Exchange Rate Volatility in the Balkans and Eastern Europe: Implications for International Investments

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Abstract Our paper's objective is to study the volatility of exchange rates from the region that have not yet adopted the Euro and are not members of the Exchange Rate Mechanism II by considering the exchange rate regime and the implications of currency volatility for foreign capital flows. We model exchange rate volatility by using standard deviations of daily logarithmic changes in the exchange rates, rolling standard deviations, Hodrick-Prescott filters to detect the trends in volatility and ARIMA models. We find that currency volatility remains a strong issue for these countries and that central banks have attempted to manage it, particularly after the global financial crisis. Spikes in monthly volatility are identified for all currencies, although with some variation in time. Over the long-run, some exchange rates experienced sudden increases in volatility over the entire period, but rather quickly corrected, while others have shown an episode of high volatility at the beginning of the period and recorded a reasonable level of volatility throughout the remaining period. Exchange rate volatility "has memory", but some exchange rates are more prone to the persistent effects of shocks in volatility.

Keywords Exchange rates • Volatility • Eastern Europe • Balkans

JEL Classification Codes F31 • F37 • G17

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1 Introduction

The evolution of exchange rates represents a major source of concern from both a micro- and a macroeconomic perspective, given the cvasi-generalised adoption of floating rates since 1973. The choice of an optimal exchange rate regime is still an unresolved question of international macroeconomics, but recent financial history has generated a growing support for "clear-cut" exchange rate regimes—such as hard pegged rates or free floating rates—, considered more appropriated in the current framework of higher financial integration fuelled by unprecedented capital mobility at the global level. From the perspective of international investments, currency movements are highly relevant, as they influence the risk of an international investment not only directly, through their own volatility, but also through the link between foreign asset returns and exchange rate changes. In a framework of increasing international portfolio investments and of business opportunities diversification at the global level, but also of higher financial market integration, investors critically evaluate the exchange rate risk, particularly when investments are made in emerging markets, as is the case with the Balkan and Eastern European countries. A number of studies have shown that a lack of control over currency risk might put investors in the difficult position of not being able to overcome the costs of holding foreign assets with the gains obtained from foreign investments (Jorion 1985; Eun and Resnick 1994; Bugar and Maurer 2002).

The recent financial crisis had a noteworthy impact on global financial markets and under these circumstances it is critical to understand the exposure of international investors to the various risk factors abroad and, in the framework of our research, to currency risk. Various authors study the impact of global financial turmoil on exchange rate policies in 21 emerging countries between 1994 and 2009 and found that currency volatility increases more than proportionally with the global financial stress for most countries in their sample; also, the authors evidence regional contagion effects between neighbouring emerging countries (Coudert et al. 2011). Other authors investigate the group of BRIC countries and argue that high currency volatility was one of the consequences of the years of uncertainty about sustainable recovery and governments' trouble to manage their enormous fiscal deficits after 2008 (Mellet 2011).

At present, the exchange rate regimes of countries from the Balkans and Eastern Europe are rather varied, but this may be explained by the structural diversity of these countries and by their needs and past efforts to actively control inflation and exchange rate volatility. Table 1 summarizes the exchange rate regimes and monetary policy frameworks for the countries in the Balkans and Eastern Europe at the end of 2013, according to the latest report issued by the International Monetary Fund (IMF 2013).

The adoption of a specific exchange rate regime has a demonstrated impact on currency volatility. A paper that studies changes in exchange rate regimes in Visegrad countries finds that path-dependent volatility had a limited effect on exchange rate developments and that the introduction of floating regimes tends to

Table 1 De facto exchange regimes for Balkan and Eastern Europe countries, end 2013

Country	Currency	Exchange rate regime	Monetary policy framework
Croatia	Kuna (HRK)	Crawl-like arrangement	Exchange rate anchor—Euro
Czech Republic	Koruna (CZK)	Free floating	Inflation targeting
Hungary	Forint (HUF)	Floating	Inflation targeting
Poland	Zloty (PLN)	Free floating	Inflation targeting
Romania	Leu (RON)	Floating	Inflation targeting
Russia	Rouble (RUB)	Managed exchange rate arrangement	Various indicators are monitored for the monetary policy. The central bank has taken preliminary steps toward inflation targeting
Serbia	Dinar (RSD)	Floating	Inflation targeting
Turkey	Lira (TRY)	Floating	Inflation targeting

Source: IMF (2013)

increase exchange rate volatility (Kocenda and Valachy 2006). In the past two decades, some of these countries became members of the European Union—Czech Republic, Hungary and Poland in 2004, Romania and Bulgaria in 2007, and Croatia in 2013—, with direct effects on their monetary and exchange rate policies. As a fact, five of them changed their monetary policy rule by the adoption of inflation targeting regime: the Czech Republic in 1998, Poland in 1999, Hungary in 2001 and Romania in 2005. Eventually, these countries will have their currencies replaced by the Euro, but not before at least 2 years spent in the Exchange Rate Mechanism II (ERM II). Joining ERM II assumes the establishment of a fixed exchange rate of the respective currency against the Euro with a variation margin of ± 15 % around the parity. Currently, only two countries are members of the ERM II (Denmark and Lithuania), while the prospects of the others to join the system remain uncertain. An important point is worth mentioning here, though: even if ERM II allowed for a rather relaxed band for the exchange rates against the Euro, in reality the effective margins for the ERM II currencies were much smaller: the Danish krone operated at a margin lower than 1 %, the Latvian lats at a 1 % margin, while the Estonian kroon and the Lithuanian litas had 0 % margins before Euro adoption. This indicates, on one hand, a serious commitment of these countries' central banks to ensure the highest possible level of stability of exchange rates against the Euro, and, on the other hand, a considerable pressure on the future members of ERM II to smooth out exchange rates fluctuations before joining the system, as moving from a highly volatile exchange rate to a rather stable one is a not on overnight process.

For what concerns the other countries in the region—Croatia, Serbia, Russia and Turkey, their characteristics in terms of monetary and exchange rate policies are

diverse. Of particular concern for Croatia is the high level of dollarization of the economy, which distinguishes it from other advanced transition countries and affects its choice of exchange rate regime. The fragilities created by large quantities of foreign currency liabilities in Croatian banks' balance sheets were the main justification for making exchange rate stability the key player of monetary policy in Croatia's highly dollarized economy (Sosic and Kraft 2004). Other authors explore a number of transition economies—Poland, Czech Republic, Slovakia and the Republic of Serbia, with regard to their abandonment of the exchange rate targeting and fixed exchange rate regimes and movement toward explicit/implicit inflation targeting and flexible exchange rate regimes (Josifidis et al. 2009). In the case of Serbia, the authors find a series of obstacles for a successful inflation targeting monetary policy rule, such as a strong and persistent exchange rate pass-through and a low interest rate pass-through. Turkey is a special case among the countries in the region: since 1990s, Turkey has experienced economic declines after three major crises in 1994, 1999 and 2001, having as common denominators macroeconomic imbalances and external shocks. The 2001 currency crisis was produced by capital market liberalization and speculative attacks under the fixed exchange rate regime, which triggered the change in exchange rate regime to floating accompanied by inflation targeting in 2006. For what concerns Russia, the government debt crisis of 1998 generated a shift to a managed floating exchange rate. The exchange rate continued to be tightly managed through 2002–2005, but in 2004 less restrictive capital control regulations were adopted and, in 2005, the Bank of Russia introduced a dual-currency basket as the operational indicator for its exchange rate policy, aiming to smooth the volatility of the Rouble exchange rate vis-à-vis other major currencies. After the global financial crisis, the Bank of Russia increased the flexibility of its exchange rate policy and more flexibility is envisaged for the period to come.

Our paper aims at investigating the volatility of the exchange rates against the Euro and the US dollar for eight currencies from the Balkans an Eastern Europe that have not yet adopted the Euro and are not members of ERM II—Czech Republic, Hungary, Poland, Romania, Serbia, Croatia, Russia and Turkey. We address the trends in volatilities by taking into account the exchange rate regimes used in each of these eight countries and using daily exchange rates between 1999 and 2013. Exchange rate volatility is modelled using monthly standard deviations of daily logarithmic changes in the exchange rates, as well as rolling standard deviations with different windows, which allows us to understand short-term versus long-term changes in volatility. We apply Hodrick-Prescott filters to detect trends in monthly standard deviations and ARIMA models to investigate the exchange rates volatility response to past levels of volatility and to potential shocks in volatility. We extend here the previous works on exchange rate volatility in Central and Eastern Europe, by investigating more currencies in the region and by using other relevant instruments for understanding currency volatility (Horobet and Tusa 2007; Horobet et al. 2011).

We contribute to the research in the field with a thorough investigation of currency volatility patterns in the region, which represents, to our knowledge, the

first attempt of this kind in the literature. In order to properly understand the evolution of currency volatility after 1999, we use a set of instruments that provide information on short-run versus long-run volatility patterns, as well as on volatility time-dependency and currency volatility sensitivity to potential shocks.

2 Data and Research Methodology

We use in our research exchange rates of the domestic currencies against the Euro and the US dollar of eight countries from the Balkans and Eastern Europe that have not yet adopted the Euro and are not members of the ERM II—more specifically Czech Republic (Czech Koruna—CZK), Hungary (Hungarian Forint—HUF), Poland (Polish Zloty—PLN), Romania (Romanian Leu—RON), Serbia (Serbian Dinar—RSD), Croatia (Croatian Kuna—HRK), Russia (Russian Rouble—RUB) and Turkey (Turkish Lira—TYR). Data on exchange rates was collected from the Pacific Exchange Rate Service, for the period between 1999 and 2013. The first observation dates from January 4th, 1999 for Czech Republic, Hungary, Poland, Romania, Russia and Turkey, from March 1st, 2002 for Croatia, and from September 4th, 2007 for Serbia.

Based on daily exchange rates, we calculate (1) the daily logarithmic returns with EUR and the USD, respectively, as base currencies; (2) the monthly standard deviation of the daily logarithmic returns against the EUR and the USD; and (3) the 30 days, 90 days and 360 days rolling standard deviations of daily logarithmic returns.

We apply the Hodrick-Prescott (HP) filter, which offers a smooth estimate of the long-term trend component of a series of data, to have a better view on the monthly standard deviations of daily logarithmic returns. The method was proposed by Hodrick and Prescott in 1997 to model post-war U.S. business cycles, and it uses a two-sided linear filter that calculates the smooth series S of a series Y by minimising the variance of Y around S, by taking into account a penalty parameter λ that constrains the second difference of S (Hodrick and Prescott 1997). Specifically, the HP filter minimizes:

$$\sum_{t=1}^{T} (y_t - s_t)^2 + \lambda \sum_{t=2}^{T} [(s_{t+1} - s_t) - (s_t - s_{t-1})]^2 \quad (1)$$

The parameter λ controls for the degree of smoothness of the series variance: the larger its value, the smoother the variance. We have used 14,400 as the value of λ for smoothing the series of monthly standard deviations, which is appropriate for the work on monthly data.

Autoregressive integrated moving average (ARIMA) models, popularly known as the Box–Jenkins methodology, offer an analysis of the stochastic properties of economic time series, based on the "let data speak for themselves" philosophy (Box

and Jenkins 1978). An ARIMA (p, d, q) is an autoregressive integrated moving average time series, where p denotes the number of autoregressive terms, d the number of times the series has to be differenced before the series becomes stationary, and q the number of moving average terms. The ARIMA (p,d,q) model of the time series $\{x_1,x_2,\ldots\}$ may be defined as:

$$\Phi_p(B)\Delta^d x_t = \Theta_q(B)\varepsilon_r \tag{2}$$

where B is the backward shift operator, $Bx_y = x_{y-1}$, $\Delta = 1 - B$ is the backward difference, and Φ_p and Θ_q are polynomials of order p and q, respectively. ARIMA (p,d,q) models are the product of an autoregressive part AR(p) of the form:

$$\Phi_p = 1 - \varphi_1 B - \varphi_2 B^2 - \ldots - \varphi_p B^p \tag{3}$$

an integrating part of the form:

$$I(d) = \Delta^{-d} \tag{4}$$

and a moving average MA(q) part of the form:

$$\Theta_q = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_p B^p \tag{5}$$

While finding d in ARIMA(p,d,q) is typically implemented with the help of stationarity tests such as Augmented Dickey-Fuller or Phillips-Perron, the method of choosing values for p and q requires a careful analysis of the autocorrelations and partial autocorrelations for the times series. Still, finding the good model is usually an iterative technique where different values for p and q are given and the model diagnostic is carried out. We verify the ARIMA properties of the series of monthly standard deviations, in order to identify the time-dependence of monthly volatility—AR terms—and the influence of possible shocks in volatility—the MA terms.

3 Results

3.1 Brief Analysis of Daily Exchange Rates

Figure 1 shows the series of daily exchange rates of the eight currencies from the Balkans and Eastern Europe against the EUR and the USD, between 1999 and 2013, while Fig. 2 presents the daily logarithmic changes (or returns) of the same exchange rates. Descriptive statistics for the daily logarithmic changes are presented in Table 2. A quick look at the graphs in Fig. 1 indicates different patterns for these countries' exchange rates against both the EUR and the USD. Overall, the CZK is the only currency with an appreciating trend between 1999 and 2013 against

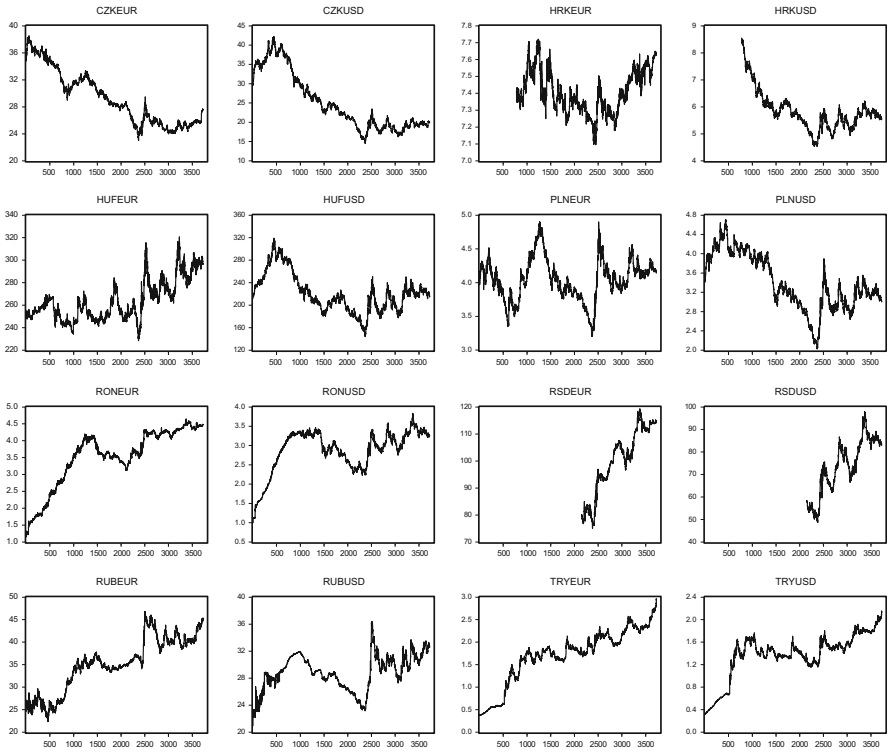

Fig. 1 Daily exchange rates against EUR and USD, 1999–2013. *Note*: The first observation is January 4, 1999 and the last observation is December 31, 2013; exchange rates are quoted with EUR and USD as base currencies

both the EUR and the USD; the RON, RSD, RUB and TRY depreciated against the EUR and USD, as a general trend, but swings in the exchange rates over these years were important, particularly in the case of the RUB and even RSD. Over the entire frame of exchange rates observations for each currency pair, the CZK appreciated by 29.2 % and the PLN by a tiny 0.06 %, while all the other currencies depreciated against the EUR, with the notable case of the TRY—a depreciation of 87.32 %. When the exchange rates against the USD are considered, three currencies recorded overall appreciations against the American currency—the HRK (54.7 %), the CZK (49.9 %) and the PLN (16.11 %). As in the EUR case, the TRY depreciated heavily, by 85.3 % overall, followed by RON, with a depreciation rate of 69.3 %.

It is worthwhile mentioning the higher stability in the RONEUR exchange rate after 2008 compared to the previous years, but which is not found in the case of RONUSD exchange rate—this is explained by the fact that on the Romanian foreign exchange market the RONEUR exchange rate is the reference rate and observed by the Romanian central bank, while the RONUSD exchange rate is determined as a cross-rate, taking into account the USDEUR exchange rate in the international foreign exchange market. By far, the HUFEUR, HUFUSD, PLNEUR,

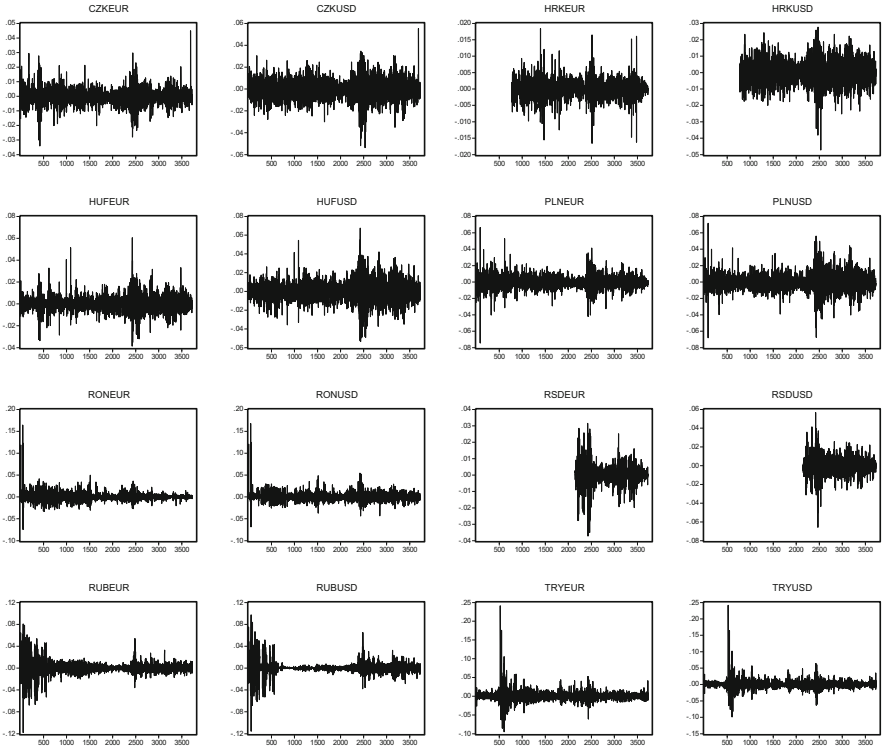

Fig. 2 Daily returns of exchange rates against the EUR and USD, 1999–2013. *Note*: The first observation is January 5, 1999 and the last observation is December 31, 2013

Table 2 Correlations between the exchange rates against EUR and USD, 1999–2013

Currency	CZK	HRK	HUF	PLN	RON	RSD	RUB	TRY
Correlation coefficient	0.6199	0.2907	0.7504	0.7261	0.7133	0.6464	0.7614	0.8459

PLNUSD and HRKEUR exchange rates display the highest volatility over the period, especially after the end of 2008. An interesting observation regards the high correlations between the exchange rates of each of the eight currencies against the EUR and the USD, presented in Table 2.

When daily exchange returns are considered, the different evolutions of exchange rates are reflected in the diverse patterns shown in Fig. 2. Again, there are exchange rates with a rather high volatility over the entire period—HRKEUR, HRKUSD, HUFUSD, PLNUSD, RSDEUR, RSDUSD, exchange rates with spikes in volatility—CZKEUR, CSKUSD, RUBEUR, RUBEUR, TRYEUR and TRYUSD, and also rather stable exchange rates—RONEUR and RONUSD. At the same time, the well documented phenomenon of volatility clustering is easily observable (Engle 1982; Bollerslev 1986; Cont 2005).

Considering the exchange rates against the EUR, an analysis of data in Table 3 shows that only one currency—CZK—appreciated, on average, against the EUR, at a rate of 0.14 % per month, while all the other currencies depreciated against the common currency—the highest average depreciation was recorded for TRY (1.11 % per month) and the lowest for HRK (0.20 % per month). The average monthly change in the value against the EUR for PLN was a surprising 0 %. At the same time, the volatility of daily returns was considerable for many currencies, either on an absolute basis (minimum and maximum values) or by taking into account their standard deviations. The most volatile exchange rates over the entire period under analysis were the TRY (a standard deviation on 5.25 % per month), the RUB (standard deviation of 4.32 % per month) and the RON (a standard deviation of 3.71 % per month), while the most stable currencies were the HRK (standard deviation of 1.09 %) and the CZK (standard deviation of 2.15 %). All exchange rate changes are non-normally distributed, with negative skewness for CZK, HRK, HUF, PLN, RON and TRY, positive skewness for RSD and RUB, and excess kurtosis—the same leptokurtic distributions are also indicated by the Jarque-Berra test of normality.

When we investigate the exchange rates against the USD (see Table 4), we observe that three currencies (CZK, HRK and PLN) recorded, on average over the period, appreciations against the USD—the highest average appreciation belongs to HRK, while all the other currencies depreciated on average against the USD—the highest depreciation was recorded for the TRY (thus confirming the results for the TRY exchange rate against the EUR). As in the EUR case, the exchange rates volatility was high, reaching 4.01 % on a monthly basis for TRY and 3.36 % per month for HUF. Daily jumps in the series of exchange rates changes are also observable in the relation to the USD—the highest were present for TRY (an appreciation of the USD of 482.8 % per month, or 24.13 % per day, on February 22, 2001) and RON (an appreciation of 335.6 % per month, or 16.78 % per day, on March 11, 2009). On average, the highest appreciations of the USD were higher compared to the appreciations against the EUR (196.3 % compared to 176.93 % on a monthly basis), as is the case with the largest depreciations of the USD (on average, the highest depreciations of the USD were 142.4 % per month, while the largest depreciations of the EUR generated an average of 121.83 % per month). The Jarque-Berra test of normality indicates leptokurtic distributions, with negative skewness for HUF, PLN, RON, RUB and TRY, positive skewness for CZK, HRK and RSD, and excess kurtosis for all exchange rate return series.

A quick look at Tables 5 and 6, which show the correlations between the logarithmic returns in the exchange rates against the EUR and the USD, indicates stronger links between the exchange rates against the USD, compared to the exchange rates against the EUR. In the case of correlations against the EUR, the highest correlation coefficient is 0.5542 between HUFEUR and PLNEUR, while the lowest is negative, with a value of −0.0118, between RSDEUR and CZKEUR. For correlations against the USD, the highest coefficient has a value of 0.8190 between HRKUSD and CZKUSD, and the lowest has a value of 0.1303 between RUBUSD and TRYUSD. The average correlation coefficient for the exchange rates against the EUR was 0.1579 and for the exchange rates against the USD was 0.5038.

Table 3 Descriptive statistics of daily returns of exchange rates against the EUR (monthly basis)

	CZKEUR	HRKEUR	HUFEUR	PLNEUR	RONEUR	RSDEUR	RUBEUR	TRYEUR
Mean	−0.0014	0.0002	0.0009	0.0000	0.0071	0.0046	0.0032	0.0111
Median	−0.0020	0.0000	−0.0040	−0.0040	0.0000	0.0040	0.0000	0.0020
Maximum	0.8980	0.3680	1.2120	1.3280	3.2760	0.6300	1.6160	4.8260
Minimum	−0.6800	−0.3300	−0.7720	−1.4820	−1.4900	−0.7440	−2.3540	−1.8940
Std. dev.	0.0215	0.0109	0.0284	0.0317	0.0371	0.0262	0.0432	0.0525
Skewness	0.2228	0.0561	0.5303	0.0805	3.8363	−0.2295	−0.2041	3.9157
Kurtosis	9.7902	10.1969	10.2694	12.5719	70.9176	9.9530	22.6156	76.5521
Jarque-Bera	7188.92	6367.97	8378.62	14,228.32	725,277.50	3192.52	59,761.47	849,410.50
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	3726	2950	3726	3726	3726	1578	3726	3726

Table 4 Descriptive statistics of daily returns of exchange rates against the USD (monthly basis)

	CZKUSD	HRKUSD	HUFUSD	PLNUSD	RONUSD	RSDUSD	RUBUSD	TRYUSD
Mean	−0.0022	−0.0030	0.0001	−0.0008	0.0063	0.0044	0.0024	0.0103
Median	0.0000	−0.0040	−0.0020	−0.0060	0.0030	0.0020	0.0000	0.0000
Maximum	1.1040	0.5540	1.3480	1.4340	3.3560	1.1340	1.9460	4.8280
Minimum	−1.0720	−0.9420	−1.0720	−1.3580	−1.3660	−1.3100	−2.3040	−1.9680
Std. dev.	0.0286	0.0232	0.0336	0.0326	0.0304	0.0320	0.0311	0.0401
Skewness	−0.0867	−0.1011	0.1054	0.1825	3.5556	−0.1982	0.2057	3.8914
Kurtosis	6.0587	5.1561	6.5913	8.6597	61.9480	8.0236	30.6822	77.0268
Jarque-Bera	1457.14	576.42	2009.25	4993.76	547,323.40	1669.66	118,994.70	860,168.20
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	3726	2950	3726	3726	3726	1578	3726	3726

Table 5 Correlations between daily returns of exchange rates against the EUR, 1999–2013

	CZKEUR	HRKEUR	HUFEUR	PLNEUR	RONEUR	RSDEUR	RUBEUR	TRYEUR
CZKEUR	1.0000	0.1480	0.4740	0.4366	0.1289	−0.0118	0.0804	0.1269
HRKEUR	0.1480	1.0000	0.1344	0.1307	0.0762	0.0661	0.1015	0.0804
HUFEUR	0.4740	0.1344	1.0000	0.5542	0.1534	0.0598	0.0640	0.2194
PLNEUR	0.4366	0.1307	0.5542	1.0000	0.2457	0.0274	0.1974	0.2545
RONEUR	0.1289	0.0762	0.1534	0.2457	1.0000	0.0305	0.1926	0.2054
RSDEUR	−0.0118	0.0661	0.0598	0.0274	0.0305	1.0000	0.0110	0.0414
RUBEUR	0.0804	0.1015	0.0640	0.1974	0.1926	0.0110	1.0000	0.1918
TRYEUR	0.1269	0.0804	0.2194	0.2545	0.2054	0.0414	0.1918	1.0000

Note: The correlations for HRKEUR and RSDEUR are calculated for the period March 1, 2002–December 31, 2013, and September 4, 2007–December 31, 2013, respectively

Table 6 Correlations between daily returns of exchange rates against the USD, 1999–2013

	CZKUSD	HRKUSD	HUFUSD	PLNUSD	RONUSD	RSDUSD	RUBUSD	TRYUSD
CZKUSD	1.0000	0.8190	0.7976	0.7273	0.4376	0.6601	0.2667	0.2905
HRKUSD	0.8190	1.0000	0.7692	0.7376	0.5969	0.7464	0.5281	0.3752
HUFUSD	0.7976	0.7692	1.0000	0.7775	0.4595	0.6484	0.2805	0.3686
PLNUSD	0.7273	0.7376	0.7775	1.0000	0.4563	0.6406	0.3106	0.3529
RONUSD	0.4376	0.5969	0.4595	0.4563	1.0000	0.6264	0.1672	0.2191
RSDUSD	0.6601	0.7464	0.6484	0.6406	0.6264	1.0000	0.4975	0.4187
RUBUSD	0.2667	0.5281	0.2805	0.3106	0.1672	0.4975	1.0000	0.1303
TRYUSD	0.2905	0.3752	0.3686	0.3529	0.2191	0.4187	0.1303	1.0000

Note: The correlations for HRKUSD and RSDUSD are calculated for the period March 1, 2002–December 31, 2013, and September 4, 2007–December 31, 2013, respectively

3.2 Analysis of Exchange Rate Volatility

We now turn our attention to the in-depth study of exchange rate volatility. After a brief analysis of descriptive statistics for the monthly standard deviations of exchange rate returns against the EUR and USD, we investigate the trends in monthly volatility using the Hodrick-Prescott filter, we observe the volatility behaviour over short-run and long-run using rolling standard deviations with various windows, and we model monthly volatilities with the help of ARIMA models. Combined, the results of these three approaches offer us a more comprehensive view over the time-dependencies of exchange rate volatilities in the Balkans and Eastern Europe.

Tables 7 and 8 provide descriptive statistics for the monthly series of volatilities for the 16 exchange rates under scrutiny. For what concerns the exchange rates against the EUR, the means of monthly volatilities range between 0.22 % for HRK and 3.91 % for TRY, with the highest monthly volatility recorded for TRY (27.55 % for February 2001) and the lowest for 0.06 % for HRK (June 2008). When the exchange rates against the USD are considered, the average monthly volatilities range between 2.72 % for RUB and 3.98 % for HUF; the highest monthly volatility belongs again to TRY (27.55 % in February 2001) and the lowest to CZK (1.36 % in June 2007). The most volatile series of monthly standard deviations were the ones for TRYEUR and TRYUSD, while the series with the lowest volatility were the HRKUSD and HRKEUR. As indicated by skewness and kurtosis, all series of monthly standard deviations show negative asymmetry and excess kurtosis, thus presenting the attributes of a leptokurtic distribution.

As a possible indication of potential shock transmission between exchange rates volatilities, we have also calculated the correlations between monthly standard deviations both against the EUR and USD (see Tables 9 and 10). The average correlation for the monthly standard deviations against the USD is 0.7127, higher than in the case of monthly standard deviations against the EUR (0.2763), thus indicating that potential shocks in the exchange rates against the USD might be transmitted quicker than the shocks in the exchange rates against the EUR. The explanation, in our view, resides in the controlled exchange rates against the EUR for many of these currencies, while the exchange rates against the USD are rather freely moving, taking into account mainly the USDEUR exchange rate in the international foreign exchange market. The highest correlation for the volatilities against the EUR is recorded for RONEUR and RSDEUR, while against the USD is found for HUF and PLN (0.9507). At the other end, the lowest correlations were −0.0835 for the monthly standard deviations of RUBEUR and HUFEUR and 0.2358 for the monthly standard deviations of RUBUSD and TRYUSD.

Controlling for the smoothness in series variance, the application of the HP filter shows three distinct patterns of evolution for the eight currencies under analysis (see Fig. 3). The first pattern is observable for CZK, HRK, HUF and PLN (except for HRKEUR): a decreasing volatility trend from January 1999 until the end of 2006, followed by increasing volatility until the end of 2009, and subsequent

Table 7 Descriptive statistics of monthly standard deviations of exchange rates returns against the EUR, January 1999–December 2013

	SD_CZKEUR	SD_HRKEUR	SD_HUFEUR	SD_PLNEUR	SD_RONEUR	SD_RSDEUR	SD_RUBEUR	SD_TRYEUR
Mean	0.0043	0.0022	0.0056	0.0063	0.0067	0.0048	0.0074	0.0391
Median	0.0037	0.0021	0.0049	0.0056	0.0059	0.0037	0.0053	0.0305
Maximum	0.0146	0.0072	0.0238	0.0239	0.0497	0.0176	0.0429	0.2755
Minimum	0.0017	0.0006	0.0013	0.0019	0.0013	0.0008	0.0014	0.0096
Std. dev.	0.0023	0.0010	0.0030	0.0033	0.0051	0.0034	0.0066	0.0346
Skewness	1.9921	1.7834	1.8777	2.3104	4.0759	1.6353	2.6069	3.9073
Kurtosis	7.7998	8.3931	9.7045	10.7258	32.1602	5.4875	10.3601	22.0575
Observations	180	142	180	180	180	76	180	180

Table 8 Descriptive statistics of monthly standard deviations of exchange rates returns against the USD, January 1999–December 2013

	SD_CZKUSD	SD_HRKUSD	SD_HUFUSD	SD_PLNUSD	SD_RONUSD	SD_RSDUSD	SD_RUBESD	SD_TRYUSD
Mean	0.0345	0.0285	0.0398	0.0379	0.0333	0.0374	0.0272	0.0391
Median	0.0322	0.0276	0.0357	0.0338	0.0299	0.0334	0.0165	0.0305
Maximum	0.1045	0.0686	0.1378	0.1434	0.2256	0.1190	0.1912	0.2755
Minimum	0.0129	0.0130	0.0148	0.0130	0.0044	0.0158	0.0012	0.0096
Std. dev.	0.0136	0.0095	0.0178	0.0192	0.0212	0.0174	0.0312	0.0346
Skewness	1.9649	1.4986	1.8577	2.0673	4.9760	2.1692	2.3760	3.9073
Kurtosis	8.7826	6.4021	8.3965	9.1878	41.5775	9.2007	9.2682	22.0575
Observations	180	141	180	180	180	75	180	180

Table 9 Correlations of monthly standard deviations of exchange rates against the EUR

	SD_CZKEUR	SD_HRKEUR	SD_HUFEUR	SD_PLNEUR	SD_RONEUR	SD_RSDEUR	SD_RUBEUR	SD_TRYEUR
SD_CZKEUR	1.0000	0.2076	0.5822	0.5465	0.2340	0.3612	0.2080	0.0698
SD_HRKEUR	0.2076	1.0000	0.1321	0.3040	0.3013	0.2091	0.3630	−0.0179
SD_HUFEUR	0.5822	0.1321	1.0000	0.4998	0.0410	0.2740	−0.0835	0.1189
SD_PLNEUR	0.5465	0.3040	0.4998	1.0000	0.3319	0.2304	0.4841	0.1819
SD_RONEUR	0.2340	0.3013	0.0410	0.3319	1.0000	0.6097	0.5627	0.2479
SD_RSDEUR	0.3612	0.2091	0.2740	0.2304	0.6097	1.0000	0.2725	0.4329
SD_RUBEUR	0.2080	0.3630	−0.0835	0.4841	0.5627	0.2725	1.0000	0.0321
SD_TRYEUR	0.0698	−0.0179	0.1189	0.1819	0.2479	0.4329	0.0321	1.0000

Table 10 Correlations of monthly standard deviations of exchange rates against the USD

	SD_CZKUSD	SD_HRKUSD	SD_HUFUSD	SD_PLNUSD	SD_RONUSD	SD_RSDUSD	SD_RUBUSD	SD_TRYUSD
SD_CZKUSD	1.0000	0.8799	0.8996	0.8839	0.8071	0.7143	0.5523	0.7551
SD_HRKUSD	0.8799	1.0000	0.8942	0.8473	0.8407	0.8040	0.5975	0.7039
SD_HUFUSD	0.8996	0.8942	1.0000	0.9507	0.8305	0.6722	0.5900	0.7488
SD_PLNUSD	0.8839	0.8473	0.9507	1.0000	0.8036	0.6074	0.5778	0.7386
SD_RONUSD	0.8071	0.8407	0.8305	0.8036	1.0000	0.7365	0.4314	0.8213
SD_RSDUSD	0.7143	0.8040	0.6722	0.6074	0.7365	1.0000	0.4161	0.6158
SD_RUBUSD	0.5523	0.5975	0.5900	0.5778	0.4314	0.4161	1.0000	0.2358
SD_TRYUSD	0.7551	0.7039	0.7488	0.7386	0.8213	0.6158	0.2358	1.0000

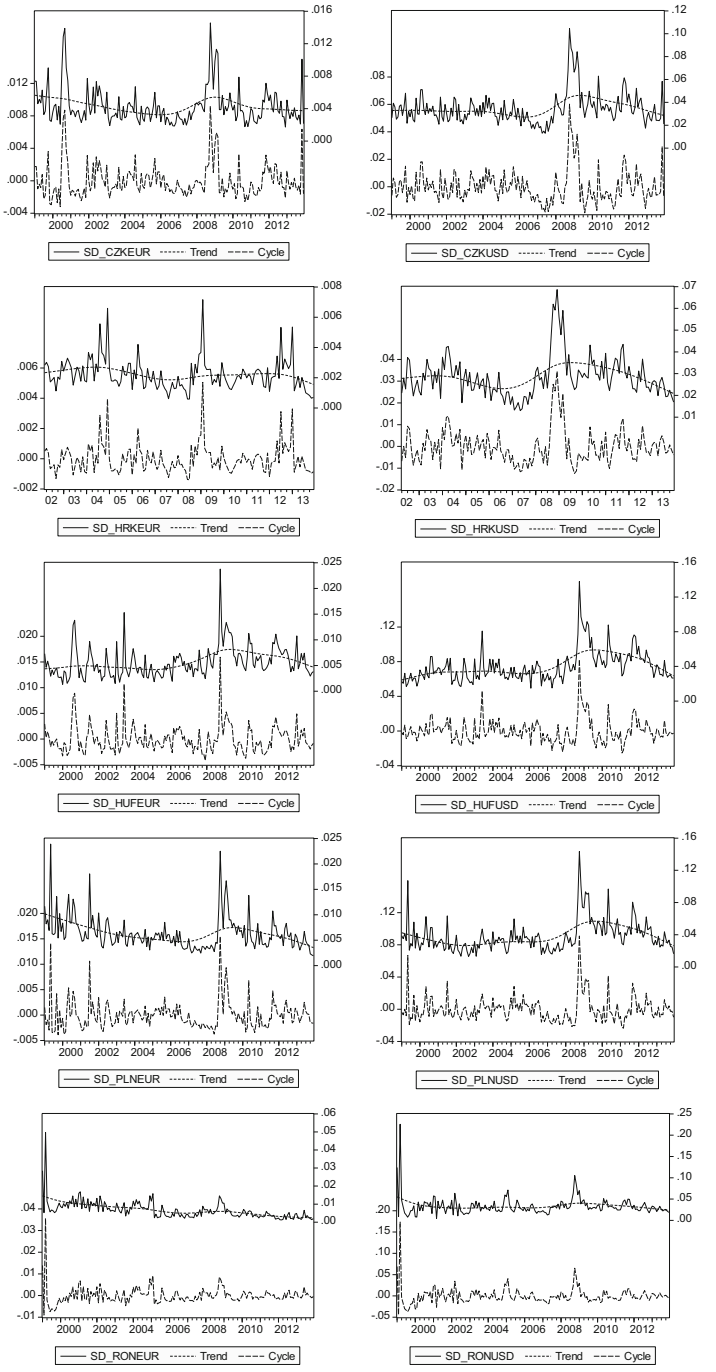

Fig. 3 (continued)

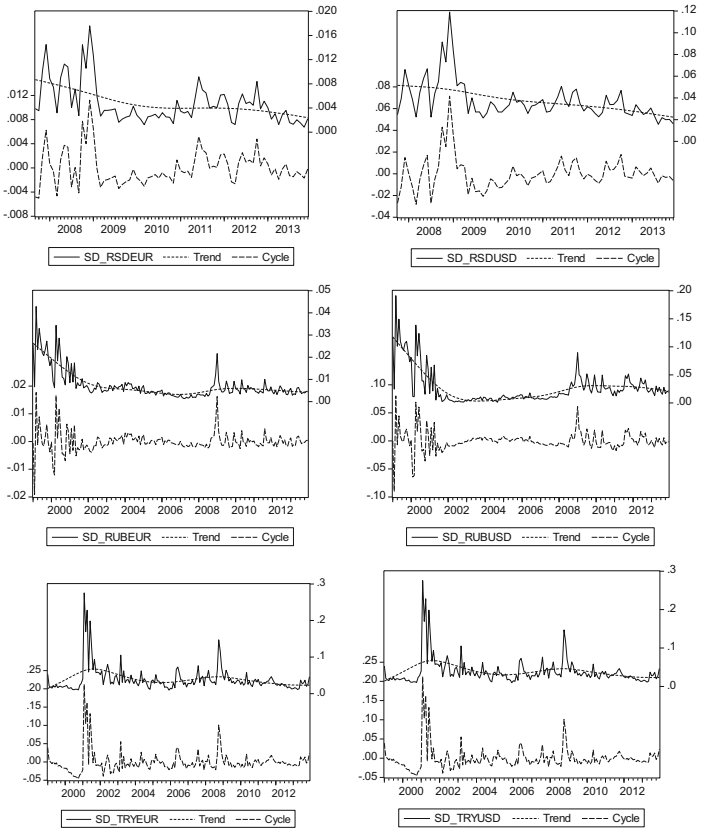

Fig. 3 Monthly standard deviations of exchange rates returns against the EUR and USD, values and HP filter, January 1999–December 2013

decline in volatilities until the end of 2013. In this group, the series of monthly volatilities were smoother for the HRKEUR, although a small increase is observable in 2008 and 2009, followed by a succeeding decline until the end of 2013. The second group of exchange rates, with a different pattern in their monthly volatility trend, is formed of RON, RUB and TRY: all three currencies had more stable monthly volatilities between 1999 and 2013, indicating the countries' central banks concern regarding the exchange rate fluctuations. The third pattern is observable in the case of the RSD (indeed, only after 2007), showing a decreasing trend in volatilities of the currency against both the EUR and USD.

The next step in our analysis focuses on the differences between short-run and long-run trends in volatility, with the support of rolling standard deviations (RSD) of daily logarithmic returns in exchange rates: the 30-days window RSD evolution

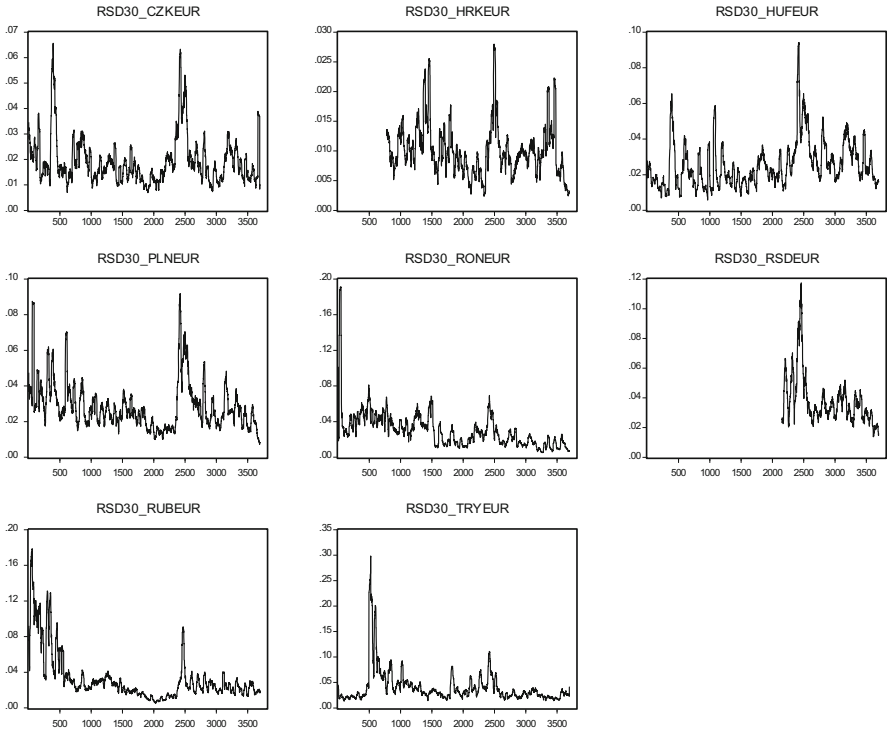

Fig. 4 (continued)

shows the short-run (1 month) shocks in volatility (see Fig. 4a, b), the 90-days window RSD shows the medium-term (3 months) shocks in volatility (see Fig. 5a, b), and the 360-days window RSD shows the long-term (1 year) shocks in volatility (see Fig. 6a, b).

A few observations are noteworthy based on our results: (1) regardless of the window length, spikes in volatility are easily observable over the entire period, particularly for some exchange rates—CZKEUR, HRKEUR, HRKUSD, HUFEUR, HUFUSD, PLNEUR, PLNUSD; (2) for other exchange rates, the spikes in volatility are present only for some months—for example, if we consider the 30-day window RSD, the RONEUR and RONUSD exchange rates have an abrupt increase in volatility at the beginning of 1999, followed by rather calm times and another (smaller) spike in 2008; the same is true for RUBEUR, RUBUSD, TRYEUR and TRYUSD exchange rates; (3) when we move from short-term to medium-term volatility, the differences between exchange rates observable in the case of short-term volatility are more obvious: on one hand, we observe exchange rates that

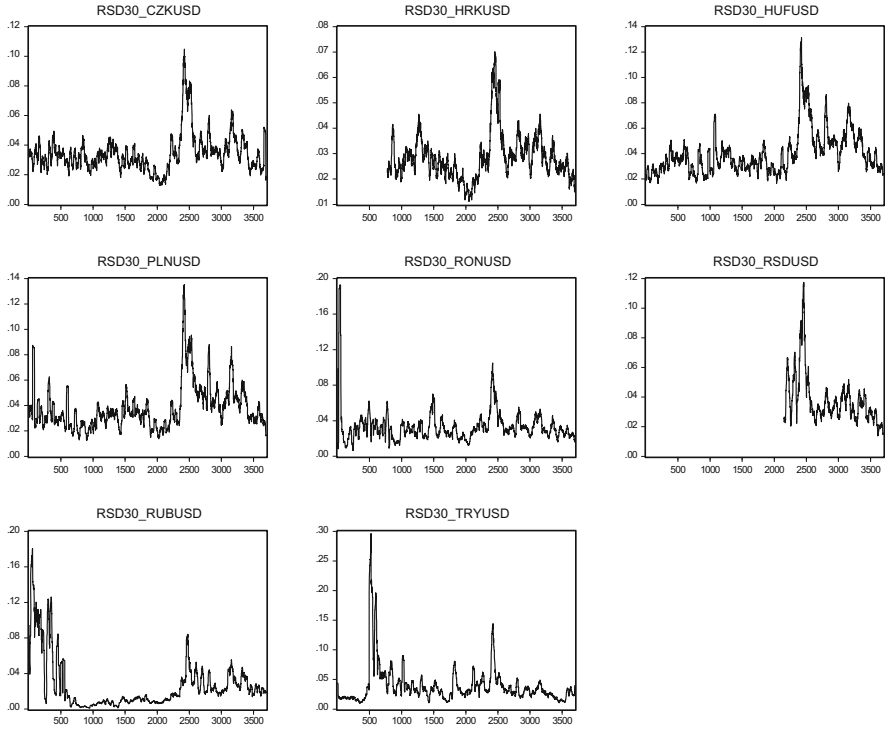

Fig. 4 (**a**) Rolling standard deviations of exchange rate returns against the EUR—30 days window, 1999–2013. *Note*: The first observation is February 15, 1999 and the last observation is December 31, 2013. (**b**) Rolling standard deviations of exchange rate returns against the USD—30 days window, 1999–2013. *Note*: The first observation is February 15, 1999 and the last observation is December 31, 2013

experienced sudden increases in volatility over the entire period, rather quickly corrected (in 3–4 months) and, on the other hand, other exchange rates that, after experiencing higher volatilities at the beginning of the period, have remained at reasonable levels of volatility throughout the remaining period; (4) the long-run RSD offers a good image of the persistency of high levels of volatility for some currencies: as one may observe, the period between 2008 and 2010 shows increased volatilities for all exchange rates that were persistent over some months before being corrected; at the same time, for some exchange rates (CZKEUR, HRKEUR, RONUSD, TRYEUR, TRYUSD) such persistency in volatility is also observable for other periods.

Table 11 presents the result of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests of stationarity for the monthly series of standard deviations for daily returns in exchange rates. All series are non-stationary in levels and stationary in the first difference—in the case of SD–RSDEUR, the ADF test

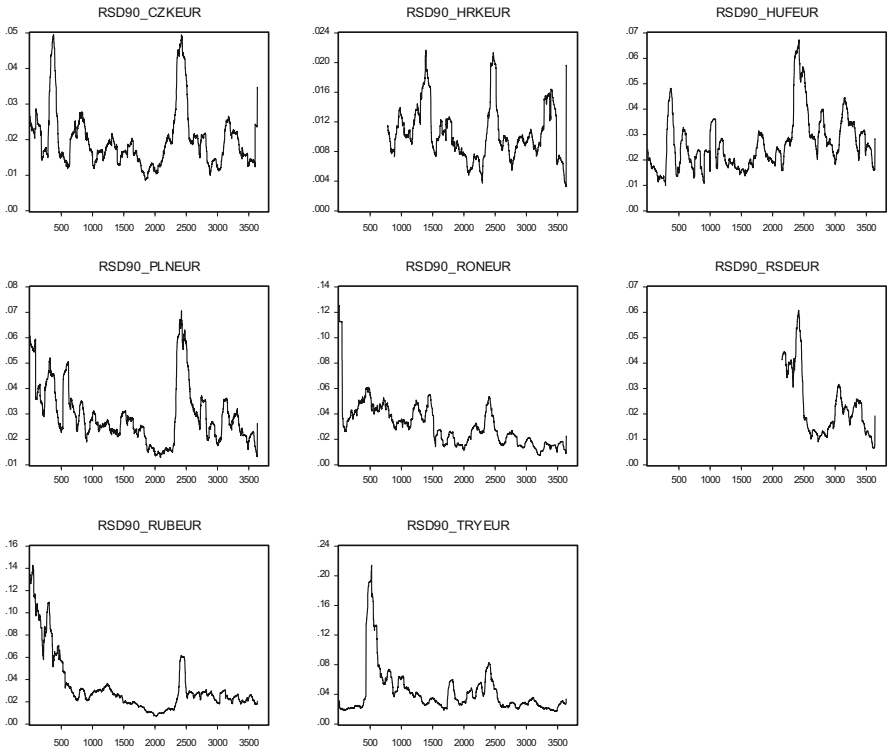

Fig. 5 (continued)

indicated stationarity in level, but the PP test confirmed non-stationarity. As a result, all SD series are I(1).

The next step in identifying a fitted ARIMA model was to study series correlogram and, based on the autocorrelation and partial autocorrelations, to try various values for p and q. We show in Table 12 the best-fit ARIMA(p,d,q) models for the monthly standard deviation series for all exchange rates, based on three model diagnostic indicators (Schwartz criterion, Adjusted R^2 and SEE). We observe that all series have AR terms, but not all of them have MA terms—MA terms are found only in the case of CZKEUR, CZKUSD, HRKEUR, HUFEUR, HUFUSD, PLNEUR, PLNUSD, RONEUR, RONUSD and RUBUSD. This result indicates, on one hand, that exchange rate volatility "has memory", sometimes even for 7 or 9 months (as is the case with HRKUSD and TRYUSD)—but all standard deviations have a memory of at least 1 month, while some exchange rates are more prone to the persistent effects of shocks in volatility (the most interesting case is the RONUSD exchange rate, where a shock in volatility seems to persistent for 4 months!).

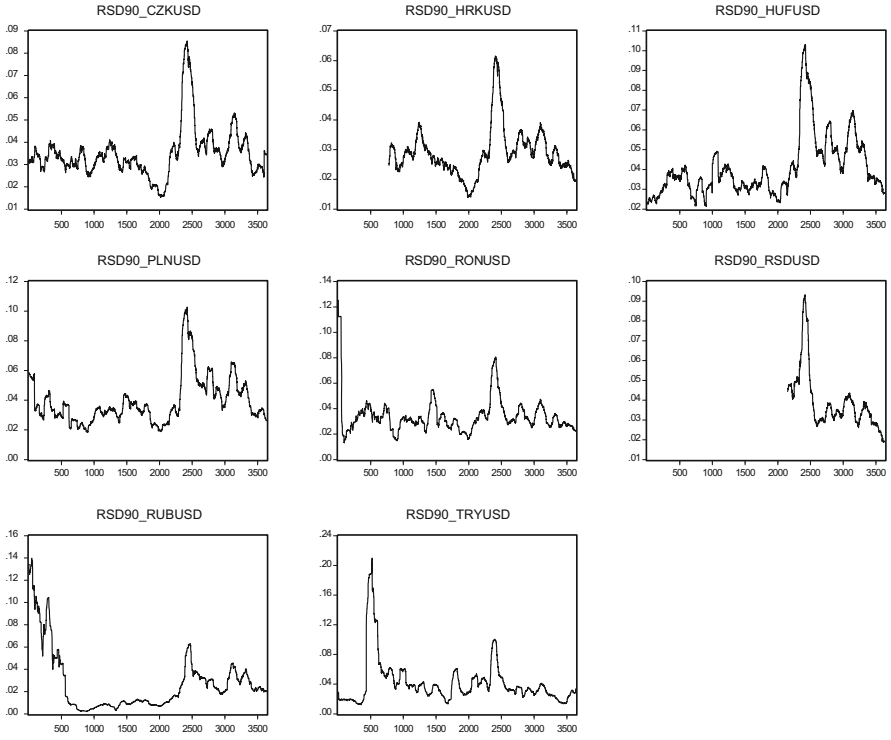

Fig. 5 (**a**) Rolling standard deviations of exchange rate returns against the EUR—90 days window, 1999–2013. *Note*: The first observation is May 14, 1999 and the last observation is December 31, 2013. (**b**) Rolling standard deviations of exchange rate returns against the USD—90 days window, 1999–2013. *Note*: The first observation is May 14, 1999 and the last observation is December 31, 2013

4 Conclusion

Our research examined exchange rate volatility for a number of eight currencies from the Balkans and Eastern Europe, with the aim of observing short-run versus long-run patterns in volatility, as well as the influence of past volatility on current volatility levels and the persistence of shocks in volatility. Our main findings point towards significant differences in volatility patterns among the currencies under investigation. First, there are currencies such as the CZK, HRK, HUF and PLN that experienced decreasing currency volatility from 1999 to 2006, followed by increasing volatility until the end of 2009 and subsequent declines in volatility until the end of 2013. Second, the RON, RUB and TRY had more stable volatilities between 1999 and 2013, which strongly indicates a serious concern of these countries' central banks regarding exchange rate fluctuations and a success of these central banks in terms of exchange rate volatility management. Third, the RSD (for which

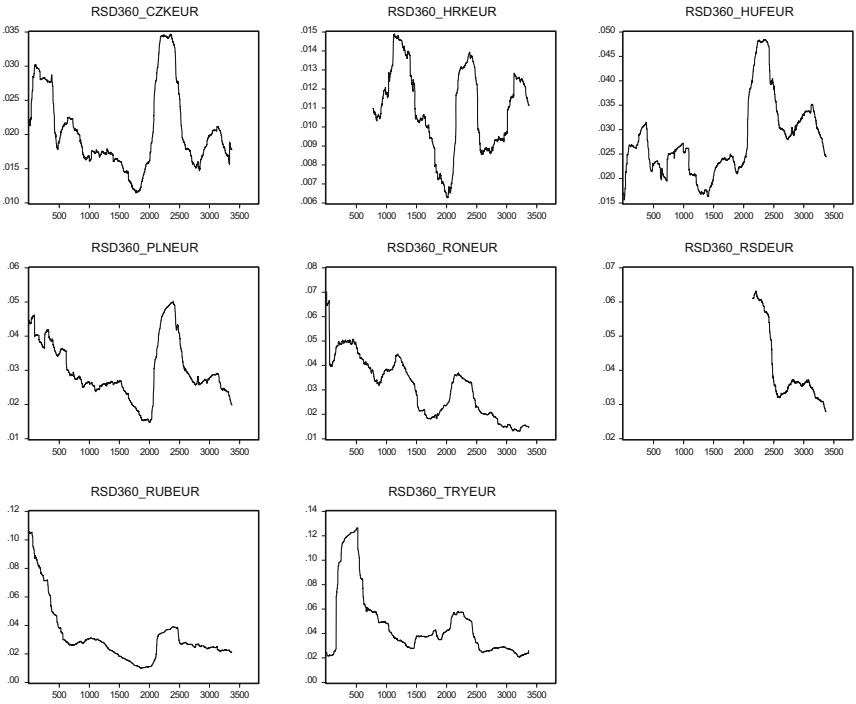

Fig. 6 (continued)

we have observations only since the end of 2007) experienced a decreasing volatility until the end of 2013.

Regarding the short-run versus long-run volatility, spikes in monthly volatility were present for all currencies, although for some of them they are observable throughout the entire period (CZK, HRK, HUF, PLN), while for others (RON, RUB, TRY) they were present in 1999–2000 and afterwards only in 2008. When long-run volatility is considered, there are exchange rates that experienced sudden increases in volatility over the entire period, but rather quickly corrected (in 3–4 months) and, on the other hand, there are currencies that, after experiencing higher volatilities at the beginning of the period, have remained at reasonable levels of volatility throughout the remaining period. The results of applying ARIMA modelling to currency volatility series indicate that exchange rate volatility "has memory", sometimes even for 7 or 9 months—but all standard deviations have a memory of at least 1 month, while some exchange rates are more prone to the persistent effects of shocks in volatility, such as the RON/USD.

Overall, our research demonstrates that currency volatility remains a strong issue for the countries in the region and that all central banks have attempted to properly manage it, particularly after the global financial crisis that emerged in 2008. At the same time, even if inflation targeting as a monetary policy rule has been adopted by almost all the countries in the Balkans and Eastern Europe, their economic

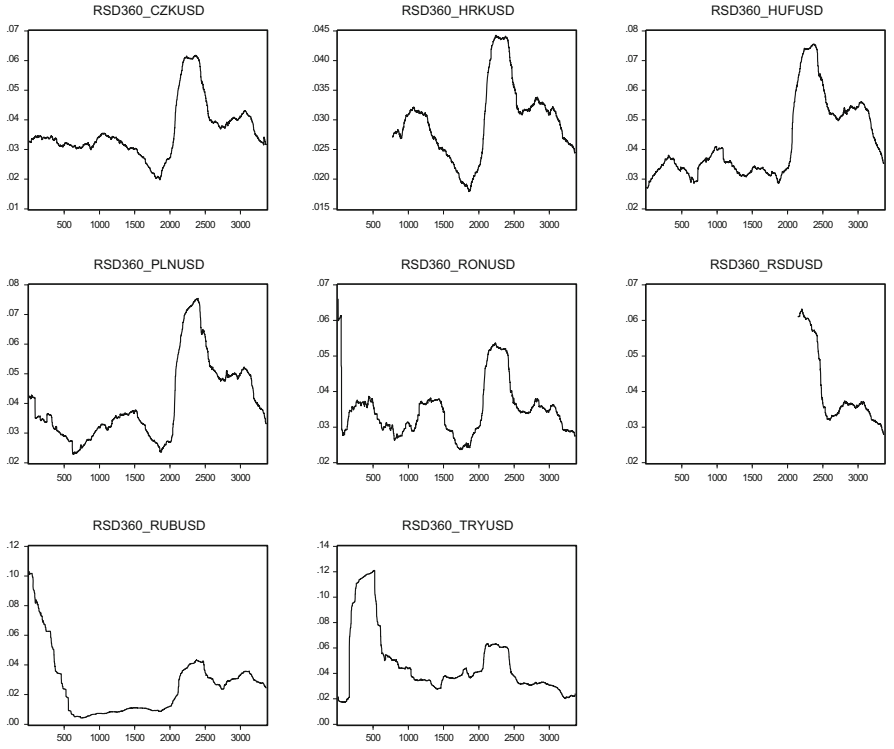

Fig. 6 (**a**) Rolling standard deviations of exchange rate returns against the EUR—360 days window, 1999–2013. *Note*: The first observation is May 26, 2000 and the last observation is December 31, 2013. (**b**) Rolling standard deviations of exchange rate returns against the USD—360 days window, 1999–2013. *Note*: The first observation is May 26, 2000 and the last observation is December 31, 2013

specificities make the adoption and implementation of a less flexible exchange rate regime that would pave the way for Euro adoption, at least for some of them, a real challenge. Our results have implications both for central banks and governments' policies, as well as for private investors that have to deal with currency risk as part of the wider range of risks they are exposed to in the region.

As any other research, our approach has limitations which can be further addressed by extending the scope of our enterprise in various directions, such as: (i) modelling currency volatility with instruments that specifically take into account the "volatility clustering" phenomenon, such as ARCH or GARCH; (ii) studying currency volatility within the overall period, during specific time intervals that are relevant for shifts in exchange rate volatility; or (iii) contrasting our results with similar results for other emerging countries, with the aim of better understanding the issue of currency volatility in a wider perspective.

Given the specific long-term endeavour of the countries in the region, which deals with the Euro adoption, another possible extension of our study might be

Table 11 Unit root tests for monthly standard deviations

	ADF		PP	
	Constant	Trend and constant	Constant	Trend and constant
SD_CZKEUR	−7.126*	−7.144*	−7.352*	−7.379*
SD_HRKEUR	−4.910*	−5.016*	−8.586*	−8.707*
SD_HUFEUR	−6.867*	−7.249*	−6.867*	−7.237*
SD_PLNEUR	−8.357*	−8.721*	−9.153*	−9.530*
SD_RONEUR	−4.456*	−6.020*	−10.779*	−12.939*
SD_RSDEUR	−1.743	−4.616*	−4.144*	−4.883*
SD_RUBEUR	−4.318*	−3.522**	−5.998*	−7.928*
SD_TRYEUR	−4.388*	−4.493*	−7.436*	−7.536*
SD_CZKUSD	−4.487*	−6.018*	−6.177*	−6.231*
SD_HRKUSD	−3.313**	−3.280***	−4.706*	−4.670*
SD_HUFUSD	−5.342*	−5.716*	−5.342*	−5.543*
SD_PLNUSD	−6.631*	−6.884*	−7.123*	−7.392*
SD_RONUSD	−5.780*	−5.766*	−12.020*	−12.004*
SD_RSDUSD	−3.732*	−4.746*	−3.662*	−4.753*
SD_RUBUSD	−3.963*	−3.752**	−5.907*	−6.115*
SD_TRYUSD	−4.388*	−4.493*	−7.436*	−7.536*

Note: ADF and PP are Augmented Dickey-Fuller and Phillips-Perron unit root tests. Test equations include either a constant or a constant and a trend. The lag length is chosen using the Schwarz information criterion for the ADF test, and the Newly West kernel estimator for the PP test
*Rejection of the null hypothesis at the 1 % levels
**Rejection of the null hypothesis at the 5% levels
***Rejection of the null hypothesis at the 10% levels

Table 12 Best-fit ARIMA models for monthly standard deviations series

	ARIMA model (p,d,q)	Schwartz criterion	Adjusted R^2	SEE
SD_CZKEUR	(1,1,1)	−9.7262	0.1762	0.0018
SD_HRKEUR	(2,1,1)	−11.0532	0.4040	0.0009
SD_HUFEUR	(1,1,1)	−9.0988	0.2098	0.0025
SD_PLNEUR	(3,1,1)	−8.8860	0.4064	0.0027
SD_RONEUR	(2,1,1)	−8.6295	0.4485	0.0031
SD_RSDEUR	(4,1,0)	−9.1031	0.3404	0.0023
SD_RUBEUR	(1,1,0)	−8.0802	0.3483	0.0042
SD_TRYEUR	(6,1,0)	−4.2102	0.2569	0.0281
SD_CZKUSD	(1,1,1)	−6.2338	0.1469	0.0103
SD_HRKUSD	(7,1,0)	−7.1370	0.1411	0.0065
SD_HUFUSD	(1,1,1)	−5.8844	0.1382	0.0123
SD_PLNUSD	(3,1,1)	−5.5072	0.3015	0.0145
SD_RONUSD	(2,1,4)	−5.7798	0.5899	0.0124
SD_RSDUSD	(3,1,0)	−5.6703	0.1009	0.0133
SD_RUBUSD	(1,1,10)	−5.3252	0.5619	0.0157
SD_TRYUSD	(9,1,0)	−4.1931	0.2757	0.0280

represented by a larger framework of analysis that would include not only monetary variables, but also socio-economical and political variables. These would allow for a better control and robustness test of our results and would permit the observation of other features of exchange rate policies in these countries.

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