Did Markets Anticipate the Removal of the Swiss Franc Cap?*

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Abstract

We look into spot and option markets of the Swiss franc around the decision of the Swiss National Bank (SNB) to abandon the 1.20 cap on the exchange rate against the euro on 15 January 2015. According to extracted risk neutral distribution from option prices on euro-Swiss franc, the market-perceived uncertainty was broadly stable prior to the decision and considerably higher thereafter. Our study also shows that the use of "utmost determination" wording by the SNB chairmen significantly contributed to lowering that uncertainty. Similarly, the evidence from a wide range of exchange rates against the Swiss franc indicates that the market liquidity as measured by the relative bid-ask spreads did not exhibit abnormal behavior immediately before the SNB's decision. We conclude that both spot and option markets perceived the 1.20 cap as credible until the very moment it was revoked.

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1 Introduction

On 6 September 2011, the Swiss National Bank (SNB) set a cap on the Swiss franc exchange rate against the euro in order 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 intensifying euro area crisis. The excessive appreciation posed a threat to price stability in a small export-oriented economy such as the Swiss. With the policy rate being already at the zero lower bound, the SNB decided to announce a minimum EURCHF exchange rate by promising to buy foreign currency in unlimited quantities.

Using exchange rate policy to steer monetary conditions at home was not new in Switzerland. During the 1977 and 1978, the US dollar depreciated significantly against the Swiss franc. The SNB reacted to 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 below 80 Swiss francs to 100 German marks”.

Similar exchange rate policies are, in principle, 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 gets exposed to various financial risks, most notably to currency risk. 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 about credibility of such policies in the long term, if a central bank experiences persistently negative equity.

In this paper, we ask whether exchange rate markets appreciated these risks and therefore expected the removal of the franc cap. We estimate a risk-neutral distribution from EURCHF option prices along the lines of Söderlind and Svensson (1997) and look for any pre-announcement movement in the distribution which could indicate that the option market saw the removal of the Swiss franc cap as increasingly likely. We find no evidence of such behavior in the priced uncertainty and therefore conclude that the exchange rate market did not anticipate the removal of the cap. Moreover, we show that speeches by the two SNB chairmen during the period of cap enforcement significantly reduced perceived

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

uncertainty by reiterating that the SNB will "[...] enforce this minimum rate with the utmost determination."

Further evidence that SNB's decision came as a surprise has roots in liquidity patterns around the event. We calculate average spreads on the FX market at the daily and 5-minute frequency and find no signs of alert in how liquidity providers were setting the bid and ask prices of other currencies immediately before 10:30am on January 15th. Comparing this to the increased illiquidity afterwards we conclude that rational liquidity providers did not place a significant probability on the cap removal.

Several other papers study the Swiss exchange rate policy over this period. Hertrich and Zimmermann (2013) explore the credibility of the Swiss franc cap and find that the cap was never perfectly credible, since the estimated probability of euro/Swiss franc exchange rate being below 1.20 was unusually high. Hanke et al. (2014) and Jermann (2014) report considerably 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 studying *(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 removal of the cap.

The rest 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

We compile two data sets: a daily data set for studying a longer time period (2011–2015) and a high-frequency data set (5- or 15-minute data) for zooming in on the event on 15 January 2015.

All our data on exchange rates and option contracts is from Bloomberg. We use quotes of spot and forward EURCHF franc exchange rate as well as option data with the same underlying.

The option data comprises 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 with a 3-month time to expiration.[2] We focus on the 3-month expiration

[2] According to Bloomberg's Help desk, all price quotes on currencies and currency options are indicative

since those are the most commonly traded option contracts. In the appendix, we explain how to back out single option implied volatilities from the five instruments. For each trading time, we therefore get five implied volatilities we use together with the forward rate to estimate the risk neutral distribution. Risk-free rates are proxied by 3-month EUR and CHF LIBOR.

We relate the estimated risk neutral distributions to SNB speeches by the SNB chairman (data collected from SNB) and various measures of financial market uncertainty: the VSMI (an option-based volatility index on the SMI) is from the SIX Swiss Stock exchange, the TED spread (a spread between a USD LIBOR rate and a T-bill rate) is from St.Louis Federal Reserve, European sovereign 5-year CDS spreads are from Bloomberg, the Swiss LIBOR target rate and 10-year bond term premium for the Swiss market is from SNB while that for the US market is from Kim and Wright (2005) and the VIX (an option-based volatility index on S&P 500) is from CBOE.

We zoom in during the morning of 15 January 2015 (the day when the SNB removed the Swiss franc cap) by estimating risk neutral distributions around the announcement time. We consider a four-hour time window around 10:30 hours Zurich time. High-frequency data on other exchange rates is at 5-minute intervals, snapped and compiled in the same way as the daily one.

3 The Model

The goal is to estimate the market's beliefs about future exchange rates in a flexible way.

An option price reflects the perceived (by the market) likelihood that the future exchange rate will be above or below the option's strike price. For instance, the payoff at expiration of a European call option with strike price 1.15 is the difference between the exchange rate and 1.15 (if positive) or zero. Thus, the market price (today) of this option is strongly related to the market's beliefs about whether the exchange rate (at the time of the options expiration) will be above 1.15. Similarly for an option with a strike price of 1.20. Combining two such options allows us to tease out the beliefs about an exchange rate between 1.15 and 1.20. More generally, using a cross section of options with different strike prices allows us to recover the broad shape of the market's (subjective) exchange rate distribution.

and not actually traded prices. For the daily analysis we consider are Bloomberg composite quotes compiled with Bloomberg's BGN method at 18:00 London time.

In particular, we assume that the distribution be can approximated by a mixture of two lognormal distribution as in Ritchey (1990). This allows for a flexible distribution (skewed, fat tails, etc) despite having few (five) parameters to estimate. The next paragraph summarizes our approach.

When the market's beliefs about the logarithm of the future exchange rate is well described by a normal distribution with mean μ and variance σ^2, then the Black-Scholes formula apply. Let $G(\mu, \sigma^2)$ be the option price according to this formula. If instead, the beliefs are better described by a mixture of two normal distributions, then the option price C can be shown to be

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

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).

The estimation of the five parameters $(\mu_1, \sigma_1^2, \mu_2, \sigma_2^2, \alpha)$ is done by minimizing the sum of weighted squared pricing errors (trade price minus model price). The weights are the inverse of the (Black-Scholes) vegas, so we effectively minimize the sum of fitted errors of the implied volatilities (see Carr and Wu (2007)). This is repeated for each trading day/time.

There are several reasons for assuming a mixture of log-normal distributions. First, non-parametric methods often generate strange results, including unstable estimates and negative probabilities (see Söderlind and Svensson (1997)). Second, the mixture of log-normals gives closed form solutions for the option and forward prices, which speeds up the estimation and allows us to impose restrictions that makes the estimations more stable.

Once the five parameters in (1) are estimated, we can show the so-called risk neutral distribution. It corresponds to the market's subjective beliefs—if the underlying asset (here, the euro/Swiss franc) embeds no risk premium.[3]

[3] If the Swiss franc has a negative risk premium, that is, is considered a safe haven, then the risk neutral probability of a value below 1.20 is likely to be somewhat larger than the market's perceived probability.

4 Results

4.1 Estimation Results from Daily Data

4.1.1 Uncertainty

Figure 1 illustrates an estimated 80% confidence band (that is, the 10th and 90th percentiles) of the Euro/Swiss franc exchange rate. The overall uncertainty priced in the market (the width of the confidence band) was broadly stable in the months prior to the removal of the cap. It rose from very low levels in mid-2014, but the increase was gradual (and not sudden as the announcement day was approaching) and the overall uncertainty was much lower than in the past.

The lower panel of Figure 1 reports a measure of skewness of the estimated distribution.[4]The estimated distribution was symmetric around the spot rate most of the time (corresponding to a zero value in the figure). If not symmetric, it was more often skewed to the right, that is, towards the franc depreciation (corresponding to positive values in the figure) than to the left. In other words, the option market was systematically attaching more probability to upside risk in the Euro/Swiss franc rate throughout the sample from September 2011 to January 2015.

One notable exception is the period around mid-2012. The risk of significant franc appreciation surged (see the sudden drops in Figure 1) as fears over the Euro area intensified and buying pressure on the Swiss franc rose.[5] Another possible reason might have been rumors that SNB was considering the removal of the cap amid a drop in euro foreign currency investments at the SNB.[6] The uncertainty fell subsequently with several speeches from the SNB board members reiterating the importance of the Swiss franc cap.[7]

Similar spikes in tail risk cannot be observed on the days prior to the removal of the minimum exchange rate. As a matter of fact, the estimated distribution was then almost perfectly symmetric around the spot. Therefore, it looks as if there were no major changes in the market beliefs about the 1.20 cap on days before 15 January 2015: the option markets did not anticipate that the cap would be removed.

[4]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 $[(P90 - S) + (P10 - S)]/(P90 - P10)$. It was also used in Mancini et al. (2012).

[5]See, for instance, the *Financial Times* article "Swiss Franc Strength Tests SNB" from 24 May 2012.

[6]See SNB (2012).

[7]See for example Danthine (2012).

Finally, we explained in the modeling part that the mixture of two log-normals was used to extract the distribution from the data. We imposed no restrictions on the two means, and hence we allow the mixture distribution to be bi-modal. We find some, but not strong evidence of bi-modality in the data.

4.1.2 SNB's Verbal Interventions and Uncertainty

Announcing the decision to impose a cap on the Swiss Franc, the SNB pledged to "[...] enforce this minimum rate with the utmost determination." The framing 'utmost determination' was subsequently used in a variety of speeches by the members of the SNB's Governing Board. In this section, we explore whether these speeches significantly affected market uncertainty and skewness. We define uncertainty as the difference between the 90th and the 10th percentile of the estimated risk neutral distribution (see Figure 1) and use the Hinkley (1975) statistic as a measure of skewness (see footnote 4).

In the period from the 6th September 2011 until the 14th of January 2015, there were 14 speeches delivered by the two chairmen of the Governing Board that contained the wording 'utmost determination." One was made by Philipp Hildebrand in December 2011 and the other 13 by Thomas Jordan. Table 2 displays the speeches together with the uncertainty and skewness on the corresponding dates and their averages over the prior time periods. To assess significance of the difference in uncertainty and skewness, we conduct Welch's two-sample t-test with unequal variances and sample sizes. The test statistic takes the form:

$$t = \frac{\bar{X}_0 - \bar{X}_1}{\sqrt{s_0^2/N_0 + s_1^2/N_1}} \tag{2}$$

where $\bar{X}_i$ is mean of sample i, s_i^2 unbiased variance of elements of this sample and N_i is the sample size with $i = 1$ for days when a speech by a SNB official was made and 0 otherwise. It can be shown to follow a t-distribution (in our case, with 14 degrees of freedom).[8]

We test if the mean of the former sample is equal to that of the latter against the alternative of speech days being associated with lower uncertainty and skewness. As can be seen from Table 2, the average uncertainty on the days of the speeches is significantly lower both

[8] The t-distribution has ν degrees of freedom $\nu = A/B$ where $A = \left(s_0^2/N_0 + s_1^2/N_1\right)^2$ and $B = s_0^4/(N_0^2\nu_0) + s_1^4/(N_1^2\nu_1)$, where $\nu_i = N_i - 1$.

when “non-speech periods” are 60-day and 90-days (N_0). No similar pattern is observed for skewness. We thus conclude that the SNB’s “utmost determination” talk might have reduced the uncertainty about the exchange rate dynamics.

Needless to say, other market forces could have affected the uncertainty of the Euro/Swiss Franc on the days of the speeches. We therefore try to isolate the effect of ‘utmost determination’ speeches by controlling for a host of other possible driving factors of uncertainty. In particular, we run the following regression with uncertainty (u_t) as the dependent variable

$$u_t = \alpha + \beta d_t + \gamma X_t + \varepsilon_t \tag{3}$$

where d_t is equal to one on the days with speeches and zero otherwise, while X_t is a vector of control variables reported in Table 3 together with all the estimated coefficients. In addition to SNB officials’ speeches we include a dummy for a single Mario Draghi ”do all it takes to preserve the euro” speech (d_{Draghi}). We try to explain levels of uncertainty with levels of VSMI and VIX which should capture the general uncertainty of investors; 5-year sovereign European CDS spread since it reflects the euro debt crisis magnitude and sentiment about euro; change in SNB’s 3-month LIBOR target rate (”TARGET”) which should gauge the bank’s determination to defend the cap. We also include the EURCHF spot rate and 10-year term premia on the US and Swiss market as well as the TED spread as measure of funding liquidity. Equation (3) estimates the contemporaneous (same day) effect of speeches on uncertainty. In addition, we look at the effect of speeches on next-day uncertainty by estimating the following regression:

$$u_t = \alpha + \beta d_{t-1} + \gamma X_t + \varepsilon_t \tag{4}$$

Beyond estimating the equations (3) and (4), we also run the same regressions with an additional AR(1) term of the dependent variable on the right hand side—to correct for the autocorrelation of the error term. Finally, we also aggregate the daily data to monthly by constructing a monthly 0-1 dummy for speeches and taking monthly averages of control variables. The results are reported in Table 3.

As the table shows, uncertainty exhibits a strong autoregressive structure and co-moves with the spot rate as well as the target LIBOR change and TED spread. More interestingly, the use of ‘utmost determination’ by the SNB chairmen apparently had a dampening effect on uncertainty even when controlling for other drivers of uncertainty. We estimate that a day with the speech is related to a drop in uncertainty (difference between the 90th and 10th percentiles) of 40-55 pips on the same day and a drop of 34-75 pips on the following day. Consequently, these speeches likely reinforced the credibility of the minimum exchange rate over time and therefore made the discontinuation of the policy appear unlikely.

4.1.3 Liquidity

An event like SNB's decision to remove the Swiss franc floor is bound to have consequences for FX market liquidity. First, following the sudden movements of the spot rate, market participants start to rebalance their portfolios which increases liquidity demand. Second, the introduced uncertainty about the spot rate dynamics makes providing liquidity more risky. A rational liquidity provider may therefore start to widen the bid-ask spread as soon the event is perceived as inevitable — or at least highly probable. An unexpected cap removal should thus be not associated with a spread widening or a liquidity drought just beforehand.

Looking at the EURCHF spread only might be uninformative, because SNB intervened on the market before January 15th. Nonetheless, should a cap removal be expected, liquidity providers would try to create a buffer to withstand the possible negative consequences by increasing the ask and lowering the bid quotes of the other currency pairs they trade. It is therefore natural to expect movements in those spreads just before the policy shift if the latter is considered probable.

In Figure 3 we look at the weighted average spread across exchange rates of 11 currencies to CHF, including USD, YEN and GBP, but excluding EUR. The weight for each currency pair is the share of its base currency in the global foreign exchange market turnover in 2013 as taken from the BIS Triennial Central Bank Survey (e.g. the share of all USDXXX pairs is 87%, that of all YENXXX pairs is 23% etc.), normalized such that the weights sum up to one.

There is considerable seasonality in bid-ask spreads, especially around late December/early January. As can be seen in Figure 3, January 14th is usually about the time when the spread comes down again, and when a relatively calm period takes over. January 14th, 2015 was no exception, and neither the magnitude of the spike beforehand (if anything, it was lower than usually for early January) nor its subsequent correction hinted at expectation of a drastic policy shift. To sum up, liquidity on the CHF segment of the global currency market behaved normally until SNB removed the cap—and then surged considerably.

4.2 Zooming in on the January 15th, 2015

We now take a closer look at the time around the announcement of the new SNB policy by using high-frequency data (5- or 15-minute data).

4.2.1 Uncertainty

The results from using high-frequency data around the announcement on 15 January 2015 are illustrated in Figure 2. As before, the upper panel plots 80% confidence bounds around the spot. There are 4 missing (incomplete) observations at 15-minute intervals, as shown in Table 1 (row "Ask"): one before and three after the SNB announcement at 10:30 Zurich time.[9]

The estimated distribution (based on ask quotes) was remarkably stable prior to the removal and reflected high uncertainty thereafter. Results from the bid quotes (not shown) are very similar. The distribution was broadly symmetric throughout this 4-hour window (lower panel of Figure 2). Once again, it seems that the option market had not anticipated the removal of the cap.

4.2.2 Liquidity

Using high-frequency data we find further support for the claim that liquidity providers did not expect the cap to be removed to be dropped on January 15th. In Figure 4 we show the average weighted spread of several USD and EUR pairs. The weight for a particular currency pair is taken to be its share of trading volume on the swap derivatives market in 2014.

During the week of the event (late Sunday 11 Jan to Friday 16 Jan) the average spread is

[9] Table 1 illustrates the number of available data points at 5, 10 and 15-minute frequencies. As it can be noticed, the sample with 15-minute observations is the most balanced one. There are 13 complete Ask quotes, 12 complete Bid quotes and 10 complete Mid quotes. The main reason why there are fewer complete observations necessary to calculate the five implied options is that butterfly strategies have relatively low liquidity with respect to risk reversals and especially comparing to ATM options.

mostly lower than its median value before January 10th (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 removing the cap hit the market.[10] This would probably only happen either the liquidity providers had severely underestimated the possible impact of the SNB's decision on the market liquidity or had not expected such decision at all.

5 Conclusion

We ask whether spot and option markets for the Swiss franc anticipated the removal of the 1.20 cap in mid-January 2015. According to our estimates, the market-perceived uncertainty was broadly stable prior to the announcement and considerably higher thereafter. From mid-2014 onwards, the estimated risk neutral distribution broaden somewhat, but in a gradual way and much less than in several previous episodes when the market was testing the SNB commitment to the floor. Moreover, we find that the speeches of the two SNB chairmen from September 2011 until January 2015 likely reinforced the credibility of the cap and thus made the discontinuation of the policy appear unlikely. Finally, we show that liquidity providers did not act as if they had expected the cap to be removed on January 15th, as can be read from the FX market liquidity patterns around the event.

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[10]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 a lot of missing data, makes figures less descriptive. They are available at request.

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Appendix

As mentioned in section 2, the option data consist of five daily implied volatilities on an at-the-money (ATM) forward option, a 25-delta risk reversal, a 25-delta butterfly, a 10-delta risk reversal and a 10-delta butterfly with a 3-month time to expiration. Here we define the five instruments and explain how to back out single option implied volatilities we need in order to estimate risk neutral distributions.

In particular, a European ATM forward option gives the buyer the right, but not the obligation, to buy (call option) or sell (put option) the underlying asset on a specified day in the future—at a strike price that equals the current forward rate. The buyer pays an option premium to the seller which is quoted in terms of option's implied volatility σ.[11] By the put-call parity, a put and a call option with the same strike price have the same implied volatility which is σ_{ATMF} for put and call options with strike price equal to the current forward rate.

A 25-delta risk reversal is a portfolio with two positions: a long position in a call option with a strike price, say K_2, such that the delta of the option is 0.25, and a short position in a put option with a strike at K_1 so that it's delta is -0.25. Both options are out of the money, so the strike price of the put is lower than the forward price, which in turn is lower than the strike price of the call ($K_1 < F < K_2$). Assuming that the risk reversal is quoted as the difference of the two implied volatilities

$$rr = \sigma_2 - \sigma_1 \tag{5}$$

where σ_2 and σ_1 are the implied volatilities of the options with strike prices K_2 and K_1, respectively.

Finally, a 25-delta butterfly is a portfolio that is long one 25-delta straddle and short one delta-neutral straddle. A straddle is an option strategy which consists of a long position in a call option and a long position in a put option.[12] The 25-delta butterfly is typically quoted as the average implied volatility of the K_2 and K_1 options minus the at-the-money volatility

$$bf = \frac{\sigma_2 + \sigma_1}{2} - \sigma_{ATM} \tag{6}$$

Given the definitions in (5) and (6), we can back out implied volatilities from 25-delta and 10-delta strategies given σ_{ATM}.[13] We therefore have five implied volatilities for each trading day to use in the estimation together with the forward rate. The strike prices

[11] For a very simple reason, different pricing models produce different premiums in terms of currency. Implied volatility is therefore a universal measure of an option's value and one missing peace of information you need to calculate the dollar premium for that option.

[12] A delta-neutral straddle would be such a strategy that it's value is not affected by the movements in the underlying.

[13] We calculate the ATM volatility from σ_{ATMF} by using the forward-spot parity and the Black-Scholes formula, see for example Malz (2014).

can be calculated from the equations defining the deltas in the Black-Scholes model (see, for instance Wystup (2006)). For instance, for 14 January 2015 the strike prices are (1.139,1.1795,1.2,1.2152,1.2462).

Tables and Figures

Table 1: **The number of available observations around 8:30–12:30 on 15 January 2015**

	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
Total	50	50	25	25	17	17

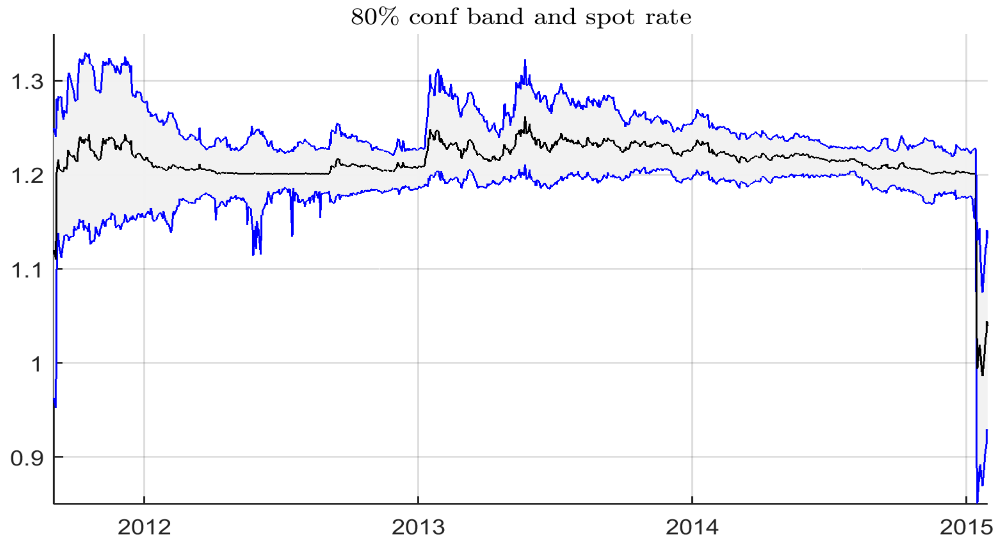
Table 2: **Speeches and the Welch's t-test.** This table reports all the major speeches where "utmost determination" (or an equivalently strong notion) to support the exchange rate floor was mentioned. Mean uncertainty and skewness are calculated at speech days (column '0') and over the last 60 and 90 days before the speech (if there were fewer days since the previous speech than 60 or 90, we just took the days since the previous speech). A Welch's t-test is conducted to see if mean uncertainty/skewness at the speech day is significantly different (positive statistics meaning less uncertainty) from the mean uncertainty/skewness before those.

Date	Speaker	uncertainty (in pips)			skewness (in percent)		
		60	90	0	60	90	0
15.12.2011	Philipp Hildebrand	1660	1835	1419	-2.93	-5.85	-1.37
07.02.2012	Thomas Jordan	1143	1143	1236	-1.22	-1.22	-8.34
27.04.2012	Thomas Jordan	672	672	532	-1.54	-1.54	-0.58
14.06.2012	Thomas Jordan	759	759	479	-3.04	-3.04	19.85
03.09.2012	Thomas Jordan	515	515	469	10.01	10.01	13.61
16.11.2012	Thomas Jordan	573	573	423	-1.56	-1.56	-4.17
13.12.2012	Thomas Jordan	438	438	434	-4.45	-4.45	-3.14
26.04.2013	Thomas Jordan	772	729	676	15.79	10.68	3.53
08.10.2013	Thomas Jordan	774	822	557	7.49	7.10	-6.83
12.12.2013	Thomas Jordan	555	555	565	-0.38	-0.38	-4.54
25.04.2014	Thomas Jordan	509	536	425	-3.43	-3.35	-5.20
19.06.2014	Thomas Jordan	406	406	364	-5.05	-5.05	-4.71
11.12.2014	Thomas Jordan	505	474	437	0.23	0.04	-0.36
18.12.2014	Thomas Jordan	412	412	580	0.95	0.95	-3.02
Welch's t, 14 df		1.349*	1.841**		0.916	0.625	

Table 3: **Utmost Determination Dummy.** The table reports the coefficient estimates of equations (3) and (4) (columns 'baseline') as well as the same regressions' estimates including an AR(1) term of the dependent variable (columns 'AR(1)'). For baseline estimates, we report t-stats (in brackets) with Newey-West standard errors. For AR(1) specifications, the t-stats are calculated using the regular standard errors. Durbin-Watson statistic and the adjusted R-squared are reported at the bottom of the table.

	equation (3)		equation (4)		monthly
	baseline	AR(1)	baseline	AR(1)	baseline
intercept	-533.55	-53.72	-534.64	-54.20	-480.03
	-10.10	-1.92	-10.13	-1.93	-1.97
d_t	**-54.66**	**-40.25**	**-75.21**	**-33.54**	**-51.61**
	-1.45	**-2.15**	**-2.15**	**-1.93**	**-1.34**
d_{Draghi}	35.37	49.09	53.18	4.68	-147.14
	0.27	0.76	0.41	0.07	-1.40
VSMI	26.69	3.73	26.82	3.83	19.76
	9.97	2.65	10.03	2.72	1.75
TED	1453.16	152.11	1459.71	153.22	1204.83
	8.85	1.77	8.90	1.78	1.63
eu5yrCDS	-0.16	0.05	-0.17	0.05	-0.01
	-0.82	0.54	-0.88	0.54	-0.01
ch10yrTerm	-72.18	-54.37	-72.07	-54.59	-108.56
	-1.61	-2.45	-1.61	-2.46	-0.49
TARGET	-741.71	-888.96	-517.86	-726.66	-300.39
	-1.37	-3.31	-1.00	-2.81	-0.67
VIX	13.42	2.83	13.38	2.79	21.62
	6.13	2.55	6.13	2.52	2.35
us10yrTerm	-85.55	-5.77	-86.57	-6.20	-89.51
	-3.22	-0.43	-3.26	-0.47	-0.74
$1.20 - spot$	-1.49	-0.31	-1.49	-0.31	-1.51
	-25.81	-8.41	-25.80	-8.41	-5.41
AR(1) term		0.84		0.83	
		49.18		49.01	
DW stat	0.31	2.12	0.31	2.12	1.78
adj. R^2	0.87	0.97	0.87	0.97	0.92

Figure 1: **Estimated confidence bands.** The upper panel plots the estimated 80% confidence bound of the spot rate. The lower panel illustrates the skewness of the estimated mixed normal distribution using the Hinkley (1975) statistic where S is the spot rate, and $P10$ and $P90$ stand for the 10th percentile and the 90th percentile of the distribution, respectively.



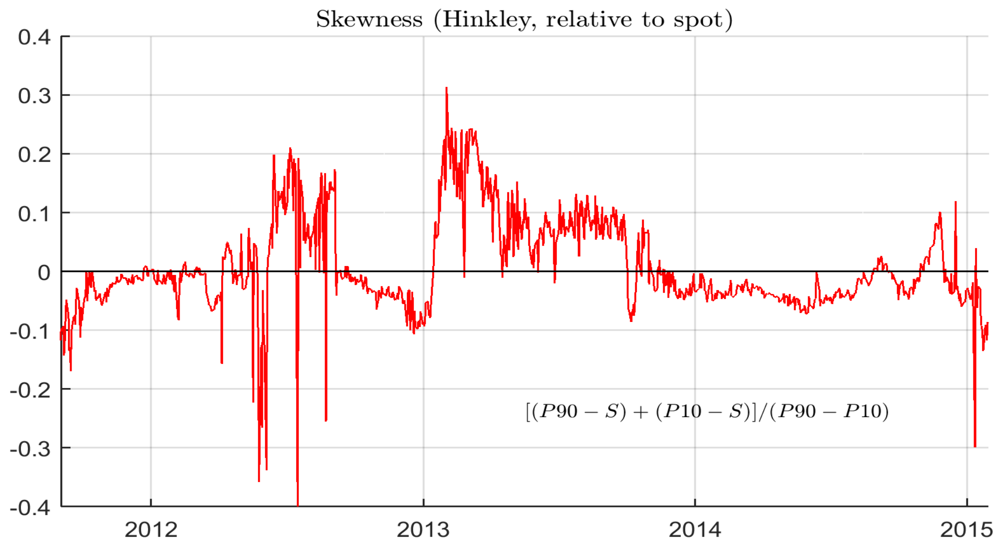


Figure 2: **4-hour window around the announcement.** The upper panel plots the estimated 80% confidence bound of the spot rate. The lower panel illustrates the skewness of the estimated mixed normal distribution using the Hinkley (1975) statistic where S is the spot rate, and $P10$ and $P90$ stand for the 10th percentile and the 90th percentile of the distribution, respectively.

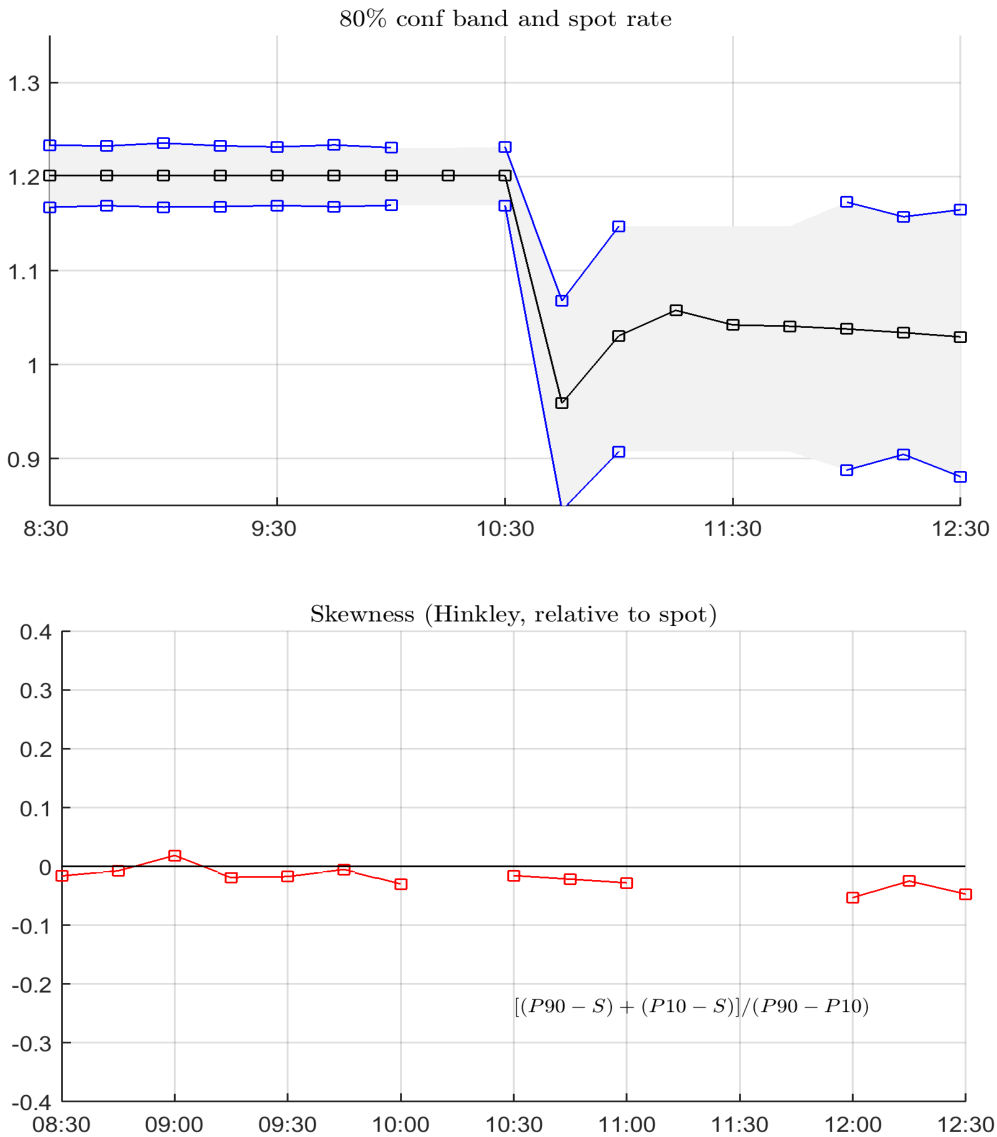


Figure 3: **Evidence from spreads.** This figure shows the average weighted spread of 11 currency pairs, the counter currency being CHF. The red line is the 5-day moving average, and two red circles correspond to the first two observations after the news hit the market.

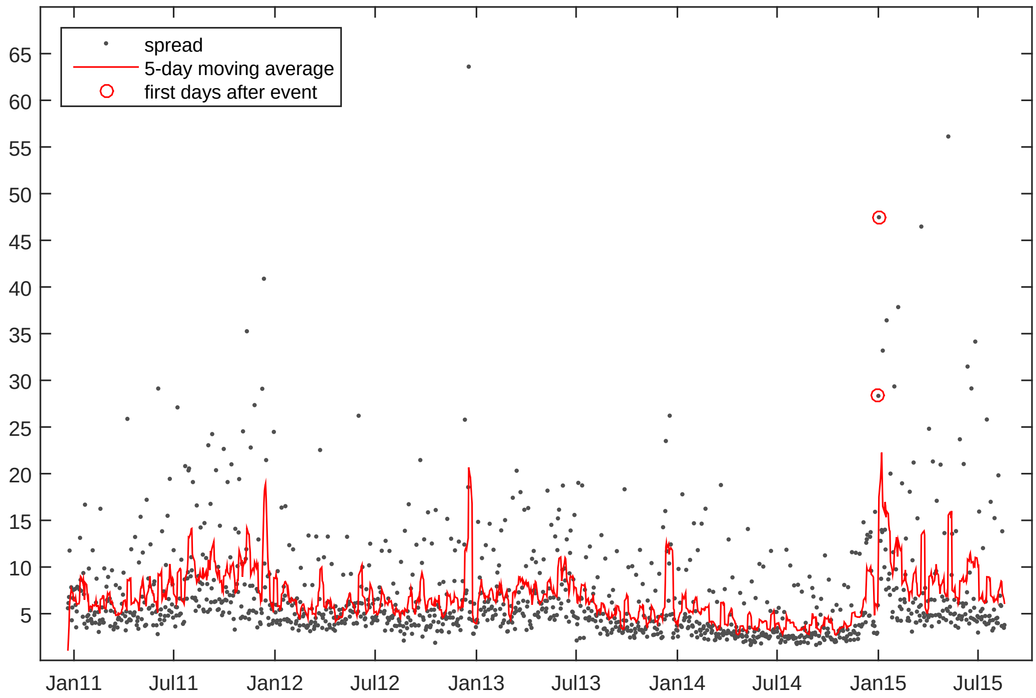


Figure 4: **Evidence from spreads in high frequency.** This figure shows the average weighted spread of 9 currency pairs jointly accounting for about 30% of the swap derivatives market. The red line is the median weighted average spread estimated for each hour on the sample of data from December 26th, 2014 to January 10th, 2015.