Conventional and unconventional balance sheet practices and their impact on currency stability

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Abstract: The principal objective of this study is to examine the different policy implications of balance sheet expansion and the impact on currency stability on a monthly basis. Balance sheets can evolve due to conventional and unconventional monetary practices, generally through foreign exchange reserve policies or by qualitative and quantitative easing. Monetary policy instruments are measured by different balance sheet ratios. Currency stability is captured by two methods, one focuses on monthly number of extreme currency fluctuations through the contravention of normal distribution at tails, and another utilises conditional volatility. The sample contains seven European central banks between 2006 and 2014: one manages a key currency, four has a safe haven currency while two of them are considered as an emerging currency. The key currency issuer central bank presented a significant interaction between its balance sheet ratios and currency stability only, where monetary expansion calmed its currency market.

Keywords: central bank balance sheet; monetary expansion; extreme currency fluctuation.


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1 Introduction

This paper focuses on the problem of the influence of central bank balance sheets on currency stability. Traditionally short-term key policy rates are considered as a monetary policy instrument with an influence on foreign exchange (FX) rates (Ball, 1999). However, it loses most of its power under zero lower bound (ZLB). Non-standard (or unconventional) policy measures such as monetary easing (purchases of government and corporate bonds) and liquidity provision (in domestic or foreign currencies, with longer maturities or widened list of acceptable collaterals) are focusing on the support of funding conditions for the banking system and economic agents (Fiordelisi et al., 2014).

The main problem is the unknown relationship between the above-mentioned unconventional steps and the FX markets. Are they calmed down or their turbulent behaviour will become even more erratic? Bagus and Howden (2009) supports the later idea when they raise the concept that “the quality of money depends on central bank balance sheets” in light of quantitative and qualitative monetary easing. Furthermore, they connect this concept with central bank credibility, suggesting that the “quality of a central bank’s reserve assets represent the credibility of communicated policies [of price stability]” (Bagus and Howden, 2009, p.61). However, this study suggests the opposite: an efficient liquidity management under unconventional practices can isolate domestic financial sector to meet its demand to the limited supply of funds on the international markets. The by-product of these practices can be the decreasing number of extreme currency fluctuations or reduced conditional volatility. The paper applies key definitions of calm market and balance sheet activities.

The main added value of this study is to show that balance sheet practices are unrelated to extreme currency fluctuations because they occur at different times. This hypothesis was tested via two vector autoregression (VAR) models with \(i = 1\) lags of only \(m\) monthly number of extreme fluctuations \(NoX_m\) as the null hypothesis, and the monthly number of extreme fluctuations enhanced with additional balance sheet \(BS_m\) information as the alternative hypothesis (1) and the same procedure on \(\sigma\) conditional variances (2). Main objectives of current paper are to identify the nature of interactions between them. Two regressions were formulated to capture this interaction:

\[
\Delta \sigma_t = \alpha \Delta \sigma_{t-1} + \beta \Delta BS_{t-1} + \varepsilon_t \\
\Delta NoX_t = \gamma \Delta NoX_{t-1} + \delta \Delta BS_{t-1} + \eta_t.
\]

Equations (1) and (2) formulated the main research question: is \(\Delta BS_{t-1}\) significant? Which BS components (such as lending, security purchases, FX reserve accumulation, leverage, non-transparency, etc.) were proved to be significant? A negative \(\beta\) or \(\delta\) coefficient supports the idea of markets were calmed by unconventional measures, while positive coefficients would reinforce increased turbulence. Tests were made on monthly basis (monthly balance sheet data, number of extreme daily currency fluctuations and conditional volatility) due to the availability of central banking data.

Assuming that the European central bank (ECB) affects the risk premiums of all other European economic area (EEA) member central banks (due to their relatively small and open economies, which limits the degree of their monetary autonomy), the need for accommodative decisions should raise further uncertainties in currency pricing. The main added value of this study is to evaluate how unconventional balance sheet actions are
connected to extreme currency fluctuations. These results are important for individual and institutional investors or from corporate risk management point of view because they suggest the key points when they have to pay attention currency fluctuation by using balance sheet data as an indicator. For another central bank, this approach makes spillover effects more understandable. Literature focused on exchange rates mostly from the pegging point of view or considered currency changes as an automatism of interest rate differentials or analysed asset market and monetary policy interactions regardless of FX markets – but the actual question of unconventional practices to currency stability is missing.

This paper is structured as follows: Section 2 summarises the theoretical background of balance sheet expansion, while Section 3 introduces a model to describe currency fluctuations. Section 4 presents recent developments in monetary policies according to an examination of central bank balance sheets, press releases, and annual reports, summarises data and the methodological background for extreme returns, and the last section includes the results and discussion.

2 Theoretical background of balance sheet expansion and currency stability

This section summarises recent literature on central bank balance sheets, unconventional measures and FX rates. The ultimate objective of monetary policy is to indirectly influence target agent activity in a market economy through central bank instruments. Menkhoff (1997) divides these operations into the following activity components: balance of payments (FX operations or capital control decisions about minimum reserves), open market (security purchases), refinancing (covered lending) and fiscal (government security operations). Price stability is defined as a primary objective for the monetary policy in the European Union, and without prejudice to the objective of price stability economic growth and full employment is supported.

Central bank assets are interest-bearing instruments supported by liabilities. Thus, the monetary authority operates as a private market intermediary with large numbers of counterparties who are subject to reserve requirements and fulfil collateral eligibility criteria (Champ et al., 2011; Issing et al., 2001). The choice of the counterparties determines the crisis management needed: a bank-lending based economy calls for reactivation after a sudden stop in funding liquidity, whereas counterparties can be by-passed in a capital-market-based environment to maintain external financing (Lenza et al., 2010). The quality of the central bank’s assets is related to their intentions to manage markets via collateral policy or open market operations, with an impact on the quality of the liabilities (especially money) from an accounting perspective (Bagus and Howden, 2009; Caruana, 2012).

Balance sheet expansion can have many reasons behind it. Foreign reserves can be increased alone via discrete programs of accumulation (for example, to meet the Guidotti–Greenspan rule or due to FX anchor-driven currency intervention) or devaluation of a national currency. Quantitative easing is a broader expansion of a central bank’s balance sheet and monetary base, without altering the composition of high-quality conventional assets (Lenza et al., 2010). Thus, the expansion is not reduced to reserves only. A non-standard (unconventional) measure like this is used when key policy interest rate hits zero, and the traditional instrument of the central bank loses much of its
Conventional and unconventional balance sheet practices

stimulating power under deflation (Farmer, 2013; Bagus and Schiml, 2009). At such a
time, the environment can no longer be influenced solely by the level of a very short-term
interest rate (Lenza et al., 2010). The central bank balance sheet expansion under
quantitative easing helps to reduce the risk premiums5 of high-quality assets by
increasing their prices (Shirai, 2014). This action also meets Bank of International
Settlement requirements to maintain financing liquidity6 during turbulent times
(BIS, 2011) – even in a different currency! For qualitative easing the bank acquires
lower-quality assets to stabilise a market or to bail out an insolvent and illiquid banking
system (Lenza et al., 2010; Bagus and Schiml, 2009) while keeping its balance sheet size
the same. The intent of these measures can be different: a focus on the re-establishment
and enhancement of transmission channels, such as money market spreads and longer
risk premium maturities; or the exploiting of neglected transmission channels, such as
corporate papers and bonds, ETFs, and Real Estate Investment Trust papers, as happened
in Japan (Lenza et al., 2010; Shirai, 2014; Bagus and Schiml, 2009). Financial stability
can be supported via a liquidity provision to funding in domestic and foreign currencies,
whereas macroeconomic stability can be maintained through bond purchases, large-scale
FX interventions, and credit provisions in the private sector, as Stone et al. (2011)
suggest. Central banks’ asset holdings are losing their irrelevance under unusual financial
distress when active credit policy will have substantial benefits (Cúrdia and Woodford,
2011).

Recent literature about the monetary policy – currency market interactions has
focused largely on the subject of direct and indirect interventions, when exchange rate
fluctuation was only a by-product of the interest rate differentials, exchange rate pressure
(Stavárek, 2010) or an input for IS as well as Phillips curves (Ball, 1999; Woodford,
2009; Batini et al., 2009; Gabrisch, 2016; Bouzgarrou and Chebbi, 2015). Monetary
policy spillover on asset prices was also quite popular, without regardless of currency
movements (Taguchi et al., 2015; Fiordelisi et al., 2014), or stating that the degree of
exchange rate stability depends on current account balance, gross national debt, foreign
trade or financial development (Aizenman et al., 2016). A significant amount of paper
considers the monetary policy as an external variable during currency market analysis, to
identify structural changes in the environment, like interactions among currencies rather
than on the impacts of unconventional balance sheet practices. Gray (2014) points to the
intensified co-movements since August 2007, while Tamakoshi and Hamori (2014) detail
the asymmetric responses in correlations with higher dependency during joint
appreciation periods of the US dollar (USD), the euro (EUR), the British pound (GBP)
and the Swiss franc (CHF). Stelios (2014) showed similar results for emerging markets,
where the BRIC (Brazil, Russia, India and China) countries have become more
internationally integrated after the US financial crisis. Asymmetric behaviour was in the
crosshairs of the study by Dimitriou and Kenourgios (2013), with the decrease in
exchange rate correlations during tumultuous periods. Chatratha et al. (2014) focused
more on the impact of news, analysing the US high-frequency data of the co-jump
statistics. Central Eastern European currencies responded to central bank verbal
interventions only during a crisis period, as Egert and Kočenda (2014) suggest, following
their research on macro data (CPI, PPI, GDP, CA, etc.). Interest and exchange rate
interactions at the ECB were analysed by Demir (2014) without deeper analysis of
monetary instruments.
3 Modelling currency fluctuations

This section introduces a theoretical model to capture the main assumptions behind currency fluctuations and how unconventional balance sheet practices can interfere. Openness has structural a footprint on the economy and monetary policy reactions (Lubik and Schorfheide, 2007). Can we say that unconventional measures are behaving like indirect currency interventions? Traditionally the following differentials are mentioned here: key policy rates, price levels, money supply, expectations, capital control or incomes (Madura, 2008). Unconventional balance sheet practices were emerging under deflation periods ($\pi < 0$), so it is possible to assume a functional relationship (3) between them:

$$\Delta BS_t = -\omega \pi_t,$$

where $-\omega$ represents the inverted relationship between the changes in unconventional balance sheet practices $\Delta BS_t$ in $t$th month due to the negative inflation.

Present study analyses a sample of central banks: one with key currency and some others with safe haven or emerging currencies. To understand the impact of unconventional balance sheet practices on FX rates, a two country example will be presented with an open small economy and a relatively closed (denoted with *) and a big one. Future FX rate changes ($\Delta s_{t+1}$) are the functions (4) of interest rate differentials and an exogenous shock ($\epsilon$):

$$\Delta s_{t+1} = \vartheta(r_t - r^*_t) + \epsilon_{t+1}.$$  

While domestic and foreign inflation rates, as well as output-gap ($y$) differentials, can be described through the following way (5):

$$\pi_t = \pi^*_t + \lambda \text{ and } y_t = y^*_t + k.$$  

Short-term nominal interest rates in an open small economy can be described with a modified Taylor-rule (6), where FX rate changes are involved next to the traditional components of the inflation, output-gap and an $\eta_t$ exogenous monetary shock (Lansing and Ma, 2016):

$$r_t = \theta r^*_{t-1} + (1 - \theta)\{\delta_\omega \pi_t + \delta_y y_t + \delta_{\Delta s_t}\} + \eta_t.$$  

Short-term nominal interest rates in a relatively closed and big economy (with a key currency) are captured with an ordinary Taylor-rule (7):

$$r^*_t = \theta r^*_{t-1} + (1 - \theta)\{\delta_\omega \pi^*_t + \delta_y y^*_t\} + \eta^*_t.$$  

Considering a $\theta = 0$ case, subtracting equations (6) from (7) yields the following expression for the cross-country (small to key currency issuer) interest rate differential (8):

$$r_t - r^*_t = \delta_\omega \pi_t - \delta_\omega \pi^*_t + \delta_y y_t - \delta_y y^*_t + \delta_{\Delta s_t} + \eta_t - \eta^*_t.$$  

Utilising (5) equations, the (8) expression can be simplified equation (9)

$$r_t - r^*_t = \delta_\omega l + \delta_y k + \delta_{\Delta s_t} + \eta_t - \eta^*_t.$$
Therefore, equation (3) can be rewritten as follows (9):

$$
\Delta s_{t+1} = \theta(\delta_s l + \delta_s k + \delta_s \Delta s_t + \eta_t - \eta_t') + \epsilon_{t+1}.
$$

(9)

Foreign exchange rate changes are the functions (9) of asymmetric demand shocks, under weak price level \((l < 0)\) or growth \((k < 0)\) differences. The currency is not changing until exogenous monetary shocks can compensate price level and output differences (10):

$$
\delta_s l + \delta_s k = \delta_s \Delta s_t + \eta_t - \eta_t'.
$$

(10)

Let us assume the development of a crisis process within upper two-country model (without any exogenous monetary shocks), when during the first step the key currency area falls into deflation \(\pi_t' = 0\) and recession \(y_t' < 0\), and the open small economy will follow it with a lag. In the second step, there is no difference in the inflation or output growth while there is a recovery in the key currency area in the third step.

**Step 1.** \(l < 0\) and \(k < 0\), so \(\delta_s \Delta s_t < 0\), key currency will be depreciating against the small one.

**Step 2.** \(l = 0\) and \(k = 0\), so \(\delta_s \Delta s_t = 0\), key currency will be stable.

**Step 3.** \(l > 0\) and \(k > 0\), so \(\delta_s \Delta s_t > 0\), key currency will be appreciating against the small one.

Steps 1–3 was described under the conventional monetary policy when short-run interest rates are effective instruments for policy-makers. However, under deep periods of deflation and recession, ZLB can be achieved. Unconventional balance sheet practices will emerge as equation (3) suggests, adding a secondary meaning to the inflation differential \(l\). It means that exchange rates can be influenced by \(\Delta B_S\) under Steps 1–3 assumptions. The main lessons of Step 1 and 3 are that currency turbulences occur at the beginning and at the end of crisis-related monetary policies as an automatism what can be balanced out by unconventional measurements, and not when the accommodative steps are taken!

### 4 Data and methodology

The next subsection introduces the sample, summarises the changes in balance sheets of sample central banks to identify changes in ratios and to give a more detailed list of monetary policy instruments. Later it presents the statistical properties of the currency dataset, evaluating market efficiency as well. Methods are presented in the last subsections to describe the procedures to calculate a monthly number of extreme fluctuations, GARCH-based conditional variance and VAR.

#### 4.1 Balance sheet data

This study analyses a sample of seven ECBs, to cover as many strategies as possible to identify balance sheet-currency interactions. The ECB issues the Euro as key currency, while four other central banks (such as Swiss, Sweden, Danish and Czech) issues a safe haven currency (which one is favoured under times of sovereign crises and therefore
suffers from appreciation under recessions in the key currency areas) and two central banks with emerging currencies (such as Hungarian and Polish). Later two countries were interesting due to their commitment towards FX lending in euro and Swiss franc to households and non-financial corporation’s (Wosko, 2016) – making their financial stability the function of currency developments. The dataset covers the period of 2006–2014 with daily currency and monthly balance sheet data.

According to the literature, currency exchange rates should react to changes in central bank asset quality. The following summarises recent changes over the last eight years, presenting a brief description of joint actions to engender FX liquidity, followed by a chronological description of policy changes to manage funding liquidity at longer maturities, in a market that is characterised by continent-wide, parent-subsidiary commercial bank networks (Heryán and Stárek, 2012). These changes were collected from central bank press releases and annual reports between 2006 and 2014. There was a significant difference among sample central banks in their communication about the introduction, modification and withdrawal of their instruments (see Table 1): the introduction of longer maturities and liquidity in FXs became a common tool for the ECB, Swiss and Sweden national banks.

### Table 1 Monetary instruments in central bank press releases

<table>
<thead>
<tr>
<th></th>
<th>Key interest rate</th>
<th>Maturity</th>
<th>FX liquidity</th>
<th>Swap and repo</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECB</td>
<td>25</td>
<td>25</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>Swiss</td>
<td>9</td>
<td>1</td>
<td>27</td>
<td>32</td>
</tr>
<tr>
<td>Sweden</td>
<td>36</td>
<td>111</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Czech</td>
<td>36</td>
<td>4</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Denmark</td>
<td>17</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hungary</td>
<td>52</td>
<td>5</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Poland</td>
<td>29</td>
<td>3</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>

*Source: ECB, Swiss, Sweden, Czech, Hungarian, Polish, and Danish National Banks*

However, the question of unconventional balance sheet-currency stability interaction remains unanswered. This paper uses six $R$ ratios to capture balance sheet developments ($BS_{ad}$). $R_{ed}$ equity-to-debt ratio, $R_{tr}$ transparency ratio and $R_{de}$ defence ratio represent risk awareness (Farmer, 2013; Lenza et al., 2010; Bagus and Howden, 2009), while $R_{l}$ lending-to-asset, $R_{s}$ securities-to-asset and $R_{e}$ asset expansion (total assets to their initial levels on January 2006) ratios represent easing preferences. The equity-to-debt ratio (leverage) measures how the central bank’s capital can cushion losses when rising interest rates lead to falling bond prices and early repayments to avoid negative equity and monetisation of these losses. Low transparency (increased share of ‘other’ assets and securities) increases concerns about whether the currency is backed by low quality (illiquid) assets. Thus, their overall weight in the balance sheet needs to be measured. The defence ratio captures the share of foreign reserves of total assets, representing the central bank’s commitment to meeting the credit rating requirements and its ability to meet partner banks’ foreign liquidity demands (Antal and Gereben, 2011). Lending-to-asset and securities-to-asset ratios depend on central bank preferences about funding liquidity management. Subsequently, the ratios will increase with the close to
constant asset expansion levels under qualitative easing. Whereas quantitative, or quantitative and qualitative, easing allows three of them to increase.

The central bank balance sheet ratios were studied between 2006 and 2014 in three intervals: pre-crisis, the subprime crisis and the euro crisis (see Table 2). The pre-crisis period, prior to the first reciprocal swap agreement (swap line) between the Banks of Canada, England, the ECB, the Swiss National Bank, the Bank of Japan and the Federal Reserve on 3 December 2007, was followed by numerous accommodative monetary decisions until June 2011 when the ECB started to react to the emerging sovereign crisis in the Eurozone. The current study examines seven different central banks and their own currencies during these timeframes; one group showed some signs of quantitative or qualitative easing (ECB, Swiss and Sweden National Banks), while the other group had foreign asset-focused balance sheets (Danish, Czech, Hungarian and Polish National Banks), as the defence-ratios suggest. Other assets were marginal – except for in the ECB – where they were above 10% after 2007 and reached 18% after 2011, reflecting marketable asset holdings without monetary policy purpose (i.e., securities denominated in Euros, which are held outright for investment purposes at their own risk). Lending activity became visible on a monthly basis only at the ECB during the entire time frame, while the Danish national bank was an active lender in the first two periods, and the Swedish national bank was active during the subprime-crisis interval. The dominance of FX reserves can increase bias this ratio, but the Czech and Polish lending activity were completely diminished over time. However, such lending increased in Hungary in the third phase. The stimulation of security markets by the ECB emerged even more in the second half of the crisis, while it remained constant in Denmark and Hungary and became negligible at the Swiss national bank. The leverage ratio reflects the shock-absorbing capability of a central bank. This ratio was negative for the Czech national bank and positive (but close to zero) for the ECB, and the Hungarian and Polish central banks. The ratios at the Swiss, Swedish and Danish national banks were remarkably robust.

Our study investigates how the quality of the assets of central banks relates to the quality of money – represented by pricing uncertainties. This subsection summarises the findings for three groups of central banks: one that applied some quantitative easing; and the other that focused on monetary easing at the early stages of the crisis, but later developed an FX reserve focus and the last one had an FX reserve preferences in the entire time set.

4.2 Currency data

Data for the three groups of central banks are obtained for the timeframe January 2006 to October 2014. Daily closing currency data from the Bloomberg database were analysed between 1 January, 2002 and 1 October, 2014, to apply some pre-crisis period study control.

Daily closing data of the euro (EUR), the Swiss franc (CHF), the Swedish krona (SEK), the Czech Koruna (CZK), the Danish Krone (DKK), the Hungarian Forint (HUF) and the Polish zloty (PLN) were tested with the US Dollar (USD) denomination between 1 January, 2002 and 1 October, 2014. Sample currencies appreciated until the first half of 2008 after a minor correction in 2005. The interval between 2008 and 2013 was a cycle of devaluation and appreciation, revealing market pricing uncertainty (Figure 1).
Logarithmic first differentials of sample currencies were stationary but mostly asymmetric (except for CZK/USD and DKK/USD) and suffered from high excess kurtosis (Table 3). Extreme changes in currency pricing are more common than they should be under the assumption of the normal distribution; normal distribution was clearly rejected for the entire dataset. Autocorrelation or heteroscedasticity did not characterise the data.

Table 2  Central bank balance sheet ratio averages (monthly data)

<table>
<thead>
<tr>
<th></th>
<th>Defence</th>
<th>Leverage</th>
<th>Transparency</th>
<th>Lending</th>
<th>Securities</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECB</td>
<td>13%</td>
<td>6%</td>
<td>1%</td>
<td>38%</td>
<td>8%</td>
<td>96%</td>
</tr>
<tr>
<td>Swiss</td>
<td>43%</td>
<td>127%</td>
<td>1%</td>
<td>0%</td>
<td>5%</td>
<td>59%</td>
</tr>
<tr>
<td>Sweden</td>
<td>85%</td>
<td>39%</td>
<td>2%</td>
<td>2%</td>
<td>0%</td>
<td>16%</td>
</tr>
<tr>
<td>Czech</td>
<td>95%</td>
<td>–13%</td>
<td>1%</td>
<td>2%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Denmark</td>
<td>52%</td>
<td>17%</td>
<td>1%</td>
<td>37%</td>
<td>10%</td>
<td>45%</td>
</tr>
<tr>
<td>Hungary</td>
<td>92%</td>
<td>4%</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
<td>8%</td>
</tr>
<tr>
<td>Poland</td>
<td>96%</td>
<td>2%</td>
<td>1%</td>
<td>2%</td>
<td>0%</td>
<td>5%</td>
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<th></th>
<th>Defence</th>
<th>Leverage</th>
<th>Transparency</th>
<th>Lending</th>
<th>Securities</th>
<th>Expansion</th>
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</thead>
<tbody>
<tr>
<td>ECB</td>
<td>10%</td>
<td>4%</td>
<td>11%</td>
<td>35%</td>
<td>16%</td>
<td>156%</td>
</tr>
<tr>
<td>Swiss</td>
<td>49%</td>
<td>50%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>98%</td>
</tr>
<tr>
<td>Sweden</td>
<td>61%</td>
<td>21%</td>
<td>1%</td>
<td>22%</td>
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</tr>
<tr>
<td>Czech</td>
<td>97%</td>
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<td>1%</td>
<td>1%</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>Denmark</td>
<td>64%</td>
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<td>1%</td>
<td>24%</td>
<td>6%</td>
<td>48%</td>
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<tr>
<td>Hungary</td>
<td>94%</td>
<td>4%</td>
<td>2%</td>
<td>1%</td>
<td>3%</td>
<td>11%</td>
</tr>
<tr>
<td>Poland</td>
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<td>3%</td>
<td>0%</td>
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<th>Lending</th>
<th>Securities</th>
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<td>ECB</td>
<td>10%</td>
<td>4%</td>
<td>18%</td>
<td>32%</td>
<td>24%</td>
<td>221%</td>
</tr>
<tr>
<td>Swiss</td>
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<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>65%</td>
</tr>
<tr>
<td>Sweden</td>
<td>87%</td>
<td>19%</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
<td>25%</td>
</tr>
<tr>
<td>Czech</td>
<td>98%</td>
<td>–9%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Denmark</td>
<td>88%</td>
<td>14%</td>
<td>0%</td>
<td>4%</td>
<td>6%</td>
<td>17%</td>
</tr>
<tr>
<td>Hungary</td>
<td>94%</td>
<td>6%</td>
<td>1%</td>
<td>3%</td>
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<td>15%</td>
</tr>
<tr>
<td>Poland</td>
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<td>0%</td>
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<td>0%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Source: ECB, Swiss, Sweden, Czech, Hungarian, Polish, and Danish National Banks

The sample currencies followed a floating exchange rate policy or fluctuated within an ±2.25% or ±15% broad band (such as Denmark as a ERM-II member and Hungary between 2001 and 2008), while upper limits were introduced to stop excess appreciation of the Swiss franc between 2011 and 2015, and to fight deflation of the Czech koruna in 2013 (IMF, 2013). Except for these cases, the central banks did not intervene directly to manage exchange rates; the list of indirect instruments was used to manage interest rate premiums, central bank balance sheet activity, EU fund transformations and FX swaps.
and repurchase agreements. This study uses various indicators to capture asset quality and describes the main changes in the latest monetary policies to evaluate currency pricing behaviours during turbulent time periods.

Figure 1  Developments of selected European currencies between 2002 and 2014 (1 January, 2000 = 100%) (see online version for colours)

Source: Bloomberg

4.3 Extreme fluctuations and conditional variance

Parametrical (statistical) and non-parametrical approaches are available as Jiawei and Micheline (2004) or Irad (2010) suggested detecting extreme values. Non-parametrical methods are the distance-based and deviation-based solutions. The first, statistical way assumes a distribution or probability model for the given dataset, assuming that majority of the dataset is a result of a normal distributed data generating process, while a smaller subset is a product of $G_1, \ldots, G_k$ distributions (Irad, 2010).

This paper considers one parametric approach, an analogue of quantile–quantile (QQ) plots. Temporary failures in efficient market theory could be pointed to as a good approximation to capture extreme currency fluctuations. Fama (1970) points to the problem of favourable distribution of returns; despite the theoretical elegance of normal distribution, the empirical data follows some fat-tailed distribution (page 399). Here, this idea is applied to choose an adequate method to capture extreme changes in currency rates, as a sign of market uncertainty about currency pricing. Under the assumption that market efficiency can be a temporary phenomenon, a set of market returns can be separated into two groups of normal ($r_n$) and extreme returns ($X$):

$$\mathbb{R} = \mathbb{N} \cup X.$$ (11)

Therefore, ‘normality’ can be defined as a lack of extreme returns. The statistical characteristics of $N$ subset have to converge to the idealistic $N\sim(0,1,0,3)$ case, where standardised returns have zero expected value, 1 standard deviation showing symmetry (skewness = 0), and extreme fluctuations die out fast due to exponent tails (kurtosis = 3).
Table 3 Descriptive statistics of currency log differentials

<table>
<thead>
<tr>
<th>Currency</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Normal distribution</th>
<th>Autocorrelation</th>
<th>Conditional heteroscedasticity</th>
<th>Unit root</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUR/USD</td>
<td>0.0001</td>
<td>0.0060</td>
<td>0.1279</td>
<td>5.3376</td>
<td>0.0000</td>
<td>0.8582</td>
<td>0.8752</td>
<td>0.0000</td>
</tr>
<tr>
<td>CHF/USD</td>
<td>0.0002</td>
<td>0.0068</td>
<td>-0.5118</td>
<td>14.7053</td>
<td>0.0000</td>
<td>0.2655</td>
<td>0.3442</td>
<td>0.0000</td>
</tr>
<tr>
<td>SEK/USD</td>
<td>0.0001</td>
<td>0.0078</td>
<td>0.2506</td>
<td>6.7777</td>
<td>0.0000</td>
<td>0.2328</td>
<td>0.4135</td>
<td>0.0000</td>
</tr>
<tr>
<td>CZK/USD</td>
<td>0.0001</td>
<td>0.0080</td>
<td>0.0033</td>
<td>6.8158</td>
<td>0.0000</td>
<td>0.3471</td>
<td>0.5302</td>
<td>0.0000</td>
</tr>
<tr>
<td>DKK/USD</td>
<td>0.0001</td>
<td>0.0062</td>
<td>0.0165</td>
<td>4.6254</td>
<td>0.0000</td>
<td>0.5958</td>
<td>0.7195</td>
<td>0.0000</td>
</tr>
<tr>
<td>HUF/USD</td>
<td>0.0000</td>
<td>0.0099</td>
<td>-0.3468</td>
<td>6.4052</td>
<td>0.0000</td>
<td>0.9039</td>
<td>0.9442</td>
<td>0.0000</td>
</tr>
<tr>
<td>PLN/USD</td>
<td>0.0001</td>
<td>0.0092</td>
<td>-0.1089</td>
<td>6.7951</td>
<td>0.0000</td>
<td>0.3415</td>
<td>0.6148</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

*Source:* Author calculation using Kevin Sheppard’s MFE toolbox for Matlab
Fat-tailed returns ($r_{fat}$) are computed by the difference on the tails between theoretical normal and empirical distribution, utilising the ‘S’-shaped form described by Gabaix et al. (2003) to see the difference between theoretical and empirical returns under $p_L$, low probability (12).

$$r_{fat,+p_L} \gg r_{normal,p_L} \quad \text{or} \quad r_{fat,-p_L} \ll r_{normal,p_L} \quad \text{where} \quad p_L \ll p_{E(r)}. \quad (12)$$

Conditional volatility ($\sigma$) can increase during turbulent times of pricing uncertainties what can be measured with a GARCH(1,1) model (13) of monthly currency data:

$$r_t = \sigma_t \cdot \varepsilon_t \quad \text{and} \quad \sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2,$$

where $\varepsilon_t$ is the normal distributed error-term and $\alpha + \beta < 1$ (Bollerslev, 1986).

### 4.4 Vector autoregression

Vector autoregressive (VAR) processes can describe the data generation process of a small set of time series variables, where all of them are treated as being a priori endogenous, and allowance is made for rich dynamics. This procedure captures the dynamic interactions for a set of $K$ time series variables $y_t = (y_{1t}, \ldots, y_{Kt})'$. The basic model of order $p$ VAR has the form of equation (14) (Lütkepohl and Kratzig, 2004).

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t. \quad (14)$$

where the $A_i$’s are $(K \times K)$ coefficient matrices and $u_t = (u_{1t}, \ldots, u_{Kt})'$ is an unobservable error term, assumed to be a zero-mean independent white noise process with a time-invariant, positive definite covariance matrix: $u_t \sim (0, E(u_t u_t'))$.

This study examines two setups of first-order VAR models. First, the number of extreme returns and monthly conditional variances will be regressed to themselves to see the significance of previous data in the model (15, 16):

$$\Delta \sigma_t = \alpha \Delta \sigma_{t-1} + \varepsilon_t \quad (15)$$

$$\Delta \sigma_t = \gamma \Delta \sigma_{t-1} + \eta_t \quad (16)$$

Secondly, balance sheet ratios ($R$) are involved as well to check the significance of their coefficients and the increase in coefficients of determination ($r^2$) as it was mentioned in the introduction (17, 18):

$$\Delta \sigma_t = \alpha \Delta \sigma_{t-1} + \beta \Delta B_{S,t-1} + \varepsilon_t \quad (17)$$

$$\Delta \sigma_t = \gamma \Delta \sigma_{t-1} + \delta \Delta B_{S,t-1} + \eta_t \quad (18)$$

### 5 Discussion of empirical results

To evaluate the interactions between unconventional balance sheet practices and currency pricing, the study tests the patterns of the appearance of extreme returns over time.
When monetary policy remains conventional, extreme returns should occur less often than unconventional periods. This section summarises some basic statistics of currencies and their volatilities and extreme returns. Subsequently, their properties are characterised under different monetary environments described previously.

5.1 Extreme currency fluctuation

Compared with the original descriptive statistics, the fat-tailed method provides a subset of normal returns (Table 4). The first moment (mean) remained around zero, while the second moment (standard deviation) decreased due to data reduction. This method is insensitive to the third moment, as a convergence to zero (symmetry) depends on luck. Fat tailedness is reduced; kurtosis is near 3. The number of extreme returns remains moderated; their overall weight remains under 8% of the sample.

Table 4 Extreme returns by fat tailed method

<table>
<thead>
<tr>
<th></th>
<th>EUR</th>
<th>CHF</th>
<th>SEK</th>
<th>CZK</th>
<th>DKK</th>
<th>HUF</th>
<th>PLN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean r(n)</td>
<td>0.0005</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0004</td>
<td>0.0005</td>
<td>0.0006</td>
<td>0.0006</td>
</tr>
<tr>
<td>Standard deviation r(n)</td>
<td>0.0045</td>
<td>0.0054</td>
<td>0.0059</td>
<td>0.0059</td>
<td>0.0048</td>
<td>0.0080</td>
<td>0.0068</td>
</tr>
<tr>
<td>Skewness r(n)</td>
<td>0.1495</td>
<td>0.0017</td>
<td>0.0317</td>
<td>0.0821</td>
<td>0.1291</td>
<td>0.0579</td>
<td>0.0443</td>
</tr>
<tr>
<td>Kurtosis r(n)</td>
<td>2.5980</td>
<td>2.6940</td>
<td>2.5670</td>
<td>2.7479</td>
<td>2.4595</td>
<td>2.5062</td>
<td>2.7277</td>
</tr>
<tr>
<td>X+ threshold</td>
<td>0.0119</td>
<td>0.0130</td>
<td>0.0153</td>
<td>0.0156</td>
<td>0.0121</td>
<td>0.0204</td>
<td>0.0188</td>
</tr>
<tr>
<td>X– threshold</td>
<td>-0.0092</td>
<td>-0.0133</td>
<td>-0.0135</td>
<td>-0.0137</td>
<td>-0.0096</td>
<td>-0.0171</td>
<td>-0.0154</td>
</tr>
<tr>
<td>No X+</td>
<td>86</td>
<td>102</td>
<td>85</td>
<td>90</td>
<td>87</td>
<td>65</td>
<td>71</td>
</tr>
<tr>
<td>No X–</td>
<td>201</td>
<td>77</td>
<td>134</td>
<td>137</td>
<td>189</td>
<td>135</td>
<td>152</td>
</tr>
<tr>
<td>No normal</td>
<td>3320</td>
<td>3321</td>
<td>3320</td>
<td>3320</td>
<td>3320</td>
<td>3320</td>
<td>3320</td>
</tr>
<tr>
<td>Elapsed time (s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.09</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author calculation

The objective here is to capture the effects of balance sheet expansion on extreme currency fluctuation. Table 5 compares pre- and post-balance sheet expansion phases from the aspect of fat-tailed returns. Expansive phases can be characterised by significant increases in extreme fluctuation with a focus on the subprime crisis. This test supports the initial hypothesis of the functional relationship between asset quality and money quality but proves only that the two phenomena happened in the same timeframe in the cases of ECB, SNB, SR, and MNB.

5.2 Conditional volatility

The GARCH (1,1) model fit was aimed at the extraction of conditional variances to cross-check our results for the monthly number of extreme fluctuations. The previous month’s volatility had a significant impact on the present month’s volatility in most cases, with a higher coefficient than 0.66, whereas innovations were less important (Table 6).
Table 5  Extreme returns before and after monetary expansion (Fat Tailed Method)

<table>
<thead>
<tr>
<th>Central bank</th>
<th>t-test</th>
<th>Inflexion point</th>
<th>Start of previous period</th>
<th>Inflexion date</th>
<th>End of next period</th>
<th>Share of extreme days Before (%)</th>
<th>After (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECB</td>
<td>1</td>
<td>2</td>
<td>20060303</td>
<td>20070903</td>
<td>20090303</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>SNB</td>
<td>1</td>
<td>2</td>
<td>20061003</td>
<td>20080303</td>
<td>20090501</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>SR</td>
<td>1</td>
<td>2</td>
<td>20061103</td>
<td>20071203</td>
<td>20090903</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>CNB</td>
<td>1</td>
<td>1</td>
<td>20090803</td>
<td>20101001</td>
<td>20141001</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>DNB</td>
<td>1</td>
<td>1</td>
<td>20020101</td>
<td>20060901</td>
<td>20070903</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>MNB</td>
<td>1</td>
<td>1</td>
<td>20020101</td>
<td>20070202</td>
<td>20090403</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>PNB</td>
<td>0</td>
<td>1</td>
<td>20020101</td>
<td>20060703</td>
<td>20091002</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

*: $H = 1$ signs significant difference between extreme return set of previous period and current one ($t$-test, $p = 0.05$), highlighted periods contained subprime crisis.

Source: Author calculation

Table 6  GARCH (1,1) coefficients – monthly data (2006–2014)

<table>
<thead>
<tr>
<th>EUR/USD</th>
<th>CHF/USD</th>
<th>SEK/USD</th>
<th>CZK/USD</th>
<th>DKK/USD</th>
<th>HUF/USD</th>
<th>PLN/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00*</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.12*</td>
<td>0.21</td>
<td>0.18</td>
<td>0.10</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.82**</td>
<td>0.74**</td>
<td>0.60</td>
<td>0.86**</td>
<td>0.78**</td>
<td>0.66**</td>
</tr>
</tbody>
</table>

*sign. at $p < 0.10$; **sign. at $p < 0.05$.

Source: Author calculation, UCSD toolbox

5.3 VAR to test extreme currency fluctuation and balance-sheet interactions

The number of monthly extreme currency fluctuations negatively related to each other in time, indicating that these glitches in pricing are short-term phenomena (Table 7). Balance sheet developments had a calming influence on currency fluctuations in general; the changes in different ratios, or in balance sheet overall size, decreased the number of extreme fluctuations. The Swiss National Bank was one exception, where reserve accumulation was driven by a dramatic franc appreciation, with a temporary intervention zone as a result. The Hungarian, Polish and Czech national banks followed a conservative monetary policy, where the majority of their assets were categorised as FX reserves. Therefore, their balance sheet sizes were influenced largely by currency fluctuations. The central banks of Sweden and Denmark were active in their lending activities only during the first phase of the crisis (2008–2010); later, they followed a CEE-like strategy but suffered from appreciation as in Switzerland and the Czech Republic. The ECB’s security purchase programs had a smoothing impact on the euro exchange rate pricing, while its balance sheet expansion was significant. The determination coefficient ($r^2$) was increased due to the additional balance sheet data.
### Table 7  Vector autoregression – monthly number of extreme currency fluctuations (1 lag)

<table>
<thead>
<tr>
<th>Entire</th>
<th>EUR/USD</th>
<th>CHF/USD</th>
<th>SEK/USD</th>
<th>CZK/USD</th>
<th>DKK/USD</th>
<th>HUF/USD</th>
<th>PLN/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^2$</td>
<td>0.22</td>
<td>0.19</td>
<td>0.16</td>
<td>0.03</td>
<td>0.11</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Monthly number of extreme fluctuation $(t-1)$</td>
<td>-0.46</td>
<td>-0.44</td>
<td>-0.39</td>
<td>-0.16</td>
<td>-0.34</td>
<td>-0.19</td>
<td>-0.18</td>
</tr>
<tr>
<td>Constant</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.38</td>
<td>0.24</td>
<td>0.24</td>
<td>0.06</td>
<td>0.14</td>
<td>0.07</td>
<td>0.12</td>
</tr>
<tr>
<td>Monthly number of Extreme fluctuation $(t-1)$</td>
<td>-0.43</td>
<td>0</td>
<td>-0.41</td>
<td>-0.13</td>
<td>0</td>
<td>-0.16</td>
<td>0</td>
</tr>
<tr>
<td>Reserves/Assets</td>
<td>-108.29</td>
<td>6.14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Equity/Assets</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.27</td>
<td>-12.49</td>
<td></td>
</tr>
<tr>
<td>Other/Assets</td>
<td>0</td>
<td>0</td>
<td>-111.99</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lending/Assets</td>
<td>0</td>
<td>-687.99</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Securities/Assets</td>
<td>-97.91</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Assets expansion</td>
<td>-10.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3.51</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Constant</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

Nonzero beta coefficients are significant at $p < 0.10.$

**Source:** Author calculation, JPL toolbox

### Table 8  Vector autoregression – monthly conditional variances (1 lag)

<table>
<thead>
<tr>
<th>Entire</th>
<th>EUR/USD</th>
<th>CHF/USD</th>
<th>SEK/USD</th>
<th>CZK/USD</th>
<th>DKK/USD</th>
<th>HUF/USD</th>
<th>PLN/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^2$</td>
<td>0.02</td>
<td>0.00</td>
<td>0.04</td>
<td>0.07</td>
<td>0.04</td>
<td>0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Conditional volatility $(t-1)$</td>
<td>0.00</td>
<td>0</td>
<td>-0.19</td>
<td>-0.27</td>
<td>-0.20</td>
<td>-0.29</td>
<td>-0.20</td>
</tr>
<tr>
<td>Constant</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.16</td>
<td>0.21</td>
<td>0.33</td>
<td>0.19</td>
<td>0.25</td>
<td>0.12</td>
<td>0.08</td>
</tr>
<tr>
<td>Conditional volatility $(t-1)$</td>
<td>0</td>
<td>-0.06</td>
<td>0</td>
<td>-0.24</td>
<td>-0.42</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reserves/Assets</td>
<td>-0.01</td>
<td>0.00</td>
<td>0</td>
<td>0.12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Equity/Assets</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Other/Assets</td>
<td>0.00</td>
<td>0.03</td>
<td>-0.07</td>
<td>0.13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lending/Assets</td>
<td>-0.01</td>
<td>0</td>
<td>0</td>
<td>0.13</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Securities/Assets</td>
<td>-0.01</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Assets expansion</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Nonzero beta coefficients are significant at $p < 0.10.$

**Source:** Author calculation, JPL toolbox
The change in monthly conditional volatility generally depended on its value for a ‘calming’ effect; volatile months were followed by smoother ones (Table 8). The introduction of balance sheet ratios increased the determination in every case. The ECB accommodative lending and security market policies verified the upper result of the calming impact, while the decrease in transparency accelerated pricing uncertainties for the euro, Swiss franc and Czech koruna. Despite the fact that the Czech National Bank (CNB) was the most conservative bank in the sample, its lending and reserve activities indicated some sort of volatility. The reason for this can be found in its strong fundamentals: meaning, that when the CNB has to be accommodative, there are serious troubles in the market.

Both of the methods had the same result: currency turbulences are not related to or even calmed by unconventional decisions.

6 Conclusion

The objective of current study was to test the interactions between structural changes of central bank balance sheets and currency stability. By doing so, the development of central bank balance sheet and currency data was analysed on a sample of seven ECBs between 2006 and 2014. A theoretical model of FX rate changes suggested that asymmetric start and end of a crisis period with deflation can generate currency fluctuations by itself, what can be smoothed out by unconventional balance sheet practices. Currency stability was measured through temporal patterns of extreme currency fluctuations and conditional volatility, while balance sheet developments were studied by examining six different ratios representing monetary activism.

Results can be generalised the following way: the ECB went through different steps of monetary easing until arrived at a quantitative and qualitative easing stage around 2011. Safe haven central banks (such as the Swiss, Sweden and Danish) used easing policies to support their banking system until 2011 when their struggle with appreciation started. Emerging central banks (the Hungarian and Polish) remained conservative, maintaining their large FX reserves while their currencies were depreciating. The Czech Koruna had both a safe haven and emerging properties, its appreciating tendencies supporting the first one, but the passive behaviour of the Czech National Bank supports the latest. The ECB manages a key currency in the sample only and its increasing commitment towards unconventional measure were captured in the case of monthly extreme fluctuation as well as the conditional variance of the data. The applied practices such as reserve policy, security accumulation or lending were able to calm down market forces, smoothing out currency variances and reducing the occurrence of extreme fluctuations.

This study has some unsettled points as well: balance sheet ratios can be biased by the enormous FX reserves. However, their changes were used during calculations. Results can be hard to generalise, because of they were the product of a unique historical data generating process, however, the sample period is focusing on the different stages of crisis intensification.

Previous currency literature focused mostly on the future introduction of the euro and FX convergence, while later it was focusing on crisis phenomena (divergences, appreciations). Interactions between monetary policy and asset pricing have a wide
literature, but FX market is considered mostly under DSGE assumptions as the part of an IS curve, or Phillips curve or interest rate premium or as a component of Taylor-rule.

References


Notes
1 A limited appearance of extreme fluctuations or low conditional variances.
2 With ratios to describe a central bank’s commitment to lending, security accumulation, foreign reserve accumulation or maintaining a leverage.
3 Treaty on the European Union, Article 2.
4 Eurozone financial activity, based on commercial banks with almost 2000 clients for the European Central Bank (ECB), requires more attention for market influencing. The US economy is focused more on capital markets with a small number (twenty) of primary dealers of the Federal Reserve (FED), resulting in some programs to support the trading of asset based commercial papers and money market investments (Bagus and Schiml, 2009).
5 Risk premium management can be even more complicated for the ECB when long-term interest rates fluctuate in response to the fiscal conditions of the member states (Hamori and Hamori, 2010). Ellison and Tischbirek (2014) distinguish among short- and long-term interest rates: the first should respond to inflation, while the second should respond to output by selling short-term treasury bills and re-investing the proceeds in long-term ones.
6 Funding liquidity: to raise cash either via the sale of an asset or by borrowing (BIS, 2011).
7 Bagus and Howden (2009) and Farmer (2013) define the period of December 2008–March 2009 as quantitative easing, while Chen et al. (2012) added the ‘Eurosystem’s Covered Bond Purchase Program’ to the list between May 2009 and June 2010 as well.
8 Missing data were managed trough the listwise deletion approach, following Graham (2012).