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[1] The views expressed herein are those of the authors and not necessarily those of the Swiss National Bank (SNB). The SNB does not accept any responsibility for the contents and opinions expressed in this paper.

## Abstract

We use a regime switching approach to model the implementation of the SNB monetary policy. The regime switching technique is crucial to assess the flexibility inherent in the SNB's monetary policy concept. The empirical findings support the idea that repo operations are instrumental in smoothing the implementation of monetary policy in normal times while changes in the official operational target accompanied by the accommodating use of repo operations produce the aimed effects in distressed periods. A significant contribution also came from some new measures designed to improve liquidity in the Swiss franc money market during the financial crisis in 2007-8.

## Keywords

implementation of monetary policy, Libor, repo, Swiss franc money market, regime switching model

## JEL Classification

E5, G15

# 1 Introduction

Central banks rely on different mechanisms to implement their monetary policy. The recent market turmoil highlighted how varying tools can entail completely different outcomes, in particular in terms of short term interest rate patterns. During the recent financial market crisis, the ability of the Swiss National Bank (SNB) in stabilising its target rate was observed with much interest by many specialists. For instance, by means of its Survey magazine[1], the International Monetary Fund pointed out that "(T)he Swiss (monetary) approach imparts a degree of flexibility, which has served it well during the turbulence in financial markets." Probably the most noticeable characteristic of the SNB's monetary concept is the sense of balance between its long term objective of price stability and its implementation mechanism that is distinguished by a pragmatic short term flexibility. The intellectual background of this combination is discussed in Baltensperger, Hildebrand and Jordan (2007). The former property, i.e. a firm long term anchor for nominal stability, has assured stable prices, which is an important prerequisite for the smooth functioning of the economy. The latter quality, i.e. short term flexibility in policy implementation, has two aspects. First, it assures the regular functioning of liquidity provision in normal times and a swift response to exogenous shocks to the financial market. Second, it is an effective tool to achieve the intended policy stance in turbulent times.

The objective of this paper is twofold. First, we propose an econometric representation that captures the main characteristics of the SNB implementation mechanism. An antecedent in the literature is Jordan and Kugler (2004). Our model differs from it in several respects. On the one hand, it takes account of the official operational target, which is a range for the three-month Swiss franc Libor. On the other hand, it incorporates the crucial role of SNB repo transactions, which provide the banking system with liquidity. A distinguishing characteristic of this dual mechanism in the monetary policy implementation is its adaptability in stress periods. We capture this feature in a regime switching model, where the regime mechanism depends on the tightness of money market conditions. Conceptually, the state dependency of the model ties with the flexibility of the SNB's monetary policy concept. Second, we analyse how the market reacted to monetary policy decisions and to new funding facilities introduced by the SNB to confront the financial crisis in 2007–8. In particular, we investigate whether the announcement and provision of US dollar funding to the Swiss money market, Swiss franc liquidity to the Eurosystem as well as un-

[1] See Ross (2008).

scheduled decisions about the SNB target range were associated with significant effects on the 3M-Libor.

The structure of the remaining part of the paper is as follows: In Section 2 we review the main characteristics of the SNB monetary concept and its repo operations, and in Section 3 we explain the empirical set up. Section 4 contains the empirical results. Section 5 concludes.

# 2 The monetary policy concept and its repo operations

In this section, we shortly review the main characteristics of the SNB's monetary policy concept and the Swiss franc repo market. More comprehensive contributions on the concept can be found in Jordan and Peytrignet (2001, 2007) and Meyer (2000). Veyrassat (2001, 2004) and Kraenzlin (2007) provide more detailed descriptions about the repo operations. We also shortly survey the new measures taken by the SNB to steer the money market during the financial crisis in 2007-8. A more exhaustive presentation can be found in a box of the SNB's Monetary Policy Report of the fourth Quarter in 2008 (SNB, 2008).

## 2.1 The monetary policy concept

At the end of 1999, the SNB abandoned the monetary targeting approach. The new monetary policy framework is characterised by three main elements: (1) an explicit definition of price stability; (2) a conditional inflation forecast as main indicator for future policy decisions; (3) a range for the 3M-Libor as operational target. The overriding objective of price stability is considered to be achieved with an inflation rate, measured by the national consumer price index, of less than 2% per annum. An inflation forecast for the next 12 quarters which takes into account all relevant information is the main indicator for policy decisions. The first two elements are complemented by the announcement of a target range for the three-month Swiss franc Libor. As documented in SNB (1999), the main reasons for choosing an off-shore market rate are the following: the Libor is the common money market rate, it is sensitive to all shocks relevant for monetary policy, and, by its very nature, it differs from repo rates, i.e. unlike a repo operation the Libor represents the indicative rate of "unsecured" interbank loans, which can give rise to liquidity and credit premia.

To understand the relevance of the last point, it is worth emphasizing the different implications of targeting "secure" and "unsecure" interest rates. The

Libor represents the short term interest rate at which banks lend money to each other without posting collateral. Hence, it is an unsecure interest rate since the lender bears credit and liquidity risks. The related risk premia can increase substantially during financial crisis, as has been observable since the outbreak of the financial crisis in August 2007. By contrast, repos are loans backed by securities. Thus, the repo rate is virtually free of risk. By targeting a range for the Libor, the SNB automatically takes into account the actual borrowing cost on the money market that includes risk premia and that ultimately determines the cost of borrowing in a broader sense (i.e. mortgages, corporate debts or derivative pricing).

## 2.2 Repo market

A repo transaction is a loan secured by collateral. The cash taker sells securities to the cash provider and repurchases them after an agreed period. The cash taker pays the cash provider a repo rate depending on the maturity of the transaction. The Swiss franc repo market can be divided in two main parts, namely the SNB repo market, characterised by transactions between the SNB and banks, and the repo interbanking market.

The SNB provides the banks with liquidity via repo transactions on a daily basis. Repos are auctioned in the morning in a fixed tender (as a rule) or are concluded in the course of the day on a bilateral basis. The liquidity provided is credited to non-interest-bearing sight deposits which the banks keep with the SNB. In normal times, the demand for sight deposits is determined by payment transactions, by the need for precautionary balance, and by the minimum reserve requirements stipulated in the National Bank Act.[2] According to these provisions, the banks must cover certain short term liabilities with coins and banknotes denominated in Swiss francs as well as sight deposits held with the SNB. The liquidity provided by the SNB is then traded on the interbank market. Interest rates on the money market are thus influenced by the price and volume of the liquidity injected by the SNB. In other words, the SNB indirectly steers the Libor by fixing rates and the amount to be allotted in the repo transactions.

## 2.3 New measures during the financial crisis in 2007-8

The SNB, as other central banks, has faced the crisis with three main measures: unscheduled monetary decisions, repo transactions in US dollar and a swap

[2] Foreign banks are not required to fulfil the minimum reserve requirements rule. The main reason for participation of foreign banks in repo auctions of the SNB is to refinance loans denominated in Swiss francs.

arrangement through which the ECB can access Swiss franc liquidity to provide the Swiss franc funding allotted to banks in its jurisdiction.

### 2.3.1 Monetary policy assessments

After a tightening stance from June 2004 to September 2007, lifting the midpoint of the target range for the 3M-Libor from 0.25% to 2.75%, the SNB kept the target range unchanged at 2.25%–3.25% from mid-September 2007 to mid-September 2008. Facing a rapid deterioration in global economic outlook and drop in inflation, the SNB went through an unprecedented relaxation of the monetary policy with four consecutive cuts of the target range in a very short period from 8 October to 11 December 2008. The monetary policy assessments on 6 October , 11 November and 20 November 2008 were unscheduled. On these occasions the the midpoint of the target range by 1.75 percentage points. At the scheduled assessment mid-December the SNB cut its target range by further 50 basis points down to 0.50%.

### 2.3.2 US dollar funding

This new facility was designed to facilitate the US dollar funding of SNB counterparties in the Swiss repo system. On 12 December 2007, the SNB announced the first provision of this funding. It was jointly introduced with the Bank of Canada, the Bank of England, the European Central Bank (ECB) and the Federal Reserve (Fed). The first operation took place on 17 December 2007 when the SNB offered US dollar repo transactions for the maximum amount of USD 4 billion in addition to its Swiss franc open market operations. The dollar repo transaction against SNB-eligible collateral was conducted in the form of a variable rate tender auction and it provided funds for 28 days, with settlement on 20 December 2007. To back these operations, the SNB concluded a reciprocal swap agreement (swap line) with the Fed. A second operation was announced on 10 January 2008 and was implemented on 14 January. In a joint statement with the G10 central banks, the SNB announced on 11 March 2008 the intention to continue as long as necessary with US dollar repo auctions. The characteristics of this facility changed during the year. In particular it was increased in terms of frequency, maturities and maximum amount offered.

### 2.3.3 Swiss franc funding

Foreign banks in the euro area with no direct access to SNB operations exerted an upward pressure on short term Swiss Franc money market rates. On 15 Oc-

tober 2008, the SNB and the ECB (Eurosystem) jointly announced the intention to conduct EUR/CHF foreign exchange swaps with the aim to provide Swiss francs against euro with a term of 7 days at a fixed price. The operations took place each Monday starting on 20 October 2008. To back these operations, the SNB and the ECB entered into a temporary swap arrangement through which the ECB can access Swiss franc liquidity to provide Swiss franc liquidity to banks in its jurisdiction.

On 7 November 2008, the SNB and the Polish central bank (NBP) announced to cooperate to provide Swiss franc liquidity by establishing a temporary EUR/CHF swap arrangement. On 28 January 2009, a similar initiative was announced together with the Hungarian central bank (MNB). This new facility is similar to the existing one with the SNB and the ECB. The rationale was to allow the NBP and the MNB to offer Swiss franc funding to banks in their jurisdictions in the form of foreign exchange swaps.

# 3 Empirical Setup

## 3.1 Economic explanation

The implementation of the SNB's monetary policy concept relies on two main elements: a decision about which part of the target range (upper half, centre or lower half) it is aiming, and about the volume of repo transactions. According to the expectations hypothesis, monetary policy surprises should have an impact on asset prices rather than actual changes in the central banks' target rate. Thus, following Kuttner (2004), we compute a measure of surprise target rate changes by using the nearest-to-maturity futures contracts on the Swiss franc three-month Libor. In order to enhance the measurement precision and to minimise endogeneity problems, we measure the price change over 30 minutes, i.e. 10 minutes before and 20 minutes after the exact release time of a monetary policy decision.[3] We call this variable $surpr_t$. The repo operations are represented by the one-week repo rate on day $t$, $repo_t$ (its difference is denoted $\Delta repo_t$) and the allotted volume in the morning auctions. We compute the first difference of the allotment ratio (i.e. allotted divided by bid volume) and call it $\Delta allotratio_t$.[4] The intraday data set necessary to compute the monetary policy surprise and

[3] For further information about the timing and surprise effect of SNB monetary policy assessments, cf. Ranaldo and Rossi (2007).

[4] In the morning auction, the SNB adds up all bids and decides the proportion to be allotted. Normally, it allots on a pro rata basis, i.e. after a minimal allotment to each bank, the remaining demand is accommodated in percentage of the amount bid.

the data on the repo operations are from the SNB.[5]

The Libor evolves according to credit conditions in the money market. However, the flexibility of the SNB concept enables it to react to unexpected events. To take account of these features, our empirical model allows the Libor to behave according to regimes characterised by normal and distressed markets. Empirically, the regime depends on the tightness of money market conditions, which is proxied by the standardised (to have zero mean and unit variance) spread between the Libor and repo rates, denoted $z_t$. This spread can be seen as a broad measure of risk premia on interbank lending. In troubled times, this spread typically widens.

Other factors can determine the evolution of the Libor. It can follow an autoregressive pattern. Also, there can be some exogenous variables that correspond to those market factors that the SNB may take into account to fix its morning repo rates but that are outside its control. Below, we limit the empirical analysis to the VIX index, i.e. $vix_t$.[6]

The remaining variables capture the new funding facilities introduced by the SNB in the wake of the financial crisis. We use information publicly available to set up a dataset containing the announcement and implementation days of the US dollar and Swiss franc funding auctions. We keep these two facilities and their announcements as well as their execution times separate in order to distinguish their effects. The dummy variable, called $swap_t$, equals 1 when a CHF funding auction takes place and 0 otherwise.

## 3.2 Econometric model

Our regime switching technique models the coefficients as changing smoothly with the regime that we generally call $z$. In practice, this means that the coefficient of a regressor is

$$b(z) = [1 - G(z)]b_1 + G(z)b_2 \tag{1}$$

where $G(z)$ is a logistic function $G(z) = 1/[1 + \exp(-3(z - c))]$. When $z$ (the standardised Libor–Repo spread) is low, then the effective slope is $b_1$, when $z = c$, then the slope is $(b_1 + b_2)/2$, and with a very high $z$ the slope is effectively $b_2$. This function is illustrated in Figure 2 (using the value of $c$ estimated below).

[5] We are grateful to Marcel Zimmermann for providing us the dataset.

[6] All other variables we considered, such as the overnight volatility on the exchange rate market, were insignificant.

The formation process of the Libor can be structured as follows:

$$\begin{aligned}\Delta libor_t = \phi \Delta libor_{t-1} + \delta(z_{t-1}) surpr_t + \chi(z_{t-1}) \Delta repo_t \\ + \varphi \Delta allotratio_t + \psi swap_t + \lambda vix_{t-1} + \alpha + \varepsilon_t \end{aligned} \quad (2)$$

This equation means that changes in the Libor can be due to five main drivers. First, it can be affected by unexpected changes in the official target range, i.e. $surpr_t$. We carefully considered the timing of the news releases. When the SNB announces its decision on the target range for the Libor before (after) the Libor rate fixing, i.e. at noon CET, the decision is supposed to impact on the Libor rate on the same day (day after). Second, the Libor might respond to changes in repo rates, i.e. $\Delta repo_t$. Since the SNB morning auction is set at 9:10 CET, we consider the effects of the repo operations on the same day of the Libor fixing. The coefficients on these two variables are allowed to change with the regime variable (the standardised Libor–Repo spread, lagged one day) as illustrated in equation (1).

Third, a broader provision of liquidity should decrease the Libor. We attempt to capture this effect by looking at the change in volume allotted at the morning repo auctions, i.e. $\Delta allotratio_t$. Fourth, we analyse whether the new funding facilities had some bearing on the Libor rates. In the equation above, we take the representative case of the implementation of the Swiss franc funding provided by the Eurosystem, i.e. $swap_t$. However, we also inspected the implementation and announcement effects of the US dollar funding. Fifth and finally, the VIX index, i.e. $vix_{t-1}$, is a proxy for exogenous variables. These three last variables in equation (2) are not allowed to change with the regime—as preliminary regressions indicated that the coefficients related to $\Delta allotratio_t$ and $vix_{t-1}$ do not change significantly across regimes and that Swiss franc funding auctions took place only in the high regime (e.g. $swap_t$).

We estimate the parameters by GMM (actually, nonlinear least squares) and the t-stats account for heteroskedasticity and autocorrelations. In total, there are 10 parameters ($c$ in (1), and $\phi, \delta_1, \delta_2, \chi_1, \chi_2, \varphi, \psi, \lambda, \alpha$ in (2)).

### 3.3 Limitations

It is worth emphasizing some limitations of the model presented above.[7] In particular, the repo conditions have changed over time. In mid-August 2007 (i.e. at the beginning of the credit crunch) the SNB expanded its list of collateral

[7] In 2007, there was some criticism in the press about the representativeness of the Libor. We believe this criticism is inapplicable to this study (e.g. we consider changes in Libor in a high-frequency domain).

eligible in the repo transactions.[8] On 16 October 2008, the SNB introduced a special purpose vehicle (SPV) as a long term financing to sustain the Swiss financial sector. Specifically, SNB created a SPV to perform an orderly liquidation of illiquid securities and other troubled assets held by the UBS. We controlled whether there was a particular response of the Libor on the announcement day of the SPV. This simple, ad hoc event study analysis rejected this hypothesis. A final possible shortcoming of our study comes from the inception of the SNB Bills, an instrument to absorb liquidity, on 15 October 2008. Again, a simple event study analysis shows no particular effect on the announcement day.

We considered several alternative specifications of the model. In particular, we analysed a bivariate VAR model in a regime switching setting where the first equation features the Libor dynamics and the second equation the repo rates. We also analysed treating the regime mechanism as dependent on the spread between the Libor and the Overnight Index Swap (OIS) rates rather than between the Libor and repo rates. These alternative models deliver the same picture as the results presented below. We also considered an error correction mechanism between the Libor and repo rates, the actual changes of the midpoint target range in addition to the monetary surprise as well as one or more lags for the regressors and auto-regressive terms. They turned out to be insignificant. It is also worth noting that our results are not sensitive to the specific parameter 3 in the logistic function. We obtain similar results when it is replaced with any figure from one up to large positive numbers.

# 4 Empirical Findings

The empirical analysis is based on daily data from January 2000 to the end of 2008. Figure 1 shows the behaviour of the regime variable $z$ (the standardised Libor–repo spread) across time. The high regime arises especially at the end of the sample period after Lehman Brothers filed for bankruptcy. Figure 2 depicts the pattern of the regime function. It shows that the high regime kicks in when the standardised Libor–repo spread is above the estimated value at 1.3.

Table 1 exhibits the main results. The upper part of the table shows the estimated coefficients and the related t-statistics that remain unchanged across regimes. The regime dependence of these regressors were insignificant in preliminary regressions (not shown) or some of them were implemented only in the high regime (e.g. $swap_t$). The middle of the table reports the estimate for the

[8] On 11 December 2008 and the day after, the SNB offered one-year Repo contracts at the same rate of the one-week repo. There was little demand for longer repo maturities.

standardised value of $c$ of the logistic function. At the bottom left-hand (right-hand) side of the table we report the estimated coefficients and t-statistics in normal (distressed) times, which we refer to as the "low regime" ("high regime"). Similarly, Table 2 shows the changes in the estimated coefficients between the two regimes. Low-regime (high-regime) days occurred 2084 (263) times.

Two main results emerge from our analysis. First, the Libor reacts very differently to repo and target range changes in the two regimes. In normal times (low regime), the repo rate appears to be the main driver. The Libor-repo rate link has the largest effect, i.e. a change of 25 basis points in the one-week repo rate translates, on average, into a change in the Libor of 5 basis points. This finding suggests that market participants scrutinize the SNB repo operations to understand its monetary policy stance which, in turn, affords a smooth implementation of monetary policy. On the other hand, during a crisis, an unexpected change in the target range is extremely effective in determining the Libor. An unanticipated lowering of the target range by 25 basis points implies, on average, a decrease in the Libor by 30 basis points.[9]

Second, three variables play a significant role, regardless of the regime. We find that the new Swiss franc funding facility in the Eurosystem had a significant effect in reducing the Libor. By contrast and not surprisingly, a no significant effect from US dollar funding is discernible. Moreover, favourable effects also came from the repo operations of the morning auctions, which play an auxiliary role in implementing a monetary policy decision. Accordingly, a larger allotment of liquidity leads to a decrease in the Libor. Finally, a high value of the VIX index is associated with a lower Libor. The main explanations for this link are that (1) during the tightening phase from mid-2004 to mid-2007 the stock market volatility was relatively low and (2) the Swiss franc tends to appreciate when volatility is high[10], which may require a counterbalancing interest rate move in order to preserve the price stability in the medium term.

# 5 Conclusion

We use a regime switching approach to model the implementation of the SNB's monetary policy. A regime switching technique is crucial to assess the flexibility inherent in its monetary policy concept. The empirical findings support the idea that the repo operations are instrumental in smoothing the monetary policy

[9] One could raise the question whether monetary policy surprises are more effective in turbulent times since there are more. Our specification should be seen as free of this problem since we control for the regime.

[10] See the safe haven effects of the Swiss franc analysed by Ranaldo and Söderlind (2007)

stance in normal times whereas (unexpected) decisions on the official operational target accompanied by a larger liquidity provision in the repo operations produce the aimed effects during distressed periods. Also, there is empirical evidence that the new facility designed to ease funding problems in the Swiss franc money market had the intended effects.

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Table 1: Estimates from the regime-switching model.

This table shows the estimated coefficients and t-statistics from the regime-switching model. The upper part of the table refers to the regressors that remain unchanged across regimes. In the middle of the table, we report the estimate for the normalised value of c of the logistic function. At the bottom of the table, on the left-hand (right-hand) side we report the estimated coefficients and t-statistics in normal (distressed) times, which we refer to "low-regime" ("high-regime").

| regime-independent regressors | coeff | t-stats |
|---|---|---|
| constant | 0.008 | 7.503 |
| VIX(-1) | -0.032 | -5.242 |
| ChfAuc | -0.015 | -1.945 |
| AllotRatio | -0.004 | -2.831 |

| Logistic function | coeff | t-stats |
|---|---|---|
| c_logistic_mean | 1.358 | 1.989 |

| | **Low-Regime** | | **High-Regime** | |
|---|---|---|---|---|
| regime-dependent regressors | coeff | t-stats | coeff | t-stats |
| drepo | 0.217 | 4.21 | -0.064 | -1.001 |
| Surpr | 0.411 | 3.200 | 1.283 | 14.185 |

| | |
|---|---|
| R2 | 0.39 |
| nObs | 2347 |

Table 2: Changes in the estimated coefficients between the two regimes.

This table shows the changes in the estimated coefficients and t-statistics between the "Low-Regime" and "High-Regime" for the three regime-dependent regressors.

| | change in coefficient | t-stats |
|---|---|---|
| drepo | -0.280 | -3.285 |
| Surpr | 0.872 | 5.539 |