

# 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 utilizes 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*

*JEL codes: C32, F31, F35, G15, E44, E58*

## **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 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 foreign exchange 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 pp. 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<sup>1</sup> and balance sheet activities<sup>2</sup>.

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<sup>1</sup> A limited appearance of extreme fluctuations or low conditional variances.

<sup>2</sup> With ratios to describe a central banks commitment to lending, security accumulation, foreign reserve accumulation or maintaining a leverage.

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 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  $\sigma_t$  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:

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

$$\Delta NoX_t = \gamma\Delta NoX_{t-1} + \delta\Delta BS_{t-1} + \eta_t \quad (2)$$

Equation (1) and (2) formulated the main research question: is  $\Delta BS_{t-1}$  significant? Which BS components (like 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 affects the risk premiums of all other 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 foreign exchange markets – but the actual question of unconventional practices to currency stability is missing.

This paper is structured as follows: Section 2 summarizes 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, summarizes 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 summarizes recent literature on central bank balance sheets, unconventional measures, and foreign exchange 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 (foreign exchange 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<sup>3</sup>, 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<sup>4</sup> needed: a

<sup>3</sup> Treaty on the European Union, Article 2

<sup>4</sup> 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).

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 foreign exchange 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 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 premiums<sup>5</sup> of high-quality assets by increasing their prices (Shirai, 2014). This action also meets Bank of International Settlement requirements to maintain financing liquidity<sup>6</sup> during turbulent times (BIS, 2011) – even in a different currency! For qualitative easing the bank acquires lower quality assets to stabilize 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, like money market spreads and longer risk premium maturities; or the exploiting of neglected transmission channels, like 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 foreign exchange 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 article 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

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<sup>5</sup> 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.

<sup>6</sup> Funding liquidity: to raise cash either via the sale of an asset or by borrowing (BIS, 2011).

interventions only during a crisis period, as Égert 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-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:

$$\Delta BS_t = -\omega\pi_t \quad (3)$$

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 foreign exchange rates, a two country example will be presented with an open small economy and a relatively closed (denoted with \*) and a big one. Future foreign exchange rate changes ( $\Delta s_{t+1}$ ) are the functions (4) of interest rate differentials and an exogenous shock ( $\varepsilon$ ):

$$\Delta s_{t+1} = \vartheta(r_t - r_t^*) + \varepsilon_{t+1} \quad (4)$$

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

$$\pi_t = \pi_t^* + l \text{ and } y_t = y_t^* + k \quad (5)$$

Short-term nominal interest rates in an open small economy can be described with a modified Taylor-rule (6), where foreign exchange 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):

$$r_t = \theta r_{t-1} + (1 - \theta)\{\delta_\pi \pi_t + \delta_y y_t + \delta_s \Delta s_t\} + \eta_t \quad (6)$$

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

$$r_t^* = \theta r_{t-1}^* + (1 - \theta)\{\delta_\pi \pi_t^* + \delta_y y_t^*\} + \eta_t^* \quad (7)$$

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

$$r_t - r_t^* = \delta_\pi \pi_t - \delta_\pi \pi_t^* + \delta_y y_t - \delta_y y_t^* + \delta_s \Delta s_t + \eta_t - \eta_t^* \quad (8)$$

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

$$r_t - r_t^* = \delta_\pi l + \delta_y k + \delta_s \Delta s_t + \eta_t - \eta_t^*$$

Therefore equation (3) can be rewritten as follows (9):

$$\Delta s_{t+1} = \vartheta(\delta_\pi l + \delta_y k + \delta_s \Delta s_t + \eta_t - \eta_t^*) + \varepsilon_{t+1} \quad (9)$$

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):

$$\delta_\pi l + \delta_y k = \delta_s \Delta s_t + \eta_t - \eta_t^* \quad (10)$$

Let's 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

Step 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, zero lower bound 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  $\Delta BS_t$  under Step 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, summarizes 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 sub sections to describe the procedures to calculate a monthly number of extreme fluctuations, GARCH-based conditional variance and vector autoregression (VAR).

##### 4.1 Balance Sheet Data

This study analyses a sample of seven European central banks, to cover as many strategies as possible to identify balance sheet-currency interactions. The European Central Bank (ECB) issues the Euro as key currency, while four other central banks (like 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 (like Hungarian and Polish). Later two countries were interesting due to their commitment towards foreign exchange (FX) lending in euro and Swiss franc to households and non-financial corporations (Woško, 2016) – making their financial stability the function of currency developments. The dataset covers the period of 2006 to 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 summarizes recent changes over the last eight years, presenting a brief description of joint actions to engender FX (foreign exchange) 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 Stavárek, 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 foreign exchanges became a common tool for the ECB, Swiss, and Sweden national banks.

Table 1: Monetary Instruments in Central Bank Press Releases

	key interest rate	maturity	FX liquidity	swap and repo
ECB	25	25	32	31
Swiss	9	1	27	32
Sweden	36	111	16	7
Czech	36	4	0	6
Denmark	17	2	0	1
Hungary	52	5	0	4
Poland	29	3	0	8

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 ( $BS_m$ ).  $R_{ed}$  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 European Central Bank, the Swiss National Bank, the Bank of Japan, and the Federal Reserve on December 3, 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 (European Central Bank<sup>7</sup>, 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.

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

	defence	leverage	transparency	lending	securities	expansion
January 2006 - November 2007 (pre-crisis)						
ECB	13%	6%	1%	38%	8%	96%
Swiss	43%	127%	1%	0%	5%	59%
Sweden	85%	39%	2%	2%	0%	16%
Czech	95%	-13%	1%	2%	0%	5%
Denmark	52%	17%	1%	37%	10%	45%
Hungary	92%	4%	2%	2%	3%	8%
Poland	96%	2%	1%	2%	0%	5%
December 2007 - May 2011 (subprime-crisis)						
ECB	10%	4%	11%	35%	16%	156%
Swiss	49%	50%	0%	0%	2%	98%

<sup>7</sup> 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 Programme" to the list between May 2009 and June 2010 as well.

Sweden	61%	21%	1%	22%	0%	118%
Czech	97%	-17%	1%	1%	0%	3%
Denmark	64%	13%	1%	24%	6%	48%
Hungary	94%	4%	2%	1%	3%	11%
Poland	95%	4%	2%	3%	0%	8%
June 2011 - October 2014 (sovereign or Euro-crisis)						
ECB	10%	4%	18%	32%	24%	221%
Swiss	84%	14%	0%	0%	1%	65%
Sweden	87%	19%	1%	0%	1%	25%
Czech	98%	-9%	0%	0%	0%	2%
Denmark	88%	14%	0%	4%	6%	17%
Hungary	94%	6%	1%	3%	2%	15%
Poland	99%	4%	0%	0%	0%	2%

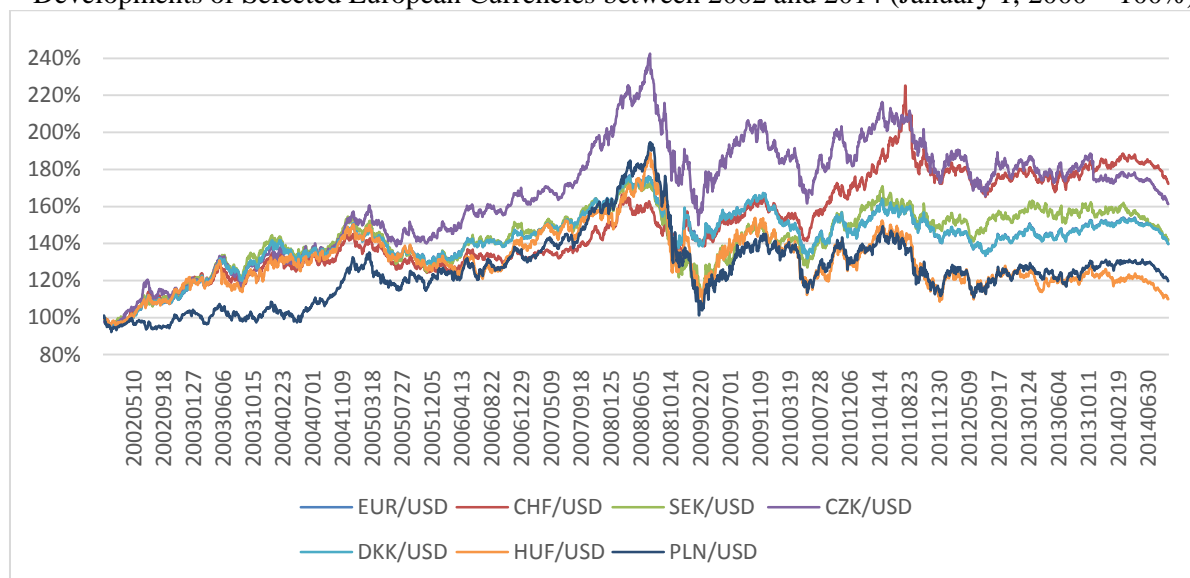
Source: ECB, Swiss, Sweden, Czech, Hungarian, Polish, and Danish National Banks

Our study investigates how the quality of the assets of central banks relate to the quality of money – represented by pricing uncertainties. This subsection summarizes 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 January 1, 2002, and October 1, 2014, to apply some pre-crisis period study control.

Figure 1:  
Developments of Selected European Currencies between 2002 and 2014 (January 1, 2000 = 100%)



Source: Bloomberg

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 January 1, 2002 and October 1, 2014<sup>8</sup>. Sample currencies appreciated until the first half of 2008 after a minor correction in 2005. The

<sup>8</sup> Missing data was managed through the listwise deletion approach, following Graham (2012).

interval between 2008 and 2013 was a cycle of devaluation and appreciation, revealing market pricing uncertainty (Figure 1).

Table 3: Descriptive Statistics of Currency Log Differentials

currency	mean	standard deviation	skewness	kurtosis	normal distribution	autocorrelation	conditional heteroscedasticity	unit root
					Jarque-Bera test (p)	Ljung-Box test (p)	ARCH-LM test (p)	ADF test (p)
EUR/USD	0.0001	0.0060	0.1279	5.3376	0.0000	0.8582	0.8752	0.0000
CHF/USD	0.0002	0.0068	-0.5118	14.7053	0.0000	0.2655	0.3442	0.0000
SEK/USD	0.0001	0.0078	0.2506	6.7777	0.0000	0.2328	0.4135	0.0000
CZK/USD	0.0001	0.0080	0.0033	6.8158	0.0000	0.3471	0.5302	0.0000
DKK/USD	0.0001	0.0062	0.0165	4.6254	0.0000	0.5958	0.7195	0.0000
HUF/USD	0.0000	0.0099	-0.3468	6.4052	0.0000	0.9039	0.9442	0.0000
PLN/USD	0.0001	0.0092	-0.1089	6.7951	0.0000	0.3415	0.6148	0.0000

Source: author calculation using Kevin Sheppard's MFE toolbox for Matlab

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 data set. Autocorrelation or heteroscedasticity did not characterize the data.

The sample currencies followed a floating exchange rate policy or fluctuated within an  $\pm 2.25\%$  or  $\pm 15\%$  broad band (like 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.

#### 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 data set, assuming that majority of the  $\mathbb{S}$  dataset is a result of a  $\mathbb{N}$  normal distributed data generating process, while a smaller subset is a product of  $\mathbf{G}_1, \dots, \mathbf{G}_k$  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  $\mathbb{R}$  market returns can be separated into two groups of  $\mathbb{N}$  normal ( $r_n$ ) and  $\mathbb{X}$  extreme returns (11):

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

Therefore, "normality" can be defined as a lack of extreme returns. The statistical characteristics of  $\mathbb{N}$  subset have to converge to the idealistic  $\mathbb{N} \sim (0,1,0,3)$  case, where standardized returns have zero expected value, 1 standard deviation showing symmetry (skewness=0), and extreme fluctuations die out fast due to exponent tails (kurtosis=3).



*Fat-tailed returns* ( $r_{fat}$ ) are computed by the difference on the tails between theoretical normal and empirical distribution, utilizing 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).

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

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

$$r_t = \sigma_t * \varepsilon_t \text{ and } \sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2, \quad (13)$$

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  $y_t = (y_{1t}, \dots, y_{Kt})'$ . The basic model of order  $p$  VAR has the form of (14) (Lütkepohl and Kratzig, 2004).

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

Where the  $A_i$ 's are ( $K \times K$ ) coefficient matrices and  $u_t = (u_{1t}, \dots, u_{Kt})'$  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):

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

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

Second, 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):

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

$$\Delta NoX_t = \gamma \Delta NoX_{t-1} + \delta \Delta BS_{t-1} + \eta_t \quad (18)$$

## 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 summarizes some basic statistics of currencies and their volatilities and extreme returns. Subsequently, their properties are characterized under different monetary environments described previously.

### 5.1 Extreme Currency Fluctuation

Compared to 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

	EUR	CHF	SEK	CZK	DKK	HUF	PLN
mean r(n)	0.0005	0.0001	0.0003	0.0004	0.0005	0.0006	0.0006
standard deviation r(n)	0.0045	0.0054	0.0059	0.0059	0.0048	0.0080	0.0068
skewness r(n)	0.1495	0.0017	0.0317	0.0821	0.1291	0.0579	0.0443
kurtosis r(n)	2.5980	2.6940	2.5670	2.7479	2.4595	2.5062	2.7277
X+ threshold	0.0119	0.0130	0.0153	0.0156	0.0121	0.0204	0.0188
X- threshold	-0.0092	-0.0133	-0.0135	-0.0137	-0.0096	-0.0171	-0.0154
No X+	86	102	85	90	87	65	71
No X-	201	77	134	137	189	135	152
No Normal	3320	3321	3320	3320	3320	3320	3320
elapsed time (sec)	0.09						

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 characterized 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.

Table 5: Extreme Returns Before and After Monetary Expansion (Fat Tailed Method)

central bank	t-test H	inflection point	start of previous period	inflection date	end of next period	share of extreme days	
						before	after
ECB	1	2	20060303	20070903	20090303	1%	16%
	1	4	20090303	20110902	20130201	12%	9%
SNB	1	2	20061003	20080303	20090501	1%	20%
SR	1	2	20061103	20071203	20090903	0%	17%
	1	5	20110103	20120601	20130703	12%	6%
CNB	1	3	20090803	20101001	20141001	8%	7%
DNB	1	1	20020101	20060901	20070903	5%	0%
MNB	1	1	20020101	20070202	20090403	5%	11%
PNB	0	1	20020101	20060703	20091002	6%	10%

Notes: \*: 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

## 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 6: GARCH (1,1) Coefficients – Monthly Data (2006-2014)

	EUR/USD	CHF/USD	SEK/USD	CZK/USD	DKK/USD	HUF/USD	PLN/USD
$\omega$	0.00	0.00	0.00	0.00	0.00	0.00*	0.00
$\alpha$	0.12*	0.21	0.18	0.10	0.18	0.18	0.11
$\beta$	0.82**	0.74**	0.60	0.86**	0.78**	0.66**	0.82**

Notes: \*\* sign. at p<0.05; \* sign. at p<0.10

Source: Author calculation, UCSD toolbox

## 5.3 Vector Autoregression 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



Notes: nonzero beta coefficients are significant at  $p < 0.10$   
Source: Author calculation, JPL toolbox

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 7 European central banks between 2006 and 2014. A theoretical model of foreign exchange 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 generalized 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 (like 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 foreign exchange 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 measures were captured in the case of monthly extreme fluctuation as well as the conditional variance of the data. The applied practices like 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 foreign exchange reserves. However, their changes were used during calculations. Results can be hard to generalize, 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 foreign exchange convergence, while later it was focusing on crisis phenomena (divergences, appreciations). Interactions between monetary policy and asset pricing have a wide literature, but foreign exchange 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.

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