



# Managing Sustainable Growth

Proceedings of the Joint International Conference Organised by

- University of Primorska, Faculty of Management, Slovenia
- Eastern European Economics, USA, and
- Society for the Study of Emerging Markets, USA

Portorož, Slovenia, 28–30 May 2015

## **MIC 2015: Managing Sustainable Growth**

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University of Primorska, Faculty of Management, Slovenia  
Eastern European Economics, USA, and  
Society for the Study of Emerging Markets, USA  
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## Foreword

The traditional Management International Conference (MIC) was organized in Portorož, Slovenia, in co-operation of University of Primorska, Faculty of Management, (Slovenia), Eastern European Economics (USA), and Society for the Study of Emerging Markets (USA).

The focus of the conference was Managing Sustainable Growth. In this view the conference aimed to analyse various aspects of sustainable economic growth and development and to offer researchers and professionals the opportunity to discuss the most demanding other issues of sustainability. The conference was carried out in three tracks:

- MIC Track (traditional Management International Conference, organised by University of Primorska, Faculty of Management)
- Economics Track (organised by Eastern European Economics)
- Finance Track (organised by Society for the Study of Emerging Markets)

We would like to extend a sincere thank to all the participants and presenters for their contributions and participation. This year, we received 157 submissions and selected the best 129 papers from authors from 29 countries, and the total number of participants reached 200 (together with panel discussions and workshops). All abstracts of papers were included in the Book of Abstracts, ready for the conference. After the conference authors were invited to submit full papers to the supporting journals (*Borsa Istanbul Review*, *Comparative Economic Studies*, *Eastern European Economics*, *Economic Systems*, *Emerging Markets Finance and Trade*, *International Journal of Sustainable Economy, Management, and Managing Global Transitions*) or to the Conference Proceedings. In the Conference Proceedings authors submitted 38 papers. We use this opportunity to thank all the reviewers for doing a great job in reviewing all full papers and for their precious time.

Special thanks go to the keynote speaker, Prof. Dr. Dean Fantazzini from Moscow School of Economics, Moscow State University, Russian Federation.

We would also like to thank:

- the participants of the panel discussion on COMPETE project 'Mark up in Food Value Chains' which was based on research project supported by the European Commission's Seventh Framework Programme,
- the participants of the workshop 'Innovative and Creative Ways to Enhance Teaching and Learning' which was based on learning techniques that have been developed by members of the international MirandaNet Fellowship,
- the editors of the supporting journals, and
- to PhD students who participated at the Doctoral Students' Workshop.

Last but not least, we extend our sincere thanks to everybody who participated in the programme boards and organisation of the MIC 2015.

Dr. Suzana Laporšek

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## **When Can We Call It “Extraordinary Circumstances”? Examination of Currency Exchange Rate Shocks**

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*Abstract.* Immediately after Swiss Central Bank withdrew from controlling CHF/EUR exchange rate in January 2015, CHF/HRK rate rose 15%, thereby substantially propagating Croatian credit default rates, non-performing loans and inciting broad socio-political consequences. The purpose of this paper is to examine (ab)normality of currency exchange rate distributions across Europe, focusing on Croatia, with the aim of identifying situations which could be defined as extraordinary circumstances. These can be embedded as triggering events in wide array of legal contracts. Historical data on exchange rates of European currencies is obtained and observed for its statistical distribution characteristics. “Fat tails” are found to be rule rather than exception, even witnessing shocks with magnitude of more than 100 standard deviations. Aside from lessons for risk management in a financial system which should endure these quakes, there are implications for policymakers, but above all for citizens struggling to fulfil their credit obligations under unexpected conditions.

*Keywords:* Exchange rate shock, volatility, Croatia, Swiss Franc, Croatian Kuna, extreme events

### **1 Introduction and research context**

On April 25<sup>th</sup> 2015 more than 20.000 people went to the streets of Zagreb (Croatian capital) to protest, demanding changes in contract agreements with their banks. They took loans which were denominated in Swiss Francs, and had to repay them in the said currency. Banks marketed strongly these loans, introducing them in the beginning of 2004, as they had lower interest rates. According to banks’ methodology at the time many people were not creditworthy for any other kind of loans, so by the end of 2014. share of these loans went up to 16% in the total amount of all loans, while the share in housing-loans (mortgages) was more than a third (38%)<sup>1</sup>.

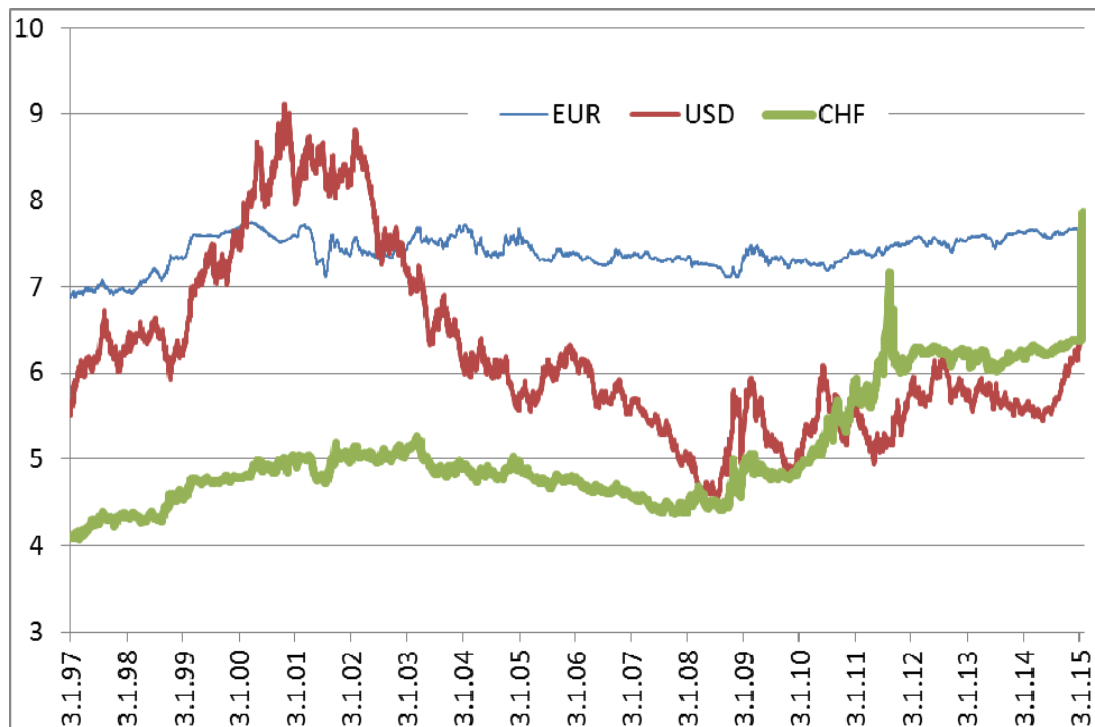
After Swiss Central Bank in January 2015 withdrew from controlling CHF/EUR exchange rate, the CHF/HRK rate rose more than a 15% in a day. This happened because Croatian currency (Kuna – HRK) is virtually pegged to Euro, and Croatian monetary system can be described as quasi-currency board. It was the second substantial increase in the CHF/HRK rate. The first occurred in August 2011, which led to bizarre, but for many also disastrous consequences: after 7 years of orderly repaying their loans some homeowners not only did not repay a fraction of their original loans, but were substantially more indebted, with principals now higher than those they received in the first place, and with instalments higher than what they could afford. This, of course, propagated credit default rates, non-performing loans and incited broad socio-political consequences. The motivation for this research arises from the above circumstances.

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<sup>1</sup> Source: Croatian National Bank (2015): Neke činjenice o kreditima u švicarskim francima i nekim mogućnostima državne intervencije. <http://www.hnb.hr/priopci/2015/hrv/hp21012015.pdf> (accessed 25.5.2015.; in Croatian only). It may be worth to note that the author is not indebted in CHF and has no personal interest in this matter.

Graph 1. depicts the daily nominal exchange rates of EUR/HRK, USD/HRK and CHF/HRK, as well as the quasi-currency board policy of the Croatian National Bank and the peg to Euro<sup>2</sup>. For this paper it is important to notice two intense moves of the Swiss Franc exchange rate in August 2011 and January 2015.

Graph 1. Daily nominal exchange rates of EUR/HRK, USD/HRK and CHF/HRK

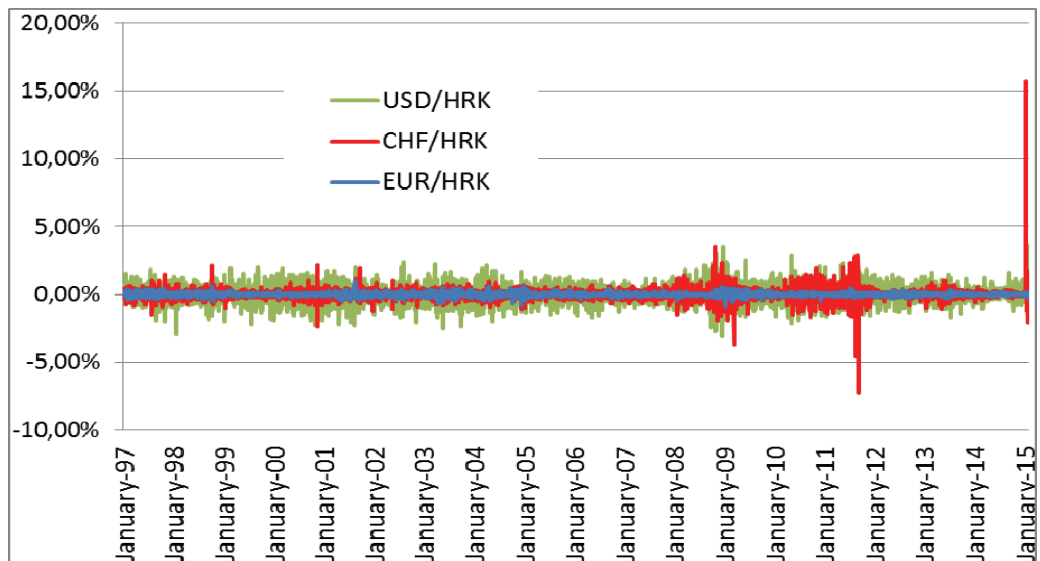


Source: Croatian National Bank

Graph 2. shows much higher level of volatility of the CHF/HRK against EUR/HRK rate, as well as strong shocks in 2011 and 2015 in the Swiss Franc exchange rate.

<sup>2</sup> The policy of the Croatian National Bank is not the object of interest of this particular paper, more insight about it can be found at Kraft (2003) and elsewhere.

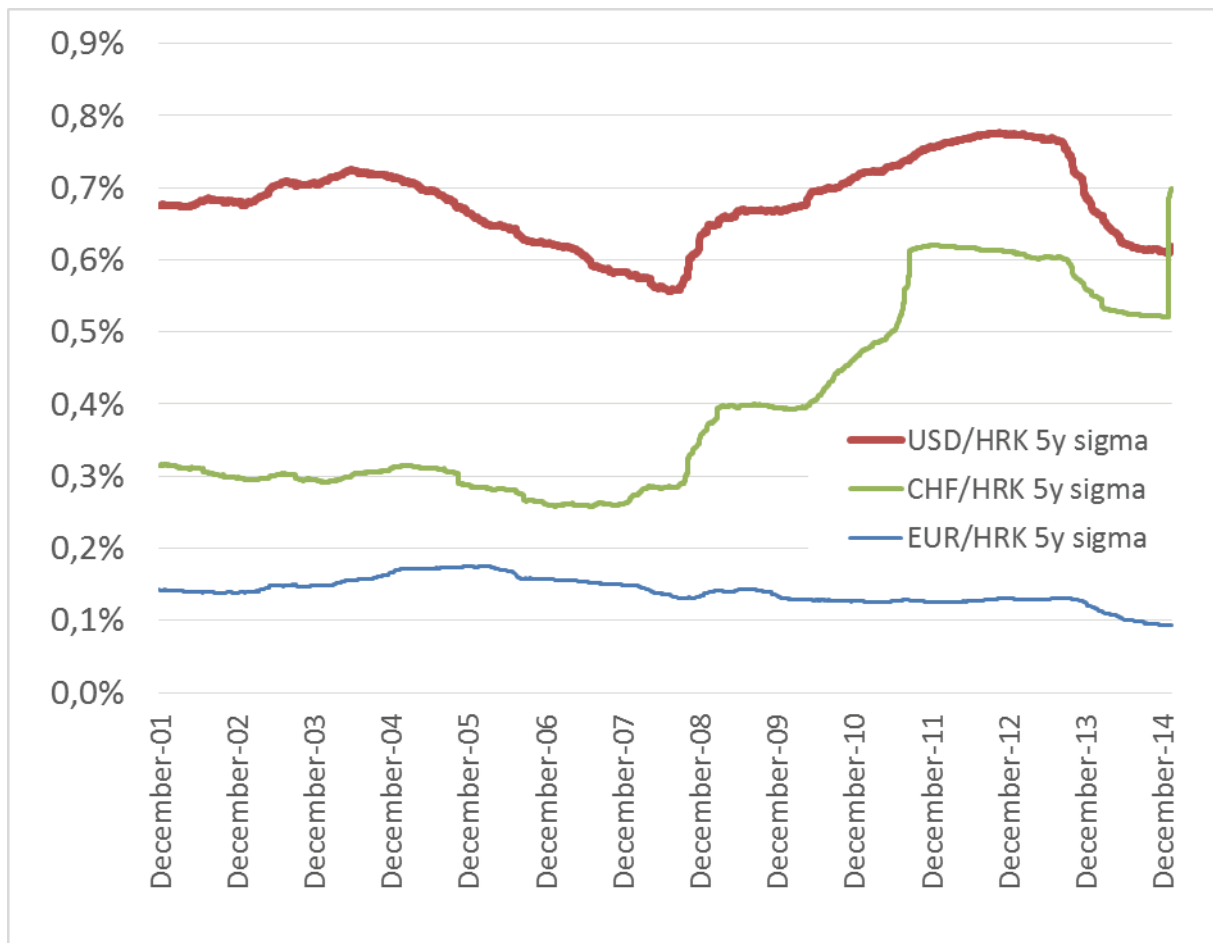
Graph 2. Daily returns of USD/HRK, CHF/HRK and EUR/HRK



Source: Author's calculation, Croatian National Bank data

By the time the loans denominated in Swiss Francs began to be offered in Croatia (beginning of 2004) standard deviation of daily returns of CHF/HRK was approximately 0,3%, regardless the period used for calculation (standard deviation was calculated three times: by using data from 1, 3 and 5 previous years). Graph 3. portrays moving 5-year volatility of the daily returns on USD/HRK, CHF/HRK and EUR/HRK rates.

Graph 3. Moving 5-year standard deviation of daily returns on USD/HRK, CHF/HRK and EUR/HRK



Source: Author's calculation, Croatian National Bank data

Volatility of the CHF/HRK did not revert to the long-run mean value; instead three shocks (February 2009, September 2011, and January 2015) pushed the volatility to new, higher levels, which indicated an increase in the risk of being indebted in Francs for Croatian citizens.

In the context of the strong and unexpected shocks in the CHF/HRK rate some Croatian debtors tried to invoke *Rebus Sic Stantibus* clause, which is a section in agreements or treaties that provides for the unenforceability of a treaty due to fundamentally changed, or extraordinary circumstances. This legal doctrine is one of the oldest norms of international law, and dates back to Ancient Roman laws. As such it is also codified and embedded in the Croatian Civil Obligations Act<sup>3</sup>. However, the challenge arose in clearly defining the “extraordinary circumstances”.

The goal of this paper is to examine (ab)normality of currency exchange rate distributions across Europe, focusing on Croatia, with the aim of identifying situations which could be defined as

<sup>3</sup> Croatian Civil Obligations Act (Official Gazette No. 35/2005, 41/2008, 125/2011), Article 369.: „Should, after entering into a contract, extraordinary circumstances arise, that it was impossible to foresee at the time of entering into a contract, making it excessively onerous for one party to perform or if under such circumstances a party would suffer an excessive loss as a result of the performance, it may request variation or even termination of the contract.“

extraordinary circumstances. These can be embedded as triggering events in wide array of legal contracts and provide a tool for appealing to *Rebus Sic Stantibus* clause.

Knowing that financial data is most often composed with fat-tailed distributions, the question arises: how to determine the occurrence of extraordinary circumstances (i. e. abnormal events) in an ambient characterized by frequent abnormality?

The hypotheses of this paper are as follows:

- a) the distributions of daily returns of CHF/HRK, as well as other currency pairs in Europe are non-normal,
- b) strong moves (shocks) in exchange rates happen much more often than normal distribution would suggest,
- c) variances of the EUR/CHF rate (consequently CHF/HRK as well) versus other examined currencies are not homogeneous; in other words volatility of the EUR/CHF rate is significantly different (higher) than the volatility of other rates
- d) when applying extreme value distribution to the CHF/HRK exchange rate largest shocks could be considered as extraordinary circumstances.

After the above introduction and the presentation of the research context, the next chapter offers a brief review of literature. The third chapter presents the methodology and the data used. Results are submitted and discussed subsequently. Finally, conclusion presents the main findings.

## 2 Review of Literature

Volatility is known to be high within exchange rates (*"Volatilities at least double during the crisis for most of the currencies"*<sup>4</sup>), but to the best of our knowledge, prior similar research (with comparable context and hypotheses) has not been performed.

Exchange rate volatility and extraordinary events in exchange rates are rarely examined per se, but often in a wider context of exchange rate economics. Excellent review of exchange rate economics can be found at Tica (2006.). For example, exchange rate volatility is observed as an independent variable while trying to model determinants of export (Bilgees et al., 2010.) or its effects on international trade flows (Nuroglu & Kunst, 2012.), in the context of financial crises (Coudert et al., 2011.) when examining spillover effects between financial markets (Bubák et al., 2011.), when explaining interconnectedness of spot and forward volatility (Della Corte et al., 2011.), or regime switching in volatility modelling (Calvet & Fisher, 2004.), etc.

Andersen et al. (2001.) researched 10 years of continuously recorded 5-min returns on DEM/USD and JPY/USD, which allowed them examine daily volatilities, introduced the term of realized volatility, and *"(...) found that the distributions of realized daily variances, standard deviations, and covariances are skewed to the right and leptokurtic, but that the distributions of logarithmic standard deviations and correlations are approximately Gaussian"*<sup>5</sup>.

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<sup>4</sup> Ozer-Imer & Ozkan 2014:399

<sup>5</sup> Andersen et al. 2001:54

Tica (2006) analysed real exchange rate movements in transition countries and writes about “*unprecedented volatility of exchange rates*”<sup>6</sup>, but did not investigate the magnitude of shocks or the scope of the volatility within the rates he observed.

Pong et al. (2004.) compared four methods for forecasting volatility, but then again did not focus on defining extraordinary events.

As for the Croatian Kuna currency exchange, there are many researchers that deal with its exchange rate. Examples can be found at Tatomir (2009.), who measured exchange market pressure, Payne (2000.), who examined the role of exchange rate in the money demand, Nikić (2000.), who contributed to the ever-present discussion (in Croatian public sphere) on the Croatian exchange rate arrangement, Koški (2009.), who studied the effect of exchange rate change on the Croatian trade balance, while Ahec-Šonje & Babić (2003.) attempted to measure and predict Croatian currency disturbances. Erjavec et al. (2012) examined the role of the exchange rate regime in absorbing macroeconomic shocks for a group of Central and East European countries, but – like the other mentioned researchers – have not dealt with the exchange rate shocks. This has left a gap which this paper attempts to fulfil.

### 3 Data and methodology

Data is obtained from Croatian National Bank (CNB)<sup>7</sup> and Quandl<sup>8</sup>. CNB data consists of daily nominal midpoint exchange rates of Euro (EUR), US Dollar (USD) and Swiss Franc (CHF) vs. Croatian Kuna (HRK), and comprises 4542 data points from January 3<sup>rd</sup> 1997 to January 31<sup>st</sup> 2015.

Historical data taken from Quandl contains currency pairs where Euro is the base (primary) currency versus daily quotes of 13 European currencies: Swiss Franc - CHF, Czech Koruna - CZK, Danish Krone - DKK, Pound Sterling - GBP, Croatian Kuna - HRK, Hungarian Forint - HUF, Iceland Krona - ISK, Macedonian Denar - MKD, Norwegian Krone - NOK, Polish New Zloty - PLN, Romanian Leu - RON, Serbian Dinar - RSD, and Swedish Krona – SEK. They are accompanied by US Dollar (USD) and Japanese Yen (JPY), as major global currencies. All in all, from this source one can observe in parallel the value of 1 Euro in 15 different currencies.

Quotations (4091 for 13 pairs) are used to compute daily changes for each pair. The data used spans across all available data given by the source; the examined period ranges from September 6<sup>th</sup> 1999 to May 11<sup>th</sup> 2015. The exceptions are EUR/MKD and EUR/RSD, where data for MKD begins with April 18<sup>th</sup> 2006 (2365 observations), and for RSD with May 9<sup>th</sup> 2001 (3654 observations).

It could be argued that when selecting daily frequency of the data one opts for a lot of noise within because they are often inconsequential, meaningless and that they exhibit tendency of market participants to overreact. Hence, monthly frequencies could be used to smooth out daily disturbances and to reveal underlying trends (if there are any). This is a valid claim, so t-test was performed to compare monthly and daily frequencies of the data.

However, in the Croatian context it is important to use daily frequencies because of the Croatian credit-takers debt repayment mechanism. They are obliged to repay their dues in regular instalments, every month on the agreed date. The monthly annuity is calculated by multiplying the amount of

<sup>6</sup> Tica 2006:156

<sup>7</sup> Free access available at <http://www.hnb.hr/tecajn1/estatistika-tec aja.htm> (visited 5.12.2015.)

<sup>8</sup> Free access available at <https://www.quandl.com/collections/markets/exchange-rates-versus-eur> (visited 5.12.2015.). Quandl reports that the data they provide on exchange rates “(...) is an amalgamation of rates from multiple sources. These include exchanges, brokerages, newspapers and central bank sources”.

Swiss Francs with the official exchange rate on the day of the payment. Therefore, if an enormous positive shock in the exchange rate occurs on the payment day, the credit-taker has no option but to absorb it and pay it to the bank. If on the next day a large negative shock balances out the positive shock from the previous day, the credit-taker cannot withdraw the yesterday's expense. Hence, the focus is on the daily frequencies.

The data is used to obtain usual descriptive statistical indicators (measures of central tendencies and distribution indicators). Standard normality tests are performed in order to examine the possibility of normal distribution of daily changes in exchange rates.

Strength of daily change (shock) in exchange rate is measured by dividing the most recent daily return of the respective exchange rate with the standard deviation of previous daily returns of the respective exchange rate. However, standard deviation changes over time; one can expect to attain dissimilar results when calculating standard deviation using daily data from one preceding year when compared by using daily data for past five years.

Therefore, moving standard deviation is calculated within three different periods: a) one, b) three and c) five years. Moving standard deviation for the period of one year is measured by using 360 most recent data points, for three years by 1080, and for five years with 1800 observations. Consequently, for each of the currency pairs the intensity of the shock was calculated as follows. We define:

- $X_i = \text{CHF, CZK, DKK, GBP, HRK, HUF, ISK, MKD, NOK, PLN, RON, RSD, SEK, USD, JPY}$ ,
- $\text{EUR}X_{it}$  = return of a currency exchange rate on a day  $t$  over the previous day  $t-1$ ,
- $S_j\text{-EUR}X_{it}$  = the intensity of the move of the daily return in a currency exchange rate on a day  $t$ ,
- $j$  = number of years (1 / 3 / 5),
- $\sigma\{\text{EUR}X_{it}(t-1, t-2, \dots, t-k)\}$  = standard deviation of the daily return of a currency exchange rate calculated for previous  $k$  observations,
- $k = 360$  for  $j = 1$ ,  $k = 1080$  for  $j = 3$ , and  $k = 1800$  for  $j = 5$ .

Using these terms we compute:

$$\text{a) } S1\_EURX_{it} = \text{EUR}X_{it} / \sigma\{\text{EUR}X_{it}(t-1, t-2, \dots, t-360)\}, \quad (1)$$

$$\text{b) } S3\_EURX_{it} = \text{EUR}X_{it} / \sigma\{\text{EUR}X_{it}(t-1, t-2, \dots, t-1080)\}, \text{ and} \quad (2)$$

$$\text{c) } S5\_EURX_{it} = \text{EUR}X_{it} / \sigma\{\text{EUR}X_{it}(t-1, t-2, \dots, t-1800)\}. \quad (3)$$

Using the same notation for CNB data, the severity of daily shocks in terms of standard deviations of previous daily returns were stated as:

$$\text{a) } S1\_XHRK_{it} = XHRK_{it} / \sigma\{XHRK_{it}(t-1, t-2, \dots, t-250)\}, \quad (4)$$

$$\text{b) } S3\_XHRK_{it} = XHRK_{it} / \sigma\{XHRK_{it}(t-1, t-2, \dots, t-750)\}, \quad (5)$$

$$\text{c) } S5\_XHRK_{it} = XHRK_{it} / \sigma\{XHRK_{it}(t-1, t-2, \dots, t-1250)\}, \quad (6)$$

whereas data from CNB does not contain weekends and other non-working days.

After calculating exchange rate currency shocks by using data obtained by Quandl, the identical computation was performed with data obtained by CNB. Although this may seem redundant or superfluous, it is important to notice that CNB's exchange rate list is the official and representative data used in Croatian legislative documents and agreements. Quandl, on the other hand, is used for international comparison.

The assumption of inequality of variances can be verified with the F-test. However, F-test is known to be sensitive to non-normality, so the more robust Levene test as well as the Brown-Forsythe modification of Levene test were used as well.



For the purpose of this paper we define  $S5\_X_{it} \equiv$  extraordinary movement if:

$$S5\_X_{it} > 5\sigma(S5\_X_{it}) \vee S5\_X_{it} < -5\sigma(S5\_X_{it}) \wedge X_{it} = \text{has unit root} \quad (7)$$

In other words, extraordinary movement is defined as a daily shock<sup>9</sup> ( $S5\_X_{it}$ ) which is above or below a range of +5/-5 standard deviations of previous daily shocks (where standard deviation is calculated by using previous 5 years of data), while the rate does not revert to mean (is not stationary). Extreme shocks should not be regarded as extraordinary circumstances if soon after the shock currency rates revert to previous levels, hence we impose the non-stationarity condition. The number of five standard deviations was chosen because it covers 99,33% of the population according to the extreme value distribution (type I – Gumbel) with the cumulative distribution function stated as:

$$f(x; \alpha, \beta) = e^{-e^{-\frac{x-\alpha}{\beta}}} \quad (8)$$

where  $\alpha = 0$  and  $\beta = 1$ . For comparison, five standard deviations cover 99,99997% of the population when standard normal distribution is applied.

Standard statistical models usually emphasize average behaviour (central tendencies, etc.), while extreme value distribution focuses on extraordinary, erratic, rare events (i. e. “black swans”<sup>10</sup>).

## 4 Results

Table 1. exhibits standard descriptive statistics for 15 rates where Euro is the base rate. The largest volatility is found at Iceland’s Krona, which is followed by Swiss Franc.

Table 1: Descriptive statistics for EUR $X_t$  rates

| 6-Sep-1999<br>to<br>11-May-2015 | Valid<br>N | Aritm.<br>mean | Median  | Min.    | Max.    | Range   | Std. dev. | Skewness | Kurtosis |
|---------------------------------|------------|----------------|---------|---------|---------|---------|-----------|----------|----------|
| EURCHF                          | 4090       | -0,010%        | 0,000%  | -9,874% | 4,239%  | 14,113% | 0,322%    | -6,763   | 243,517  |
| EURCZK                          | 4090       | -0,007%        | -0,006% | -2,195% | 2,742%  | 4,937%  | 0,297%    | 0,427    | 8,527    |
| EURDKK                          | 4090       | 0,000%         | 0,000%  | -1,107% | 0,701%  | 1,808%  | 0,051%    | -0,916   | 95,725   |
| EURGBP                          | 4090       | 0,003%         | 0,000%  | -2,902% | 2,449%  | 5,351%  | 0,351%    | 0,022    | 4,043    |
| EURHRK                          | 4090       | 0,000%         | 0,000%  | -2,989% | 2,339%  | 5,328%  | 0,303%    | -0,307   | 15,996   |
| EURHUF                          | 4090       | 0,005%         | -0,004% | -3,292% | 4,426%  | 7,718%  | 0,399%    | 0,799    | 10,907   |
| EURISK                          | 4090       | 0,018%         | 0,002%  | -9,356% | 15,866% | 25,222% | 0,675%    | 1,644    | 105,975  |
| EURJPY                          | 4090       | 0,005%         | 0,026%  | -4,063% | 3,831%  | 7,894%  | 0,543%    | -0,205   | 4,511    |
| EURMKD                          | 2365       | 0,001%         | 0,006%  | -2,478% | 3,259%  | 5,736%  | 0,397%    | 0,223    | 8,666    |
| EURNOK                          | 4090       | 0,001%         | -0,011% | -2,013% | 2,109%  | 4,122%  | 0,315%    | 0,432    | 4,709    |
| EURPLN                          | 4090       | -0,001%        | -0,019% | -2,803% | 4,084%  | 6,887%  | 0,448%    | 0,617    | 6,838    |
| EURRON                          | 4090       | 0,024%         | 0,006%  | -2,427% | 4,266%  | 6,693%  | 0,412%    | 0,481    | 6,207    |
| EURRSD                          | 3654       | 0,020%         | 0,011%  | -2,978% | 3,654%  | 6,633%  | 0,461%    | 0,139    | 8,439    |
| EURSEK                          | 4090       | 0,002%         | -0,000% | -1,771% | 2,123%  | 3,894%  | 0,295%    | 0,237    | 3,650    |
| EURUSD                          | 4090       | 0,002%         | 0,005%  | -2,183% | 2,564%  | 4,747%  | 0,446%    | -0,041   | 2,056    |

Source: Author’s calculations, Quandl data

Skewness is in HUF, ISK and PLN strongly positive which indicates that their distributions are asymmetrical with heavy tails to the right, while CHF is strongly different from zero and skewed to

<sup>9</sup> As before, daily shock  $S5\_X_{it}$  is a ratio of a currency rate’s daily change ( $X_{it}$ ) and the 5-year standard deviation of its previous daily changes.

<sup>10</sup> Taleb (2007).



the left. The EUR/CHF exchange rate is also extremely leptokurtic (sharp peak around the mean with long, fat tails), as well as ISK, and DKK.

Table 2. Normality tests for EURX<sub>i</sub> rates

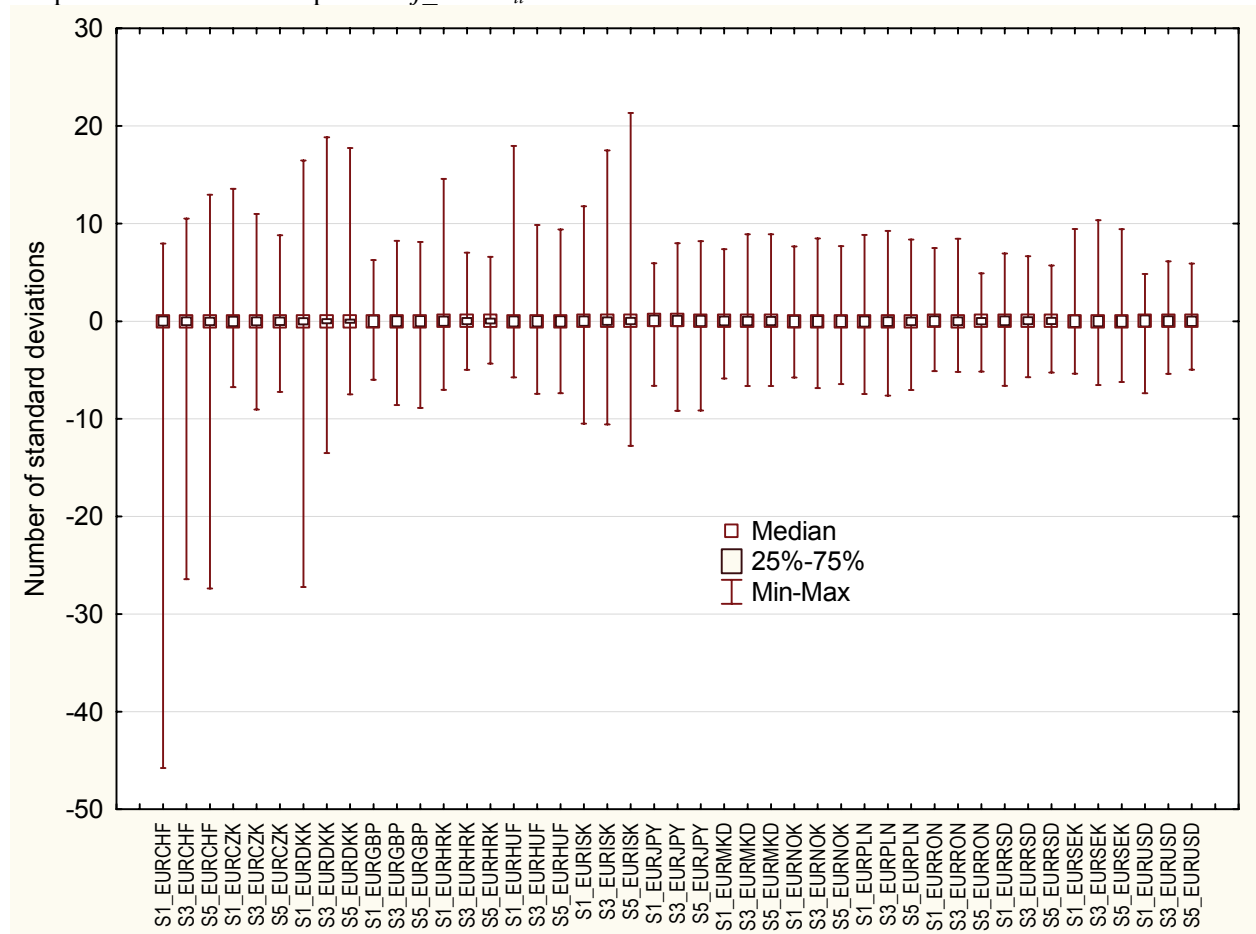
|               | Kolmogorov-Smirnov | Lilliefors | Shapiro-Wilk's W test |
|---------------|--------------------|------------|-----------------------|
| <b>EURCHF</b> | d=,16540, p<,01    | p<,01      | W=,61077, p=0,0000    |
| <b>EURCZK</b> | d=,08490, p<,01    | p<,01      | W=,90989, p=0,0000    |
| <b>EURDKK</b> | d=,26369, p<,01    | p<,01      | W=,48466, p=0,0000    |
| <b>EURGBP</b> | d=,05455, p<,01    | p<,01      | W=,96486, p=0,0000    |
| <b>EURHRK</b> | d=,16005, p<,01    | p<,01      | W=,79340, p=0,0000    |
| <b>EURHUF</b> | d=,09159, p<,01    | p<,01      | W=,90640, p=0,0000    |
| <b>EURISK</b> | d=,12383, p<,01    | p<,01      | W=,70418, p=0,0000    |
| <b>EURJPY</b> | d=,06131, p<,01    | p<,01      | W=,95698, p=0,0000    |
| <b>EURMKD</b> | d=,09894, p<,01    | p<,01      | W=,89149, p=0,0000    |
| <b>EURNOK</b> | d=,06149, p<,01    | p<,01      | W=,94770, p=0,0000    |
| <b>EURPLN</b> | d=,07337, p<,01    | p<,01      | W=,93416, p=0,0000    |
| <b>EURRON</b> | d=,09079, p<,01    | p<,01      | W=,93721, p=0,0000    |
| <b>EURRSD</b> | d=,10229, p<,01    | p<,01      | W=,88977, p=0,0000    |
| <b>EURSEK</b> | d=,05368, p<,01    | p<,01      | W=,96200, p=0,0000    |
| <b>EURUSD</b> | d=,04690, p<,01    | p<,01      | W=,98067, p=0,0000    |

Source: Author's calculations, Quandl data

The Kolmogorov-Smirnov test for normality is based on the maximum difference between the sample cumulative distribution and the hypothesized cumulative distribution. Since the d-statistics are significant, the hypotheses that the respective distributions are normal are rejected. Kolmogorov-Smirnov difference statistics based upon Lilliefors probabilities as well as the significant Shapiro-Wilk tests also suggest the need to reject the hypotheses of normality of the distributions.

Graph 4. visually represents the magnitude of shocks within each currency pair, calculated within 1, 3 and 5 years of previous data. It can be seen that the widest range of shocks can be found within EUR/CHF rates, with more than 40-sigma daily moves.

Graph 4. Box & Whisker plot of  $S_j\_EURX_{it}$



Is EUR/CHF similarly volatile as all the other rates, or is the variance of the Swiss Franc significantly different? In all instances the hypothesis of homogeneous variances should be rejected, with the exception of EUR/CHF vs. EUR/HRK which is expected due to the Kuna-Euro peg (Table 3.).

Table 3. Testing for homogeneity of variance of EUR/CHF vs other currencies

|                          | F-test | p - level | Levene F(1,df) | p - level | Brown-Forsythe F(1,df) | p - level |
|--------------------------|--------|-----------|----------------|-----------|------------------------|-----------|
| <b>EURCHF vs. EURCZK</b> | 1,170  | 0,000     | 46,952         | 0,000     | 47,667                 | 0,000     |
| <b>EURCHF vs. EURKK</b>  | 40,456 | 0,000     | 1015,054       | 0,000     | 1007,916               | 0,000     |
| <b>EURCHF vs. EURGBP</b> | 1,189  | 0,000     | 264,358        | 0,000     | 265,194                | 0,000     |
| <b>EURCHF vs. EURHRK</b> | 1,126  | 0,000     | 3,011          | 0,083     | 3,201                  | 0,074     |
| <b>EURCHF vs. EURHUF</b> | 1,541  | 0,000     | 279,159        | 0,000     | 279,265                | 0,000     |
| <b>EURCHF vs. EURISK</b> | 4,403  | 0,000     | 510,162        | 0,000     | 509,204                | 0,000     |
| <b>EURCHF vs. EURJPY</b> | 2,848  | 0,000     | 971,432        | 0,000     | 965,998                | 0,000     |
| <b>EURCHF vs. EURMK</b>  | 1,524  | 0,000     | 168,066        | 0,000     | 168,646                | 0,000     |
| <b>EURCHF vs. EURNOK</b> | 1,044  | 0,168     | 135,109        | 0,000     | 134,715                | 0,000     |
| <b>EURCHF vs. EURPLN</b> | 1,935  | 0,000     | 511,323        | 0,000     | 507,893                | 0,000     |
| <b>EURCHF vs. EURRON</b> | 1,643  | 0,000     | 368,499        | 0,000     | 364,988                | 0,000     |
| <b>EURCHF vs. EURUSD</b> | 2,049  | 0,000     | 353,340        | 0,000     | 353,417                | 0,000     |
| <b>EURCHF vs. EURSEK</b> | 1,186  | 0,000     | 96,486         | 0,000     | 97,399                 | 0,000     |
| <b>EURCHF vs. EURTRY</b> | 7,117  | 0,000     | 605,393        | 0,000     | 596,412                | 0,000     |
| <b>EURCHF vs. EURUSD</b> | 1,925  | 0,000     | 700,164        | 0,000     | 701,744                | 0,000     |

Source: Authors' calculation, Quandl data

After examination of Quandl data the similar (yet somewhat broadened) analysis was performed with the data from Croatian National Bank. Table 4. brings descriptive statistics for three rates where Kuna is the variable rate, while Table 5. shows the results of the normality tests. The outcomes are very similar to those obtained by using Quandl data: CHF/HRK rate is extremely leptokurtic, while neither of the rates could be considered as normally distributed.

Table 4. Descriptive statistics for  $X_t$ HRK rates

| 3-Jan-1997<br>to<br>31-Jan-2015 | Valid<br>N | Aritm.<br>mean | Median  | Min.    | Max.    | Range   | Std. dev. | Skewness | Kurtosis |
|---------------------------------|------------|----------------|---------|---------|---------|---------|-----------|----------|----------|
| <b>EURHRK</b>                   | 4542       | 0,003%         | 0,002%  | -0,880% | 1,005%  | 1,885%  | 0,135%    | 0,072    | 3,449    |
| <b>USDHRK</b>                   | 4542       | 0,007%         | -0,007% | -3,442% | 3,651%  | 7,093%  | 0,658%    | 0,058    | 1,549    |
| <b>CHFHRK</b>                   | 4542       | 0,014%         | 0,006%  | -7,243% | 15,720% | 22,963% | 0,468%    | 7,546    | 297,650  |

Source: Author's calculations, CNB data

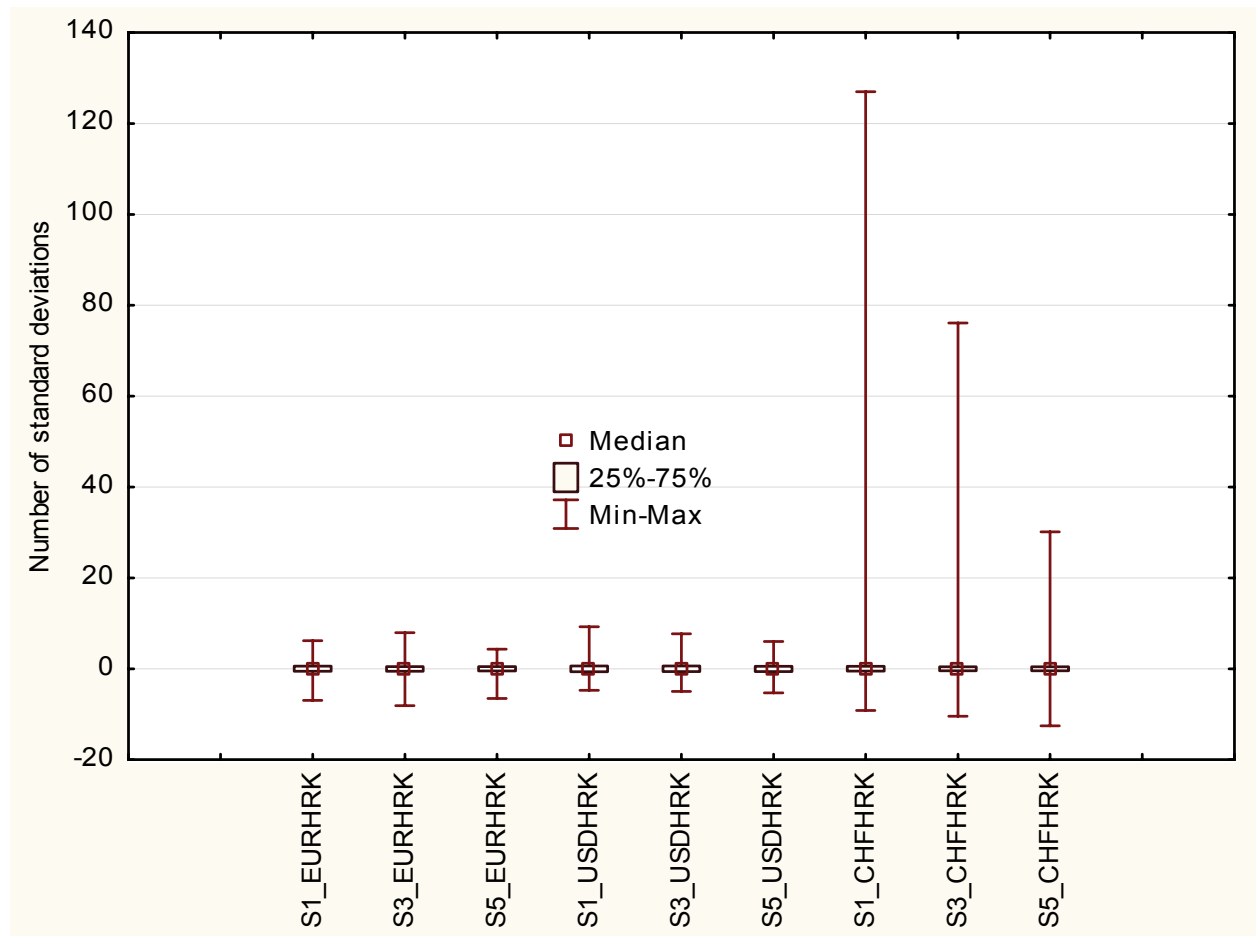
Table 5. Normality tests for  $X_t$ HRK rates

|               | <b>Kolmogorov-Smirnov</b> | <b>Lilliefors</b> | <b>Shapiro-Wilk's W test</b> |
|---------------|---------------------------|-------------------|------------------------------|
| <b>EURHRK</b> | d=,0601, p<,01            | p<,01             | W=,9643, p=0,0000            |
| <b>USDHRK</b> | d=,0278, p<,01            | p<,01             | W=,9884, p=0,0000            |
| <b>CHFHRK</b> | d=,1304, p<,01            | p<,01             | W=,6689, p=0,0000            |

Source: Author's calculations, CNB data

Graph 5. shows that there is a much wider range of shocks in the daily exchange rate of the Swiss Franc when compared to Dollar and Euro (all versus Kuna). As expected, the range of shocks is higher when the standard deviation was calculated using only one previous year of data. This illustrates the cap policy implemented by Swiss Central Bank in the previous period, which disallowed large oscillations and made subsequent shocks wider in terms of standard deviations.

Graph 5. Box & Whisker plot of  $Sj\_X_{it}HRK$



CHF/HRK rate is significantly more volatile than EURHRK or USDHRK, which indicates that Croatian credit-takers in francs are subject to a higher risk than those indebted in euros or dollars<sup>11</sup> (Table 6.).

Table 6. Testing for homogeneity of variance of CHF/HRK vs EUR/HRK and USD/HRK

|                          | F-test | p - level | Levene<br>F(1,df) | p - level | Brown-Forsythe<br>F(1,df) | p - level |
|--------------------------|--------|-----------|-------------------|-----------|---------------------------|-----------|
| <b>CHFHRK vs. EURHRK</b> | 12,030 | 0,000     | 720,027           | 0,000     | 718,712                   | 0,000     |
| <b>CHFHRK vs. USDHRK</b> | 1,977  | 0,000     | 790,877           | 0,000     | 789,819                   | 0,000     |

Source: Authors' calculation, CNB data

Using Augmented Dickey-Fuller unit root test (Table 7.) we cannot reject the hypotheses of non-stationarity of the exchange rates on “raw” input (data level) when examining CHF/HRK and USD/HRK rates. It is important, therefore, to notice that the variance and mean of CHF/HRK and USD/HRK rates are non-stationary, meaning that they change over time and do follow (unobserved) trends. This implies that extreme shocks to CHFHRK rate (as presented in Table 8.) sometimes send it into different, altered “orbit” around whom it afterwards fluctuates, suggesting that these shocks are not one-time idiosyncratic events, but sometimes indicate substantial, fundamental shifts.

<sup>11</sup> Credit arrangements in USD are very rare in Croatia.

Table 7. Augmented Dickey-Fuller unit root tests on daily nominal CHF/HRK, EUR/HRK and USD/HRK rates

|        | t-stat | p-level |
|--------|--------|---------|
| CHFHRK | 0,55   | 0,99    |
| USDHRK | -1,42  | 0,57    |
| EURHRK | -2,97  | 0,04    |

Source: Authors' calculation, CNB data

If we observe the amplitude of extreme events within all the data examined in this paper and sort them by rank (Table 8.), it can be seen that the most radical of them are attributed to Swiss Franc moves (especially CHF/HRK).

Table 8. Extreme shocks of  $S_j \text{ EUR}X_{it}$  and  $S_j \text{ X}_{it}\text{HRK}$  rates

| Largest positive shocks |               |                  | Largest negative shocks |               |                  |
|-------------------------|---------------|------------------|-------------------------|---------------|------------------|
| Rank                    | Rate          | No. of std. dev. | Rank                    | Rate          | No. of std. dev. |
| 1                       | S1_CHFHRK_CNB | 126,99           | 1                       | S1_EURCHF     | -45,78           |
| 2                       | S3_CHFHRK_CNB | 76,11            | 2                       | S5_EURCHF     | -27,38           |
| 3                       | S5_CHFHRK_CNB | 30,16            | 3                       | S1_EURDKK     | -27,22           |
| 4                       | S5_EURISK     | 21,34            | 4                       | S3_EURCHF     | -26,43           |
| 5                       | S3_EURDKK     | 18,84            | 5                       | S3_EURDKK     | -13,51           |
| 6                       | S1_EURHUF     | 17,96            | 6                       | S5_EURISK     | -12,77           |
| 7                       | S5_EURDKK     | 17,74            | 7                       | S5_CHFHRK_CNB | -12,53           |
| 8                       | S3_EURISK     | 17,49            | 8                       | S3_EURISK     | -10,57           |
| 9                       | S1_EURDKK     | 16,46            | 9                       | S1_EURISK     | -10,49           |
| 10                      | S1_EURHRK     | 14,59            | 10                      | S3_CHFHRK_CNB | -10,45           |

Source: Authors' calculation, Quandl and CNB data

If one would assume that daily changes in foreign exchange currency are normally distributed, then the probabilities of  $k$ -sigma events are given in Table 9.

Table 9. Probabilities of  $k$ -sigma events

| $k$ | Probability in any given day      | Expected occurrence                        |
|-----|-----------------------------------|--------------------------------------------|
| 3   | 0,135%                            | Once in 740,8 days                         |
| 4   | 0,00317%                          | Once in 31,574 days (126 years)            |
| 5   | 0,0000287%                        | Once in 13,954 years                       |
| 6   | 0,0000001%                        | Once in 4,054,379 years                    |
| 7   | 0,00000000013%                    | Once in 3,125,329,374 years                |
| 8   | $6,22165 \times 10^{-14}\%$       | Once in $6,4291626 \times 10^{12}$ * years |
| 9   | $1,12865 \times 10^{-17}\%$       | Once in $3,544057 \times 10^{16}$ years    |
| 10  | $7,62008 \times 10^{-22}\%$       | Once in $5,249289 \times 10^{18}$ years    |
| 20  | $2,75636 \times 10^{-87}\%$       | Once in $1,451189 \times 10^{84}$ ** years |
| 50  | $1,0805979 \times 10^{-543}\%$    | Once in $3,7016544 \times 10^{540}$ years  |
| 75  | $1,873015 \times 10^{-1222}\%$    | Once in $2,1355941 \times 10^{1221}$ years |
| 100 | $1,344179 \times 10^{-2172}\%$    | Once in $2,9757941 \times 10^{2169}$ years |
| 127 | $1,346573656 \times 10^{-3503}\%$ | Once in $2,9705022 \times 10^{3500}$ years |

\* This number is roughly 21 times larger than the number of stars in our galaxy  
 \*\* This number is roughly 15.000 times larger than the number of atoms in the visible universe

Source: Author's calculation based upon Dowd et al. (2011)

The frequency of extremely rare events (Table 9.), namely shocks in daily currency exchange rates, when compared to realized, historical shocks (Table 8.) is striking. Even after abandoning the normal distribution and employing extreme value probability distribution function, after calculating location and scale parameters ( $\alpha=-0.00221647$ ,  $\beta=0.01105763$ ), the 15,179% shock in the EUR/CHF rate in January 2015 is expected to occur once in 40,7 billion years (to be more precise once in 40.749.049.019,06 years, which amounts to probability of  $9,81618 \cdot 10^{-12}\%$  in a day). This fits well into the “extraordinary circumstances” condition.

In order to compare the daily frequency of the data with monthly frequencies (arithmetic mean of the exchange rate from the past month) t-tests for dependent samples were computed.

Table 10. T-test for Dependent Samples

|                            | Mean  | Std. dev. | Diff.  | Std.Dv. - Diff. | t      | p-level |
|----------------------------|-------|-----------|--------|-----------------|--------|---------|
| <b>Monthly avg. EURHRK</b> | 7,409 | 0,186     |        |                 |        |         |
| <b>Daily EURHRK</b>        | 7,411 | 0,187     | -0,003 | 0,043           | -3,984 | 0,000   |
| <b>Monthly avg. USDHRK</b> | 6,246 | 1,028     |        |                 |        |         |
| <b>Daily USDHRK</b>        | 6,249 | 1,033     | -0,003 | 0,132           | -1,286 | 0,198   |
| <b>Monthly avg. CHFHRK</b> | 5,084 | 0,644     |        |                 |        |         |
| <b>Daily CHFHRK</b>        | 5,094 | 0,656     | -0,010 | 0,082           | -8,197 | 0,000   |

Source: Author's calculation

Table 10. shows that there is a significant difference between monthly average and daily exchange rate of the EUR/HRK and CHF/HRK rates. Still, since the data violates the assumption of normality these results could be put in question. Hence, nonparametric methods were applied, as they do not rely on the estimation of parameters describing the distribution of the variables. The Sign test is a nonparametric alternative to the t-test for dependent samples<sup>12</sup>. Another nonparametric alternative is the Wilcoxon matched pairs test<sup>13</sup>. Their results are given in Table 11.

Table 11. Nonparametric Tests

|                                               | Wilcoxon Matched Pairs |       |         | Sign      |       |         |
|-----------------------------------------------|------------------------|-------|---------|-----------|-------|---------|
|                                               | T                      | z     | p-level | % - v < V | z     | p-level |
| <b>Monthly avg. EURHRK &amp; daily EURHRK</b> | 4828807                | 2,992 | 0,003   | 52,149    | 2,873 | 0,004   |
| <b>Monthly avg. USDHRK &amp; daily USDHRK</b> | 4977656                | 1,291 | 0,197   | 50,266    | 0,342 | 0,732   |
| <b>Monthly avg. CHFHRK &amp; daily CHFHRK</b> | 4535144                | 6,348 | 0,000   | 51,817    | 2,427 | 0,015   |

Source: Author's calculation

Since both standard and non-parametric tests show significant difference between monthly and daily frequencies of the exchange rates<sup>14</sup>, and given all the previous tests, it could be stated that the debt repayment mechanism in Croatia is prone to overreactions. It obliges credit-takers to repay their debt in monthly instalments where the amount is calculated by using daily exchange rate on the day of the payment, but the daily moves in the exchange rates are shown to be most often non-normal, with

<sup>12</sup> The only assumption required by this test is that the underlying distribution of the variable of interest is continuous; no assumptions about the nature or shape of the underlying distribution are required. The test simply computes the number of times (across dates) that the value of the monthly rate (A) is larger than that of the daily rate (B). Under the null hypothesis (stating that the two variables are not different from each other) we expect this to be the case about 50% of the time. Based on the binomial distribution we can compute a z value for the observed number of cases where  $A > B$ , and compute the associated tail probability for that z value.

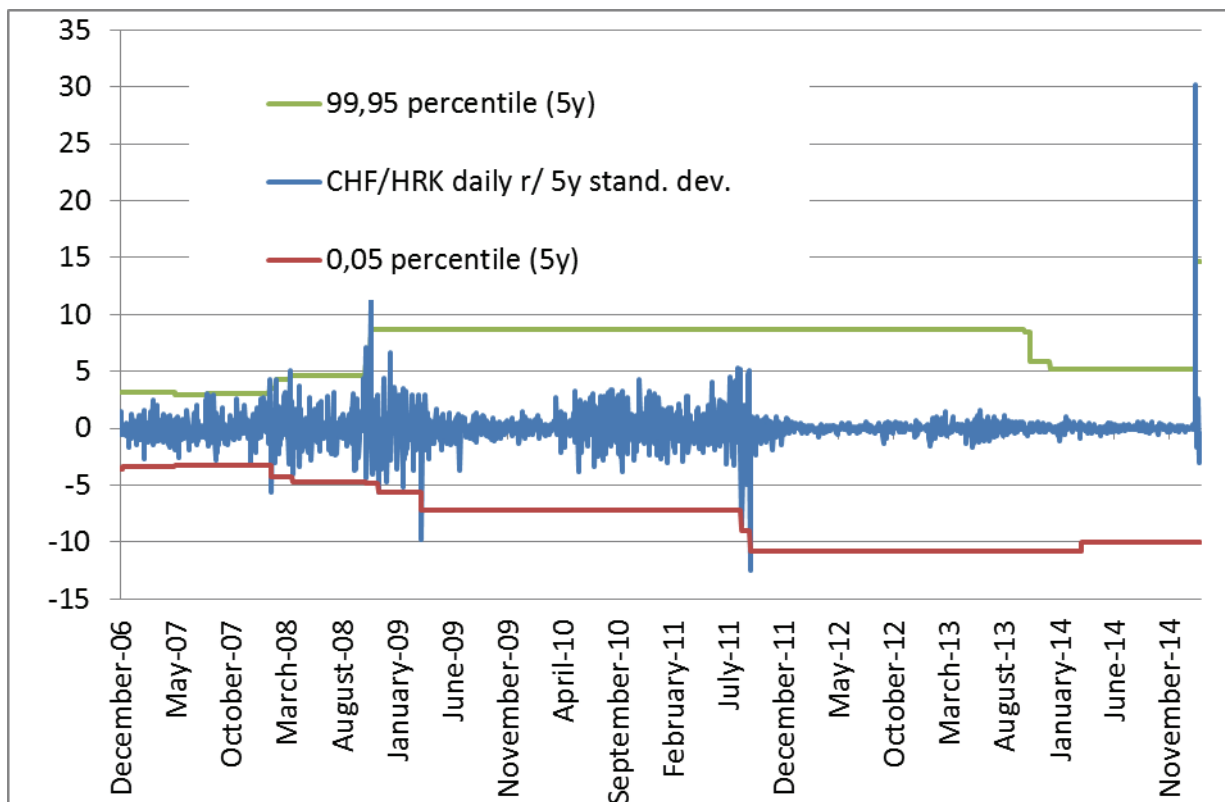
<sup>13</sup> The procedure assumes that the rates were measured on a scale that allows the rank ordering of observations and that allows rank ordering of the differences between frequencies of rates. Thus, the required assumptions for this test are more stringent than those for the Sign test. However, if they are met, that is, if the magnitudes of differences contain meaningful information, then this test is more powerful than the Sign test.

<sup>14</sup> Except for USD/HRK, but (as stated before) the amount of loans in Croatia denominated in USD is very small.

extremely large variances. Therefore, more equitable method would be to calculate the monthly payment by using the average exchange rate in the past month, as the monthly average rates exhibit lower volatility.

In the pursuit of identifying the most extreme events which could be regarded as extraordinary circumstances, another non-parametric method was used.  $S5\_CHFHRK_{it}$  shocks were plotted with upper and lower 0,05 percentile 5-year historical bands. On Graph 6. the vertical axis represents the magnitude of oscillations in the CHF/HRK rate measured by the rate of daily return to the 5-year moving standard deviation, including 99,9% of the shocks within the upper and lower band. The bands are also time-varying, based upon the latest 5 years. This is a scheme very similar to Value-at-Risk historical method. It can be seen that there are breaches of the bands, which could indicate exceptional incidents. However, it could be seen that the bands are linear which somewhat oversimplifies the nature of the rate movements.

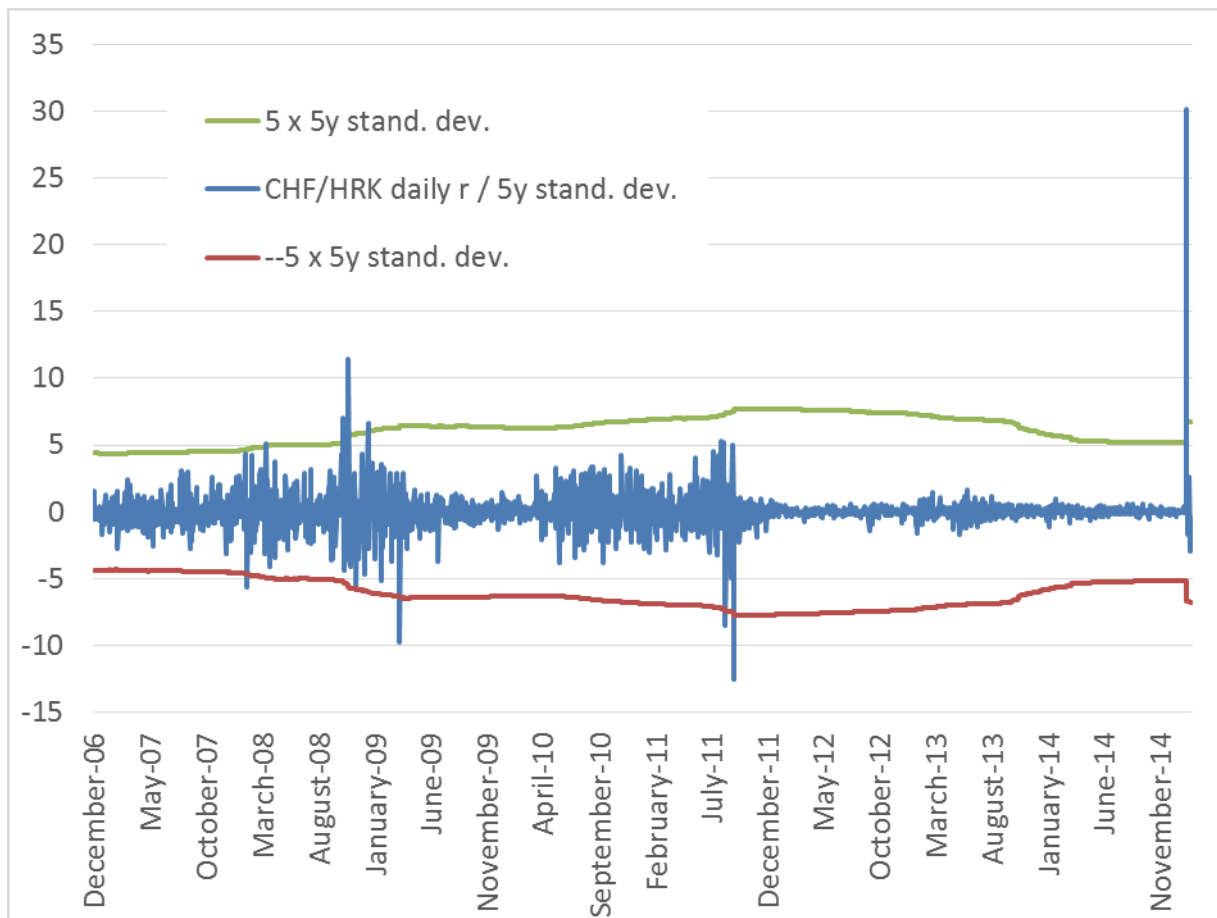
Graph 6. Daily shocks of CHF/HRK excluding top and bottom 0,1 percentiles



Source: Author's calculation, CNB data

Lastly, for the purpose of defining extraordinary events in the CHF/HRK exchange rate movements we propose computing moving standard deviation of  $S5\_CHFHRK_{it}$  shocks for preceding 5 year period as a measure of “volatility of volatility” (second order standard deviation), as stated in the Equation 7. This framework allows us to employ historical distributions of shocks. Afterwards we construct a range of  $+5/-5$  second order deviations, i.e. limits of 10 (total) second order deviations within which we assume non-extraordinary movements of currency exchange. Without the stationarity (Table 7.) breaching these limits could be considered as fundamental changes.

Graph 7. Daily shocks of CHF/HRK within second order standard deviations

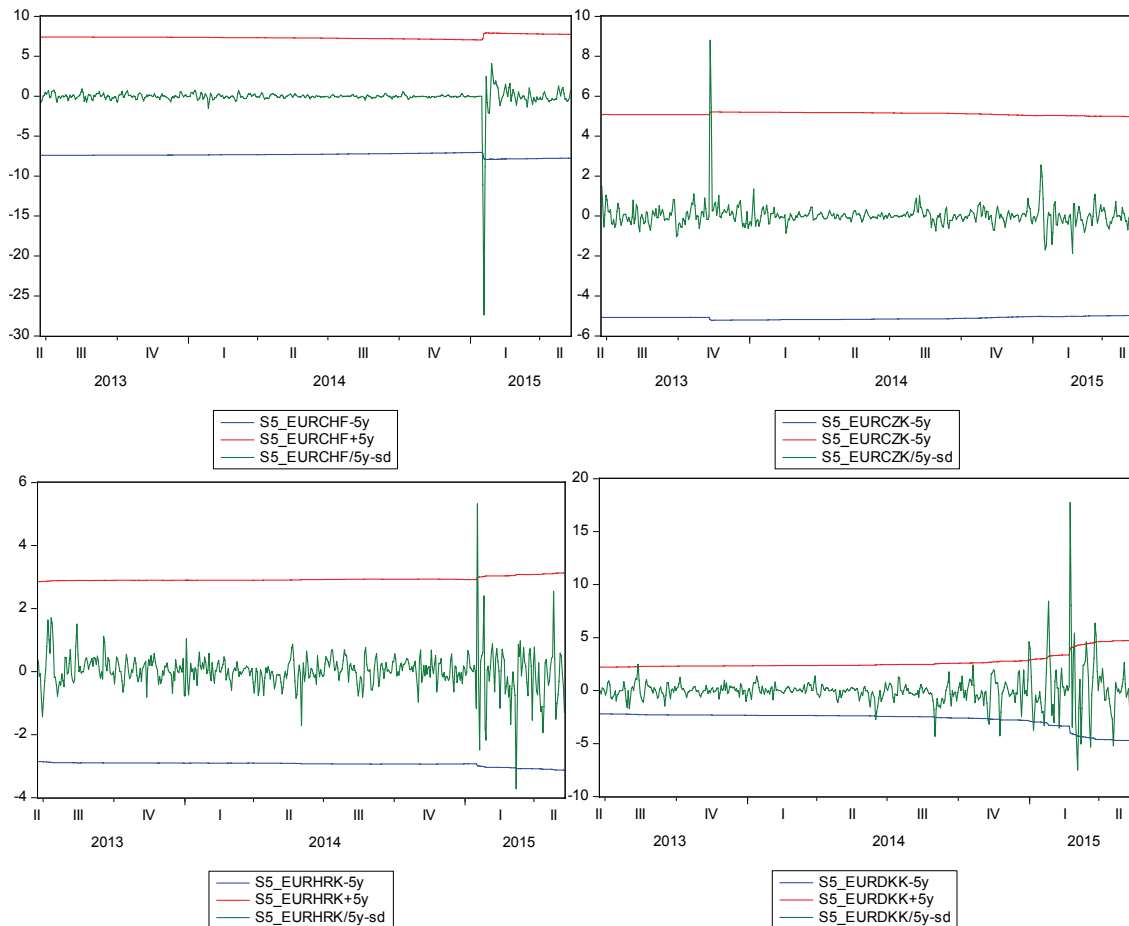


Source: Author's calculation, CNB data

When applying the above mentioned methodology (Eq. 7.) to other European rates, most of them do not exhibit extraordinary events, i.e. there are no breaches of the bands. Exceptions are Swiss Franc, Czech Koruna, Croatian Kuna, and Danish Krone (Graph 8.).



Graph 8. Daily shocks of EUR/CHF, EUR/CZK, EUR/HRK, and EUR/DKK within second order standard deviations



Source: Author's calculation, Quandl data

## 5 Conclusions

Extreme events in currency exchange rates happen much more often than one would usually expect. We presume that movements in currency exchange rate can be considered abnormal, i. e. fundamentally changed or extraordinary above certain threshold, and that crossing that threshold can be used as a trigger. All the methods used in this paper, regardless of their assumptions, indicate that the extreme events of 2011. and 2015. in CHF/HRK rates are way beyond reasonable expectations and could therefore be considered as extraordinary circumstances. Consequently, *Rebus Sic Stantibus* clause could be put in motion.

The lack of mean reversion in the CHF/HRK rates observed in the unit root test indicates that the debtors with loans linked to Swiss Francs in Croatia now have obligations at significantly altered heights, considerably different than those agreed upon when entering into contracts. However, they knowingly and wilfully consented to variable (non-fixed) rates, meaning that they accepted the uncertainty and currency exchange risks. Uncertainty about the future cannot be reduced (only hedged up to certain point).

On the other hand, consenting to “simple”, usual uncertainty about the future does not imply passively accepting the total spectrum of possible outcomes, as Rebus Sic Stantibus clause establishes. When scrutinizing CHF/HRK rates the orders of magnitude of shocks are beyond every possible level of imagination. The extreme events that happened are at the very edge of “possible” and go beyond common description of “black swan” events. In the light of these extraordinary events the demands of the debtors to renegotiate and reprogram their loans seem justifiable and valid.

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