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Toward Removal of the Swiss Franc Cap: Market Expectations and Verbal Interventions*

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Abstract

We ask whether the markets expected the Swiss National Bank (SNB) to discontinue the 1.20 cap on the Swiss franc against the euro in January 2015. In the run-up to the SNB announcement, neither options on the euro/Swiss franc nor FX liquidity indicated a significant shift in market expectations. Furthermore, we find that the SNB's verbal interventions during the period of cap enforcement increased the credibility of the cap by reducing the uncertainty of future euro/Swiss franc rate. We conclude that the markets did not anticipate the discontinuation of the policy.

Keywords: Swiss franc, implied volatilities, market expectations
JE L Classifications: E58, E44, G12

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1 Introduction

On September 6, 2011, the Swiss National Bank (SNB) set a cap on the Swiss franc's exchange rate against the euro to avert the risk of deflation resulting from a "massive overvaluation of the Swiss franc," see SNB (2011). The franc had appreciated significantly against the euro and the US dollar in the months prior to the announcement amid the intensifying euro area crisis. The appreciation posed a threat to the small open Swiss economy. With the policy rate already being at zero, the SNB decided to announce a minimum euro/Swiss Franc exchange rate by promising to buy foreign currency in unlimited quantities if necessary.

Using exchange rate policy to steer monetary conditions at home was not new in Switzerland. For instance, during the years 1977 and 1978, the US dollar depreciated significantly against the Swiss franc. The SNB reacted to the growing signs of recession and deflation caused by the franc appreciation by introducing an exchange rate target of 0.8 Swiss francs for 1 German mark on 1 October 1978. It announced that the Swiss franc exchange rate was to be influenced in such a way that the German mark rate "clearly settles at a level [above] 80 Swiss francs to 100 German marks."

In principle, a commitment to keeping the domestic currency low is always credible because a central bank can print unlimited amount of its own currency to buy foreign exchange.[1] However, as the balance sheet of the central bank grows in size and becomes increasingly volatile, the central bank becomes exposed to various financial risks. Excessive volatility could lead to significant balance sheet losses and even to negative equity positions. As noted by Danthine (2012) and Jordan (2011), this is not a problem in the short term but could generate doubts regarding credibility in the long term.

In this paper, we ask two questions. First, did exchange rate markets understand these risks and expect the discontinuation of the Swiss franc cap? Second, how were the market beliefs affected by central bank verbal interventions and overall conditions on the financial markets?

To analyze the first question, we estimate 'market beliefs' from option prices on the euro/Swiss franc exchange rate and market liquidity from the bid-ask spreads of various currency pairs with the Swiss franc – and study the dynamics of the two in the run-up to January 15, 2015. The evidence suggests that the exchange rate market did not anticipate the discontinuation of the cap.

[1] Which is different from a currency peg, where the central bank is *buying* its own currency in the hope that the currency reserves will not deplete before the goal is achieved.

We study the second question by regressing the market beliefs during the period of the cap on the SNB's verbal interventions and a variety of financial market indicators. We consider a verbal intervention to be a speech made by a member of the SNB Governing Board that contained the wording "utmost determination" and/or "unlimited quantities" when discussing the Swiss franc cap. We show that these verbal interventions significantly reduced perceived uncertainty of the future euro/Swiss franc rate.

Several other papers study the SNB's exchange rate policy over this period. Hertrich and Zimmermann (2015) explore the credibility of the Swiss franc cap and find that the cap was never perfectly credible, as the estimated probability of the euro/Swiss franc exchange rate being below 1.20 was high. Hanke et al. (2015) and Jermann (2016) report increasingly lower estimates of the break probability and conclude that the market's confidence in the SNB's commitment increased over time, especially from late-2012 until the end of their samples. We contribute to this literature by providing evidence on *(a)* whether the option-implied distributions can be explained by central bank actions and measures of financial market uncertainty, and *(b)* the liquidity patterns around the discontinuation of the cap.

Our study also touches upon a large literature on central banks' verbal interventions in the foreign exchange market. Beine et al. (2009) show that issuing commentary statements during foreign exchange interventions tends to reduce exchange rate volatility. Fratzscher (2008) finds that communication policies by the central banks of the US, euro area and Japan have generally constituted an effective policy tool in influencing exchange rates in the desired direction. More specifically, Burkhard and Fischer (2009) find that SNB's repeated references of non-sterilized interventions during the period 2002 – 2005 depreciated the domestic currency and proved to be a useful communication tool. Jansen and De Haan (2005) study the reaction of the conditional mean and volatility of the euro/US dollar exchange rate to statements by European Central Bank (ECB) officials and conclude that those statements mainly influenced the conditional volatility.

The reminder of the paper is organized as follows. In section 2, we introduce the dataset. Section 3 lays out the methodology, and section 4 reports our findings.

2 Data

The section begins by illustrating the option data we use to extract market beliefs regarding the future exchange rate of the Swiss franc against the euro. The second part of the section introduces the spot market data we use in our analysis of bid-ask spreads. Finally, the third part illustrates our dataset of the SNB's verbal interventions together with other financial market variables we control for in the analysis.

2.1 Option data

The option data are from Bloomberg and comprise five implied volatilities on the following instruments: delta-neutral straddle, 25-delta risk reversal, 25-delta butterfly, 10-delta risk reversal and 10-delta butterfly. We use composite indicative quotes calculated daily at 17:00 New York time. The maturities in the sample are 3, 6, 9 and 12 months, but the main analysis is focused on the 3-month maturity because these are the most commonly traded option contracts.

These instruments can be used to back out implied volatilities and option prices for five different call options (see Malz (2014) and Wystup (2006)), which are used together with the forward price in the estimation. For instance, for January 14, 2015, the strike prices for the 3-month options are (1.1403,1.1796,1.1999,1.2166,1.2470) and the 3-month forward is 1.1997. Risk-free rates are proxied by euro and Swiss franc Libor rates of the same maturity as the options. The sample period runs from the beginning of September 2011 until the end of April 2015.

We also focus in on the morning of January 15, 2015, which is the day when the SNB discontinued the Swiss franc cap. Table 1 illustrates the number of available data points at 5, 10 and 15-minute frequencies. As the table indicates, the sample with 15-minute observations is the most balanced, and therefore, we chose that particular sample for our analysis. The main reason that there are fewer 'complete' observations in higher frequencies (5- and 10-minute intervals) is that butterfly strategies have relatively low liquidity.

2.2 Spot market data

Our analysis of the bid-ask spreads uses Bloomberg spot market data on the 11 most traded currency pairs against the Swiss franc: USD, GBP, CAD, AUD, NZD, MXN, TRY, SEK, HKD and SGD. We also use Bloomberg intraday bid and ask quotes on 9 important currency pairs snapped at 5 minute intervals: AUDUSD, AUDEUR, JPYUSD, JPYEUR, GBPEUR, CHFUSD, SEKUSD, SEKEUR and NOKEUR. Similar to option data, we use the composite indicative quotes from Bloomberg obtained at 17:00 New York time.

2.3 SNB's verbal interventions and control variables

Announcing the decision to impose a cap on the Swiss Franc against the euro, the SNB pledged to "enforce this minimum rate with the utmost determination and [...] buy foreign currency in unlimited quantities." The same wording was subsequently used in a variety of speeches by the members of the SNB Governing Board. In particular, there were 27 speeches during the period from September 6, 2011, to January 14, 2015, that contained the wording "utmost determination" and/or "unlimited quantities"; see Table 2. Most of these verbal interventions were delivered by Thomas Jordan, four of them by Fritz Zurbrügg, three of them by Jean-Pierre Danthine, and one of them by Philipp Hildebrand.

Our dataset also includes a number of financial market variables that we control for when market beliefs on SNB's verbal interventions. First, we collect major announcements and regular policy decisions by the ECB that might have considerably affected the option market for the euro/Swiss franc rate, see Table 2. In addition, our dataset includes VIX (an option-based volatility index on S&P 500) published by CBOE, the TED spread (a spread between a USD LIBOR rate and a T-bill rate) published by St.Louis Federal Reserve, the 5-year European sovereign CDS spread from Bloomberg (differenced, as the level of the CDS spread is non-stationary) and the 10-year US term premium of Kim and Wright (2005) available from the Federal Reserve's official website.

3 Estimating market beliefs from option data

Our goal is to estimate market beliefs regarding future exchange rates in a flexible way. We first explain how we extract the risk-neutral distribution from option prices. Subsequently, we explain how the risk neutral-distribution can be adjusted to obtain a real or "physical" distribution.

3.1 The risk-neutral distribution of the euro/franc exchange rate

The price of an option is driven primarily by the market's belief regarding whether the option will pay off at maturity – and if so, by how much. For instance, a European put option with a strike price of 1.20 only pays off if the exchange rate (at maturity) is below 1.20. If this option is trading at a non-zero price, then an exchange rate below 1.20 is considered a possibility. Our paper extends this logic by using a cross section of options (with different strike prices) to recover the broad shape of the market's (subjective) distribution of the euro/franc exchange rate.

Option pricing theory holds that if the market beliefs regarding the logarithm of the future exchange rate are well described by a normal distribution with mean μ and variance σ^2, then the option prices would follow the Black-Scholes formula. For the subsequent analysis, we let $G(\mu, \sigma^2, X)$ denote the Black-Scholes price of a call option with strike price X.

To allow for a more flexible distribution (skewed, fat tails, etc), we instead assume that it can be approximated by a mixture of two lognormal distributions as in Ritchey (1990). In this case, the price of a European call option C can be shown to be

$$C(\alpha, \mu_1, \sigma_1^2, \mu_2, \sigma_2^2, X) = \alpha G(\mu_1, \sigma_1^2, X) + (1-\alpha) G(\mu_2, \sigma_2^2, X), \tag{1}$$

where α is the weight on the first lognormal distribution with mean μ_1 and variance σ_1^2. Similarly, $1-\alpha$ is the weight on the second lognormal distribution (with mean μ_2 and variance σ_2^2). Clearly, the Black-Scholes model is a special case.

For each trade time we estimate the five parameters $(\mu_1, \sigma_1^2, \mu_2, \sigma_2^2, \alpha)$ by minimizing the sum of weighted squared pricing errors, trade price $C(X_i)$ minus model price, for the options and the forward (which can be seen as an option with a zero strike price). That is, we minimize

$$\sum_{i=1}^{6} w_i [C(X_i) - C(\alpha, \mu_1, \sigma_1^2, \mu_2, \sigma_2^2, X_i)]^2, \tag{2}$$

where X_i are the six different strike prices (which is zero for the forward). The weights w_i of the options are the inverse of the (Black-Scholes) vegas, and thus, we effectively minimize the sum of fitted errors of the implied volatilities (see Carr and Wu (2007)). The weight of the forward price is the same as for the most important option. The estimation is repeated for each trading day/time and for each maturity (3 to 12 months).

To obtain reliable estimates, we impose two conditions on the parameters: that σ_1 and σ_2 do not differ too much and that μ_1 and μ_2 are not too far from the forward price. This mitigates the effects of sometimes noisy data.[2]

There are several advantages of assuming a mixture of lognormal distributions. First, non-parametric methods often generate unstable estimates and negative probabilities (see Söderlind and Svensson (1997)). Second, the mixture of lognormals gives closed form solutions for the option and forward prices, which speeds up the estimation and allows us

[2] Specifically, we impose $3/4 < \sigma_1/\sigma_2 < 4/3$ and $4/5 < \mu_i/F < 5/4$, where F is the forward price.

to impose restrictions that make the estimations more stable. Third, the approach allows for a systematic discussion of the role of risk premia. However, a mixture of lognormals may fail to provide a good approximation of market beliefs in certain situation. For instance, if the market assigned a zero probability of an exchange rate below 1.20, then our estimates would give slightly higher numbers.

The five parameters $(\mu_1, \sigma_1^2, \mu_2, \sigma_2^2, \alpha)$ completely characterize the so-called risk-neutral distribution. It corresponds to the market's subjective beliefs in case the underlying asset (here, the euro-Swiss franc) embeds no risk remium.

In the regression analysis below, we focus on two key features of this distribution: the uncertainty and skewness. Let Px denote the xth percentile of the distribution generated by the five parameters discussed above and let S be the spot exchange rate. Then, we measure uncertainty and skewness as

$$\text{uncertainty} = \frac{P90 - P10}{2.36} \tag{3}$$

$$\text{skewness} = \frac{(P90 - S) + (P10 - S)}{P90 - P10}. \tag{4}$$

These are considerd to be robust measures of the variance and skewness (see, for instance, Hinkley (1975)). Indeed, we find that they are more stable than the traditional central second and third moments of the estimated distributions.

3.2 The physical distribution of the euro/franc exchange rate

We adjust the risk-neutral estimates to illustrate the physical distribution of the future euro/Swiss franc exchange rate. To do so, we take the following steps. First, we estimate the *ex post* risk premium (current forward rate minus the spot rate 3 months ahead) on current market risk factors (implied volatility from the options discussed above, VIX and the TED spread) on daily data for 2002–2011. These results indicate, for instance, a negative 1–3% risk premium during the height of the financial crisis. Second, we use the estimated coefficients together with the observed risk factors to predict[3] risk premia for 2011:09 to 2015:04. Third, we adjust the mean of each lognormal distribution by an amount proportional to its standard deviation (assuming that more volatility causes a higher risk premium) such that the option pricing model generates the same risk premium

[3]Using predicted rather than fitted values is dictated by the fact that options are priced by the market participants with the *ex ante* risk premium in mind, but we only have the *ex post* (historical) values.

as in step two.[4]

4 Results

The first part of our results concerns daily data and specifically the option market data and the spot market data. In the second part of the section, we zoom-in January 15, 2015, and analyze high-frequency data from options and spot markets around the announcement by the SNB to discontinue the Swiss franc cap.

4.1 Evidence from daily option market data

This subsection is structured as follows. First, we present examples of the estimated risk-neutral distribution on selected dates and illustrate the evolution of that distribution over time and toward SNB's decision to discontinue the Swiss franc cap. Second, we relate the measures of uncertainty and skewness implied by the estimated distribution to the speeches by SNB officials intended to reinforce the cap and ask whether these verbal interventions significantly affected the estimated measures. Third, we show how the effect of the SNB's verbal interventions propagates over time.

4.1.1 Toward the discontinuation of the Swiss franc cap

Figure 1 shows a few examples of the estimated probability density functions (pdf) for the 3-month horizon. The left subplot highlights how the distribution changed between early and mid-January 2013. On January 4, 2013, the distribution was concentrated around 1.20 with a somewhat extended upper tail. Eleven days later, the distribution had shifted upwards and was considerably more dispersed (higher uncertainty) and had an even more extended upper tail (higher skewness). Similarly, the right subplot compares the distributions on January 14 and 15, 2015. On January 14, the distribution was concentrated around 1.20, but on the day after the distribution had shifted downwards and was much more dispersed.

[4]It is straightforward to show that the physical distribution is obtained by replacing the risk-neutral means μ_i by $\mu_i - \kappa_i$ where κ_i is the covariance of the exchange rate with the pricing kernel. We also note that the forward price is $F = \alpha \exp(\mu_1 + \sigma_1^2/2) + (1-\alpha)\exp(\mu_2 + \sigma_2^2/2)$ and that the expected log future exchange rate is $\mathrm{E} \ln S_{3m} = \alpha(\mu_1 - \kappa_1) + (1-\alpha)(\mu_2 - \kappa_2)$. Combining a value of the risk premium $\ln F - \mathrm{E} \ln S_{3m}$ with the assumption that $\kappa_1/\kappa_2 = \sigma_1/\sigma_2$ allows us to recover the physical distribution.

To illustrate the evolution of these distributions over time, Figure 2 depicts the estimated 80% confidence band (10th and 90th percentiles) from the daily estimated distribution of the euro/Swiss franc exchange rate for the 3-month horizon over the period from September 2011 to April 2015. The *10th percentile* drifted slowly upward during late 2011 (from approximately 1.12) to just below 1.20 in early 2013. It essentially remained there until autumn 2014, when it began to drift downward toward 1.16–17. The *90th percentile* drifted downward for much of 2012 but increased dramatically in late January 2013 and peaked at 1.31 in May 2013. Thereafter, it drifted slowly downwards to approximately 1.23 in January 2015.

The distance between the 10th and 90th percentiles can be interpreted as a measure of *uncertainty*. This is shown in the upper panel of Figure 3. Except for a few spikes (halfway into 2012, early 2013, and halfway into 2013) the uncertainty had been gradually decreasing until autumn 2014, when the band began to widen again. Nonetheless, the width was still much lower in magnitude than at the inception of the franc cap. This result is in line with Hertrich and Zimmermann (2015), who find that the 'break probability', i.e., the probability that the SNB will discontinue the cap within the option expiration, was high at the inception of the Swiss franc cap and that it dropped considerably over time.

Interestingly, the dynamics of the "two-sided" vs. "one-sided" increases in uncertainty are different. In the upper panel of Figure 3, the spike in early May 2012 and a less-pronounced one at the end of 2014 are short-lived and come down within a month, whereas those in January and April 2013 are much more persistent. By comparing with Figure 2, it becomes apparent that the former spikes are attributable to a simultaneous rise in the 90th and fall in the 10th percentile (hence "two-sided"), whereas the latter stem from an increase in the 90th percentile only. This is also illustrated in the lower panel of Figure 3 that shows the *skewness*, which compares the distance from the 10th percentile to the spot rate with the distance from the 90th percentile to the spot rate. High skewness indicates a tendency toward depreciation (and vice versa). It can be concluded that after the investors suddenly adjusted their beliefs towards franc depreciation in January and April 2013, they were rather slow to dispose with them.

Together, these figures suggest important changes in the market beliefs over the 2011–2015 period, but there is little to indicate any dramatic shifts from December 2014 to January 2015. It seems as if the option market did not anticipate that the cap would be removed anytime soon.

The previously presented results are all for the 3-month horizon, as this is the most commonly traded option contract. However, comparison with other horizons reveals some interesting patters. Figure 4 depicts 80% confidence bands for both the 3-month horizon (as before) and the 12-month horizon. The most evident difference is that there is greater uncertainty (wider confidence band) for the longer horizon, but the changes are typically parallel. However, there are several occasions (January and April 2013, in particular) when the 3-month band changes more dramatically than the 12-month band. One possible interpretation of these two events is that the market then expected something (a depreciation) to happen relatively soon.

Finally, Figure 5 illustrates the effect of adjusting the estimated risk-neutral confidence band for risk premia to create a real (physical) confidence band. The adjustment is fairly small before January 15, 2015, but more important after that. In particular, the safe haven properties (negative risk premium) of the Swiss franc means that the appreciation tendency is somewhat smaller than indicated by the risk-neutral confidence band.

4.1.2 The SNB's verbal interventions and market beliefs

In this section, we explore whether the SNB's verbal interventions reinforced the cap by significantly affecting uncertainty and skewness. We consider a verbal intervention to be a speech made by a member of the SNB Governing Board that used the words "utmost determination" and/or "unlimited quantities"; see section 2.3 and table 2.

We run the following regression

$$y_t = \alpha + \beta y_{t-1} + \gamma d_t + \Theta X_t + \varepsilon_t, \tag{5}$$

where y_t is either uncertainty or skewness as measured in Figure 3, d_t is a dummy variable that takes the value of one on the day of the verbal intervention and zero otherwise, and X_t is a vector of control variables. We include a lagged dependent variable on the right hand side to reduce the serial correlation in the error term and apply the Newey-West standard errors when producing t-statistics to account for any residual autocorrelation.

Apart from affecting contemporaneous levels of uncertainty and skewness captured by equation (5), the SNB speeches might have also affected the next day's levels of those variables. Therefore, we also run the following regression

$$y_{t+1} = \alpha + \beta y_t + \gamma d_t + \Theta X_{t+1} + \varepsilon_{t+1}, \tag{6}$$

Table 3 shows the regression results. We find that SNB's verbal interventions significantly reduced the estimated uncertainty regarding the future value of the euro/Swiss franc exchange rate. They were especially effective in lowering the uncertainty on the following day (column $t + 1$). (The γ coefficient in equation (6) is significant at the 1% level, but that in equation (5) only on the 15% level.) Thinking in terms of changes instead of levels, the SNB's verbal interventions resulted in statistically significant decline in uncertainty from day of the speech to the next day.[5]

Considering skewness, Table 3 provides some indication that the SNB's speeches had a positive effect on the estimated skewness measure, that is, drove the asymmetry of the risk-neutral distribution towards franc depreciation. However, the coefficient is significant only at the 15% level.

The control variables exhibit some interesting patterns. In particular, ECB announcements increased uncertainty of the future euro/Swiss franc rate. Problems in the global banking sector measured by the TED spread have a strong positive effect on uncertainty and tend to drive down the skewness (indicating appreciation of the Swiss franc). The same applies to the VIX. Interestingly, the troubles in the euro zone measured by the first-difference of average CDS spread across EU countries have no significant impact on uncertainty of future euro/Swiss franc exchange rate. The stronger the signs of global economic recovery measured by the 10-year US term premium, the lower is the uncertainty and the more negative is the skewness measure. Finally, the bottom of Table 3 shows that the closer the spot rate is to 1.20 the lower the uncertainty and the less positive is the skewness measure (indicating appreciation).

We perform a number of robustness checks and find that our main result holds independently of whether we use all the speeches of the Governing Board members or subsamples of them (e.g. Thomas Jordan only, Thomas Jordan and Jean-Pierre Danthine), or whether the dependent variable is a proxy for uncertainty, i.e., the 3-month at-the-money option-implied volatility instead of our estimated measure; see Table 4. The results also hold irrespective of the maturity of the option contracts from which we extract the measures of uncertainty and skewness and of whether we use the estimated physical instead of the

[5] If we use the lagged dependent variable of the second order, y_{t-2}, instead of y_{t-1} on the right-hand side of the two equations, thus essentially fitting 2-day changes around SNB's interventions, the result remains intact.

risk-neutral density.[6]

4.1.3 Propagation of the SNB's verbal interventions over time

We have seen that the speeches by the members of the SNB Governing Board reduced the market uncertainty both on the day of the speech and on the day after. In fact, the impact might have persisted even after the next day and it would be interesting to trace its propagation. We do so in an event study framework (Fama et al., 1969).

The event study proceeds as follows. First, we work with daily changes (in uncertainty or skewness). Second, we define the "normal" change as that prevailing on average over day $t-45$ to day $t-1$, where t is the day of a speech. That is, we use a rolling mean model (Brown and Warner, 1980). Third, the "abnormal" change on day t is the actual change minus the normal change as defined before. Fourth and finally, to test whether the abnormal change is statistically significant we use the standard deviation on days $t-45$ to $t-1$. This is motivated by the fact that the speeches were delivered at distant points in time, and hence there should be little temporal dependence. We use an estimation window of 44 days (two months), but have ascertained that other choices (e.g. 22 days, or 1 month) have a negligible impact on the results.

Figure 6 shows the average (across speeches) *cumulative changes* in the uncertainty and skewness at different days after a speech, as well as the 95% confidence interval around them. In line with the previous findings, we see that the first day's change in uncertainty is negative and marginally significant. During the next three days, the uncertainty continues to decline significantly, and it is the fourth day after a speech on which uncertainty stabilizes around a lower level relative to the day before the speech. Further in line with our previous results, the pattern for skewness is weaker.

4.2 Evidence from daily spot market data

An event such as the SNB announcing its intention to remove the Swiss franc cap is bound to have consequences for FX market liquidity. Following the sudden movements of the spot rate, market participants tend to rebalance their portfolios which increases liquidity demand. In addition, the introduced uncertainty concerning the spot rate dynamics makes providing liquidity a riskier business, and hence, a rational liquidity provider may therefore

[6] All these results are available upon request.

begin to widen the bid-ask spread as soon the event is perceived to be highly probable. Therefore, an unexpected removal of the Swiss franc cap should not be associated with widening spreads prior to the announcement by the SNB.

Considering the euro/Swiss franc spread alone might be uninformative, as the SNB is a dominant player on that market. Therefore, Figure 7 depicts a weighted average of the bid-ask spreads across the exchange rates of 11 currencies relative to the Swiss franc, excluding the euro.[7]

The solid line in the figure shows a moving average over the last 5 days. (The dots are the daily data.) While the bid-ask spreads had already increased in late December 2014, this is the usual seasonality pattern observed at the end of the year. If anything, this increase was smaller in 2015 than in previous years. The key evidence is instead the spike in the bid-ask spreads after 15 January.

Overall, it seems as if liquidity on the Swiss franc segment of the global currency market did not behave abnormally until the SNB discontinued the cap – and then surged considerably.

4.3 Zooming-in January 15, 2015

This section studies the hours surrounding the removal of the cap. Similarly to the previous section regarding the results from the daily data, we consider both option and spot market data.

4.3.1 Option market

The results from using high-frequency option data for 8:30 to 12:30 on January 15, 2015, are illustrated in Figure 8. As before, we show the 10th and 90th percentiles. There are 4 missing (incomplete) observations at 15-minute intervals, as shown in Table 1 (row "Ask"): one before and three after the SNB's announcement at 10:30 Zurich time.[8]

The estimated distribution was remarkably stable prior to the removal and reflected high uncertainty thereafter. The distribution was broadly symmetric throughout this 4-hour

[7] The weight for each currency pair is the share of its base currency in global foreign exchange market turnover in 2013 as taken from the BIS Triennial Central Bank Survey (http://www.bis.org/publ/rpfx13.htm). For instance, the share of all USDXXX pairs is 87%, that of all YENXXX pairs is 23%, and so forth. We normalize such that the weights sum up to one.

[8] We use ask quotes for the estimation. Results from the bid quotes can be shown to be very similar.

window. Once again, it seems that the option market had not anticipated the removal of the cap.

4.3.2 Spot market

Using high-frequency bid-ask data we find further support for the claim that the market did not expect the cap to be removed on January 15. In Figure 9, we show the average weighted spread of the major currency pairs. During the week of the event (late Sunday January 11 to Friday January 16) the average spread is generally lower than its median value before January 10 (after controlling for intra-week and intra-day seasonality), and no apparent spike is noticeable. However, the seasonal trend is exceeded immediately after the news about the removal of the cap hit the market.[9]

5 Conclusion

We examine option prices and spot rates of the Swiss franc around the decision of the Swiss National Bank (SNB) to discontinue the 1.20 cap on the exchange rate against the euro in January 2015. The market-perceived uncertainty estimated from option prices was broadly stable prior to the decision and considerably higher thereafter. Similarly, we find no evidence from the spot market that the liquidity exhibited abnormal behavior prior to the SNB's decision. Our study also shows that the use of the wording "utmost determination" and/or "unlimited quantities" by the members of the SNB Governing Board significantly reduced the uncertainty of the future euro/Swiss franc rate. Therefore, we conclude that both spot and option markets perceived the 1.20 cap to be credible until the very moment it was revoked.

[9] A similar pattern appears when the average weighted spread is calculated on a broader set of currencies jointly accounting for 70% of the derivatives market. However, the frequency of those observations is 30 minutes, which, given considerable missing data, makes the figures less descriptive. They are available upon request.

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Tables and Figures

Table 1: **Available observations around 8:30–12:30 on January 15, 2015.** Open prices are the first available quotes snapped at the beginning of the corresponding period, whereas Last prices are the last quotes available before the corresponding period ends. Quotes are compiled by Bloomberg with the BGN method.

	5-minute		10-minute		15-minute	
	Open	Last-Price	Open	Last-Price	Open	Last-Price
Ask	17	17	16	16	13	13
Bid	11	11	12	12	12	12
Mid	6	6	9	9	10	10

Table 2: **List of the SNB's verbal interventions and ECB announcements.** The table reports the speeches by the members of the SNB's Governing Board used to create the dummy variable d_t in the equations (5) and (6). It also reports the regular monetary policy decisions by the ECB and several key policy announcements.

SNB		ECB	
8-Nov-11	Jordan	8-Sep-11	regular
15-Dec-11	Hildebrand	6-Oct-11	regular
24-Jan-12	Danthine	3-Nov-11	regular
7-Feb-12	Jordan	8-Dec-11	LTRO
15-Mar-12	Jordan	12-Jan-12	regular
22-Mar-12	Danthine	9-Feb-12	regular
10-Apr-12	Jordan	8-Mar-12	regular
27-Apr-12	Jordan	4-Apr-12	regular
31-May-12	Danthine	3-May-12	regular
14-Jun-12	Jordan	6-Jun-12	regular
3-Sep-12	Jordan	5-Jul-12	regular
8-Nov-12	Zurbrügg	26-Jul-12	"whatever it takes"
16-Nov-12	Jordan	2-Aug-12	OMT
28-Nov-12	Jordan	6-Sep-12	regular
13-Dec-12	Jordan	4-Oct-12	regular
19-Feb-13	Jordan	8-Nov-12	regular
26-Apr-13	Jordan	6-Dec-12	regular
20-Jun-13	Jordan	10-Jan-13	regular
8-Oct-13	Jordan	7-Feb-13	regular
21-Nov-13	Zurbrügg	7-Mar-13	regular
12-Dec-13	Jordan	4-Apr-13	regular
27-Mar-14	Zurbrügg	2-May-13	regular
25-Apr-14	Jordan	6-Jun-13	regular
19-Jun-14	Jordan	4-Jul-13	regular
20-Nov-14	Zurbrügg	2-Aug-13	regular
11-Dec-14	Jordan	5-Sep-13	regular
18-Dec-14	Jordan	2-Oct-13	regular
		7-Nov-13	regular
		5-Dec-13	regular
		9-Jan-14	regular
		6-Feb-14	regular
		6-Mar-14	regular
		3-Apr-14	regular
		8-May-14	regular
		5-Jun-14	negative depo rate & TLTRO
		3-Jul-14	regular
		7-Aug-14	regular
		4-Sep-14	regular
		2-Oct-14	regular
		6-Nov-14	regular
		4-Dec-14	regular

Table 3: **The SNB's verbal interventions and the estimated distribution.** This table reports estimated betas of equations (5) and (6) and their Newey-West t-stats (in brackets). The left-hand variables are uncertainty and Hinkley's measure of skewness at the horizon of 3 months. The right-hand variables are (from top to bottom) a constant, the dummy for the SNB speeches, a dummy for the ECB key policy decisions, TED spread, first-difference of European sovereign CDS spread, the S&P 500 option-implied volatility index, 10-year term premium on US Treasuries, the difference between the spot EURCHF rate and 1.20 and the lagged dependent variable. The normally distributed Durbin h-statistic and the adjusted R-squared of the regression are reported at the bottom of the table.

	Uncertainty		Skewness	
	t	t+1	t	t+1
c	-44.705	-44.944	76.288	77.256
	(-3.19)	(-3.22)	(3.30)	(3.31)
d_t	**-16.4**	**-21.3**	**42.67**	**20.28**
	(-1.58)	**(-2.82)**	**(1.34)**	**(0.67)**
ECB	17.273	16.653	2.117	2.464
	(1.92)	(1.87)	(0.05)	(0.06)
TED spread	120.04	120.98	-109.91	-108.16
	(2.56)	(2.58)	(-1.50)	(-1.48)
EU CDS	0.601	0.579	0.341	0.391
	(1.45)	(1.41)	(0.56)	(0.64)
VIX	3.389	3.43	-4.802	-4.833
	(3.75)	(3.79)	(-4.02)	(-4.03)
10Y TP (US)	-19.672	-19.808	-95.093	-95.234
	(-2.77)	(-2.79)	(-3.82)	(-3.83)
Spot - 1.20	0.165	0.166	0.34	0.339
	(3.92)	(3.93)	(5.03)	(5.01)
AR(1)	0.892	0.892	0.864	0.864
	(38.02)	(37.96)	(43.74)	(43.68)
D stat	2.33	2.17	-13.06	-13.08
adj. R^2	0.98	0.98	0.85	0.85

Table 4: **Robustness check: the SNB's verbal interventions and uncertainty in $t + 1$.** The table shows the coefficient estimates on the dummy variable d_t in equation (6) and its t-stats for three different d_t, i.e., all of the SNB's verbal interventions (row 'All'), speeches by Thomas Jordan (row 'Jordan') only and speeches by Thomas Jordan and Jean-Pierre Danthine (row 'Jordan & Danthine'). The left-hand variable is either the uncertainty measure defined in the text (column 'Our measure') or at-the-money option volatility from Bloomberg (column 'Proxy').

	Our measure	Proxy
All	-21.3	-9.0
	(-2.82)	(-2.15)
Jordan	-21.2	-12.2
	(-2.25)	(-2.37)
Jordan & Danthine	-20.0	-10.4
	(-2.39)	(-2.18)

Figure 1: **Estimated probability density functions (pdfs) for selected dates.** The figure shows estimated pdfs for the 3-month horizon.

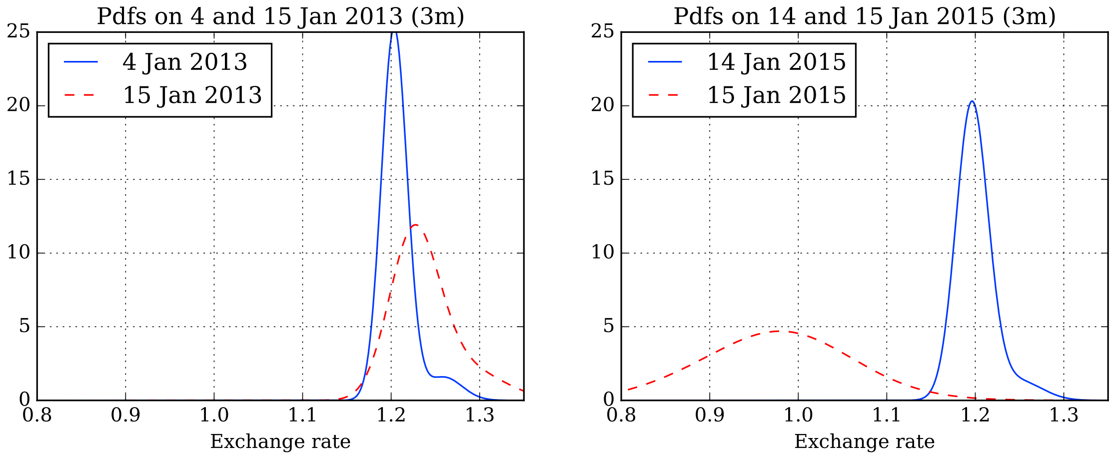


Figure 2: **Estimated confidence bands.** The figure shows the estimated 80% confidence band of the spot rate for the 3-month horizon.

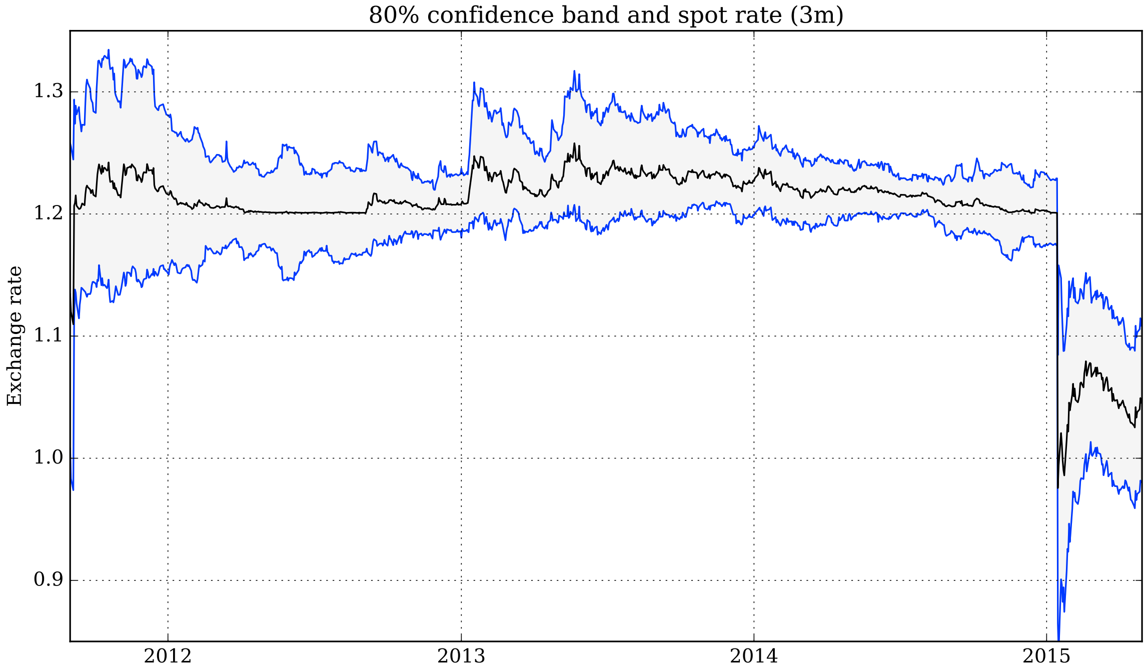


Figure 3: **Estimated volatility and skewness.** The illustrates the volatility and skewness of the estimated mixed lognormal distribution for the 3-month horizon. The uncertainty is measured as the difference between the 90th and 10th percentiles, (divided by 2.56 to make it comparable with a standard deviation from a normal distribution). The skewness measure is from Hinkley (1975). If Px denotes the xth percentile of the distribution and S the spot rate, then the skewness is measured as $[(P90-S)+(P10-S)]/(P90-P10)$. The skewness is averaged over three days.

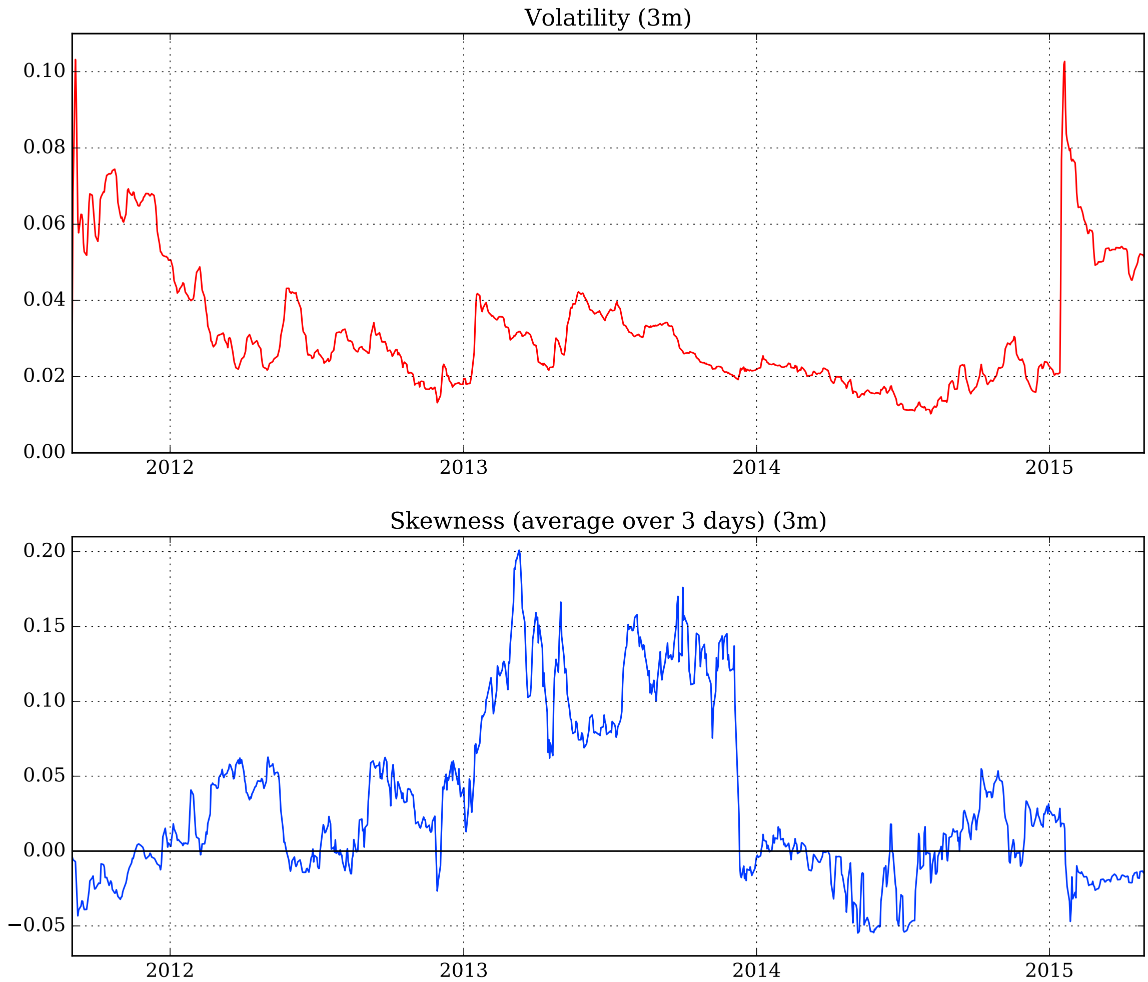


Figure 4: **Estimated confidence bands.** The figure shows the estimated 80% confidence bands of the spot rate for the 3- and 12-month horizons.

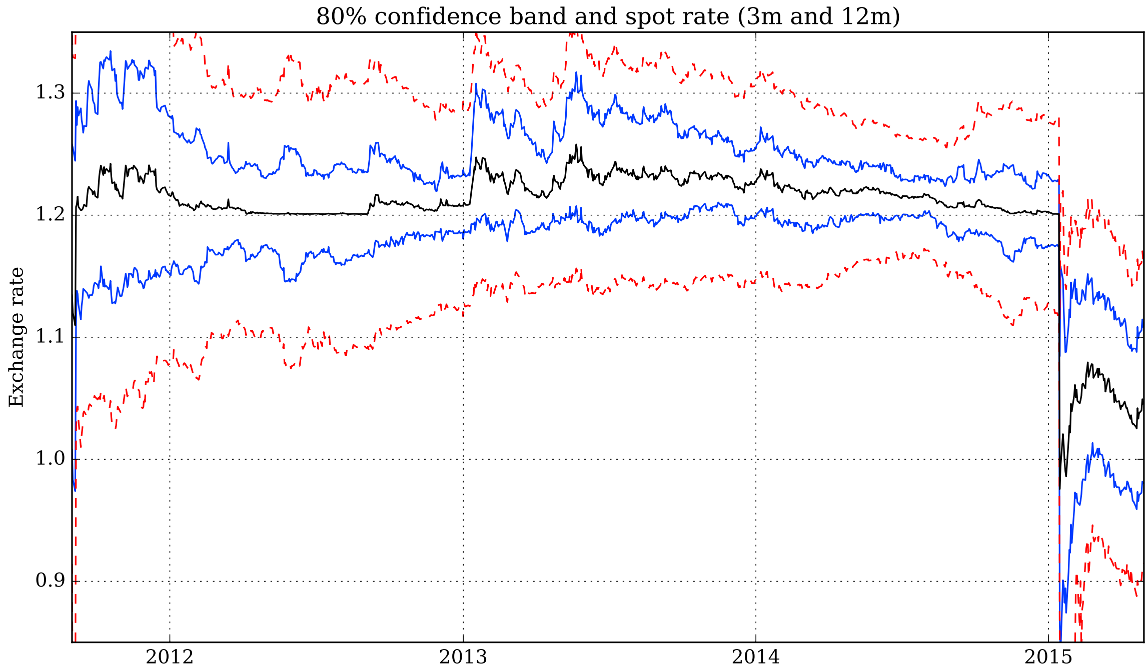


Figure 5: **Estimated confidence bands.** The figure shows the estimated 80% risk-neutral and physical confidence bands of the spot rate for the 3-month horizons.

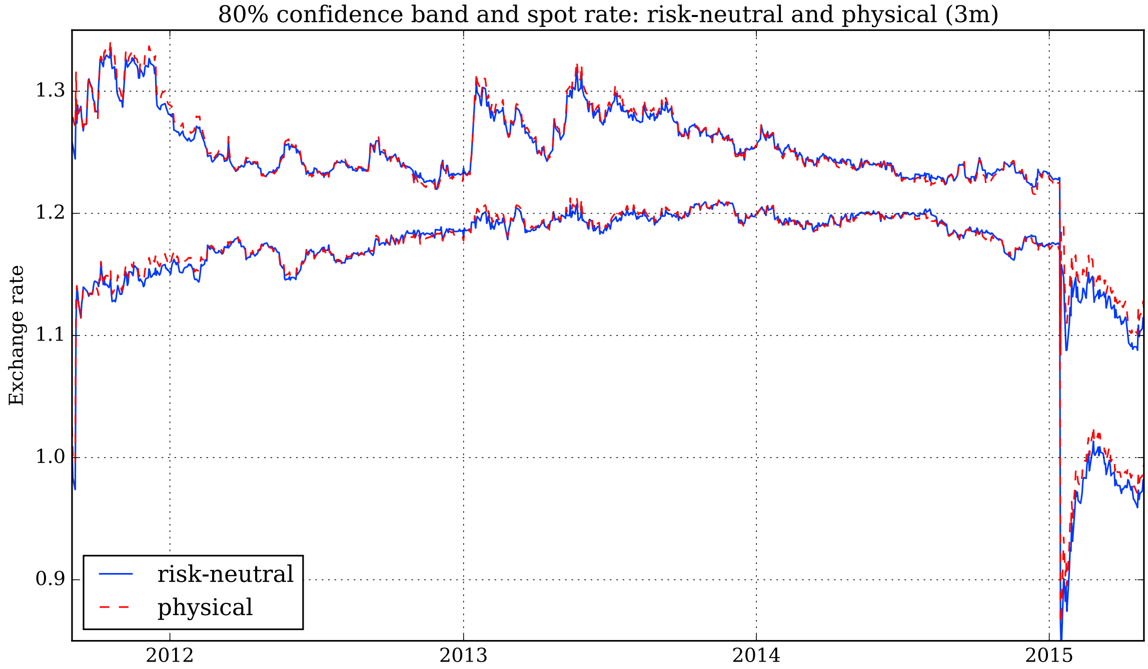


Figure 6: **Event study.** The figure shows the cumulative average uncertainty (upper panel) and skewness (lower panel) and the 95% confidence band (red dashed line) over the speech day (day 0) and on the five subsequent days.

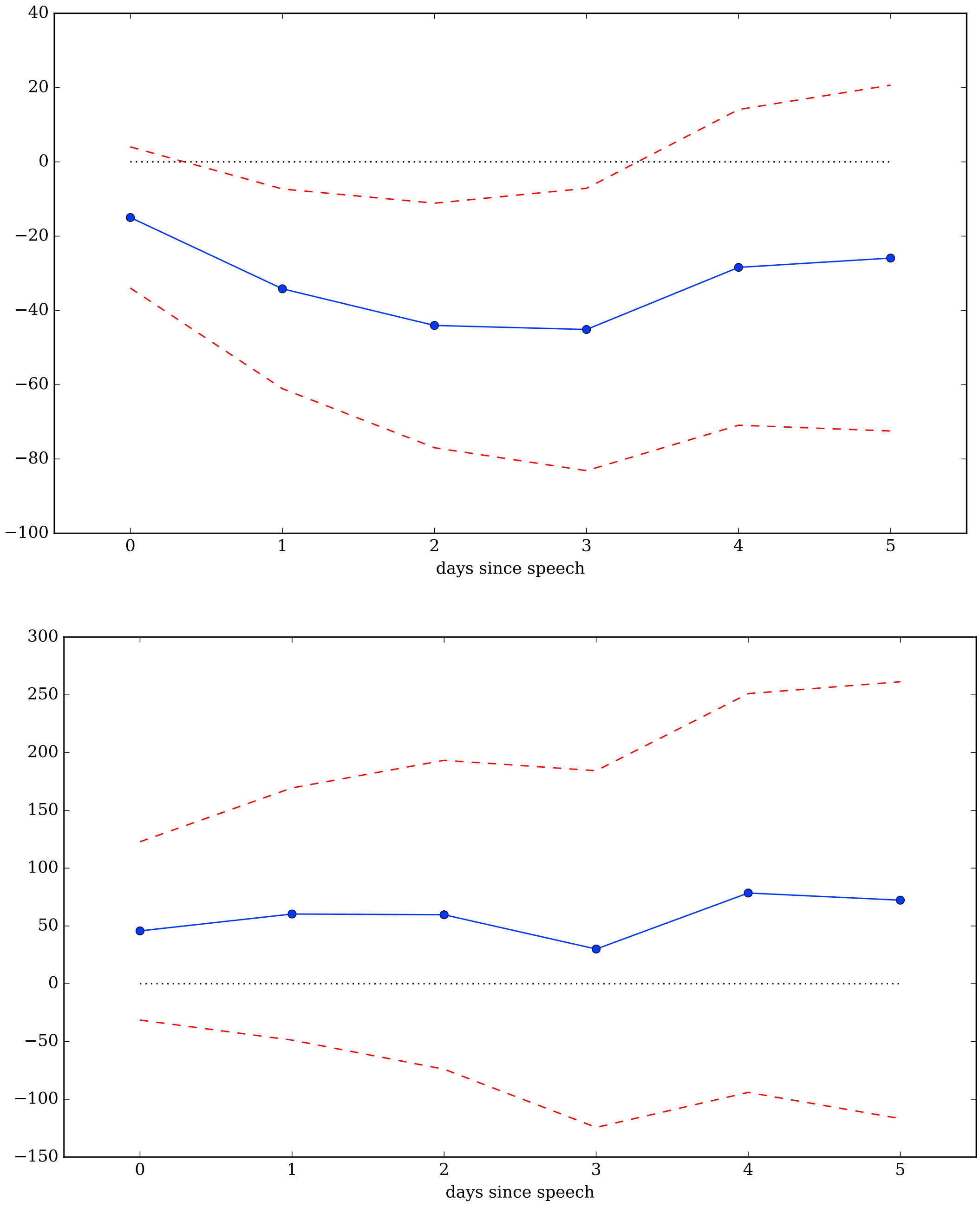


Figure 7: **Evidence from spreads.** This figure shows the average volume-weighted spread (in pips) of 10 currency pairs, the counter currency being CHF. The time window is 2011-09-06 to 2015-06-01. The red line is the 5-day moving average, and three red squares correspond to the first observations after the SNB announcement.

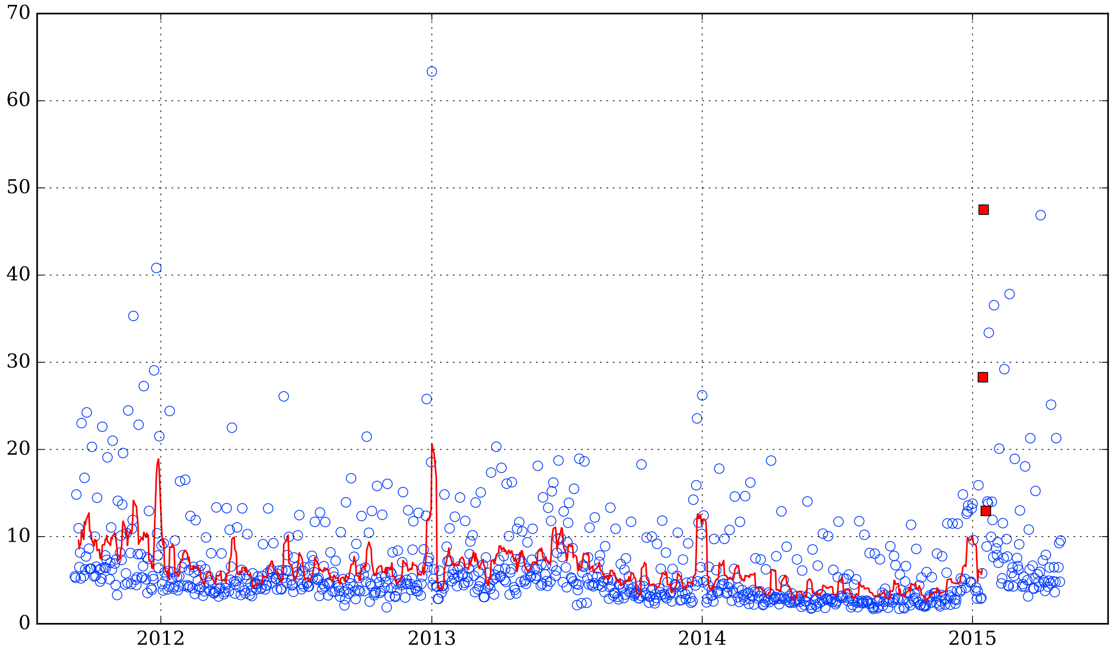


Figure 8: **4-hour window around the announcement.** The figure plots the estimated 80% confidence band of the spot rate.

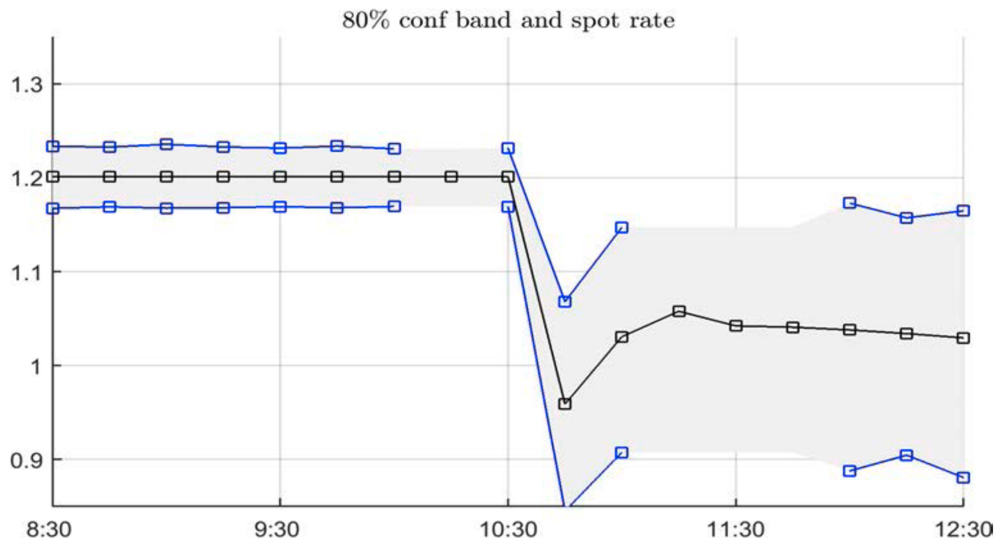
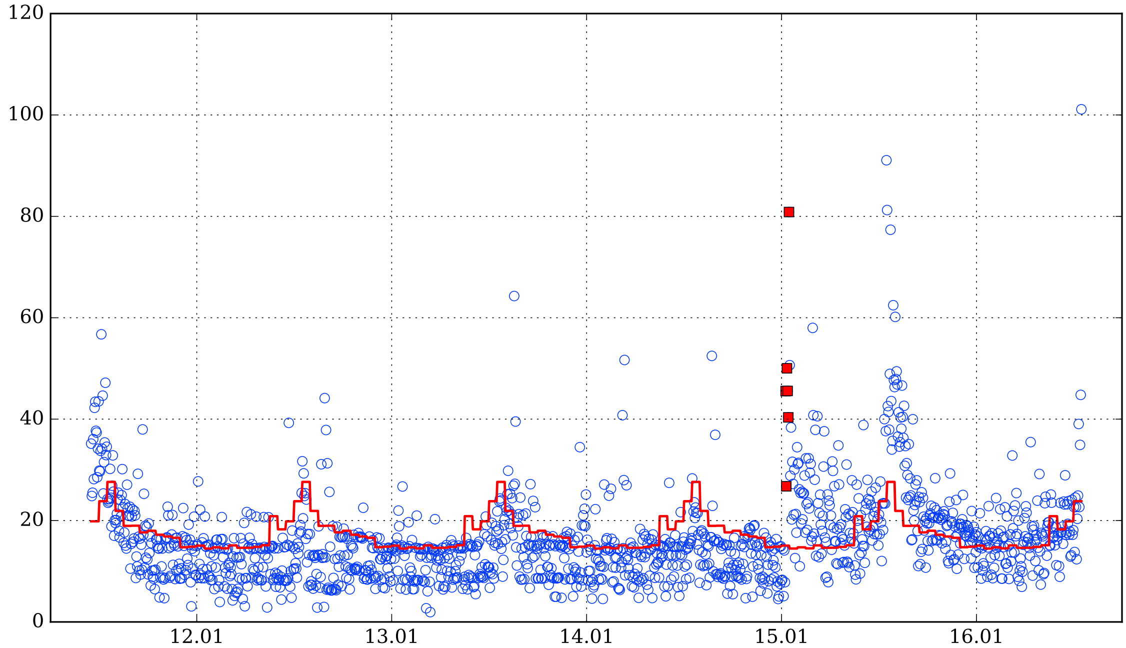


Figure 9: **Evidence from spreads in high frequency.** This figure shows the average weighted spread (in pips) of 9 currency pairs. The red line is the median weighted average spread estimated for each hour on the sample of data from December 26th, 2014 to January 10th, 2015. Red squares are the first observations of the average weighted spread after the SNB aanouncement.



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