THE EURO CRISIS AND CONTAGION AMONG CENTRAL AND EASTERN EUROPEAN CURRENCIES: RECOMMENDATIONS FOR AVOIDING LENDING IN A SAFE HAVEN CURRENCY SUCH AS CHF

Gábor Dávid Kiss, Tamás Schuszter*

Abstract:

This study analyses the Czech, Hungarian, and Polish currencies by examining the statistical characteristics of the Swiss franc as well as the ECB monetary policy in order to indicate shocks in these markets between 2002 and 2013. The abundance of monetary easing decisions can be used as a viable sign of market misbehaviour in addition to the low probability of extreme exchange rate fluctuations. Indeed, the temporal distribution of extreme currency fluctuations provides vital information about the nature of the recent crisis. Contagions can be defined as increased correlations during periods of crisis, while divergence means a significant decrease in this regard. Methodologically, common movements in this study were calculated by using DCC-GARCH modelling. The findings of this study underline the special features of the Swiss franc exchange rate, notably that its extreme fluctuations can be managed by using swap agreements and that it tended towards divergences during the crisis era. These results support the idea of avoiding lending in reserve currencies.

Keywords: currency market, CEE, DCC-GARCH, extreme interval, contagion
JEL Classification: G15, G01, C32, E44, E58

1.   Introduction

The Czech, Hungarian, and Polish national banks follow an independent floating currency regime despite their future obligation to adopt the euro and have the primary statutory objective of achieving and maintaining price stability. The combination of a harmonised monetary aim and floating currency regime is the product of the unique style of capitalism characterised by underdeveloped capital markets, poor savings accumulation, and overconcentrated banking systems (Farkas, 2011), resulting in substantial capital imports that accelerated the domestic credit booms in the pre-crisis era (Kovács, 2009, Árvai *et al*., 2009).

This study analyses the patterns of currency fluctuations and common movements in Swiss franc (CHF) denomination because of its significant impact on Hungarian bank solvency. In particular, it examines the inadequacy of CHF as an underlying currency for foreign currency loans (FCYLs) for Central and Eastern European (CEE) households because of its special role as a reserve currency. A reserve currency suffers a sudden appreciation owing to enormous liquidity inflows under mistrustful periods, which erodes the credit quality of FCYL debtors. This is important because FCYLs have a significant share of the overall loans market in 18 EU Member States, especially outside the Eurozone, while CHF loans have a significant share in Slovenia, Romania, Serbia, Croatia, Austria, Poland, and Hungary (Yesin, 2013).

Although FX liquidity shortages have been manageable by using temporal swap agreements and repos over the past five years, this approach is only adequate to manage the liabilities of banks. The heterogeneity of debtors makes it difficult to draw any firm conclusions about their FX risk-bearing capacities, while conventional channels of FX risk management (*e.g.* futures or options markets) are not always adequate for them (especially for households). This study thus focuses on central banks' actions in order to capture their direct or indirect impacts on spot currency pricing. Methodologically, we adopt a CEE sample between 1 January 2002 and 31 December 2013 (N=3035), using daily closing data[1] on the Czech koruna (CZK), Hungarian forint (HUF), and Polish zloty (PLN). Capital markets are complex networks with extreme market events such as tail properties (Gabaix *et al.*, 2003), which thereby encourage collective market behaviour (Bonanno *et al.*, 2001).

The present study is structured into three parts. The first section summarises the policy context of currency markets to introduce the central bank reaction curves that are used to study the eras of monetary tightening (from 1 March 2005 to 31 July 2007) and easing (from 1 August 2007 to 31 December 2013) by the European Central Bank (ECB). In this section, we also distinguish two specific crisis periods, namely the subprime crisis between 1 August 2007 and 31 January 2010 and the sovereign crisis between 1 February 2010 and 31 December 2013. The next section presents the proposed market model, defines extreme fluctuations and collective types of behaviour, and summarises the methodological background to capture them. The last section explains the empirical results on the temporal properties of extreme currency fluctuations and collective behaviour and then concludes the study by evaluating the danger of CHF denomination for CEE currencies. The relevance of these findings is supported by the current FCYL crisis in Hungary caused by euro crisis-triggered CHF appreciation in the medium run as well as the mandatory EUR adoption in the long run.

2. Policy Context

This section focuses on the policy aspects and past reactions of Eurozone monetary policy in order to study monetary tightening and easing decisions. Our research adopts reaction curves to define different periods of the permanent crisis of the past five years. After the introduction of the primary objective of the ECB, discount rates, regular and irregular liquidity programmes, and swap lines are analysed to distinguish the two periods of the crisis. Although decisions about the discount rate have a trivial impact on exchange rates because of interest rate parity, this tool becomes obsolete in a deflation environment.

---

1   The database of the Polish National Bank was the data source: http://www.nbp.pl/homen.aspx?c=/ascx/ArchAen.ascx.

FX liquidity programmes such as swap lines and repo contracts focus on the management of supply shortages in a *de jure* independent floating regime.

The subprime crisis started as an asset-side problem in the United States, but it affected bank networks on a global scale as a liability-side problem between 1 August 2007 and 31 January 2010. Ultimately, this issue was managed through the introduction of zero bound interest rates and FX liquidity programmes among key central banks as well as cooperation between the ECB and the Danish, Swiss, and CEE central banks. The second phase affected the sovereign bonds markets in both the United States and the Eurozone between 1 February 2010 and 31 December 2013. Joint actions here focused on swap lines, while each key central bank also developed its own toolbox to better manage the yield curve.

2.1 Monetary Policy of the ECB

The primary objective of the European System of Central Banks is to achieve and maintain price stability, as financial stability is crucial because the transmission of monetary policy can be hampered when massive financial turbulences occur (ECB, 2011). According to Borio (2014), the key central banks were relatively lucky because they were able to support financial stability without endangering price stability.

The first soft easing steps were taken in the third quarter of 2007, affecting reserve policy, while the first temporal swap agreement was introduced at the end of that year. The ECB started to defend against inflation by increasing discount rates in the first three quarters of 2008, but the collapse of Lehman Brothers caused a sudden decrease in discount rates. In 2011, there were weak attempts to increase discount rates, but these were inadequate to abandon the zero bound interest rate policy given the pessimistic mood still present in the market. Indeed, the toolbox of monetary policy instruments widened constantly, with open market operations and fine-tuning operations enhanced by using non-standard measures including the second covered bond purchase programme and the Securities Markets Programme.

The swap lines of USD liquidity providers became popular in the early phase of the crisis as a temporary tool to manage the lack of foreign liquidity after December 2007. As BIS (2011) and Ács (2011) point out, their rising popularity was a strong indicator of currency market misbehaviour. Indeed, these temporary solutions became so successful that after a short break between February 2010 and May 2010, they were used until November 2013, when they were converted into standing swap arrangements[2]. There were also numerous enhancements to USD liquidity-providing operations; for example, the initial one-month maturity auction was expanded with overnight, one-week, and three-month maturities as well as with biweekly allocations in 2008. In addition, bilateral CHF–EUR[3] and GBP–EUR[4] swap agreements were established on 4 November 2008 and 17 December 2010, respectively, while CEE and Danish central banks were supported by repo and swap contracts at the end of 2008[5] (BIS, 2011; Antal and Gereben, 2011). The market situation seemed to become more intense in November 2011, when a framework

---

2   Press release: http://www.ecb.europa.eu/press/pr/date/2013/html/pr131031.en.html.

3   Press release: http://www.ecb.europa.eu/press/pr/date/2009/html/pr090116.en.html.

4   Press release: http://www.ecb.europa.eu/press/pr/date/2010/html/pr101217.en.html.

5   Loan-to-deposit ratios exceeded the level of 100% in our sample (except for the Czech Republic), weakening banks' liquidity positions and creating constant demand for FX liquidity (Kovács, 2009, EBF, 2012).

for bilateral swap agreements in USD, CAD, JPY, EUR, GBP, and CHF was announced by the Bank of Canada, Bank of England, Bank of Japan, ECB, Federal Reserve, and Swiss National Bank[6].

Figure 1 | Significant Decisions on Monetary Easing and Tightening by the Governing Council of the ECB between 2008 and 2013
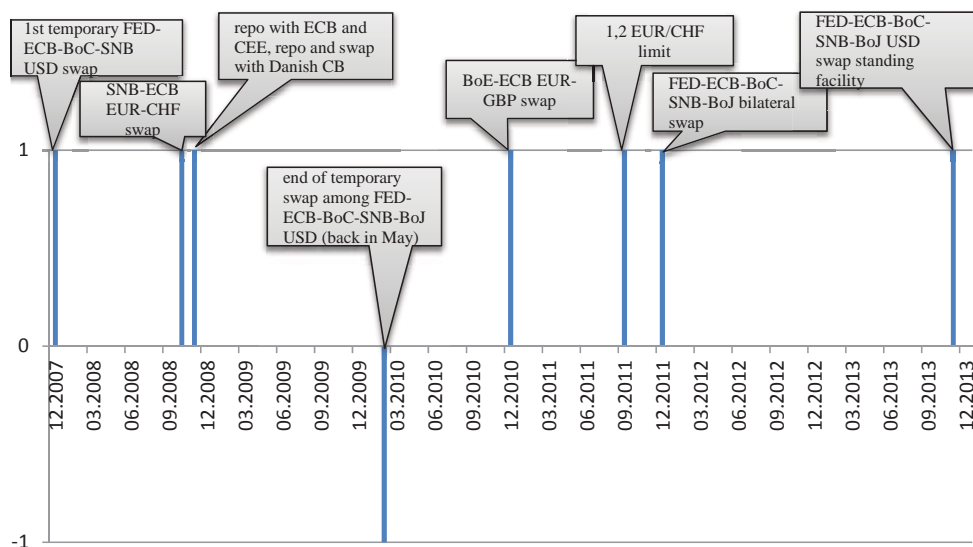
Note: '1': easing, '-1': tightening

Source: author's calculations, based on ECB (2002–2012)

Figure 1 presents the Governing Council's responses to monetary easing according to the annual reports of the ECB. Two phases of the crisis were distinguished by the temporary end of swap agreements in January 2010. The subprime phase (1 August 2007 to 31 January 2010, from N=633) had one intense period at the fall of Lehman Brothers, while the sovereign phase (1 February 2010 to 31 December 2013, N=990) was characterised by different stages of Greek, Spanish, and Irish close-to-default stories and grave CHF appreciation.

3. Definitions and Methodology

The current study focuses on extreme currency fluctuations and financial contagion, a widely studied subject with a broad variety of definitions and methodological backgrounds (Kuusk and Paas, 2013). Common movements in the capital market are mostly based on the exploration of variables (Van Horen *et al*., 2006), while a multivariable generalised autoregression conditional heteroscedasticity (GARCH) model-supported dynamic conditional correlation (DCC) estimation is a common tool for currency-related analyses (Kuper and Lestano, 2007; Babetskaia-Kukharchuk *et al*., 2008; Stavárek, 2009). The contagion literature is supported by experiences of the recent crisis, which presented

---

6   Press release: http://www.ecb.europa.eu/press/pr/date/2011/html/pr111130.en.html.

unique and enormous changes in currency correlations (Muller and Verschoor, 2009; Haile, and Pozo, 2008). Currency mismatch was a key factor for the financial crises in Hungary and Poland (Goldstein and Turner, 2004; Dietrich *et al.*, 2011), which can be fatal when strongly related to the bank sector as it was in Hungary (Kaminsky and Reinhart, 1999)[7]. Moreover, the contagion literature for CEE currencies is supported by the field of euro convergence analyses (Stavárek, 2009), because it indicates future ERM II readiness. Higher correlation can mitigate asymmetric shocks (Babetskaia-Kukharchuk *et al.*, 2008), while the historically high level could eliminate the need to apply expensive FX risk-covering techniques. Dynamics are synchronised among CEE currencies and EUR, requiring deeper monetary policy and FX liquidity coordination[8].

3.1 Definitions

The scope of the current study requires precise definitions for phenomena related to extreme events, such as extreme and normal returns, subsets of collective behaviour (*e.g.* contagion), and divergence and interdependence among the complex system of capital markets. To understand the nature of capital markets, it is necessary to choose a reliable model that allows extreme jumps and collective types of behaviour. A more heterogeneous and hierarchic market should be assumed than suggested by the efficient market hypothesis. Therefore, the null hypothesis of efficient markets will be tested against the alternative hypothesis of complex markets (see Fama, 1970, who requires the lack of autocorrelation and normally distributed returns for efficiency).

To model the network structure of a market *(n)* (1), it is necessary to define the actors *(a)*, shape of the network *(sh)*, and level of market efficiency *(e)* to understand the time series:

$$n(a, sh, e). \tag{1}$$

The mainstream model of efficient markets (2) has the following structure:

$$r_n(a_r, sh_r, e_f) \, , \tag{2}$$

where r_n denotes normally distributed returns, a_r represents rational actors (Simon, 1955), sh_r is random networks (Erdős and Rényi, 1960), and e_f is the sign of Fama-type efficiency. Erdős–Rényi random networks are capable of modelling competitive and efficient markets with dynamic recombination and fast information propagation, but they cannot describe preferential connectivity (Watts and Strogatz, 1998). From a statistical perspective, they thus need normally distributed, homoscedastic, and non-autocorrelated returns.

To describe real-world capital markets, extreme jumps and forms of collective types of behaviour must be included. An extreme event can be defined as a $w_x \in W$ event for a W stochastic variable with a $w_x >> w_n$ or $w_x << w_n$ significantly higher impact than that expected, in a limited time and space with a $p(w_x) << p(w_n)$ significantly lower probability than that expected (Jentsch *et al.*, 2006). The dynamic property of extreme events is related to their definition proposed by Jentsch *et al.* (2006), namely that 'power-laws represent

---

scale-free systems'. Extreme events are not generated randomly; rather, they occur in systems with complex dynamics that are far from equilibrium and dominated by the system's variability and collective effects (Kantz *et al.*, 2006). Therefore, we sort capital market returns into two complementary subsets, namely extreme and normal returns, according to the definition of extreme events.

Definition: normal returns r_n have a higher probability than 5% or fit the projected theoretical normal distribution well. This definition suggests that the subsample of normal returns has close to level 3 kurtosis (fourth moment), which would be useful to test the results of the separation in the future.

Definition: extreme returns r_x can be defined as an extreme event in capital markets. They have both a really low probability $p(r_x) << p(r_n)$ and a high impact on the tails $r_{x-} << r_n << r_{x+}$. This definition is thus also able to meet the requirements put forward by Jiawei and Micheline (2004) about extreme values. Two approaches are applied in this study to capture extreme returns: one based on low probability and one that utilises the fat-tailed distribution property.

Definition: improbable returns r_{vx} (3) refer to those returns that are under the 5% probability threshold. This approach can be rigid on the third and fourth moments:

$$p_{r_{vx}} < 5\,\%. \tag{3}$$

Definition: fat-tailed returns r_{fx} (4) result from an extreme change in the m_j market, causing fat tails for the r^{mj} return's probability distribution. This occurrence is related to the skewness of the distribution, although their probability and value differ markedly from expected returns $E(r)$. This means that fat-tailed returns can be selected from the difference in the tails between the theoretical normal distribution and empirical data, utilising the latter's 'S-shaped' form in QQ plots:

$$r_{fx+} \gg E(r), \text{ or } E(r) \gg r_{fx-}, \text{ where } pr_{fx} \ll p_{E(r)} \tag{4}$$

Both improbable and fat-tailed returns are referred to as extreme returns in the present study.

Definition: a capital market shock captures the ability of returns to fluctuate between the r_n normal subset and r_x extreme subset. $r_{n/x} \neq 0$ indicates the existence of this transition between both subsets (5), while $r_{n/x} = 0$ indicates its absence (*i.e.* a sign of an efficient market only with normal returns) (6):

$$r_{n\,x}^{m_i} \neq 0 \rightarrow r^{m_i} = \begin{cases} r_n^{m_i} \\ r_x^{m_i} \end{cases}, \tag{5}$$

$$r_{n/x}^{m_i} = 0 \rightarrow r^{m_i} = r_n^{m_i}. \tag{6}$$

If extreme returns represent a higher volume than that expected from the normal distribution, the capital market should be modelled as a complex system (as suggested by the dynamic properties of extreme events) (7):

$$r_{n/x}(a_{br}, sh_s, e_l), \tag{7}$$

where $r_{n/x}$ denotes a capital market shock due to the fat-tailed distribution of returns, a_{br} represents bounded rational actors (Arrow, 1986, Vriend, 1996), sh_s means a scale-free

network, and e_l denotes the lack of efficiency because of autocorrelated and heteroscedastic time series. Scale-free complex networks were described by Barabási and Albert (1999) to explain internal heterogeneity through preferential connections, which could be responsible for spontaneous synchronisations ('large cooperative phenomena') or phase transitions such as the structural collapse of the former market hierarchy. Because these systems are far from equilibrium as self-organised criticality describes, extreme events are inherent properties of the system that are indicated by the power-law distribution. The ability of scale-invariant complex networks to model capital markets was evaluated by Vitali *et al*. (2011) at a global scale and by Benedek *et al*. (2007) for Hungary.

Bonanno *et al*. (2001) summarise the three main statistical phenomena for a complex capital market: time series have both short- and long-range memories with asymptotic stationarity, there is high sectoral intraday cross-correlation, and collective market behaviour emerges during extreme market events. The latter property is important for the current study. Collective market types of behaviour have three well-known versions in the literature: contagion, divergence, and interdependence. These phenomena relate to how market mood changes based on the categorisation of different assets or countries.

A three-level definition was published by the World Bank for the contagion effect to capture the different dynamics in real economies and capital markets. The restrictive definition[9] of contagion focuses on cross-country correlations, which increase during times of crisis relative to tranquil times.

Definition: contagion (8) occurs between $m_k m_j$ markets when the $\rho^{m_k m_j}$ cross-market correlation becomes significantly high because of the shock derived from one market ($r_{n/x}{}^m$) spreading to others or as a result of other external factors (Forbes and Rigobon, 2002, Campbell *et al*., 2002, Bekaert *et al*., 2005):

$$r_{n/x}^{m_i} \neq 0 \rightarrow \rho_n^{m_k m_j} < \rho_x^{m_k m_j} . \tag{8}$$

Definition: interdependence (9) occurs between $m_k m_j$ markets when the $\rho^{m_k m_j}$ cross-market correlation is not significantly different, but the level of correlation is consistently high (Forbes and Rigobon, 2002):

$$r_{n/x}^{m_i} \neq 0 \rightarrow \rho_n^{m_k m_j} \approx \rho_x^{m_k m_j} . \tag{9}$$

Definition: divergence (10) occurs between $m_k m_j$ markets when the $\rho^{m_k m_j}$ cross-market correlation becomes significantly low because of the shock derived from one market ($r_{n/x}{}^m$) spreading to others or as a result of other external factors (Bearce, 2002a):

$$r_{n/x}^{m_i} \neq 0 \rightarrow \rho_n^{m_k m_j} > \rho_x^{m_k m_j} . \tag{10}$$

Definition: autonomous monetary policy allows central banks to set prime rates according to the prevailing macroeconomic conditions, and it thus can be viewed as a range of decisions (Bearce, 2002b). Autonomy is related to independence from monetary policies in the key currency areas and can be reduced by the degree of monetary interdependence, which is based on trade relationships and cross-border production chains (Plümper and Troeger, 2008). Global liquidity is able to limit this autonomy by increasing the vulnerabilities of a financial system through substantial mismatches

---

9   See http://go.worldbank.org/JIBDRK3YC0, which was also cited by Forbes and Rigobon (2002).

across currencies, maturities, and countries, while the supply of global liquidity stems from one or more 'core countries' (BIS, 2011). This definition is necessary since the formerly presented collective behaviours are able to hinder monetary autonomy because of their impact on the external debt of the public and private sectors as well as on price stability.

3.2 Methods

Contagions and divergences between currencies were tested through three steps: first, market efficiency was tested, then extreme trading days and periods were cleared, and finally the DCCs were calculated. The functions of the MFE and UCSD Matlab toolboxes were applied in this regard. Returns on an efficient capital market should be normally distributed and non-autocorrelated (Fama, 1970). In this study, returns were calculated as the logarithmic differentials of the currency rates. The definition of contagion and divergence requires conditional correlations as well, which can be biased by heteroscedasticity (Forbes and Rigobon, 2002). A Jarque–Bera test was thus used to study the normal distribution, which is based on the third and fourth moments of the returns. To test the reduction of heteroscedasticity and autocorrelation, ARCH-LM and Ljung–Box tests were utilised.

Extreme trading days were defined in two ways: (i) improbable returns were indicated when their probability was less than 5% according to the empirical cumulative distribution function (this application is the simplest version of the Value-at-Risk approach) and (ii) fat-tailed returns were selected on the base logic of a QQ plot. QQ plots are common tools for visualising the normal distribution of time series (represented by a straight line), with dots signifying the empirical distribution. The normal distribution of the empirical data is observable if these dots fit the line; however, most financial data have an 'S' shape in the QQ plot, suggesting a power-law distribution and fat tails (Clauset *el al.,* 2009). By relying on the definition of QQ plots proposed by Deutsch (2002), the above separation can be expressed in the following way (11):

$$X_i = \phi_1^{-1}(P_i) = \phi_1^{-1}(i/N) \text{ for all } i < N, \text{ therefore,}$$

$$r_n \approx \mu_2 + \sigma_2 X_i,$$
$$r_{fx}^+ > \mu_2 + \sigma_2 X_i,$$
$$r_{fx}^- < \mu_2 + \sigma_2 X_i,$$
(11)

where ϕ denotes the standardised normal distribution, X_i is the theoretical empirical standard normal distribution, N represents the sample number, and P is the probability. The theoretical empirical standard normal distribution is represented in the QQ plot by a line with a $\mu_2 + \sigma_2 X_i$ slope. Therefore, it is reasonable to define the tails through the QQ plot, where the turning point of the extremity is defined as the first empirical data point in the lower quartile to the right of the normality line on the positive side and to the left of the normality line on the negative side. The entire time series can then be divided (12) into extreme and normal subsets according to the above definitions:

$$r \begin{cases} r_{fx} \begin{cases} r_{fx}^+ : r_{empirical,l} > r_{theoretical_{normal},l} \\ r_{fx}^- : r_{empirical,i} < r_{theoretical_{normal},i} \end{cases}, \\ r_n : r_{theoretical_{normal},i} < r_{empirical,k} < r_{theoretical_{normal},l} \end{cases}$$
(12)

where $r_{empirical,i}$ is the ith element of the empirical distribution and $r_{theoretical_{normal,\,i}}$ denotes the projected normal distribution, $i < k < l$.

Under the assumption of poor market efficiency, time series are mostly biased by autocorrelation and heteroscedasticity due to fat-tailed distributions and volatility clustering. This study follows the steps taken by Cappeiello *et al.* (2006) to fit DCC to the time series. First, heteroscedasticity must be ruled out by using univariate GARCH models to manage the unique volatility properties (see Stavárek, 2010) and then Engle's (2002) DCCs are fitted to the homoscedastic residuals. For the univariate step, the Asymmetric Power GARCH (APARCH)[10] model is the most powerful tool to handle the bias of heteroscedasticity due to the asymmetric fat-tailed assumptions of the distribution (Ding *et al*., 1993). Three parameters of APARCH have to be defined: p and q determine the lag number of residuals and volatility, while o is a non-negative scalar integer that represents the number of asymmetric innovations. A further advantage of the APARCH model is its flexibility, as it is easy to convert both GJR GARCH and TARCH and the basic GARCH form. The lag length was optimised on a 1–4 scale and selected according to the estimation's Akaike's Information Criterion (AIC). The DCCs were then fitted to the homoscedastic standardised residuals of the GARCH models in the multivariate case.

This study applies DCC-GARCH[11] to analyse the daily common movements of the selected markets. Cross-market correlation is then compared by using both the Ansari–-Bradley test and two-sided t-test because the variance test is not based on the assumption of a normal distribution, as in the case of the widely used t-tests. The contagions, divergences, and interdependences initiated by one market's extreme days must be detected for 10 intermarket correlations. First, however, it is necessary to decide between interdependence (non-significant changes in correlations) and significant correlation changes (such as divergence and contagion), which can be expressed by the overall weight of significantly different correlations (13):

$$\underline{\sum \left(s_{m_1 m_2}, s_{m_1 m_3}, \ldots, s_{m_j m_k}, \ldots, s_{m_{n_1} m_n} \right)} \begin{cases} 50\%, where\, is\, contagion\, or\, divergence \\ \leq 50\%, where\, is\, interdependence \end{cases} \qquad (13)$$

where $s = \begin{cases} 1, when\, correlations\, are\, significant\, different \\ 0, when\, correlations\, are\, nonsignificant\, different \end{cases}$ and N denotes the number of involved market pairs. Contagions are characterised by significantly higher correlations and divergences by significantly lower correlations according to the following definitions (14). To select between these two forms, the following algorithm was used:

10   The estimation was based on the UCSD toolbox developed by Kevin Sheppard: http://www.kevinsheppard.com/wiki/UCSD_GARCH.

11   The estimation was based on the Oxford MFE toolbox developed by Kevin Sheppard: http://www.kevinsheppard.com/wiki/MFE_Toolbox.

$$
g = \begin{cases} 1, if \left(\rho_{na} = \begin{cases} 0, ifs = 0 \\ \rho_n, ifs = 1 \end{cases} < \rho_{xa} = \begin{cases} 0, ifs = 0 \\ \rho_x, ifs = 1 \end{cases} \right) \\ 0, if \left(\rho_{na} = \begin{cases} 0, ifs = 0 \\ \rho_n, ifs = 1 \end{cases} \geq \rho_{xa} = \begin{cases} 0, ifs = 0 \\ \rho_x, ifs = 1 \end{cases} \right) \end{cases},
$$

then $\dfrac{\sum \left(g_{m_1 m_2}, g_{m_1 m_3}, \ldots, g_{m_j m_k}, \ldots, g_{m_{n-1} m_n} \right)}{N} \begin{cases} > 50\%, where\, is\, contagion \\ \leq 50\%, where\, is\, divergence \end{cases}$ (14)

Thus, contagion was expressed by weighting the entire set of correlations, which is a strict rule.

4. Results

CHF exchange rates were appreciating and relatively stable against other currencies before the subprime crisis (see Figure 2). The first phase of the crisis was then characterized by sharp depreciation for CEE currencies; however, an appreciating CHF typified the second phase against the background of the rising euro crisis. This study describes this process during the crisis period. Specifically, the basis statistics of our sample currencies are first summarised after a comparison of the fourth moments to capture the tendency towards extreme changes. The occurrences of extreme fluctuations are then presented both in light of the time of crisis as well as significant central bank measurements. Currency common movements are finally analysed to present the time-varying dynamics.

Figure 2 | CHF Exchange Rates against Other Currencies
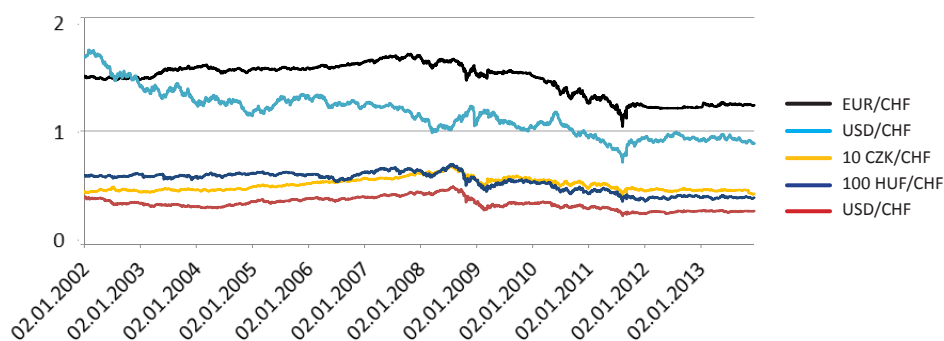
Source: National Bank of Poland

CHF showed an excess fourth moments even before the crisis; indeed, even JPY had a lower volume of extreme returns (see Table 1). CHF denomination was reasonable only for EUR or USD, while CAD and the Norwegian krone also remained relatively stable during the crisis period. However, CHF provided the highest chance of improbable but significant change, indicating serious uncertainties in currency pricing.

Table 1 | Fourth Moments of our Sample Currencies by Different Denominators

		EUR	PLN	CZK	HUF	USD	Lowest 4th moment
Denominator currency (2002–2007 q2)	**CAD**	3.58	3.63	3.68	6.57	3.96	80%
	JPY	4.03	3.66	3.86	7.01	4.02	0%
	AUD	4.40	3.91	4.60	9.01	5.06	0%
	XDR	4.97	4.01	4.22	10.01	3.58	0%
	CHF	4.43	4.27	5.05	10.89	3.47	20%
	DKK	4.27	4.73	5.99	16.76	3.76	0%
	NOK	5.36	3.86	3.83	7.81	4.20	0%
	GBP	3.94	4.11	4.03	11.28	3.50	0%
Denominator currency (2007 q3–2013)	**CAD**	5.28	5.64	4.86	5.12	6.61	80%
	JPY	6.67	7.96	5.86	6.76	6.14	0%
	AUD	10.54	7.01	10.96	6.63	8.25	0%
	XDR	5.88	7.52	8.41	6.48	7.31	0%
	CHF	39.44	10.16	16.65	10.18	14.31	0%
	DKK	14.77	9.07	12.30	8.56	5.41	0%
	NOK	9.24	11.97	5.59	7.02	5.18	20%
	GBP	6.27	5.93	6.48	5.30	7.84	0%

Source: author's calculations

The null hypothesis of efficient markets was rejected (see Table 2) because of the lack of normally distributed returns as the zero p-values of the Jarque–Bera test suggest, even though only HUF and PLN seemed to be autocorrelated[12]. In addition, fat-tailness was indicated by excess kurtosis, where CHF denomination provided a higher volume of extreme returns. Heteroscedasticity appeared across the entire sample according to the results of the ARCH-LM test, while the logarithmic differentials as returns were covariance stationary according to the augmented Dickey–Fuller (ADF) test with auto lag selection. The results of the fat-tailed heteroscedastic returns also supported the idea of complex markets and motivated us to focus on CHF denomination more in depth.

---

12   Currencies are often non-autocorrelated contrary to the stock and bond markets
      (Kiss and Kosztopulosz, 2012).

**Table 2 | Asymmetry, Kurtosis, and P-Values of the Descriptive Statistics**

Currency	Skewness	Kurtosis	Normal distribution	Auto-correlation*	Heterosce-dasticity*	Stationarity
			Jarque–Bera	Ljung–Box	ARCH-LM	ADF
EUR/CHF	2.2811	58.2547	0.0000	0.0879	0.6414***	0.0000
PLN/CHF	-0.0317	11.4430	0.0000	0.0010**	0.0679***	0.0000
CZK/CHF	0.7751	20.4055	0.0000	0.9222	0.9776***	0.0000
HUF/CHF	-0.0048	13.2339	0.0000	0.0109**	0.2468***	0.0000
USD/CHF	0.2092	11.7481	0.0000	0.3686	0.5835***	0.0000

Notes: * second lag, ** autocorrelation, *** heteroscedasticity

Source: author's calculations

This setup simplifies comparing the differences between these approaches: improbable returns represent the larger set of returns where a Value-at-Risk system could close the position, while fat-tailed returns represent special cases where ordinary assumptions such as normally distributed returns do not hold. Monetary easing and tightening periods were thus compared by using these data. The overall weight of extreme returns remained under 5% according to the applied methods. Further, improbable returns had a higher volume, while fat-tailed returns reflected the asymmetric behaviour of USD and EUR with more extreme depreciation (see Figure 3). The pre-crisis era of tightening monetary policy lacked extreme returns in EUR. Moreover, USD provided more extreme fluctuations in the pre-crisis and subprime periods; however, this tendency changed during the sovereign crisis, when EUR presented more trading days with extreme depreciation. Therefore, the key currencies suffered more pricing uncertainty in the second phase of the crisis.

Figure 3 | Number of Extreme Trading Days within the Monetary Periods of the ECB Key Currencies with CHF Denomination

extreme returns in different currencies and in different periods of time
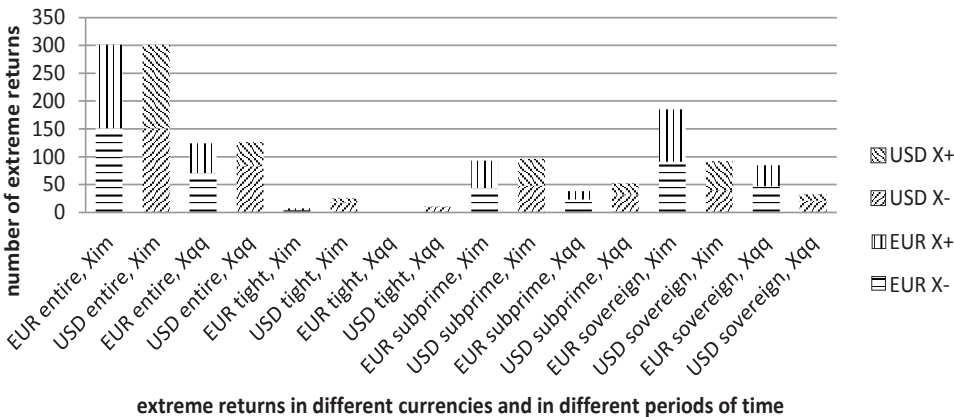
Notes: Xim: improbable return, Xqq: fat-tailed return

Source: author's calculations

HUF provided the most trade days (178) with extreme returns in the sample, but PLN was remarkably close (159) (see Figure 4). CZK was similar to the key currencies with 131 days (EUR: 124, USD: 126). CEE currencies were relatively stable before the crisis, but the subprime period resulted in extreme depreciation for both HUF and PLN. The sovereign crisis had an even more severe impact on the Hungarian currency than on the others. This result highlights the true nature of the sovereign phase: the importance of fundamental conditions. The result is clear: extreme trading days were concentrated during the crisis period. Monetary responses and currency fluctuations overlapped during the subprime crisis, contrary to the euro crisis measures, which had a strong impact on the currency market, ending the previous abundance of fat-tailed extreme jumps (except in Hungary). This finding suggests that the ECB was able to push back pricing uncertainties at a low level: returns were not fat-tailed, but only according to the 5% probability threshold.

Figure 4 | Number of Extreme Trading Days within the Monetary Periods of the ECB CEE Currencies with CHF Denomination
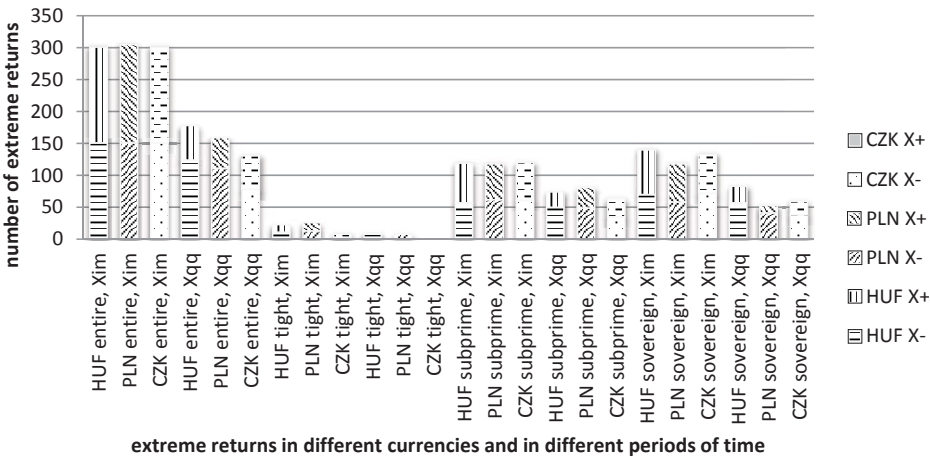

Notes: Xim: improbable return, Xqq: fat-tailed return
Source: author's calculations

Because the just-presented results illustrated that extreme returns showed clustering, we tested their density around two significant monetary decisions within a 500-day range (see Figure 5). The first decision was when the ECB started to decrease its prime rate on 2 October 2008, as the subprime crisis intensified. At this time, extreme currency fluctuations were not occurring and pricing was fuzzy, but relatively stable. Interest rate cuts were also insufficient to relax currency markets, because more extreme days occurred after this policy change. In addition, CEE currencies reacted even worse, which supports the idea of the provision of joint financial programmes at that time.

Figure 5 | Appearance of Fat-Tailed Returns before and after 2 October 2008
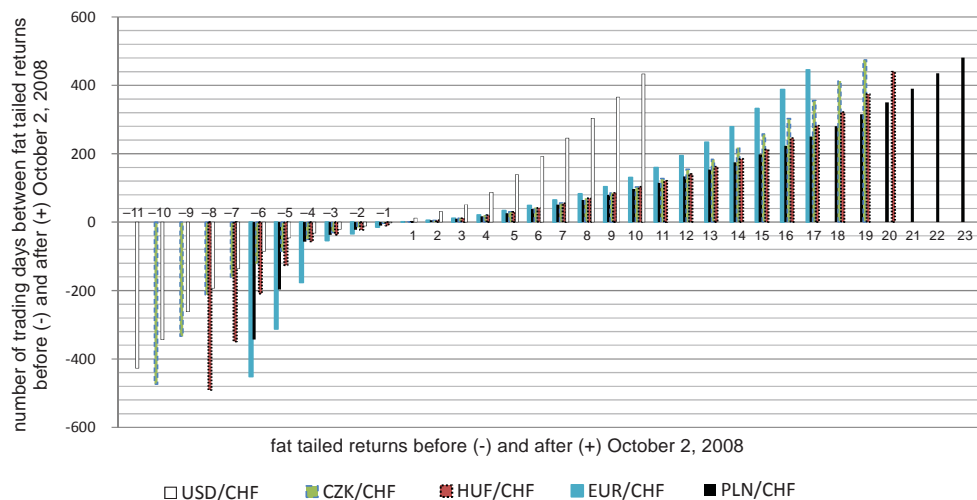
Source: author's calculations

The second decision is the announcement by the main central banks on 8 December 2011 of bilateral swap agreements (Figure 6). Extreme days started to abound before this step, but suddenly diminished after the announcement for EUR, PLN, USD, and CZK, while HUF presented more extreme fluctuations, supporting the idea that pricing uncertainty has a country-specific background.

Figure 6 | Appearance of Fat-Tailed Returns before and after 8 December 2011
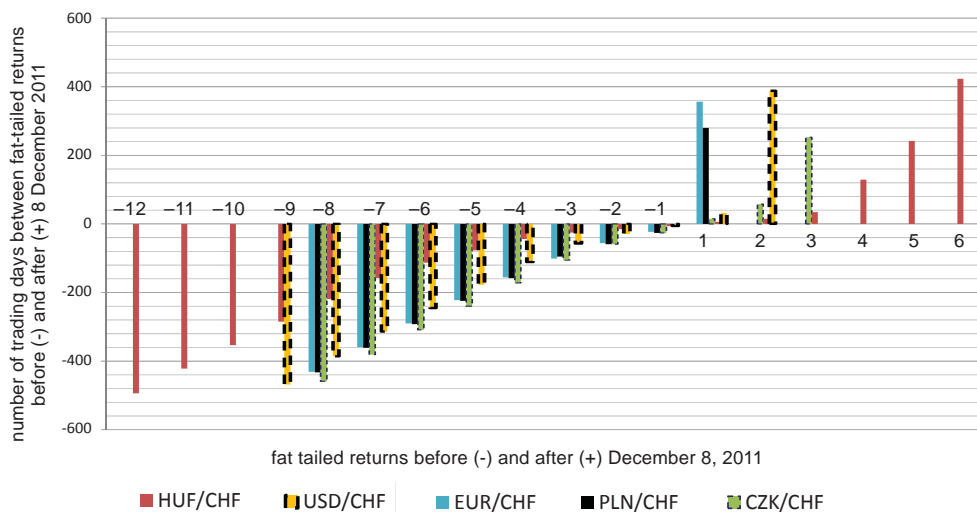
Source: author's calculations

Heteroscedasticity was managed by using univariate GARCH models, following Cappeiello *et al*. (2006), while the currencies demanded the application of less sophisticated models (Kiss and Kosztopulosz, 2012 - see Table 3). One-day volatility persistence was important according to the high level of betas, while PLN, HUF, and USD presented asymmetric behaviour with depreciation paired with increased volatility in contrast to USD, where appreciation resulted in increased volatility.

Table 3 | Results of the Selected Univariate GARCH Models

| Currency	GARCH model	AIC	Omega	Alpha(1)	Gamma(1)	Beta(1)	Ljung–Box	ARCH-LM
EUR/USD	GARCH(1,1)	0.91872	0.0018	0.0385		0.9575	0.921551	0
PLN/USD	GJR-GARCH(1,1,1)	1.25313	0.0102	0.0422	0.0317	0.9289	0.596078	0
CZK/USD	GARCH(1,1)	1.13668	0.0059	0.0435		0.9476	0.105229	0
HUF/USD	GJR-GARCH(1,1,1)	1.32693	0.0141	0.0346	0.0462	0.927	0.990811	0
USD/USD	GJR-GARCH(1,1,1)	0.99846	0.004	0.059	-0.0342	0.947	0.926537	0

Source: author's calculations

The USD currency pairs were used as control variables in Figure 7, because their poor correlation with CEE currencies is well known (Bubák *et al*., 2011; Stavárek, 2009; Babetskaia-Kukharchuk *et al*., 2008). The pre-crisis convergence between CEE currencies and EUR continued, supporting the findings of Stavárek (2009), but this decreased against CHF during the subprime and euro crises (Figure 2). This result suggests the value of examining how common movements change in different monetary environments. The latter results indicate bad news both for the creditors and for the debtors of CHF-based FCYLs. Consequently, this fluctuation provides decreasing debtor quality, damaging the solvency of the banking system.

Table 4 shows that these correlations had different dynamics when studied according to the tightening and easing policies of the ECB. The results of the t-tests presented in this table suggest that the decisions of the ECB helped define the different collective types of behaviour in currency markets. First, we compared the pre-crisis era with smooth monetary tightening (from March 2005 to July 2007) with the crisis era with two monetary easing periods (from August 2007 and December 2013). The difference between the correlations in these periods indicates the existence of contagion in Europe. The second and third comparisons of the pre-crisis period with the subprime crisis (from August 2007 to January 2010) and with the sovereign crisis (from August 2011 to December 2013) provided similar results.

If we focus only on CHF–CEE relations, we can still find significant correlations, but the common movements are weakened in HUF and CZK, suggesting divergence in CEE. This inconsistency supports the idea that both banks and their clients found themselves in an unusual situation because of the currency market dynamics during the euro crisis. These results can be interpreted as follows: the bursting asset bubble-triggered crisis involved monetary easing, while the market became uncertain about the valuation of CEE

Figure 7 | DCCs on a Daily Basis, Currencies in USD Denomination

CHF-HUF

CHF-CZK

CHF-PLN

EUR-HUF

EUR-CZK

EUR-PLN

PLN-HUF
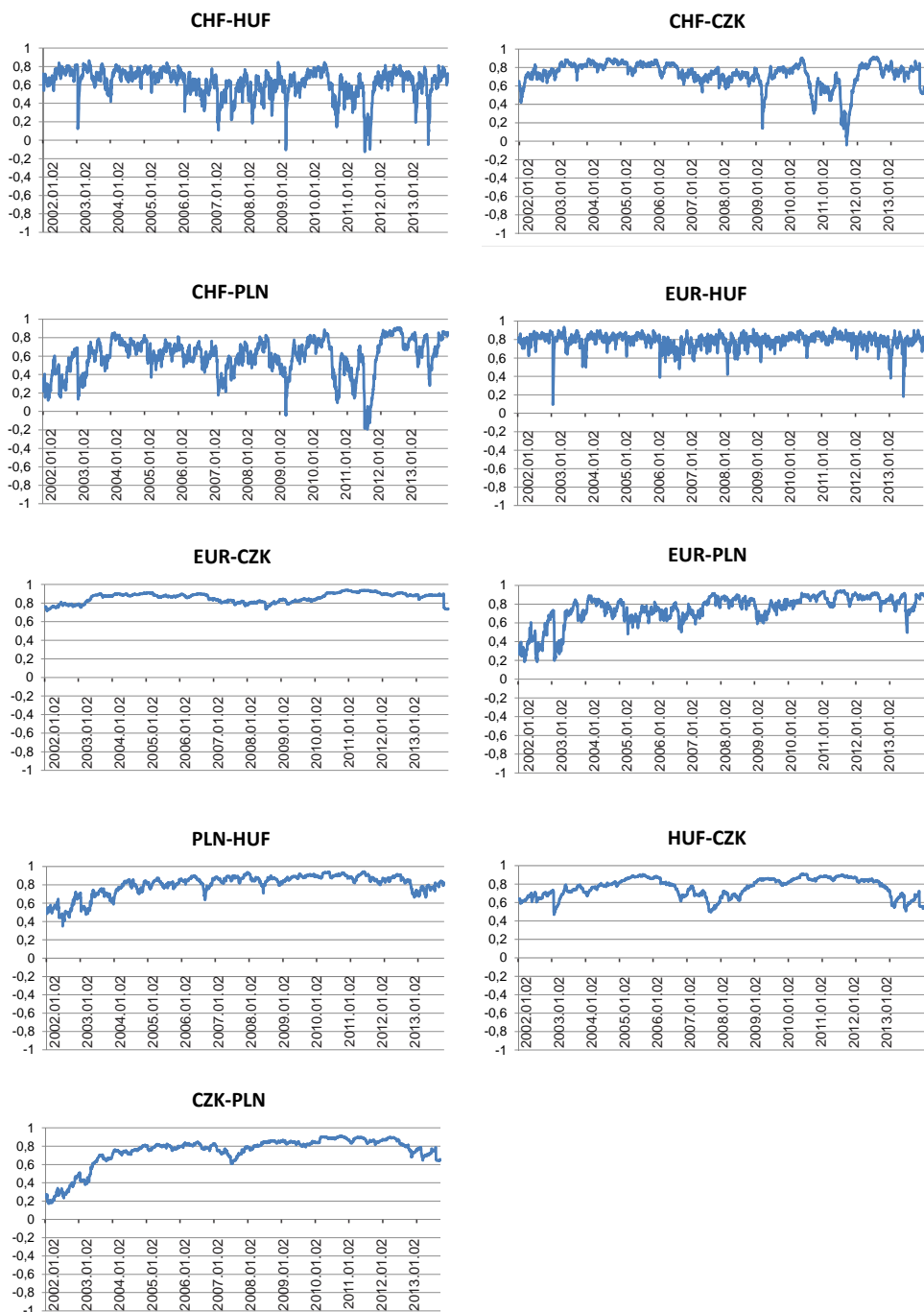
HUF-CZK

CZK-PLN

Source: author's calculations

Table 4 | Different Correlations under Tightening (T) and Easing (E) by the ECB Currencies with CAD Denomination

		CHF-HUF	CHF-CZK	CHF-PLN	EUR-HUF	EUR-CZK	EUR-PLN	PLN-HUF	HUF-CZK	CZK-PLN	entire
2005–2007 vs. 2007–2013	**t-test**	1	1	1	1	1	1	1	1	1	100%
	average T	0.6188	0.7713	0.5890	0.7672	0.8647	0.7005	0.8316	0.7933	0.7898	
	average C	0.5875	0.6843	0.6082	0.7926	0.8626	0.8344	0.8588	0.7720	0.8195	
	increase	0	0	1	1	0	1	1	0	1	56%
	var T	0.0167	0.0050	0.0156	0.0053	0.0008	0.0042	0.0020	0.0071	0.0010	
	var C	0.0268	0.0248	0.0466	0.0050	0.0027	0.0051	0.0032	0.0127	0.0049	
2005–2007 vs. 2007–2010	**t-test**	1	1	1	1	1	1	1	1	1	100%
	average T	0.6188	0.7713	0.5890	0.7672	0.8647	0.7005	0.8316	0.7933	0.7898	
	average C	0.5839	0.6973	0.5991	0.7834	0.8120	0.8007	0.8696	0.7394	0.8001	
	increase	0	0	1	1	0	1	1	0	1	56%
	var T	0.0167	0.0050	0.0156	0.0053	0.0008	0.0042	0.0020	0.0071	0.0010	
	var C	0.0186	0.0088	0.0198	0.0041	0.0005	0.0052	0.0012	0.0113	0.0039	
2005–2007 vs. 2011–2013	**t-test**	1	1	1	1	1	1	1	0	1	89%
	average T	0.6188	0.7713	0.5890	0.7672	0.8647	0.7005	0.8316	0.7933	0.7898	
	average C	0.5900	0.6761	0.6141	0.7985	0.8950	0.8560	0.8519	0.7929	0.8319	
	increase	0	0	1	1	1	1	1	0	1	67%
	var T	0.0167	0.0050	0.0156	0.0053	0.0008	0.0042	0.0020	0.0071	0.0010	
	var C	0.0320	0.0349	0.0637	0.0055	0.0014	0.0038	0.0043	0.0125	0.0052	

Note: * collective behaviour, ** contagion, *** divergence

Source: author's calculations

5. Conclusion

Capital markets have complex network structures where crises are features instead of bugs. Prices can differ from their expected value and structural failures may occur (bank defaults such as the LTCM in 1998 and Lehman Brothers in 2008), triggering even fatter-tailed returns. Currency markets are relatively efficient compared with stock or bond markets (Kiss and Kosztopulosz, 2013). Nevertheless, CEE currencies have suffered from increased fat tailness under CHF denomination (including CZK despite its better fundamental background). The monetary easing policy and bilateral swap agreements introduced by the ECB have reduced the occurrence of fat-tailed returns. Despite the relatively strong and stable CEE–EUR exchange rate, however, common movements have failed to provide credits in a safe haven currency such as CHF. Further, market panic-driven liquidity inflows appreciated the currency and the previously strong correlation was temporarily diminished. The re-emergence of the correlation even stabilised exchange rates at an unsustainable level from an FCYL point of view. The lesson of the current crisis for CEE currencies is that their relationship with CHF was altered by network dynamics during the subprime crisis, while the sovereign crisis was able to erase even the decade-old convergence. These fundamental changes negatively affected

the banking sector in those countries where foreign currency lending was popular (*e.g.* Hungary or Poland), especially given the lower quality of credits before 2008 in Hungary (Gyöngyösi, 2010), but there was room for a further decrease during the euro crisis. The above-described market phenomena affected all CEE currencies regardless of their fundamental background, but their impact on financial stability was determined by the country-specific pre-crisis conditions.

Central banks are legally responsible for financial stability, and recent changes suggest the necessity for a more sophisticated secondary objective for monetary policy. Despite the triviality of this need, it would be hard to operationalise. Indeed, recent steps towards creating a banking union (Darvas, 2013) or delegating supervisory powers to central banks (MNB, 2013, Lawson and Zimková, 2009) as well as harmonised supervision functions (Pelle, 2006) seem to be addressing this problem. However, sole institutional solutions are not enough at the national level: that is the moral of the current crisis. Even the key central banks were able to overcome pricing uncertainty by using enriched toolboxes with complete track easing on the yield curves as well as FX liquidity supply programmes. The current low inflation environment supported monetary policy because financial and price stability were both manageable at the same time. However, an exit strategy would require more joint programmes among the ECB and CEE central banks to minimise the costs of bank consolidation due to FX-related bank assets.

References

Ács, A. (2011), "A likviditás dimenziói. Dimensions of Liquidity" *Hitelintézeti Szemle*, Vol. 10, No. 3, pp. 241–261.

Antal, J., Gereben, Á. (2011), "Foreign Reserve Strategies for Emerging Economies - before and after the Crisis." *MNB Bulletin*, Vol. 6, No. 1, pp. 7–19.

Arrow, K. J. (1986), "Rationality of Self and Others in an Economic System." *Journal of Business*, Vol. 59, No. 4, pp. 386–399, http://dx.doi.org/10.1086/296376

Árvai, Zs., Driessen, K., Ötker-Robe, İ. (2009), "Regional Financial Interlinkages and Financial Contagion within Europe." IMF Working Paper 2009–6.

Babetskaia-Kukharchuk, O., Babetskii, I., Podpiera, J. (2008), "Convergence in Exchange Rates: Market's View on CE-4 Joining EMU." *Applied Economics Letters*, Vol. 15, No. 5, pp. 385–390.

Barabási, A. L., Albert, R. (1999), "Emergence of Scaling in Random Networks." *Science*, Vol. 286, No. 5439, pp. 509–512.

Bearce, D. H. (2002a), *Monetary Divergence: Domestic Policy Autonomy in the Post-Bretton Woods Era*. Ann Arbor: University of Michigan Press.

Bearce, D. H. (2002b), "Monetary Divergence Domestic Political Institutions and the Monetary Autonomy - Exchange Rate Stability Trade-Off." *Comparative Political Studies*, Vol. 35, No. 2, pp. 194–220.

Bekaert, G., Harvey, C. R., Ng, A. (2005), "Market Integration and Contagion." *Journal of Business*, Vol. 78, No. 1, pp. 39–69, http://dx.doi.org/10.1086/426519

Benedek, G., Lublóy, Á., Szenes, M. (2007), "A hálózatelmélet banki alkalmazása. Network Theory: an Application for Banking" *Közgazdasági Szemle*, Vol. 54, No. 7–8, pp. 682–702.

BIS (2011), "Global Liquidity - Concept, Measurement and Policy Implications." BIS CGFS Publications 2011–45.

Bonanno, G., Lillo, F., Mantegna, R. (2001), "Levels of Complexity in Financial Markets." *Physica A*, Vol. 299, No. 1–2, pp. 16–27.

Borio, C. (2014), "Monetary Policy and Financial Stability: What Role in Prevention and Recovery?" BIS Working Papers No. 440.

Bubák, V., Kočenda, E., Zikes, F. (2011), "Volatility Transmission in Emerging European Foreign Exchange Markets." *Journal of Banking & Finance*, Vol. 35, No. 11, pp. 2829–2841, http://dx.doi.org/10.1016/j.jbankfin.2011.03.012

Campbell, R., Koedij, K., Kofman, P. (2002), "Increased Correlation in Bear Markets." *Financial Analysts Journal*, Vol. 58, No. 1, pp. 87–94.

Cappeiello, L., Engle, R. F., Sheppard, K. (2006), "Asymmetric Dynamics in the Correlations of Global Equity and Bond Returns." *Journal of Financial Econometrics*, Vol. 4, No. 4, pp. 537–572.

Clauset, A., Shalizi, C. R., Newman, M. E. J. (2009), "Power-Law Distributions in Empirical Data." *SIAM Review*, Vol. 51, No. 4, pp. 661–703.

Darvas, Zs. (2013), "The Euro Crisis: Ten Roots but Fewer Solutions," in Farkas, B., ed., *The Aftermath of the Global Crisis in the European Union*. Newcastle upon Tyne: Cambridge Scholars Publishing, pp. 83–104.

Deutsch, H-P. (2002), *Derivatives and Internal Models*. Houndmills: Palgrave Macmillan.

Dietrich, D., Knedlik, T., Lindner, A. (2011), "Central and Eastern European Countries in the Global Financial Crisis: A Typical Twin Crisis?" *Post-Communist Economies* Vol. 23, No. 4, pp. 415–432.

Ding, Z., Granger, C. W. J., Engle, R. F. (1993), "A Long Memory Property of Stock Market Returns and a New Model." *Journal of Empirical Finance*, Vol. 1, No. 1, pp. 83–106.

EBF (2012), *The New EBF Banking Sector Statistics Database 2012*. Brussels: European Banking Federation.

ECB (2002–2012), *Annual Report*. Frankfurt am Main: European Central Bank.

ECB (2011), *The Monetary Policy of the ECB*. Frankfurt am Main: European Central Bank.

Engle, R. F. (2002), "Dynamic Conditional Correlation - A Simple Class of Multivariate GARCH Models." *Journal of Business and Economic Statistics*, Vol. 20, No. 3, pp. 377–389.

Erdős, P., Rényi, A. (1960), "On the Evolution of Random Graphs." *Publications of the Mathematical Institute of the Hungarian Academy of Sciences*, Vol. 5, No. 1, pp. 17–61.

Fama, E. F. (1970), "Efficient Capital Markets: A Review of Theory and Empirical Work." *Journal of Finance*, Vol. 25, No. 2, pp. 383–417, http://dx.doi.org/10.2307/2325486

Farkas, B. (2011), "The Central and Eastern European Model of Capitalism." *Post-Communist Economies*, Vol. 23, No. 1, pp. 15–34.

Forbes, J. K., Rigobon, R. (2002), "No Contagion, only Interdependence: Measuring Stock Market Comovements." *Journal of Finance*, Vol. 57, No. 5, pp. 2223–2261, http://dx.doi.org/10.1111/0022-1082.00494

Gabaix, X., Gopikrishnan, P., Plerou, V., Stanley H. E. (2003), "A Theory of Power-Law Distributions in Financial Market Fluctuations." *Nature*, Vol. 423, No. 6937, pp. 267–270.

Goldstein, M., Turner, P. (2004), *Controlling Currency Mismatches in Emerging Markets*. Washington, DC: Viva Books.

Gyöngyösi, Zs. (2010), "A törlesztési késedelembe eső lakossági jelzáloghitelek jellemzői a Központi Hitelinformációs Rendszer adatai alapján." Költségvetési Felelősség Intézet Budapest Munkaanyag No. 2010–1.

Haile, F., Pozo, S. (2008), "Currency Crisis Contagion and the Identification of Transmission Channels." *International Review of Economics and Finance*, Vol. 17, pp. 572–588.

Jentsch, V., Kantz, H., Albeverio, S. (2006), "Extreme Events: Magic, Mysteries and Challenges," in Albeverio, S., Jentsch, V., Kantz, H., eds., *Extreme Events in Nature and Society*. Heidelberg: Springer, pp. 1–18.

Jiawei, H., Micheline, K. (2004), *Data Mining Concepts and Techniques.* Amsterdam: Elsevier.

Kantz, H., Altman, E. G., Hallerberg, S., Holstein, D., Riegert, A. (2006), "Dynamical Interpretation of Extreme Events: Predictability and Predictions," in Albeverio, S., Jentsch, V., Kantz, H., eds., *Extreme Events in Nature and Society*. Heidelberg: Springer, pp. 69–93.

Kaminsky, G. L., Reinhart, C. M. (1999), "The Twin Crises: The Causes of Banking and Balance of Payments Problems." *American Economic Review*, Vol. 89, pp. 473–500.

Kiss, G. D., Kosztopulosz, A. (2012), "The Impact of the Crisis on the Monetary Autonomy of Central and Eastern European Countries." *Public Finance Quarterly*, Vol. 57, No. 1, pp. 27–51.

Kiss, G. D., Kosztopulosz, A. (2013), "The Adequacy of Inflation-Targeting Monetary Policy and Euro Zone Participation for the Central-East European Countries," in Farkas, B., ed., *The Aftermath of the Global Crisis in the European Union*. Newcastle upon Tyne: Cambridge Scholars Publishing, pp. 178–210.

Kovács, Gy. (2009), "Financial Stability and the Banking System, or the Imbalance of the Intermediary System." *Public Finance Quarterly*, Vol. 54, No. 1, pp. 49–67.

Kuper, G. H., Lestano, L. (2007), "Dynamic Conditional Correlation Analysis of Financial Market Interdependence: An Application to Thailand and Indonesia." *Journal of Asian Economics*, Vol. 18, pp. 670–684.

Kuusk, A., Paas, T. (2013), "A Meta-Analysis-Based Approach for Examining Financial Contagion with Special Emphasis on CEE Economies." *Eastern European Economics*, Vol. 51, No. 3, pp. 71–90.

Lawson, C., Zimková, E. (2009), "The Credit Crisis: What Lessons for Visegrad?" *Prague Economic Papers,* Vol. 18, No. 2, pp. 99–113, http://dx.doi.org/10.18267/j.pep.344

MNB (2013), "Az MNB pénzügyi felügyeleti funkciójának megerősítése - új szabályozói eszközök MNB-hez rendelése és a PSZÁF MNB-be integrálása." Magyar Nemzeti Bank Budapest Vitaanyag No. 2013–1.

Muller, A., Verschoor, W. (2009), "The Effect of Exchange Rate Variability on US Shareholder Wealth." *Journal of Banking and Finance*, Vol. 33, No. 11, pp. 1963–1972.

Pelle, A. (2006), "Opportunities in the Hungarian Financial Services Sector as Part of the Single European Market of Financial Services." *Transition Studies Review*, Vol. 13, No. 3, pp. 497–510.

Plümper, T., Troeger, V. E. (2008), "Fear of Floating and the External Effects of Currency Unions." *American Journal of Political Science*, Vol. 32, No. 3, pp. 656–676.

Simon, H. A. (1955), "A Behavioral Model of Rational Choice." *The Quarterly Journal of Economics*, Vol. 69, No. 1, pp. 99–118.

Stavárek, D. (2009), "Assessment of the Exchange Rate Convergence in Euro-Candidate Countries." *Amfiteatru Economic Journal*, Vol. 11, No. 25, pp. 159–180.

Stavárek, D. (2010), "Exchange Rate Volatility and the Asymmetric Fluctuation Band on the Way to the Eurozone." *Applied Economics Letters*, Vol. 17, No. 1, pp. 81–86.

Van Horen, N., Jager, H., Klaassen, F. (2006), "Foreign Exchange Market Contagion in the Asian Crisis: a Regression-Based Approach." *Review of World Economics*, Vol. 142, pp. 374–401,, http://dx.doi.org/10.1007/s10290-006-0072-x

Váradi, K. (2012), "Volt-e likviditási válság? A volatilitás és likviditás kapcsolatának vizsgálata. Was There a Liquidity Crisis? – Analysis of the Relationship between Volatility and Liquidity." *Hitelintézeti Szemle,* Vol. 11, No. 5, pp. 69–78.

Vitali, S., Glattfelder, J. B., Battiston, S. (2011), "The Network of Global Corporate Control." *PLoS ONE*, Vol. 6, No. 10, pp. 25995.

Vriend, N. J. (1996), "Rational Behavior and Economic Theory." *Journal of Economic Behavior & Organization*, Vol. 29, No. 2, pp. 263–285.

Watts, D. J., Strogatz, S. H. (1998), "Collective Dynamics of 'Small-world' Networks." *Nature*, Vol. 393, No. 6638, pp. 440–442.

Yesin, P. (2013), "Foreign Currency Loans and Systemic Risk in Europe." *Federal Reserve Bank of St. Louis Review*, Vol. 95, No. 3, pp. 219–235.