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The Effect of Exchange Rate Volatility on Economic Growth: Case of the CEE Countries

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Received: 20 July 2020; Accepted: 7 August 2020; Published: 10 August 2020



Abstract: The exchange rate is a key macroeconomic factor that affects international trade and the real economy of each country. The development of international trade creates conditions where volatility comes with the exchange rate. The purpose of this paper is to examine the effect of real effective exchange rate volatility on economic growth in the Central and Eastern European countries. Additionally, the effect, through three channels of influence on economic growth which vary on the measurement of exchange rate volatility, is examined. The study uses annual data for fourteen CEE countries for the period 2002–2018 to examine the nature and extends the impact of such movements on growth. The empirical findings using the fixed effects estimation for panel data reveal that the volatility of the exchange rate has a significant negative effect on real economic growth. The results appear robust with alternative measures of exchange rate volatility such as standard deviation and *z-score*. This paper suggests that policymakers should adopt different policies to keep the exchange rate stable in order to foster economic growth.

Keywords: real effective exchange rate; volatility; economic growth; CEE countries

1. Introduction

After the failure of the Bretton Woods system in 1970, the regime of the exchange rate changed across countries. From this time there has been an increase in the usage of floating exchange rates, but rather most countries have adopted flexible intermediate regimes including conventional pegs. Also, many countries do not allow their nominal exchange rate to move freely since they feel the fear of floating as [Levy-Yeyati and Sturzenegger \(2005\)](#). Thus, in countries where the fixed exchange rate is adopted, it is the responsibility of the central bank of the world's major economies to maintain the exchange rate, fixed by buying and selling currencies in order to correct the demand and supply of the money in the market. The proponents of the exchange rate regime argue that this process of maintaining fixed exchange rate regimes is difficult but keeping a stable exchange rate along with macroeconomic stability boost international trade and investment that in turn enhance growth. In 1973, floating exchange rates in Europe made nominal and real interest rates more volatile, which discourages investment due to the risk that comes with the exchange rate. The transaction cost of international trade has become more expensive and reduces the gains of investors as it constrains their decisions to develop their activity. The economists believed that floating rates may be harmful to the economy because every country uses the currency as an intermediate to purchase products and services in international trade. When the exchange rate becomes volatile, they are faced with uncertainty regarding the agreement

with other countries. The concern related to exchange rate risk is not only for policymakers but also for academics. The risk or the uncertainty regarding the unpredictable changes over time on the exchange rate can be defined as volatility. Shocks are the main source of unpredictable changes that can affect the price of goods, inflation, interest rates, portfolio investment, savings and loans (Clarida and Gali 1994).

Interest rate has become a referential to financial markets and it is a reflection of competitiveness (Bostan and Firtescu 2019). The international financial crisis, the increased pace of contagion, the liberalization of capital movements, and expansion of globalization imposed new dimensions for the importance of the interest rate.

A consideration of the empirical studies has shown the effect of the fluctuation of exchange rates on exports, trade, investment, capital market, inflation, and employment growth—in developing and developed countries (Schnabl 2008; Jamil et al. 2012; Rjoub 2012; Allen et al. 2016; Alagidede and Ibrahim 2017; Dal Bianco and Loan 2017; Latief and Lefen 2018; Vo and Zhang 2019; Hatmanu et al. 2020; Ioan et al. 2020). However, the effect of exchange rate volatility on economic growth for CEE countries has been studied by few authors and there has been a lack of studies over recent years—(Ricardo et al. 2007; Arratibel et al. 2011).

The paper aims to examine not only the effect of real effective exchange rate volatility on economic growth for Central and Eastern European countries but also to investigate the impact of volatility through three different channels on economic growth and give information for policy makers. Different from previous studies, a comprehensive analysis of the nexus between exchange rate volatility and economic growth using different measures of volatility is employed to provide the robustness of the results. Using the Fixed effects model for annual data spanning 2002 to 2018 it was revealed that low volatility encourages economic performance. Also, the impact of macroeconomic factors such as government expenditure, gross fixed capital formation, inflation, trade openness was investigated. Trade openness and gross fixed capital formation enhance economic growth.

Thus, the contribution of the current paper to exchange rate volatility and economic growth literature on CEE countries is three-fold. First, this paper attempts to fill the gap in the empirical literature related to the impact of exchange rate volatility on economic growth in CEE countries by using various measurements of volatility. The investigation of the impact of volatility on the growth of CEE countries is interesting since CEE countries are ex-communist countries with unique historical and economic experience that have a huge capacity to enhance national income by keeping stable exchange rates. Second, it examines three channels of influence where exchange rate volatility affects economic growth that differ from previous studies. Third, the study suggests policies that improve the linkage between the exchange rate fluctuation and growth.

The remaining part of this study is structured as follows. Section 2 presents the empirical literature regarding the influence of exchange rate volatility on trade, investment, and the real economy. Section 3 outlines the methodology and description of the data. In Section 4, the empirical results are given and discussed and Section 5 draws the conclusions of this research paper.

2. Literature Review

Theoretical literature on exchange rate volatility nexus economic growth is still a big debate among economists. The study by Obstfeld and Rogoff (1998) at the theoretical level posit that uncertainty on exchange rates and monetary policies followed by the government reducing the nominal interest rate and in turn causing an appreciation of the home currency can be deleterious for the home economy. In contrast, Devereux and Engel (2003) state that the effect of exchange rate volatility on the welfare of the economy depends on how prices are set. The fluctuation of macroeconomic factors and the dynamic nature of the business environment cause exchange rate volatility. The appreciation of currency happens by an upward movement while a downward movement indicates a loss in value (depreciation) against foreign currency (Anyanwu et al. 2017). Theories that explain this up and down movement in the exchange rate are the real option theory, the interest rate parity theory, purchasing power parity, traditional flow theory etc. According to the real option theory investment decisions are

tightly connected with the effect of macroeconomic uncertainty (Dixit et al. 1994). Thus, the exchange rate volatility as an indicator of uncertainty explains the behavior of investor decisions. Stable exchange rates become more attractive for firms that decide to increase their investment. Therefore, the real option theory is used to examine the nexus between exchange rate volatility and economic growth by researchers.

The empirical literature regarding the effect of exchange rate volatility on economic growth is unsettled and reviewing literature concern on channels where the exchange rate volatility affects the real economy is crucial. As it is mentioned by Schnabl (2008), the three channels where exchange rate volatility can enhance economic growth are international trade, foreign direct investment, and macroeconomic stability.

Hooper and Kohlhagen (1978) examined the effect of exchange rate unpredictability on price and international trade between the United States and Germany. The study was conducted in the period 1965–1975 and they found that uncertainty regarding exchange rates has an adverse impact on trade but a positive impact on the price of products where the exporter is a risk-lover. Inconsistent negative effect on market price was found in the case of importers where uncertainty is measured as the standard deviation of spot and forward exchange rates over three months. Bahmani-Oskooee and Gelan (2018), employed the Autoregressive Distributed Lag (ARDL) model in their study in order to investigate the effects of exchange rate risk on trade flows in the short-run and long-run for twelve African countries during the period 1971Q1–2015Q4. The ARDL method has advantages in forecasting compared to other techniques based on co-integration. The volatility of the exchange rate improves or worsens exports and imports, but in the short run, the effect is more prevalent (Senadza and Diaba 2018). Similarly, Alper 2017 examined the impact of exchange rate volatility on Turkey's trade to the 15 European countries during 2002–2013 by using Generalized Autoregressive Conditional Heteroscedasticity (GARCH) (1, 0) for calculating volatility. GARCH model is a statistical model that is considered as a reliable model for time series data to calculate volatility. The main empirical finding from Alper (2017) is that exchange rate volatility reduces export flows in the short-run. However, the effect for import sectors is both positive and negative in the long run. In addition, Turkey's trade with European Union countries is not affected by the volatility of exchange rates. Bostan and Firtescu (2019) conducted a study regarding the influence of the exchange rate on international commercial trade competitiveness of Romania. The study used statistical data for the period 2007–2014 and Ordinary Least Squares (OLS) regression is employed. Variables such as exchange rate, inflation, investments and interest rate are considered as exogenous, while Romanian exports and imports are endogenous variables. They concluded that the exchange rate is an important determinant of competitiveness, but the influence of uncertainty on export and import is different. This effect seems to be weaker for imports.

The study by Frankel and Rose (2002) examined the effect of currency union on trade and output using data over 200 countries and suggested that a currency union is beneficial for all countries as part of the trade. They concluded that for every one percent increase in total trade, common currency increased income per capita by at least one third of a percent. (Cushman 1986; Perée and Steinherr 1989) emphasized that in industrialized countries uncertainty of exchange rates reduced international trade. In contrast, positive effects are reported by (Franke 1991; Bredin et al. 2003).

The second channel to foster the real economy is to investigate the connection between exchange rate volatility and investment. Also, empirical studies have not reached a consensus on the effect of exchange rate volatility on investment. In some studies, the exchange rate volatility creates uncertainty in the economic environment and decreases investment. The decrease in investment has a negative impact on economic performance. According to the study of Campa and Goldberg (1995), who examined the effect of exchange rate volatility in US manufacturing sectors, it reported a negative effect on investment because the industries with high markup absorb fluctuation of the exchange rate by refusing real investment. Darby et al. (1999) assessed the effect of exchange rate uncertainty on investment in five developed countries—France, Germany, Italy, the United Kingdom, and the United States—by using the Dixit-Pindyck model and reported a significant negative effect on investment.

However, the study by [Aizenman \(1992\)](#) found that policies that enhance saving and investment, increase growth rate. The paper of [Dal Bianco and Loan \(2017\)](#) is based on the influence of price and real exchange rate volatility on foreign direct investment (FDI) inflows for 10 Latin American and Caribbean countries. This study used GARCH techniques and data for the period 1990 and 2012. FDI, measured as a percentage of GDP, was used as dependent variable, and the independent variables were price and real exchange rate volatility, institutional quality (i.e., political freedom) capita Gross Domestic Product, trade openness (in % of GDP), human capital (i.e., literacy rate), and infrastructural development (i.e., number of telephone lines). The authors considered that the exchange rate volatility has a negative influence on FDI inflows in this region and price volatility seems not to be relevant for the countries analyzed.

There are several studies focused on the relationship between exchange rate volatility, international trade and foreign direct investment, taking into account the connection between trade and capital flows at the international level. For example, ([Latief and Lefen 2018](#)) used GARCH models to analyze the nexus between exchange rate volatility and international trade and foreign direct investment (FDI). The sample consists of seven developing countries (Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka) and statistical data were collected for the period 1995–2016. The results of the study demonstrated the importance of the specificities of the countries. For countries like Bhutan, Maldives, and Nepal, the exchange rate volatility significantly positively affected international trade, but for countries like Pakistan, the impact on international trade had significant negative impact. While, the exchange rate volatility measured with TGARCH showed a significant positive impact on international trade for the countries such as Bhutan, Maldives, and Nepal. Regarding the relation of exchange rate volatility and FDI, for India and Pakistan, the impact was significantly positive, but for Bhutan and Nepal, the influence significantly negative.

[Dollar \(1992\)](#) examined whether the volatility of the exchange rate influences the real economy and conducted a negative impact between two variables in a sample of 95 developing countries and the positive impact of investment on growth. The study by [Bleaney and Greenaway \(2001\)](#) in 14 sub-Saharan African countries during the period 1980–1995 found that exchange rate volatility affects investment but not economic growth. [Aghion et al. \(2009\)](#) extended their study to 83 countries during the period from 1960 to 2000. They found that countries in which the financial market has not developed the negative effects of exchange rate volatility are presented. In developed countries, this negative effect is reduced because they sign hedging instruments to cover risky transactions. In the same line, the negative effect was examined by [Holland et al. \(2011\)](#) in a set of 82 advanced and emerging economies. They suggested that economic growth can increase faster when the exchange rate is stable than when the exchange rate is misaligned.

[Jamil et al. \(2012\)](#) examined the effect of volatility on growth during two periods for eleven European countries in the European Monetary Union and four countries that did not adopt the Euro as a common currency. The results are mixed for countries in the analysis, but the common currency decreases the harmful impact of exchange rate volatility on industrial production ([Janus and Riera-Crichton 2015](#)). Moreover, for Germany and Denmark, the impact of exchange rate volatility was negative for both periods, before and after the introduction of a common currency. The study by [Schnabl \(2008\)](#) establishes an adverse relation between growth and exchange rate volatility for countries in an economic catch-up process where the capital market remains underdeveloped and macroeconomic instability tends to be high. In order to examine the influence of exchange rate instability on economic growth for an annual panel of OECD countries during the period between 1980–2011, the study by [Janus and Riera-Crichton \(2015\)](#) employed Instrumental Variables estimation (IV) and showed that real effective exchange rate volatility is negatively associated with economic growth. However, the study by [Bagella et al. \(2006\)](#) established that countries with flexible exchange rate have more advantages because they absorb shocks more easily than countries with fixed exchange rate. In this way countries that implement flexible exchange rate regimes have a favorable economic performance and fluctuation of the exchange rate promotes their growth.

Both in theoretical and empirical studies, the effects of exchange rate volatility on economic growth did not show any clear cut relation between them. Although the study by [Eichengreen \(2008\)](#) did not find any significant relation between Real Exchange Rate (RER) volatility and growth, it supported the idea that: “Keeping it at appropriate levels and avoiding excessive volatility enables a country to exploit its capacity for growth”.

The theoretical and empirical studies made on both developed and developing countries show mixed results between exchange rate fluctuation and economic growth. Facing such mixed results the research questions of this study are as follow:

Does the exchange rate volatility influence economic growth in the fourteen chosen CEE countries?

Are there any factors contributing significantly in determining the degrees of this sensitivity on economic growth?

3. Methodology

3.1. Data Collection and Samples

The annual data of Central Eastern European countries was used to analyze the effect of exchange rate volatility in economic growth for the period spanning from 2002–2018. The sample consisted of fourteen CEE countries—Albania, Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, North Macedonia, Poland, Romania, Serbia, Slovakia, Slovenia—that are characterized by different exchange rate regimes from hard pegs to floaters. Thus, de facto exchange rate was employed since it provides more accurate information to assess the relation between exchange rate volatility and economic growth. The annual data of control variables were compiled from World Bank Data (WBD). Thereafter, the monthly data concern real effective exchange rate was obtained from the Bruegel database to calculate the volatility of the exchange rate.

The hypotheses that are tested in this study are:

Hypothesis 1 (H1). *There is a statistically significant negative relationship between exchange rate volatility and economic growth.*

Hypothesis 2 (H2). *There is a statistically significant negative relationship between the interaction term of exchange rate volatility and trade openness with economic growth.*

Hypothesis 3 (H3). *There is a statistically significant negative relationship between the interaction term of exchange rate volatility and real interest rate with economic growth.*

3.2. Definition of Variables and Measurement

3.2.1. Economic Growth

Economic growth refers to steady increases in real gross domestic product or national product over time. In this study the growth rate of GDP (GDP) is used that denotes the economic growth of the country.

3.2.2. Volatility

In this paper exchange rate is presented by Real Effective Exchange Rate (REER), which is nominal exchange rate, a measure of a currency against a weighted average of several foreign currencies divided by a price deflator. REER is used to calculate exchange rate volatility because the commodity price changes all the time and inflation is unstable which leads the nominal exchange rate movements to rise directly and impact trade competitiveness. In this way, the real exchange rate reflects real purchasing power and excludes inflation. In the literature, the most critical issue related is how to measure volatility and which is the appropriate definition of exchange rate volatility. In some

empirical studies moving average of the standard deviation ARCH model is used as a measure of volatility (McKenzie 1999). Following Ghosh et al. (2003), in this study *z-score* is employed to measure exchange rate volatility since de facto exchange rate volatility provides a more accurate assessment of the relationship between exchange rate volatility and economic growth. De facto exchange rate includes both the exchange rate fluctuations around a constant level and exchange rate fluctuations around a gradual depreciation path. The parameter μ corresponds to the arithmetic average of a month to month percentage exchange rate changes of the year t , and σ represents the standard deviation of the month to month percentage exchange rate changes of the year t .

$$z_t = \sqrt{\mu_t^2 + \sigma_t^2} \quad (1)$$

First the difference of the natural logarithm of the real effective exchange rate is used to calculate volatility. An alternative measure for volatility in order to provide robustness of the results is calculated as a 12-month moving standard deviation of the monthly REER in percentage (Koop and Quinlivan 2000). The monthly data includes fourteen CEE countries from January 2002 to December 2018. After calculating monthly volatility the data are transformed into annual frequency by finding the arithmetic average of 12 months.

3.2.3. Control Variables

The selection of control variables is based on the literature suggested significant factors in explaining the behavior of economic growth. A brief explanation of the control variables is given below:

Government expenditure (GEXP) is measured as a percentage of government final consumption expenditure to GDP. From Keynesian theory, it is expected that more government expenditure promotes economic growth in terms of investment, but if the level of expenditure is too much the effect will be negative.

Gross fixed capital formation (GFCF) is used as a proxy of investment rate and measured as percentage of GDP. The promotion of the economy through gross fixed capital formation is in terms of production, employment, cost, and benefit to business and household.

Inflation (INF) is measured as annual percentage change in the consumer price index as a proxy for macroeconomic stability. Inflation is a factor that effects both the exchange rate and the real economy.

Trade Openness reflects trade liberalization. It creates an opportunity for international activities and the demand and supply for goods and services of the country. It is calculated as the sum of the total value of exports and imports of goods and services as percentage of GDP. An increase in the value of trade openness reflects the extra degree of trade liberalization. The expected sign of the coefficient is positively influenced by the real economy growth.

Domestic credit to the private sector (DOMCR) is used to denote access to finance provided by the banking sector to the private sector. It is expressed as a percentage of GDP.

Interest rate (INT) represents the opportunity to invest that affects the economic growth. In this study real interest rate is used.

3.3. Empirical Model

Fixed Effects Model

In order to control for heterogeneity among countries and to identify the relationship between time varying dependent and independent variables, panel data regression is suggested by Baltagi (2008). According to Baltagi (2008) panel data regression reduces the bias and multicollinearity problems. Thus, the following regression equation for panel time series is employed to estimate the effect of real effective exchange rate volatility on economic growth:

$$Y_{it} = \alpha_i + \delta X_{it} + \beta Vol_{it} + \varepsilon_{it} \quad i = 1, 2, \dots, 14, t = 2002, 2003, \dots, 2018 \quad (2)$$

where Y_{it} is real GDP growth rate for country i at time t , while X_{it} is a vector of control variable (i.e., government expenditure as a percentage of GDP (GEXP), gross fixed capital formation (GFCF), inflation (INFL), trade openness (OPEN), domestic credit to private sector (DOMCR). Vol denotes exchange rate volatility that is measured as a standard deviation and as *z-score*.

Models with panel data can be estimated by using different methods. In this study to decide on the appropriate estimation method for panel data the Hausman test was used to compare the fixed effects versus random effect model. The Hausman test rejected the null hypothesis that the appropriate model is the random effects in favor of the fixed effects panel model (p -value = 0.000).

Figure 1 shows the exchange rate volatility measured as a *z-score* over years and exhibits significant periods of high volatility followed by more quiet periods of low volatility. During the year 2007–2008, the exchange rate is more volatile since the financial crisis had an effect on the exchange rate. After this period the exchange rate seems quieter and it has a downward trend that could be attributed to the post-crisis and the intervention of governments that contributed to currency depreciation.

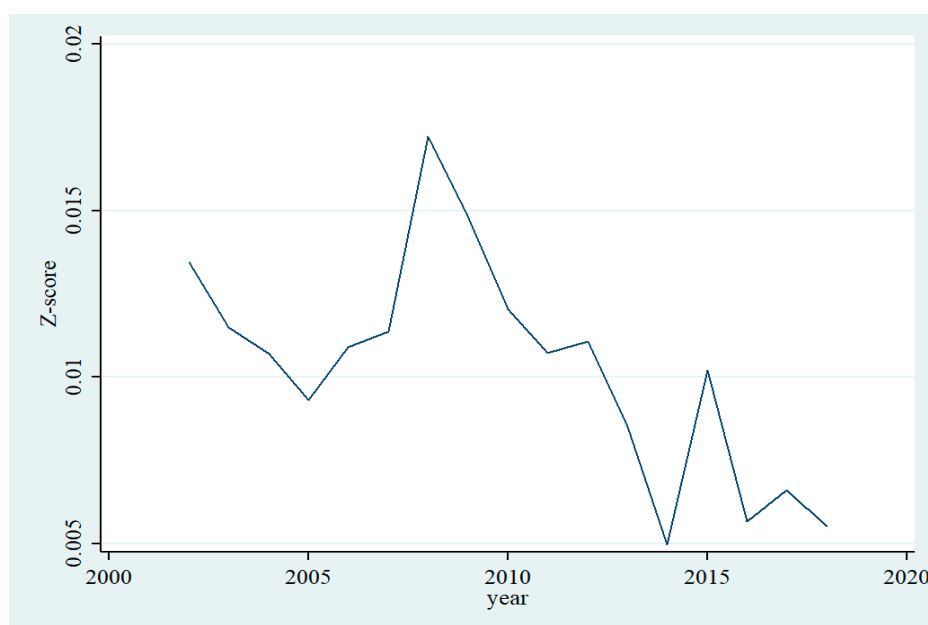


Figure 1. Z-score measure of exchange rate volatility.

4. Results and Discussion

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics of the variables of interest. The average mean of GDP growth is 3.3% and the maximum value is 11.9%. In Table 2 shows the correlation between independent variables and the results show that all coefficients are less than the threshold of 0.8 which means that there is no problem of multicollinearity between variables. The correlation between exchange rate volatility and economic growth seems negative.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	238	0.033	0.038	−0.148	0.119
lreer	224	0.011	0.045	−0.173	0.17
GEXP	238	0.18	0.026	0.104	0.229
GFCF	238	0.238	0.047	0.159	0.381
INF	238	0.034	0.035	−0.015	0.225
OPEN	238	1.129	0.338	0.537	1.923
DOMCR	238	0.466	0.181	0.002	1.046
INT	210	0.047	0.047	−0.125	0.287

Note: Variable Definition: Economic Growth (GDP), lreer log of real effective exchange rate, Government expenditure (GEXP). Gross fixed capital formation (GFCF), Inflation (INF), Trade Openness (OPEN), Domestic credit to the private sector (DOMCR) Interest rate (INT).

Table 2. Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) GDP	1.000								
(2) Vol	−0.110	1.000							
(3) z-score	−0.044	0.980 *	1.000						
(4) GEXP	−0.172 *	0.175 *	0.170 *	1.000					
(5) GFCF	0.291 *	−0.004	0.031	−0.354 *	1.000				
(6) INF	0.161 *	0.304 *	0.345 *	0.053	0.169 *	1.000			
(7) OPEN	−0.029	−0.220 *	−0.247 *	0.340 *	−0.095	−0.277 *	1.000		
(8) DOMCR	−0.393 *	−0.206 *	−0.232 *	0.247 *	0.002	−0.131 *	0.387 *	1.000	
(9) INT	−0.457 *	−0.010	−0.047	−0.229 *	−0.112	−0.388 *	−0.124	−0.011	1.000

Note: * shows significance at the 0.05 level.

4.2. Regression Results

Before running the regression, the test of Levin, [Levin et al. \(2002\)](#) was used to check for stationarity of the variables. Null hypothesis indicates that each individual time series contains a unit root against the alternative hypothesis that each variable is stationary. The panel unit root test of Levin, Lin and Chu in [Table 3](#) indicates that all variables are stationary in level since the probability values are lower than the significance level of 5% by rejecting the null hypothesis in favor of the alternative hypothesis.

Table 3. Panel Unit Root test results.

Variable	t-Statistic	Probability
Standard Deviation	−1.9732	0.0242
Z-score	−3.7001	0.0001
GEXP	−4.45342	0.0000
GFCF	−1.95738	0.0252
INF	−3.3485	0.0004
OPEN	−2.63091	0.0043
DOMCR	−6.57223	0.0000
INT	−2.06466	0.0195

[Table 4](#) reports the results from the panel data regressions of four different specifications of the effect of exchange rate volatility on economic growth. To check for robustness, the results are reported by measuring volatility in two ways as a standard deviation and as a *z-score*. Also, to provide evidence that the results are unbiased and consistent the diagnostic test of heteroscedasticity and serial correlation were performed. The heteroscedasticity for panel fixed effects model was tested using the modified Wald test for groupwise heteroscedasticity. The test results show that the models suffer from the problem of groupwise heteroskedasticity, since the chi-square values are statistically

significant at 1%, that reject the null hypothesis which states there is no groupwise heteroskedasticity. The Wooldridge test was employed to account for serial correlation problems and the results show that we failed to reject the null hypothesis that states no serial correlation at 1% level of significance. Thus, we concluded that there is presence of heteroskedasticity and serial correlation in the panel data. Furthermore, to deal with heteroskedasticity and serial correlation problems that violated the assumption of the BLUE model, robust standard errors were used.

Table 4. Economic growth and exchange rate volatility.

Explanatory Variable	(Model 1)	(Model 2)	(Model 3)	(Model 4)
Standard Deviation	−0.398 ** (0.141)		−0.273 (−0.275)	
Z-score		−0.862 * (0.401)		−1.115 (−1.179)
GEXP	−0.106 (0.209)	−0.130 (0.210)	−0.136 (−0.199)	−0.150 (−0.204)
GFCF	0.458 *** (0.128)	0.452 *** (0.133)	0.150 (−0.117)	0.162 (−0.121)
INF	0.169 ** (0.0642)	0.159 ** (0.0637)	−0.380 *** (−0.126)	−0.409 ** (0.141)
INT			−0.545 *** (0.0980)	−0.521 *** (0.0721)
OPEN	0.0693 *** (0.0209)	0.0710 *** (0.0219)	−0.525 * (−0.0248)	−0.0486 * (−0.0267)
DOMCR	−0.154 *** (0.0235)	−0.156 *** (0.0242)	−0.0736 *** (−0.0222)	−0.0725 *** (−0.0227)
Standard Deviation *INF			6.417 ** (2.507)	
Standard Deviation *OPEN			−0.296 * (0.141)	
Standard Deviation *INT			5.856 ** (−1.998)	
Z-score *INF				24.16 ** (10.44)
Z-score *OPEN				−0.784 (−0.506)
Z-score *INT				18.76 ** (6.278)
Constant	−0.0553 (0.0719)	−0.0548 (0.0739)	−0.0545 (−0.0698)	−0.0561 (−0.0722)
Time fixed effects	No	No	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Observations	238	238	210	210
Number of countries	14	14	14	14
R-squared	0.475	0.457	0.562	−0.778
Wald test	chi2(14) = 118.79 ***	Chi2(14) = 62.57 ***	chi2(14) = 120.01 ***	Chi2(14) = 321.58 ***
Wooldridge test	F(1, 13) = 72.936 ***	F(1, 13) = 56.988 ***	F(1, 13) = 73.193 ***	F(1, 13) = 31.989

Note: Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The result shows that exchange rate volatility has a significant negative effect on economic growth in the CEE countries for the period ranging from 2002–2018 in model 1 and model 2. The findings related to negative relation between exchange rate volatility and economic growth are consistent with prior theories and empirical studies (Schnabl 2008; Obstfeld and Rogoff 1998). In model 1 volatility is measured as standard deviation and it has a negative effect which shows that it has a damaging effect on growth. Apart from the investigation of the nexus between volatility and growth, in model 3 and 4 the effect of exchange rate is examined through three main channels that affect growth. The first channel is interest rate that refers to real interest rate that is influenced by debts of firms that borrow in foreign currency; second, trade as a transmission channel that is influenced by international competitiveness; third, macroeconomic stability represented by inflation is a factor that influences the decision of investors to invest in.

The effect of government expenditure seems to have a negative effect on economic growth, and it is statistically significant in model 3 and 4. This effect can be explained by the fact that increasing

government expenditure can be costly for economic growth. Imai (2018) states that the modest Balassa-Samuelson effect is present in some CEE countries that could be the driving factor for the positive association of inflation nexus growth. This effect underlines that high productivity growth which is experienced by some countries may lead to a large real appreciation in the price of tradables. Thus, it is a source of inflation which in emerging countries tends to increase faster and improve productivity compare to developed countries. High productivity growth experienced by some emerging countries in the sample is the source of a positive correlation between inflation and growth in model 1 and model 2.

Trade openness is statistically significant in all modes and enhances growth, which is consistent with other studies (Feruni and Hysa 2020). Model 2 includes *z-score* measurement for volatility and the results show the robustness of model 1 in which volatility is measured as standard deviation. In models 3 and 4 the transmission channels of volatility on growth are examined. In this model time dummies are included as a way to mitigate potential cross-sectional dependency. Thus, the negative sign of exchange rate volatility does not change in the case where transmission channels are controlled.

Models 3 and 4 examine the transmission channels of volatility on growth. In model 3 it can be seen that all transmission channels are statistically significant; meaning the effect of volatility on growth depends on macroeconomic stability, international competitiveness, and debts of firms in foreign currency.

In the case where volatility is measured as *z-score* in model 4, the transmission channel of macroeconomic stability and interest rates are statistically significant. In this case the coefficient of the interaction term of interest rate and volatility shows that the effect of exchange rate volatility on growth depends on the level of interest rates. Also, the macroeconomic stability influences the effect of volatility on growth. For these variables, we estimated the marginal effects via the partial derivative of the economic growth equation with respect to exchange rate volatility. Since the coefficient of *z-score* is negative and the interaction term with interest rate is positive, it suggests that volatility has a negative effect on economic growth and real interest rate mitigates that negative impact. This suggest that volatility has an adverse effect on economic growth through interest rate. Thus, the entire effect of the exchange rate volatility at the mean value of interest rate (0.0465) is positive and statistically significant meaning that the positive effect of volatility on economic growth is adversely influenced by interest rate. Also, the negative effect of exchange rate on growth will improve with the control of inflation and the overall effect of the interaction term at the mean value of inflation (0.0336) is significant and positive.

Different from model 4, in model 3 the coefficient of volatility measured as standard deviation has a negative sign and the interaction term (Standard Deviation*OPEN) has a negative sign, implying that volatility has a negative effect on economic growth and that international competitiveness impairs that negative effect. The entire effect of the interaction term is negative and statistically significant at 10%.

5. Conclusions

The economic performance of a country depends on the level of international trade. Foreign economic theories hold that trade openness is beneficial for economic growth. The development of international trade promotes capital formation and accelerates technical progress that in turn enhances factor productivity (Romer 1986; Rodrik 1988). Exchange rates are the main indicator that influences the price of products and services that affect the level of transaction on international trade and capital movement between countries. Central Eastern European countries operate under different exchange rate regimes from hard pegs to floating that experience a fluctuation in their exchange rate that affects international trade and the real economy of each county.

The empirical analysis is based on a panel of fourteen CEE countries spanning the period of 2002–2018. Exchange rate volatility is calculated in two different ways as a standard deviation and *z-score* and results show that both measures of exchange rate volatility (standard deviation and *z-score* measure) have a significant negative effect on economic growth. This is evident since the adoption of the Euro as home currency during the period of study has been negative for economic growth.

Moreover, trade openness in CEE countries leads to the improvement of economic growth. Also, the effect of exchange rate volatility on economic growth was investigated through three channels such as trade, investment, and macroeconomic stability—such as interest rate, trade and inflation. The marginal effects of volatility on economic growth that are calculated at the mean value of inflation, trade and interest rate show similar findings with *z-score* and standard deviation as a measure of volatility. The main channels that improve the negative effect of exchange rate volatility are interest rate and inflation. However, the international competitiveness impairs the negative effect of volatility on economic growth but it is not statistically significant. Thus, including interaction terms in the model and calculating marginal effects are essential for policy formulation since it helps to estimate the effect on economic growth caused by simultaneous changes in both exchange rate volatility and interest rate or exchange rate volatility and inflation. Therefore, exchange rate stability is the main source of economic growth and it is important that monetary authorities and government of the countries should pay attention to exchange rate by adopting an exchange rate policy that leads to stable exchange rates. The policy implication of this study is to minimize exchange rate volatility where it has a relevant role on economic growth. Also, policymakers should keep inflation and interest rates under control since they help to mitigate the negativity of volatility on growth, since the contribution to economic growth is tightly connected to international trade and investments.

Author Contributions: Conceptualization, E.H., F.M., and U.E.; methodology, E.H., F.M., and U.E.; software, E.H., F.M., and U.E.; validation, E.H., F.M., and U.E.; formal analysis, E.H., F.M., U.E., M.P., and M.C.V.; investigation, E.H., F.M., U.E., M.P., and M.C.V.; resources, E.H., F.M., U.E., M.P., and M.C.V.; data curation, E.H., F.M., U.E., M.P., and M.C.V.; writing—original draft preparation, E.H. and F.M.; writing—review and editing, E.H., F.M., U.E., M.P., and M.C.V.; visualization, E.H., F.M., U.E., M.P., and M.C.V.; supervision, E.H., F.M., U.E., M.P., and M.C.V.; project administration, E.H.; funding acquisition, M.P. and M.C.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

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

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