-ARDL test and CS-ARDL tests are used.

Pesaran, Shin & Smith (1999), the PMG-ARDL test was deemed appropriate to be used in the study because it consistently presented short- and long-term estimation results regardless of the degree of integration of the variables, except for second-order stationarity. The model, which includes the long-term relationship between the variables, is included in equation 16:

PMG-ARDL test developed by Pesaran et al. (1999) is preferred because it consistently presented short- and long-term estimation results regardless of the degree of integration of the variables, except for second-order stationarity. The estimation model is seen in Eq.16:

$$Y_{it} = \sum_{j=1}^{m} \lambda_{ij} Y_{i,t-j} + \sum_{j=1}^{n} \delta_{ij} X_{i,t-j} + \varepsilon_{i,t} \tag{16}$$

Where is Y_{it} represents the dependent variable, λ_{ij} is a scalar vector, δ_{ij} denotes a kx1 vector containing the coefficients of the explanatory variables, $X_{i,t-j}$ is a kx1 vector of independent variables, $\varepsilon_{i,t}$ represents the error terms, i= 1,2,…, N (countries) and t= 1,2,…T (years).

Cross-sectional augmented autoregressive distributive lag (CS-ARDL) suggested by Chudik, Mohaddes &, Pesaran (2015) is used for robustness of the long run coefficient estimation. This test helps to reduce any bias in the panel data as it takes

into account cross-sectional dependence and heterogeneity issues. The CS-ARDL regression equation is seen in Eq.17:

$$Y_{it} = \alpha_0 + \sum_{j=1}^{p} \lambda_{it} Y_{i,t-j} + \sum_{j=1}^{p} \beta_{it} X_{i,t-j} + \sum_{j=1}^{p} \vartheta_{it} \bar{Z}_{i,t-j} + \mu_{it} \quad (17)$$

In Eq. 17, $\bar{Z}_t = (\Delta\bar{Y}_t, \bar{X}_t), \Delta\bar{Y}_t \; and \; \bar{X}_t$ is used for panel cross-sections averages.

Time-Varying Panel Causality Analysis

The causality relationship can vary over time with the effect of global economic and political events (Tang, 2008). For this reason, Yılancı and Özgür (2019) proposed the time-varying Kónya (2006) panel causality test. This test is sensitive to cross-section dependence and heterogeneity. To apply the causality test, Eq.18 and Eq.19 are estimated using Zellner's (1962) SUR estimator.

$$\begin{aligned}
y_{1,t} &= \alpha_{1,1} + \textstyle\sum_{l=1}^{lY_1} \beta_{1,1,l}\, y_{1,t-1} + \sum_{l=1}^{lX_1} \phi_{1,1,l}\, X_{1,t-1} + \varepsilon_{1,1,t} \quad (18)\\
y_{2,t} &= \alpha_{1,2} + \textstyle\sum_{l=1}^{lY_1} \beta_{1,2,l}\, y_{2,t-1} + \sum_{l=1}^{lX_1} \phi_{1,2,l}\, X_{2,t-1} + \varepsilon_{1,2,t}\\
y_{N,t} &= \alpha_{1,N} + \textstyle\sum_{l=1}^{lY_1} \beta_{1,N,l}\, y_{N,t-1} + \sum_{l=1}^{lX_1} \phi_{1,N,l}\, X_{N,t-1} + \varepsilon_{1,N,t}
\end{aligned}$$

$$\begin{aligned}
X_{1,t} &= \alpha_{2,1} + \textstyle\sum_{l=1}^{lY_1} \beta_{2,1,l}\, y_{1,t-1} + \sum_{l=1}^{lX_1} \phi_{2,1,l}\, X_{1,t-1} + \varepsilon_{2,1,t} \quad (19)\\
X_{2,t} &= \alpha_{2,2} + \textstyle\sum_{l=1}^{lY_1} \beta_{2,2,l}\, y_{2,t-1} + \sum_{l=1}^{lX_1} \phi_{2,2,l}\, X_{2,t-1} + \varepsilon_{2,2,t}\\
X_{N,t} &= \alpha_{2,N} + \textstyle\sum_{l=1}^{lY_1} \beta_{2,N,l}\, y_{N,t-1} + \sum_{l=1}^{lX_1} \phi_{2,N,l}\, X_{N,t-1} + \varepsilon_{2,N,t}
\end{aligned}$$

In Eq.18 and Eq.19, l represents the optimal lag length determined using AIC. Cross-section-specific bootstrap critical values are determined for the members of the panel with the help of the Wald test.

In order to calculate the causality test over time, the rolling subsample size with $t = \tau - 1 + l, \tau - 1, \tau = l, l + 1, ..., T$ was used instead of the fixed subsample size of l. The existence and direction of causality is decided by comparing the test statistics obtained at each observation interval with the bootstrap critical probability values.

4. Empirical Findings

The results of three different cross-section dependency tests are shown in Table 3. Accordingly, the main hypothesis suggesting that there is no cross-sectional dependence for all data was rejected at the 1% significance level.

Table 3: Cross-Section Dependency Results

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM
lneru	271.147***	37.518***	37.334***
inf	97.400***	10.708***	10.524***
lngdp	355.089***	50.471***	50.286***
lntrade	128.664***	15.532***	15.348***

Note: *** indicates 1% significance level.

After determining the cross-section dependency in the series, the analysis is continued with the CIPS test, which is one of the second generation unit root tests. The results are seen in Table 4.

Table 4: CIPS Unit Root Test Results

Variables	Level	First Difference	Order
eru	-1.178 (1)	-2.879 (1)***	I(1)
cbi	-0.948 (1)	-1.938 (1)**	I(1)
inf	-0.909 (2)	-1.539 (2)*	I(1)
lngdp	0.508 (0)	-2.985 (0)***	I(1)
lntrade	0.319 (0)	-6.290 (0)***	I(1)

Note: *, ** and *** indicate 10%, 5% and 1% significance level, respectively.

According to the results, it was decided that the variables are stationary at the first difference (I(1)) in the constant term model. Before investigating the cointegration relationship, it is necessary to decide whether the estimation model is homogeneous or heterogeneous in order to choose the appropriate method. Slope homogeneity results are seen in Table 5.

Table 5: Slope Homogeneity Results

	t-stats.	Prob.
$\tilde{\Delta}$	57.14***	0.000
$\tilde{\Delta}_{adj}$	10.21***	0.000

Note: *** indicates 1% significance level.

According to Table 5 results, the null hypothesis that the slope coefficient is homogeneous is rejected and it is accepted that the estimation equation is heterogeneous at the 1% significance level. Since the estimation equation has a heterogeneous structure, it has been decided that it is appropriate to use a cointegration test that considers both heterogeneity and cross-sectional dependence. Pedroni and Westerlund (VR) panel cointegration tests, which are frequently preferred in the literature, are used here. These tests were extended for the presence of cross-sectional dependence by means of the cross-sectional mean-free method with the Cross-average method. On the other hand, group-specific estimation method was preferred for heterogeneity. The results are seen in Table 6.

Since the estimation equation has a heterogeneous feature, it has been decided that it is appropriate to use a cointegration test that considers both heterogeneity and cross-sectional dependence. Pedroni and Westerlund (VR) panel cointegration tests, which are frequently preferred in the literature, were preferred in our study as well. These tests were extended with the cross-sectional averages, the Cross-Average method (following the CIPS test). On the other hand, group-specific estimation method was preferred for heterogeneity. The results are seen in Table 6.

Table 6: Cointegration Tests Results

Westerlund Cointegration Test				Pedroni Cointegration Test					
Tests	Value	P-value	Robust P-value	Tests	Value	P-value	Tests	Value	P-value
G_t	-2.117	0.818	0.214	Panel v-statistic	-2.250**	0.012	Group PP type ρ-statistic	2.731***	0.003
G_a	-0.952	1.000	0.814	Panel ρ-statistic	2.001**	0.022	Group PP type t-statistic	-0.524	0.299
P_t	-5.371	0.614	0.058	Panel PP type t-statistic	-0.370	0.355	Group ADF type t-statistic	-0.269	0.393
P_a	-1.951	0.995	0.072	Panel DF type t-statistic	0.041	0.483			

Note: ** and *** indicate 5% and 1% significance level, respectively.

According to the results in Table 6, it is seen that there is a long-term relationship between the series for the Pedroni and Westerlund tests. This is supported by both group and panel statistics. Therefore, there is a long-term equilibrium relationship between the series in the estimation model.

The cointegration analysis does not provide sufficient results to interpret the long-term relationships between the series and to offer policy recommendations. Therefore, in this study, first of all, long-term coefficients will be presented.

Afterwards, country-based causal relationships will be investigated with time-varying causality analysis. In Table 7, long-run coefficients are seen.

Table 7: Long-Run Coefficients

Variables	PMG-ARDL Test Results			CS-ARDL Test Results		
	Coefficients	Std. Err.	Prob.	Coefficients	Std. Err.	Prob.
cbi	3.038	0.983	0.002	-0.476*	0.281	0.090
inf	-0.063	0.008	0.000	-0.001	0.001	0.212
lngdp	-0.179	0.125	0.153	-0.326***	0.066	0.000
lntrade	-0.245	0.278	0.379	0.240**	0.099	0.015

Note: *, ** and *** indicate 10%, 5% and 1% significance level, respectively.

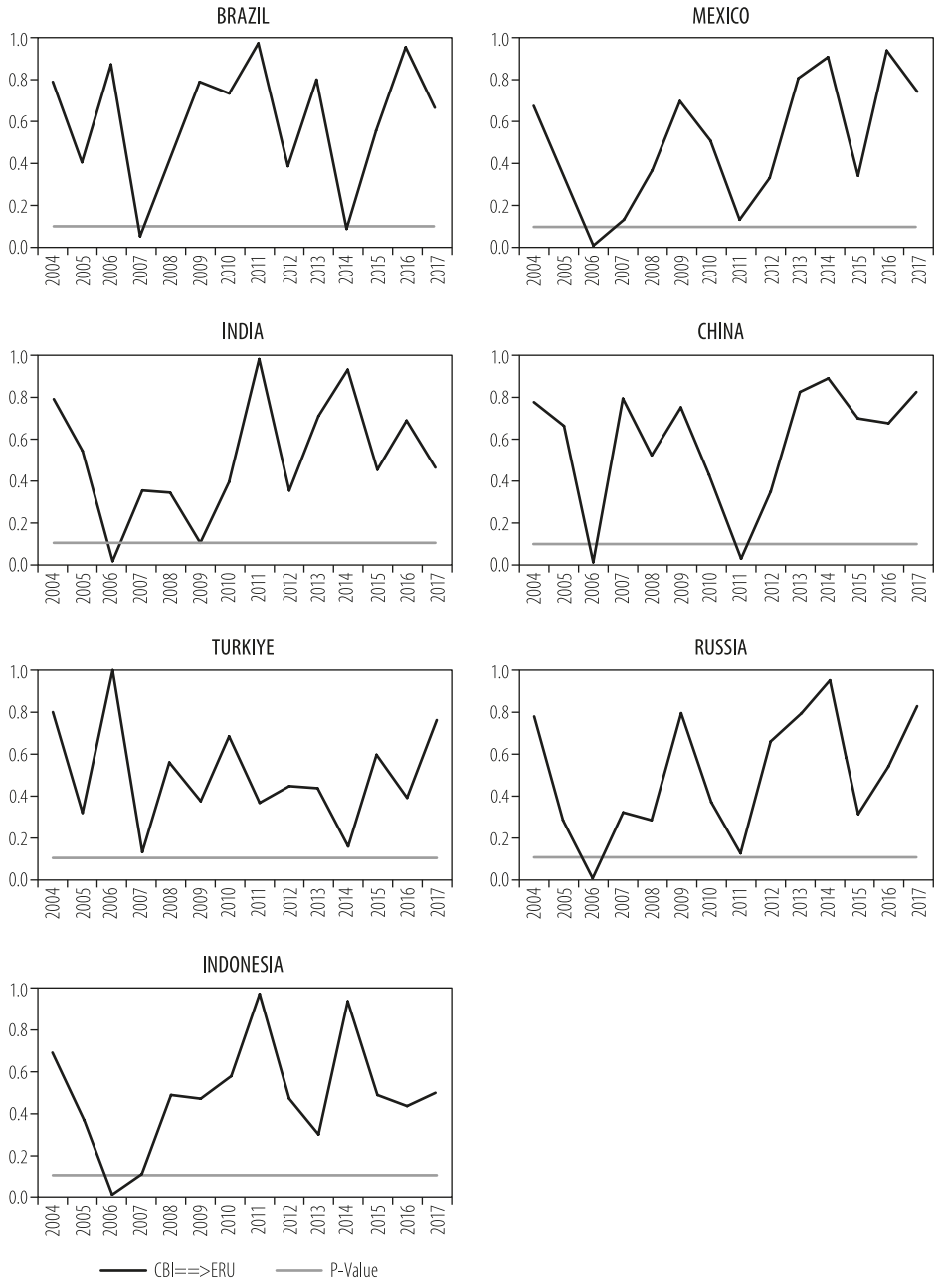
In Table 7, the results of PMG-ARDL and CS-ARDL are seen. According to PMG ARDL results, central bank independence increases exchange rate uncertainty in the long run. Increasing inflation reduces exchange rate uncertainty. Output and trade openness variables do not have a significant effect.

In our study, it was observed that the series have cross-section dependence. In this context, methods that take into account the cross-sectional dependence will allow more robust results to be obtained. According to CS-ARDL results, central bank independence and output reduce exchange rate uncertainty. Inflation does not have a significant effect on exchange rate uncertainty. Finally, an increase in openness increases exchange rate uncertainty.

The causality relationship between central bank independence and exchange rate uncertainty has been examined in a time-varying structure. The sub-sample size of the analysis using the 1998-2017 period data was determined as 7. In Figure 1, the blue lines containing the unit-specific causality results are the bootstrap p values showing the existence of causality from central bank independence to exchange rate uncertainty. The horizontal red line indicates the 10% significance level. Accordingly, the existence of a causal relationship is accepted for the periods below the red line. Time-Varying Panel Causality Analysis Results can be seen in Figure 1.

According to the results in Figure 1, there is causality from central bank independence to exchange rate uncertainty in 2007 and 2014 for Brazil, 2006 and 2009 for India, and 2006 and 2011 for China. The existence of causality in the same direction was detected in Indonesia, Mexico, and Russia in 2006.

Figure 1: Time-Varying Panel Causality Analysis Results between Central Bank Independence and Exchange Rate Uncertainty



5. Conclusion

This paper examines empirically the effect of central bank independence on exchange rate volatility by using a large dataset for the E7 countries and covering the period 1998-2017. The main determinants of exchange rate uncertainty are economic growth, inflation and trade openness that are included in the forecast equation.

Evidence for the existence of a long-term relationship between the series for the estimation equation has been obtained. In other words, economic growth, inflation and trade openness are important variables that affect exchange rate uncertainty.

The focus of our study is the relationship between exchange rate uncertainty, which is an important macroeconomic variable, and central bank independence. The relationship between these two variables may vary on time and country bases. However, due to data constraints, when the literature is examined, to the best of our knowledge, there is no study presenting empirical evidence on this subject. Therefore, we used the time-varying causality test to investigate the relationships between the series in terms of both country and time dimensions.

According to the results, the independence of the central bank is an important determinant in the management of exchange rate uncertainty. According to the time-varying causality test results, there is causality from central bank independence to exchange rate uncertainty in 2007 and 2014 for Brazil, 2006 and 2009 for India, and 2006 and 2011 for China. The existence of causality in the same direction was detected in Indonesia, Mexico, and Russia in 2006. The global financial crisis started to show its negative effects on economies in 2006. Especially after the rapid increases in housing prices, rapid decreases and the problem of inability to repay loans were felt at the beginning of 2006. This situation was accompanied by a sudden decrease in credit volume. The most important point to be noted here is that the independence of central banks had an effect on the economic disruption and thus the financial uncertainty that occurred at the beginning of the global financial crisis and during the financial crisis period (2006-2012). In other words, there is a causal relationship between the independence of all central banks and exchange rate uncertainty for emerging countries since 2006 (2007 for Brazil).

As a result, it is seen that there is a policy transfer between central bank independence and exchange rate uncertainty for emerging countries since 2006. The analysis for the long-term coefficients about the magnitude and sign of the transfer provides another important information. Central bank independence has a

significant and negative effect on exchange rate uncertainty in the long run. In other words, an increase in independence reduces uncertainty. However, panel cointegration results cover the entire period as a whole. When the country-based time-varying results are examined, it is seen that independence is effective in periods of increased instability. In other words, there is no causality relationship in the countries before 2006. Similarly, for emerging countries, the relationship between independence and exchange rate uncertainty accumulates over a certain period. This gives an idea that the analysed country group is a group that is affected by shocks.

As a result, it is seen that central bank independence affects exchange rate uncertainty (exchange rate volatility) during periods when central banks implement activist strategies or when governments support central bank independence. Considering that the activist strategies are followed by the initiative of the central bank in line with the needs of the economies, it has been observed that the activist strategies of the central banks (the independent strategies of the bank) are effective on the exchange rate uncertainty. Therefore, governments should allow central banks to implement activist strategies and follow policies to increase bank independence for strategies to combat exchange rate uncertainty, which is an important determinant of macroeconomic stability, to achieve desired results.

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