

A Strange Animal? The Swiss Franc Exchange Rate as a ‘Captured’ Random Walk*

CHRISTIAN JOCHUM** and MARCEL R. SAVIOZ***

JEL-Classification: F00, E50, F31

Keywords: nominal exchange rate, regime switching, random walk

1. Introduction

1.1. A Floating Exchange Rate History – SFR/DEM 1973–1998

The introduction of the Euro (EUR) in 1999 provides the interesting opportunity to investigate the full history of the empirical behavior of the Swiss Franc/Deutsche Mark (SFR/DEM) exchange rate in an floating currency environment. The observation period from 1973 until 1998 is sufficiently long and economically diverse to investigate two issues regarding the currency pair SFR and DEM. As will be indicated below, we first examine whether the SFR/DEM exchange rate does show behavioral discrepancies when compared with other exchange rates. Secondly, we aim to find evidence related to the view that the Swiss Central Bank was not aiming to manage the exchange rate but that it rather focused on price stability only. This view stands in contrast with market and to a lesser degree academic opinion that the Swiss monetary policy was, among other goals, also aimed at avoiding fast and lasting appreciations of the SFR against its major trading partner Germany. As this paper will show, using daily data between January 1980 and December 1998, the answers to both questions are linked and we will argue that the behavior of the SFR against the DEM was not sufficiently random to exclude

* This paper was initiated while both authors were at the University of St. Gallen. The authors would like to thank L. Feld, T. Flury, Th. Jordan, M. Lutz, U. Müller, M. Peytrignet, Th. Rose, and M. Wildi for comments and critical review. Any opinions expressed are those of the authors only and does not necessarily reflect those of UBS Global AM, the SNB or the University of St. Gallen.

** UBS Global Asset Management & University of St. Gallen, UBS Global Asset Management, Gessnerallee 3, CH-8098 Zurich.

*** Swiss National Bank & University of St. Gallen, SNB, Research, Börsenstrasse 15, Postfach, CH-8022 Zurich.

the existence of forces, which kept the exchange rate from strong, upward movements against the DEM. However, the identification of these forces (self-fulfilling market expectations and/or regulation) is beyond the scope of this paper.

1.2. A Strange Animal

Following the demise of the Bretton Woods agreement for a system of fixed exchange rates, most industrialized countries decided to float their currencies. This has given economists an unusually rich set of data, which was used to develop and estimate a series of empirical exchange rate models. But following MEESE and ROGOFF (1983) it became increasingly clear that most empirical models were in fact inferior to a simple random walk in forecasting near and medium future exchange rate movements. FLOOD and ROSE (1995) come to the conclusion "that the most critical determinants of exchange rate volatility are not macroeconomic". Hence, the observations provided by MUSSA (1979) that (1) most changes in exchange rates are unexpected and (2) that the log of the spot rate is approximately a random walk, remain valid empirical descriptions for the behavior of exchange rates.¹ CHOI (1999) has tested this assumption for a sample of (real) exchange rates and concludes that a random walk is indeed sufficient to capture the behavior of all but one rate investigated. This exception being the Swiss Franc.² BAUM, BARKOULAS and CAGLAYAN (2001) find evidence that the linearity hypothesis for the real exchange rate SFR/USD has to be rejected at the 10% significance level and GUERRA (2003) detects clear non-linear behaviour of the SFR/DEM real exchange rate over the post Bretton Woods period.

This paper will now focus on the question whether the irregularity noted by Choi can be ascribed to the behavior of the nominal Swiss Franc exchange rate. Provided that the Swiss CPI does not behave differently from CPI in other industrialized countries, the absence of a random walk in the real exchange rate is likely to be based in the nominal exchange rate.³ But, although this reasoning

1 For a survey on exchange rate behavior the reader is referred to MACDONALD and TAYLOR (1993) and FRANKEL and ROSE (1994). A promising approach towards exchange rate modeling is detailed in EVANS and LYONS (2002), who acknowledge the shortcomings of the traditional models and argue that the inclusion of market microstructure (order flow) data can significantly improve the power of the models.

2 Since financial markets tend to pay more attention to the exchange rate SFR/DEM (i.e. SFR/EUR) we decided to look at this exchange rate rather than SFR/USD as Choi did.

3 Whereas Choi used data on the monthly real exchange rate, we rather use the nominal exchange rate, because our interest in high frequency (daily) behaviour precludes the computation of a real rate.

may be appealing, it has to be seen in the context of a heavily traded currency that has been freely floating since 1973 and has never officially been part of any exchange rate regime. Hence, we would actually expect the Swiss Franc to behave exactly like a random walk.

We investigate this question by using a regime switching approach, both, for the changes and the variability of the SFR/DEM spot exchange rate. Changes in the spot rate are modeled such that the exchange rate may follow a random walk, but that deviations from this process are possible in accordance with an underlying Markov process. Equally, the variability of the exchange rate is allowed to exhibit shifts, again endogenously generating different volatility regimes. If the Swiss Franc indeed follows a random walk, then we would expect no mean reverting behavior and the volatility regimes not to be associated with certain exchange rate levels.

Daily data for the SFR/DEM exchange rate going from January 1980 to December 1998 are used. At the start of the period the SNB began to target base money, which was the case for the two decades under investigation. At the end of the period the parity of the DEM to the EUR was fixed irrevocably. Our results clearly reject the hypothesis that the nominal SFR/DEM exchange rate follows a random walk. We find that spot rate changes are best described in a two-regime model: the first regime is a random walk, but the second regime expresses the influence of mean reverting forces in the exchange rate level, which keep the exchange rate within 'elastic' bounds. Changes in the second regime tend to move the exchange rate in such a way that a lower bound of 0.80 was hardly ever broken. The conditional volatility of the exchange rate is best described by three regimes marking decreasing levels of volatility. A strong relation between a lower bound in the spot rate and switches to lower volatility is found.

This leads us to the main insight that although the SFR/DEM exchange rate behaves at times like a random walk, other times exist where "forces" hold the exchange rate within a limited range. Hence we find the full SFR/DEM exchange rate behavior to be best described as a "captured" random walk. Expressed in slightly more technical terms the SFR/DEM follows a stochastic process which exhibits complex nonlinearities.

The paper will be organized as follows: section 2 discusses the behavior of the mean in the SFR/DEM changes using the Markov regime switching framework, while section 3 extends this approach to the second moment of the exchange rate series. Finally, section 4 offers some conclusions and the appendix presents a short overview of SNB policies during the sample period.

2. Empirical Framework for Modeling SFR/DEM Exchange Rate Changes

2.1. *Rationale*

The objective of this section is to examine the null-hypothesis (H0) that the SFR/DEM exchange rate (FX) follows a random walk against the alternative hypothesis (H1) that the exchange rate is regime dependent and follows a mean reverting AR-Process in at least one regime. This second hypothesis would indicate the existence of a temporary *equilibrium* exchange rate, in the sense that deviations from this exchange rate level are not lasting. Consequently, when the exchange rate deviates far away from its equilibrium level strong forces tend to bring it back to a particular level so that the random walk is captured within probabilistic bounds.

Two possible “economic” explanations exist for a behavior in accordance with the alternative hypothesis. First, this could be the result of central bank actions, or the threat thereof, in the currency market, or secondly market forces are such that they are stabilizing the exchange rate. Still, even this second explanation does not exclude an external intervention. It only implies the presence of self-fulfilling expectations, in the sense that incentives are set in such a way that market participants tend to move the exchange rate towards a value that is believed to be an equilibrium value. Past announcements by the SNB that an excessive appreciation of the SFR/DEM exchange rate would not be tolerated, are often considered as a sufficient condition to induce such a self-stabilizing behavior of market forces even in the present.⁴ We therefore can not exclude, a priori, that the observed behavior of the exchange rate for the period 1980–1998 is not a deliberate but rather an unintentional consequence of past monetary policy. Hence, although we conclude below that hypothesis H0 can be rejected for hypothesis H1, it is equally important to note that our results do not show: (1) How the temporary equilibrium exchange rate comes into existence, and (2) whether such a temporary equilibrium exchange rate is the result of a planned policy or an unintended side-effect.

4 Compare HECHLER-FAYD'HERBE (1999), who discusses this issue.

2.2. Modeling the Behavior of the Exchange Rate Using the Markov Approach

We use an autoregressive model with Markov-switching parameters as a device to explore which of the two above economic hypothesis is supported by the data:

$$y_t = \beta_{S_t,1} + \beta_{S_t,2}x_{t-1} + \sum_{j=3}^K \beta_{S_t,j}y_{t-j+2} + \varepsilon_t \quad (1)$$

$$\varepsilon_t \sim N(0, \sigma_{\varepsilon}^2),$$

where x_t is the log of the of SFR/DEM exchange rate, and y_t is the daily change of x_t .

Assuming, for the time being, the existence of two regimes, then S_t is the unobserved Markov-switching variable, which takes the value of 1 in regime 1 and 0 in regime 2. The variable S_t follows a first-order Markov process with the following transition probabilities:

$$\Pr[S_t = 1 | S_{t-1} = 1] = p_{11} \quad (2)$$

$$\Pr[S_t = 0 | S_{t-1} = 0] = p_{22}$$

Each parameter β_{ij} in equation (1) is allowed to be regime dependent, such that:

$$\beta_{S_t,j} = \beta_{1j}S_t + (1 - S_t)\beta_{2j} \quad (3)$$

Note that the first subscript of β_{ij} stands for the regime ($i = 1, 2$) and the second for the variable ($j = 1, 2, \dots, K$). $x_{t-1}, y_{t-1}, y_{t-2}, \dots, y_{t-K+2}$ are predetermined variables conditional on S_{t-1} . It is assumed that S_t is independent of these variables. Using this Markov-switching model, the two economic hypotheses stated above can be given the following statistical form:

H0: The SFR/DEM exchange rate series is integrated of degree 1 in all regimes.

H1: The SFR/DEM exchange rate is mean reverting in at least one regime.

It is also notable that different exchange rate models are special cases of the autoregressive model with Markov-switching parameters, where i.e. the random walk model is equivalent to a one regime model with ($p_{11} = 1$) and $\beta_{1j} = 0, j = 1, \dots, K$.

The “segmented trend model” of the exchange rate of ENGEL and HAMILTON (1990) is another special case with two regimes and $\beta_{11} < 0 < \beta_{21}$, $\beta_{ij} = 0$, $i = 1, 2$, $j = 2, \dots, K$, where the exchange rate alternates between a regime with a negative and positive drift.

An equilibrium exchange rate $\bar{x}_i = -\beta_{i1}/\beta_{i2}$ ⁵ exists in regime i , if $\beta_{i2} \neq 0$ and $\text{sign}(\beta_{i1}) \neq \text{sign}(\beta_{i2})$. As the error correction representation

$$y_t = \beta_{i2}(x_{t-1} - \bar{x}_i) + \sum_{j=3}^K \beta_{ij}y_{t-j+2} + \varepsilon_t \quad (4)$$

shows, $\beta_{i2} < 0$ is a condition for the stability of the equilibrium. For testing purposes the two *statistical* hypotheses described above can also be stated as:

$$\begin{aligned} H0: & \forall i \quad \beta_{i2} = 0 \\ H1: & \exists i \quad \beta_{i1} > 0, \beta_{i2} < 0 \end{aligned} \quad (5)$$

H0 states that the second coefficient in each regime has to vanish, thus negating any influence of the current value of the exchange rate on the expected change of the exchange rate. This hypothesis is compatible with a large class of models,⁶ with the random walk model and the segmented trend model being two examples. Furthermore, lagged changes of the exchange rate may still enter equation (4) without necessarily contradicting the random walk hypothesis.⁷ Finally, for a single regime model the H0 hypothesis collapses to the H0 hypothesis of the traditional ADF-test. Alternatively, hypothesis H1 states that in at least one regime the first coefficient has to be strictly positive and the second strictly negative, which is a condition for the *existence* and the *stability* of an equilibrium exchange rate in regime i .⁸

5 In SFR/DEM the equilibrium exchange rate is: $\exp(-\beta_{i1}/\beta_{i2})$. Because x_t is in logarithm, β_{i1} has to be different from zero.

6 Note that the exchange rate is non-stationary under the H0 Hypothesis. Appropriate critical values will be used.

7 This is a consequence of Working's Theorem on time aggregation. See GRANGER (1999, pp.42–48). Also, we expect significant lags in the daily data due to day-of-the-week (trading) effects.

8 If the probability of the stationary regime is high enough, the exchange rate may become (mean) stationary even if it follows a random walk in another regime.

2.3. Empirical Results

Daily data, as provided by DATASTREAM, from January 02, 1980 until December 31, 1998 were used for the estimation. The beginning of the sample period marks the return of the SNB towards money targeting, while the end of the sample is determined by the introduction of the EUR on January 01, 1999. Figure 1 and Table 1 show the level of the exchange rate to exhibit both skewness and leptokurtosis, where the first is related to a drop in the number of observations in the vicinity of 0.80. The second is due to a (too) large number of observations on the right hand side of the distribution.

Throughout the sample period we find a slight tendency of the SFR to appreciate against the DEM, while no major structural break is discernable for the chosen period. The data describing the daily percentage changes show considerable kurtosis caused by a number of comparatively large observations and very significant evidence for volatility clustering, as indicated by the ARCH test.

Figure 1: Histogram SFR/DEM Level (1980–1998)

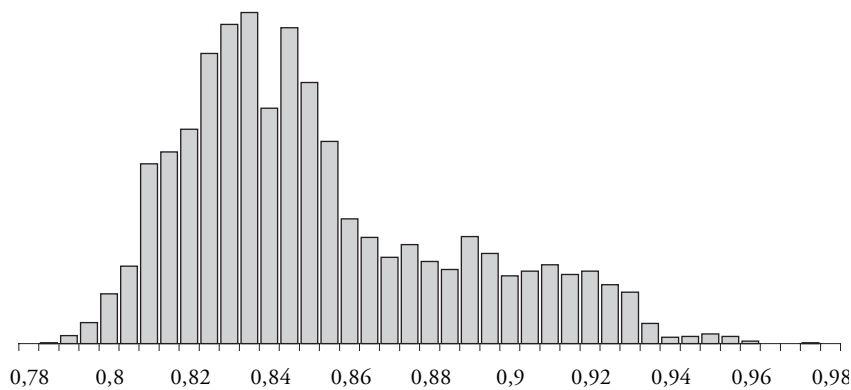


Table 1: Descriptive Statistics

Daily SFR/DEM from January 02, 1980 to December 31, 1998: 4957 observations.

	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis	ARCH(20)
Level	0.849	0.0339	0.784	0.971	0.815	2.914	
% change	-0.0025	0.438	-2.965	2.849	-0.172	7.128**	26.037**

The test for the presence of ARCH follows Engle (1982) by testing that the coefficients from the regression of the squared residual on its past values are jointly 0: $\varepsilon_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \dots + \beta_n \varepsilon_{t-n}^2$.

We now proceed to estimate model (1), using variable parameter settings, including 1 to 3 regimes and 0 to 4 lags, in order to determine the specification that best describes the data.⁹ The results are presented in Table 2. Regardless of the number of regimes underlying the model we find that the log-likelihood value does not improve a lot when more than two lagged dependent variables are included in the estimation. The Schwarz criterion indicates the correct specification to include three lagged dependent variables.

Table 2: Model (1) Identification Using LL and Schwarz Criterion

Number of regimes		Lags				
		0	1	2	3	4
1	LL	-2938.8	-2753.0	-2721.4	-2715.3	-2715.3
	SC	1.1906	1.1173	1.1062	1.1055	1.1071
2	LL	-2798.3	-2598.3	-2572.9	-2553.4	-2553.4
	SC	1.1373	1.0599	1.0531	1.0497	1.0497
3	LL	N/A	-2519.9	-2488.0	-2450.9	N/A
	SC		1.0334	1.0257	1.0158	

LL and SC represent the log-likelihood value and the Schwarz criterion, respectively.

SC = $-2LL/n + k\log(n)/n$, with k the number of variables, and $n = 4957$. N/A indicates that no stable results were obtained.

Table 2 also shows that the log-likelihood value does improve substantially when the model has two regimes instead of one, indicating that a regime shift is in fact part of the process driving the exchange rate changes. Further adding a third regime does improve the LL measure somewhat, but this is achieved at the cost of considerable instability of the 3 regime results, as convergence was not always assured uniquely. Interpreting this as insufficient evidence for the presence of 3 regimes in the mean of the daily exchange rate changes, we proceed under the two regime assumption.

Interpretation of Table 3 yields a number of interesting results. Columns I and IV represent one regime cases including 2 and 3 lagged variables, respectively.

9 The maximum likelihood estimation uses the EM-algorithm, as discussed in HAMILTON (1990). We make use of the program written by Matt Hergott for Matlab.

Consequently, these two equations can also be considered as the usual ADF-specifications¹⁰. We find that the Swiss Franc is stationary at the 5% significance level according to an ADF-Test with $K=4$, if MacKinnon values are used. With $K=5$ the 5% critical value is almost reached. This shows, given the number of observations, that the random walk hypothesis does not sufficiently describe the exchange rate behavior and that the SFR/DEM is indeed a strange animal. Also, importantly, if the exchange rate is stationary, then the usual critical values apply for significance tests. Columns II–III and V–VI show the results for the Markov-Switching model again assuming either 2 or 3 lagged variables. Columns II and V, both marking periods where the exchange rate is in regime 1, describe the results for the temporary *random walk* regime. It is evident that regime 1 is not mean reverting, because neither the constant, implying the absence of a drift in the data, nor the level of the exchange rate are significant different from zero. The lack of significance is visible, if the usual critical value $t_{0.05} = 1.96$ is used, and even more so if the ADF critical values are employed. Again, the presence of significant lagged values is not necessarily in contradiction to the random-walk-assumption.

At the same time, columns III and VI describe the *error correction* regime. This process is mean reverting. The coefficients of the constant and the level term have the correct positive and negative sign respectively, and are significantly different from zero using MacKinnon critical values for $K=4$. For $K=5$ the 5% critical value of -2.86 is almost reached, while using the usual critical values shows both coefficients to be highly significant. Therefore, *conditional* on the assumption that there are two regimes, there exists at least at the 10 percent level of significance an *equilibrium exchange rate*! The value is around 0.85 SFR/DEM and corresponds to the mean value (see Table 1). The exact values can be calculated as:

$$K=4: \exp(2.4227/0.5453) = 85.0190 \text{ SFR for 100 DEM.}$$

$$K=5: \exp(2.1263/0.4792) = 84.5368 \text{ SFR for 100 DEM.}$$

Also, from Table 3 we find that the probability to remain in the stable regime is high: $p_{11} = 0.8890$ ($K=4$), while the probability to remain in the random walk regime is considerably lower: $p_{22} = 0.1109$ ($K=4$). As a consequence we find only a comparatively low number of observations $n_i = 115$ ($K=4$) that can be

10 The respective MacKinnon critical values for 4951 observations are: 10%: -2.57 , 5%: -2.86 , 1%: -3.43 .

Table 3: Markov-switching Error Correction Model for the Exchange Rate

Coefficient	Lags = 2			Lags = 3		
	ADF I	$i = 1$ II	$i = 2$ III	ADF IV	$i = 1$ V	$i = 2$ VI
$\beta_{i,1}$	1.976* (0.674)	-5.246 (4.062)	2.423* (0.756)	1.898(*) (0.672)	-3.927 (3.888)	2.126(*) (0.773)
$\beta_{i,2}$	-0.446* (0.152)	1.181 (0.915)	-0.545* (0.170)	-0.428(*) (0.151)	0.089 (0.087)	-0.479(*) (0.174)
$\beta_{i,3}$	-0.300** (0.014)	-1.286** (0.047)	-0.137** (0.015)	-0.305** (0.014)	-1.226** (0.048)	-0.132** (0.015)
$\beta_{i,4}$	-0.113** (0.014)	-0.314** (0.075)	-0.054** (0.017)	-0.128** (0.015)	-0.595** (0.067)	-0.028 (0.017)
$\beta_{i,5}$				-0.050** (0.014)	-0.407** (0.063)	0.012 (0.016)
n_i	4951	115	4836	4951	133	4818
σ^2	0.419	0.384		0.419	0.381	
$p_{i,1}$	1.0	0.111	0.111	1.0	0.131	0.120
$p_{i,2}$	0.0	0.889	0.889	0.0	0.869	0.880
ρ_{11}	1.0	0.111		1.0	0.122	
ρ_{22}	0.0	0.889		0.0	0.878	
LL	-2721.4	-2572.9		-2715.3	-2553.4	

Standard errors in brackets. Sample 1/1/1980 to 31/12/1998: 4951 observations after adjustments. n_i number of observations classified regime i (the probability to be in the state i has to be larger than 0.5 for attribution).

p are transition (conditional) probabilities. ρ are ergodic (unconditional) probabilities.

**, *, (*) indicates statistical significance at the 1%, 5% and 10% level (using MacKinnon values).

attributed to random walk periods¹¹, or put differently, the SFR/DEM exchange rate is usually not a random walk. Furthermore, we find the expected duration of the regimes to be: duration of regime 1 = $1/(1 - p_{11}) = 1.124$, one day ($K = 4$), [$= 1.150$, one day for $K = 5$], and duration of regime 2 = $1/(1 - p_{22}) = 9.01$, nine days ($K = 4$), [$= 8.33$, eight days for $K = 5$].

It is crucial to note, that because of $p_{11} = (1 - p_{22})$ for ($K = 4$), this period's exchange rate regime (S_t) appears to be independent of the regime that prevailed last period (S_{t-1}). The probabilities of the transitions to the regimes of the next day are equal irrespective of the regime prevailing today. One can easily see that this is a property very similar to experiencing a random walk, since market participants have no advantage from knowing that there are two well-defined regimes, and which is the current regime, to predict the exchange rate of the next day.¹² In the long run though, if enough market participants believe in mean reversion to an equilibrium value in one regime, then this expectation will become self-fulfilling nevertheless.

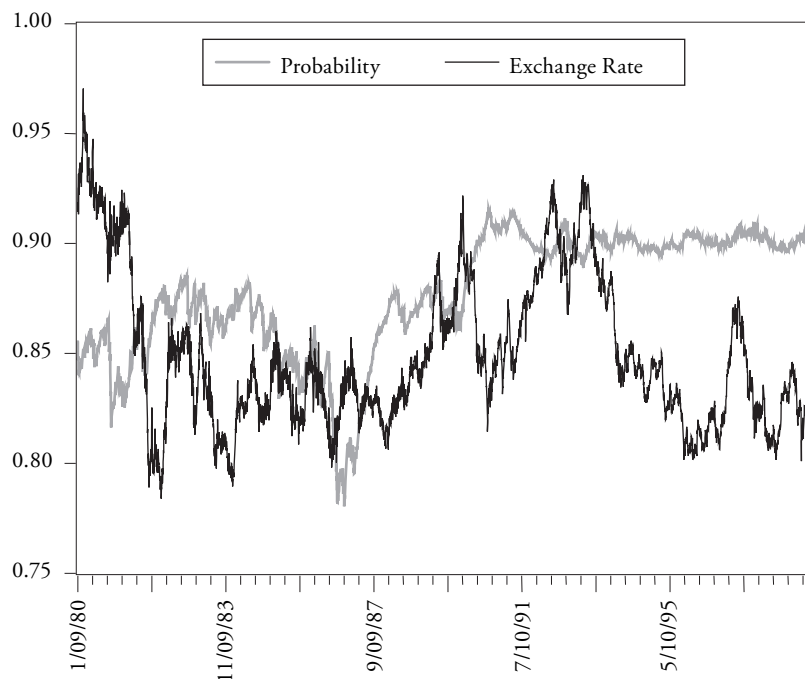
Finally, Figure 2 offers a graphical representation of the estimation results from the two regime-2 lags model and compares the behavior of the actual exchange rate with the smoothed probability that the exchange rate will be in the mean-reverting regime. Quite clearly the estimated probabilities show that a change did occur in 1990.¹³ Prior to this date the exchange rate was less likely to be in the mean reverting regime than afterwards. This observation coincides with a change in monetary policy at the end of 1990, when the Swiss National Bank stopped expressing its monetary policy using annual targets for the monetary base. For the 1991–1999 period the Swiss National Bank instead adopted multi-annual objectives. A time path for the monetary base was aimed at over a period of three to five years. As a consequence monetary policy, despite being strongly anchored in the long run, became considerably more flexible in the short run. This increased the ability of the Swiss National Bank (SNB) to take the exchange rate into account, while, at the same time, honoring the long term monetary base target. This perception may have induced further self-fulfilling mean-reverting speculation on the Swiss-Franc exchange rate market, as the financial markets

11 We expect those few observations to be well distributed over the whole sample as Figure 2 indicates that the probability of being in the mean-reverting regime is always at high levels 0.8–0.95. The high value of p_{12} , i.e. the probability of getting out of the random walk regime makes large concentrations of random walk periods seem highly unlikely.

12 For this argument compare ENGEL and HAMILTON (1990).

13 Note the minimum around 1987: The low probability of being in the mean reverting regime coincides with uncertainty in the world economic system at that time, see the appendix.

Figure 2: SFR/DEM Exchange Rate and Probability of Mean Reverting Regime



continued to acknowledge the low likelihood of a dramatic SFR appreciation against the DEM.¹⁴

Given the evidence provided so far, we cautiously conclude that the SFR/DEM exchange rate behavior is more complex than a simple random walk and that we can identify two distinct regimes with divergent time series characteristics. Since this behavior is also linked to the level of the series, we hypothesize that similar characteristics should become visible in the second moment, the variance, of the time series as well. The following section 3 will elaborate on this issue.

14 See PEYTRIGNET (1999) for a detailed description of the monetary policy of the Swiss National Bank. He distinguishes three main periods. From 1975 to 1978 the Swiss National Bank had an annual target for M1. In a second period starting in 1980 until the end of 1990 the objective was annual with respect to the monetary basis. In the third period going officially from 1991 to the end of 1999 multi-year objectives with respect to the monetary base were adopted. For a more detailed description see the appendix.

3. Exchange Rate Volatility in the Presence of Exchange Rate Bounds

3.1. *Some Considerations*

Much of the theoretical target zone literature builds in some way on the KRUGMAN (1991) model, where the exchange rate depends on fundamentals and the expected exchange rate as implied by the monetary model. Of the two fundamentals driving the system one is assumed to follow a Brownian motion whereas the other is controlled to keep the exchange rate inside a pre-specified band. Two further important assumptions are that the target zone is credible and that it is defended by marginal interventions. This produces two strong implications for the behavior of the exchange rate: First, a nonlinear relation between the exchange rate and the underlying fundamentals, since the absolute effect of a given change in the underlying depends on the relative position of the currency with respect to a reference value. Secondly, even though the fundamentals are Brownian motions the conditional volatility of exchange rate changes should be smaller in the immediate vicinity of the target bands.¹⁵ It is this second characteristic that will be the focus of the empirical results below. If the SFR/DEM exchange rate encounters an (implicit) floor that avoids an appreciation beyond a certain level, then this should also be reflected in the volatility behavior. In order to detect irregularities in the volatility a regime switching model is estimated that explicitly models jumps in the volatility process and determines periods during which the average of the second moment was low. Finding that the volatility is on average lowest during periods when the Swiss Franc is close to 0.80 to the DEM would offer support to the hypothesis that this floor was defended by the SNB and/or acknowledged by the financial markets.¹⁶

3.2. *Modeling a Volatility Process Subject to Regime Shifts*

The volatility of exchange rate series, like other economic time series, undergoes periods during which the behavior of the series shows significant changes. The much used ARCH methodology, ENGLE (1982), takes account of this phenomenon by explicitly modeling the fact that large (small) changes in the underlying

15 BERTOLA and CABALLERO (1992) extend the model and still find the qualitative implications unchanged.

16 For the significance of the value '0.80' against the DM in the context of the Swiss monetary policy see the discussion presented in the appendix.

time series tend to be followed by more large (small) changes. An estimate of the volatility of such a process will show the well known volatility clustering. But the autoregressive structure of the ARCH approach also induces a high level of persistence in the volatility series. This, of course, is not warranted if the high volatility of an economic or financial time series is result of a change in regime. In this case the ARCH methodology overestimates the true volatility persistence of the process. ENGLE and MUSTAFA (1992) used implied volatility to show that volatility persistence during the stock market crash 1987 was lower than indicated by the GARCH model.¹⁷ LAMOUREUX and LASTRAPES (1990) have attributed this to structural changes that occur during the sample of the variance process. HAMILTON and SUSMEL (1994) acknowledge this critique and propose the following application of regime switching models to ARCH volatility estimation. Typically, the ARCH process is modeled for the behavior of the residuals u_t of a first (or higher) order autoregression for the variable y :

$$y_t = \alpha + \sum_{i=1}^n \phi_i y_{t-i} + u_t \quad (6)$$

The application of the regime switching approach to (conditional) variance estimation describes regime dependent changes in the residuals u_t from regression (6). Regime switches are modelled as changes in the scale of the underlying process.

$$\begin{aligned} u_t &= \sqrt{g_{S_t}} \cdot \tilde{u}_t, \\ \tilde{u}_t &= h_t \cdot v_t, \\ h_t^2 &= a_0 + a_1 \tilde{u}_{t-1}^2 + a_2 \tilde{u}_{t-2}^2 + \dots + a_q \tilde{u}_{t-q}^2. \end{aligned} \quad (7)$$

Here $\tilde{u}_t$ is assumed to follow a standard ARCH-q process, while the disturbances v_t may be drawn either from a normal distribution ($v_t \sim N(0,1)$) or, if leptokurtosis is present in the data, from a Student- t -distribution (with n degrees of freedom). Regime dependent shifts in the volatility process are then modeled by multiplying the variable $\tilde{u}_t$ by the constant $\sqrt{g_1}$ when the regime is represented by $S_t = 1$,

17 This result is also confirmed by KIM and KIM (1996), who describe a fad model with Markov-switching hetero-scedasticity and show that their model is better able to model the quick adjustment of market volatility after the crash 1987 than this is the case for a GARCH model.

by multiplying by $\sqrt{g_2}$ when $S_t = 2$, and so on. This allows to take account of the nonlinearities reported by FRIEDMAN and LAIBSON (1989). HAMILTON and SUSMEL (1994) call specification (7) a SWARCH (N, q) model, where N describes the number of possible states and q the number of lags.

3.3. Empirical Results Describing the SFR/DEM Volatility Behavior

To investigate the optimal functional form we estimated a number of different specifications on our sample of daily return data of the SFR/DEM exchange rate. Since the descriptive statistics reported in Table 1 show considerable leptokurtosis in the data, we choose a t-distribution as underlying for the innovations of the return process. For each model the negative log-likelihood function was minimized using a set of different starting values, while the maximum number of regimes was restricted to 3 as higher order switching models have yielded only unsatisfactory results.

As a means of comparison between the different models the final value of the log-likelihood functions and the Schwarz information criterion are presented in Table 4. While the log-likelihood improves as a result of the inclusion of additional parameters, the Schwarz criterion shows that particularly the inclusion of a third lag in the conditional volatility process does not add significant explanatory power. At the same time we find strong evidence that the recognition of regime shifts in the process markedly improves the model, if compared to a standard ARCH(3) model. Using the likelihood ratio test suggested by HAMILTON and SUSMEL (1994) we test whether the 3 regime specification is equivalent to the 2 regime specification and find this nullhypothesis rejected at the 1% level. Consequently we base the following analysis on a (Student-) T-SWARCH(3,2) model that allows for the existence of three different regimes in the volatility process describing the SFR/DEM exchange rate between January 1980 and December 1998.

The estimation results show that in the context of the conditional volatility model the mean process is described by an AR(2) process, with both lags significant at the 1% level.¹⁸ The same level of significance also holds for the 2 lags included in the conditional volatility equation. Here, the drop in absolute size

18 Given the results from section 2, the assumption of a simple AR(2) process restricts the dynamics of the mean equation. But since the behavior of the residuals u_t is not significantly affected by this simplification, we proceed to use these residuals in the modeling of the volatility process. The estimation of a 'unified model' poses very considerable stability problems.

Table 4: Comparison of Specifications

Model	Parameters	L-Likelihood	Schwarz	Degrees of Freedom
T-ARCH (3)	8	-2219.18	0.909	5.06
T-SWARCH (2,2)	10	-2107.39	0.867	6.69
T-SWARCH (2,3)	11	-2103.73	0.868	6.72
T-SWARCH (3,2)	15	-2074.39	0.862	6.97
T-SWARCH (3,3)	16	-2071.63	0.863	7.01

The second column presents the final value achieved by the log-likelihood (LL) function. The degrees of freedom parameter describes the Student t -distribution.

between the first and the second lag coefficient points at one of the reasons for the absence of a significant third lag term in the ARCH process. The standard errors are presented in brackets.

$$y_t = 0.005 - 0.191 y_{t-1} - 0.051 y_{t-2} + u_t,$$

$$(0.005) \quad (0.015) \quad (0.014)$$

$$\text{where } u_t = u_t^* \cdot \sqrt{g_{s,t}}.$$

$$u_t^* = h_t \cdot v_t \text{ and } v_t \sim \text{i.i.d. Student } t \text{ distributed with 6.97 d.g.f.}$$

$$g_1 = 1, g_2 = 2.198, g_3 = 5.890$$

$$(0.188) \quad (0.552)$$

$$h_t^2 = 0.044 + 0.138 u_{t-1}^{*2} + 0.049 u_{t-2}^{*2}$$

$$(0.003) \quad (0.024) \quad (0.018)$$

$$P = \begin{bmatrix} 0.995 & 0.0021 & 0.000 \\ (0.002) & (0.001) & \\ 0.004 & 0.995 & 0.0028 \\ (0.002) & (0.002) & (0.003) \\ 0.000 & 0.0025 & 0.997 \\ & (0.001) & (0.002) \end{bmatrix}$$

As described above, the residuals from the mean equation are then multiplied with a regime dependent constant, reflecting the different average amount of variance during a particular regime. Having normalized $g_1 = 1.0$, we find that during regime 2 the variance is 2.2 times higher than during regime 1, and almost 6 times higher during regime 3 than during the periods when the exchange rate volatility is best described by regime 1. Again the parameters g_2 and g_3 are found to be highly significant.

The transition matrix shows 0.000 values at the positions p_{13} and p_{31} . These values have been restricted to zero after the unrestricted estimation has produced values smaller than $1.0e^{-06}$, which is equivalent to falling on the boundary of $p_{ij} = 0.0$. In order to estimate the standard errors of the model the optimization has been re-run using the implied constraints. Intuitively $p_{ij} = 0.0$ can be interpreted as the absence of a transition between regimes i and j during the observation period. That is, in the present case we did not observe a transition from the high volatility regime 3 directly into the low volatility regime 1 and vice versa. Hence, while the results support three different levels of volatility, we also find that no dramatic jumps in the average level of volatility occur, but that switches between the volatility regimes take place gradually. This is very much in line with the expected behavior of an exchange rate that is both free floating and not subject to sudden shifts caused by economic or political events.¹⁹

Also, the persistence of the different regimes is found to be considerable and, calculated in the form $[(1 - p_{ij}) - 1 = \text{average duration}]$, ranges from 212 days for regime 2, and 227 days for regime 1, to 357 days for regime 3. While this amount of persistence may seem considerable, it has to be seen in the context of the high number of observations. It has to be equally emphasized that the off-diagonal transition probabilities are, with one exception, statistically significant, i.e. high persistence does not avoid the eventual switch in the underlying process.

Figures 3 and 4 help to shed some light on the levels of persistence and the somewhat surprising result that the highest volatility regime tends to show the longest duration. While Figure 3 presents the underlying Swiss Franc exchange rate, Figure 4 should be interpreted as follows. The representation indicates the different levels of probability the model attaches each regime at a given point of time. Hence, for example during February 1986 the probability of being in

19 That the jumps in volatility are far more pronounced for exchange rates that are less than free floating, is shown in Jochum and Kodres (1998). They show that exchange rate targets tend to suppress movements towards the hypothetical market rate and that eventual realignments involve very considerable shifts in the volatility.

Figure 3: SFR/DEM Exchange Rate 1980–1998

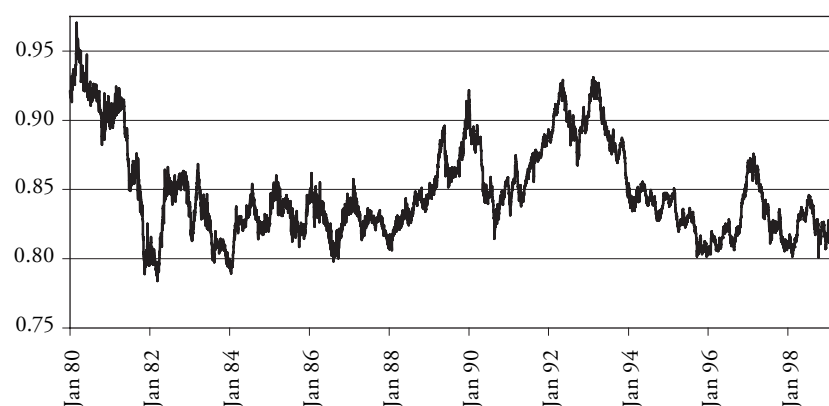
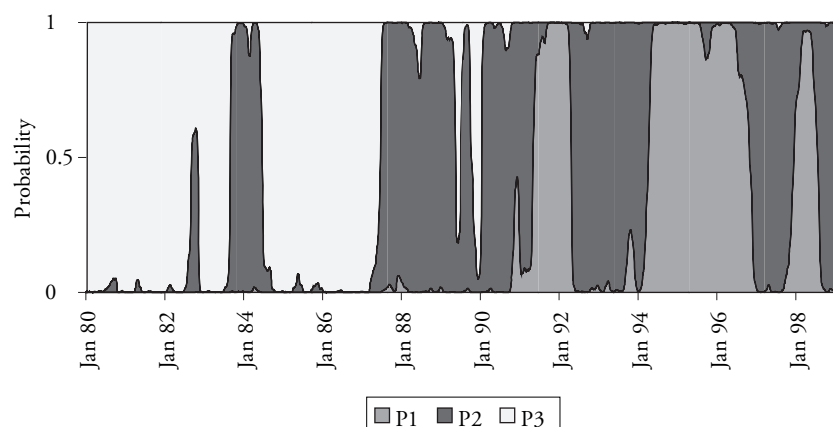


Figure 4: Transition Probabilities between Volatility Regimes



regime 3 was almost 1.0, while during most of 1989 the exchange rate volatility was characterized by regime 2. The lowest volatility regime 1 marks among other periods the early months of 1992. While changes in regime, such as in June 1984 from regime 2 into regime 3 are marked by a change in the shading, the sum of the probabilities has to add up to one at each point in time.

As we can see from Figure 4, the high volatility regime 3 basically marks the early years of the 1980ies. We also find that during the eighties the two volatility

regimes 2 and 3 prevailed, whereas during the nineties the low volatility regime 1 dominated, interrupted by switches into regime 2. From this follows that the average exchange rate volatility of the SFR was lower during the second decade than during the first one.²⁰ The high volatility during that first period thus reflects the unstable external macroeconomic environment, but also the aftermath of a considerable increase in the Swiss inflation.

The interesting question that follows from the existence of highly persistent volatility regimes is whether it is possible to connect these regimes with the level of the exchange rate and hence with the Swiss monetary policy. Table 5 provides the statistics to analyze this question, both, for the exchange rate level and the return series. Looking at the first panel, it becomes apparent that the sample mean during regime 1 is lower than during the other two regimes, and that in line with the estimation procedure the standard deviation is also lowest for regime 1.²¹ It is also noteworthy that during regime 1 the exchange rate was never lower than the lower 'bound' of 0.80, while the other 2 regimes include periods during which the exchange rate broke through the floor. This implies that while the SFR appreciated towards 0.80 or stayed in a close range thereof, the volatility of the series tended to stay low. This observation can be explained either by monetary actions of the SNB or the market's implicit acknowledgement that a strong floor exists. In both cases would upward movements (a depreciation) of the exchange rate be unlikely given the underlying strength of the currency, whereas a further appreciation is hampered by the narrowing distance to the floor. Consequently, we expect movements to be small in the immediate vicinity of the 0.80 bound.²² But as the statistics for regimes 2 and 3 show the 0.80 limit has not resisted all advances by the SFR, as we find minimum values below the 0.80 level.

20 This coincides with the finding in section 2, where we show that with the beginning of the nineties the probability of the exchange rate to show mean reversion has increased markedly.

21 In order to estimate the sample statistics each observation was attributed to one of the three regimes, depending on the regime signal of the respective date.

22 It should be noted that equations (6) and (7) do not contain the level of the exchange rate as an argument. This has two relevant consequences for the interpretation of the results: (1) observations have been attributed to the volatility regimes unconditional of the concurrent level of the exchange rate. Consequently, finding non-low volatility in the vicinity of 0.80 would have refuted the underlying assumption that 0.80 constitutes a lower bound. (2) The association of the value 0.80 with the low volatility regime is sample specific. Future periods of low volatility are not necessarily associated with this particular value. Rather, our conclusion is that a widely held perception of any bound will decrease volatility, once the exchange rate moves close to the level of the bound.

In fact, inspection of the series in Figure 3 shows that the 0.80 line was actually broken 13 times over the observation period. Nevertheless, the case for a successful target model is supported by the extremely short duration the exchange rate spent below the level of 0.80, with only 3 instances that lasted longer than 1 trading week, the longest of which were during February 1982 and December/January 1984. Adding the days the exchange rate spent below the 0.80 line only amounts to 88 observations, which is considerably less than the 480 observations which are implied by a normal distribution based on the actual mean and standard deviation of the exchange rate during the observation period. Hence we may conclude that although it was not possible to always hold the exchange rate above the target floor, monetary policy and/or market forces were successful to avoid any persistent movement below the floor value.

Table 5: Descriptive Statistics during Regimes (Daily)

	Regime 1		Regime 2		Regime 3	
	Total	Quantiles	Total	Quantiles	Total	Quantiles
Panel A: FX level						
Mean	0.839		0.850		0.852	
Std. Deviation	0.027		0.031		0.039	
Skewness	0.993		0.605		0.814	
Min	0.801		0.789		0.784	
Max	0.917		0.931		0.970	
Panel B: FX return (%)						
Mean	0.011	0.013	-0.003	-0.002	-0.009	-0.009
Std. Deviation	0.234	0.200	0.347	0.310	0.610	0.544
Skewness	-0.926	0.087	-0.210	-0.042	-0.070	-0.029
Min	-2.284	-0.053	-2.293	-0.868	-2.965	-1.642
Max	0.916	0.564	1.618	0.842	2.849	1.529

Quantiles presents the descriptive statistics after removing the top and bottom 1% from the sample. Skewness denotes excess skewness.

The second panel of Table 5 presents statistics on the exchange rate returns. As CAMPA, CHANG and REIDER (1997) show the existence of exchange rate bands should also be reflected in the skewness of the sample distribution. The intuition being that, as the exchange rate moves towards the (implicit) target perceived by the market, large movements in the opposite direction become more likely.²³ In our context, the existence of an exchange rate floor of 0.80 implies positively skewed returns as a depreciation becomes more likely in the vicinity of the floor. But as panel B shows the returns are negatively skewed for all three regimes, indicating that large appreciations are more probable than large depreciations. But if we remove the outliers in the form of the top and bottom 1 percent of the observations, skewness during regime 1 turns positive.²⁴ Hence, during periods marked by the regime with the mean closest to the floor we also find a higher probability for the exchange rate to turn away from the floor.²⁵ Also, regime 1 shows on average a positive change of 0.01%, i.e. a depreciation of the Swiss Franc, while during the other two regimes the exchange rate on average appreciates. Finally, looking at the overall picture of panel B, we find support for the 3-regime volatility model. The size of the standard deviation follows the order of the regimes and the extreme values increase as we move from regime 1 to regime 2 to regime 3, regardless whether outliers are removed or not.

4. Conclusion

Summarizing, we find that the SFR/DEM is only insufficiently described by the traditional random walk model for exchange rates. Rather the behavior of the SFR can be split into periods where a random walk fits the data, and long stretches where the level of the exchange rate has a definite influence on the expected changes taking place. During these periods the exchange rate mean

23 Among others BATES (1996) reports that over the 1984–87 period the USD/DM exchange rate distribution was considerably more positively skewed than the lognormal, reflecting that, due to the strong USD, a depreciation was more likely than a further appreciation.

24 One explanation for the existence of large positive outliers (which generate the positive skewness) may be found in the exchange rate floor itself: as the currency moves towards the floor it is slowed down in its movement by SNB activity or the prevailing market sentiment that the SNB may act. Consequently, the exchange rate will be pushed through the barrier only by larger than usual changes in the fundamentals or trading activity, the result of which would be a larger than usual movement in the FX rate.

25 Looking back at panel A one also finds the spot rate (level) skewness to be largest during regime 1.

reverts to a temporary equilibrium level of about 0.85 against the DEM. Taking the complete sample, this type of behavior is by far the dominant one with a regime probability of about 0.85 in the eighties and of 0.90 in the nineties. This high probability and persistence implies the presence of regulatory and/or market forces that drive the level of the exchange rate in this direction.

The existence of a mean reverting regime, which (stochastically) limits the evolution of the exchange rate is also reflected in the volatility of the exchange rate changes. It is found that the volatility behavior of the SFR/DEM exchange rate is best reflected in a 3 regime model. The average amount of volatility during periods that are attributed to regimes 2 and 3 have an average level of variance that is higher by a factor of 2 and 6 than during regime 1. The volatility regimes exhibit very pronounced persistence and the absence of sudden shifts from low to high volatility regimes indicates an absence of dramatic changes in the underlying fundamentals. In agreement with the underlying assumption the lowest volatility regime 1 is associated with a mean exchange rate that is closest to the implied boundary rate of 0.80 SFR/DEM. During regime 1 volatility periods this level is never breached, while drops below the floor rate occur during volatility regime 2 and 3. The persistence below the 0.80 level is extremely short and does take place far less frequently than implied by a normally distributed exchange rate. Finally, after removing outliers positive return skewness is found during regime 1, which points at a higher probability for a depreciation once the currency has moved close to the floor value.

Both, the regime switching model for the mean and the regime switching model for the variance show that a change in the behavior of the exchange rate occurred around 1991. This change coincides with a modification of the monetary policy of the SNB.

Finally, let us point at some caveats and promising routes for further research. Our paper applies two separate models, one for regime switching in the mean and the other for the volatility of the SFR/DEM exchange rate. A model integrating both features would perhaps be tractable if weekly data rather than daily data are used. Furthermore, the inclusion of money market interest rates in the model for the SFR/DEM exchange rate may give some insight as to the causes of its observed 'strange' behavior. Note that the prevalent regime is independent of the past level of the exchange rate in the presented models. The results of this paper show that it could be interesting to examine the SFR/DEM exchange rate with TAR (Threshold autoregressive) models or STAR (Smooth transition autoregressive) models. The regime switching model of FILARDO (1994) where the transition probabilities of the Markov chain could be specified as a function of level of the exchange rate observed in the past could be an alternative. Finally,

as soon as enough data will be available, the recent behavior of the SFR/EUR exchange rate may be especially interesting to examine at the light of the results presented in this study for the eighties and nineties.

Appendix: Review of SNB Policy 1973–1999

This appendix is a short reminder of the monetary policy of the Swiss National Bank under flexible exchange rate. The reader will find more detailed descriptions in PEYTRIGNET (1999) as well as in GENBERG and KOHLI (1997). Following the collapse of the Bretton Woods system of fixed exchange rates, Switzerland was among the first to switch to a floating exchange rate regime. From the beginning the pronounced goal of the Swiss monetary authorities was to attain a high degree of price stability. For that purpose a monetary aggregate in the form of M1 was chosen as intermediate target and from 1975 onwards M1 (growth) targets were publicly announced by the SNB. Subsequent growth rates were close to target until 1978 when the money supply very significantly overshot. This was the result of an attempt of the SNB to slow down the rapidly appreciating Swiss Franc, since it was widely perceived that a massive appreciation would hurt the export industry. To that end an exchange rate target of 0.80 SFR/DEM was announced and consequently the money stock target had to be abandoned during that period. The ultimately successful defense of the exchange rate caused a significant expansion of the monetary base and led to an inflation peak during the 3rd quarter of 1981 at about 7.5%. A further legacy of that period was the widely held belief in the financial markets that the SNB was supportive of a 0.80 lower bound for the SFR against the DEM.²⁶

In 1980 the SNB returned to targeting money growth, although now using base money instead of M1 as aggregate. A steady reduction in the inflation to about 1% resulted. This calm period was interrupted during 1987/88 when the revision of banking liquidity regulations and the introduction of an electronic interbanking clearing system led to a de facto increase in money supply. This expansion was further compounded by the worldwide effort to avoid a liquidity crisis following the October 1987 stock market crash.²⁷ Again inflation jumped

26 This view has been repeatedly rejected by the Swiss National Bank during the 1990ies, as the singular focus during that period was emphasized to be price stability.

27 It has also been noted that with oil prices falling in 1987, headline inflation dropped faster than core inflation, which further complicated the evaluation of underlying price pressures.

up to 6% in 1991 only to be successfully curbed during the following years. But low inflation during the 1990ies also coincided with stagnant economic growth and a rise in unemployment, which has only been reversed at the end of the decade.

Annual targets were abandoned in 1991. From then until 1999 the Swiss National Bank expressed its targets in terms of a path for base money over a horizon of five year. The main motivation was to take into account the lag existing between a change of the monetary aggregates and subsequent changes in inflation. This medium-term-orientation of monetary policy gave to the Swiss National Bank, according to its own description, the necessary leeway to take into account, over the short run, such factors as economic activity, the labor market and the exchange rate.²⁸

This flexibility, which allows a degree of freedom to react with respect to foreign or domestic shocks, has gained renewed weight with the introduction of a common European currency in 1999. It is widely assumed, according to academic and banking economists, that a sudden appreciation of the SFR vis-à-vis the EUR would hurt the Swiss economy.²⁹ According to this view, as long as price pressures remain subdued in Switzerland, the SNB will continue to consider the level of the exchange rate as a relevant macroeconomic variable. Hence, as a result of self-fulfilling market expectations and/or regulation, it can be supposed that the empirical results presented for the 1980ies and 1990ies remain valid. An interesting topic for further research will be, as soon as enough data are available, whether the SFR/EUR exchange rate continues indeed to show the characteristics of a temporary mean reverting regime process.

References

- BATES, DAVID S. (1996), "Dollar Jump Fears, 1984–1992: Distributional Abnormalities Implicit in Currency Futures Options", *Journal of International Money and Finance*, 15, pp.65–93.

28 Since the end of 1999, keeping its medium-term-orientation of monetary policy, the Swiss National Bank uses inflation forecasts over a horizon of three years as its compass. See "The Monetary policy decision of the Swiss National Bank for 2000", Quartalsheft 4, 1999, pp.19–23.

29 Although often repeated, this view is not universally shared, as evident from the discussion in TATOM (1996). He shows that a majority part of the Swiss economy is not adversely affected by a currency appreciation, but may actually gain from such a move.

- BAUM, CHRISTOPHER F., JOHN T. BARKOULAS and MUSTAFA CAGLAYAN (2001), "Nonlinear Adjustment to Purchasing Power Parity in the post-Bretton Woods Era", *Journal of International Money and Finance*, 20, pp. 379–399.
- BERTOLA, GIUSEPPE and RICARDO CABALLERO (1992), "Target Zones and Realignments", *American Economic Review*, 82, pp. 520–536.
- CAMPA, JOSE M., KEVIN P. H. CHANG and ROBERT L. REIDER (1997), "Implied Exchange Rate Distributions: Evidence from OTC Option Markets", NBER working paper 6197.
- CHOI, IN (1999), "Testing the Random Walk Hypothesis for Real Exchange Rates", *Journal of Applied Econometrics*, 14, pp. 293–308.
- ENGEL, CHARLES and JAMES D. HAMILTON (1990), "Long Swings in the Dollar: Are They in the Data and Do Markets Know it?", *American Economic Review*, 80, pp. 689–713.
- ENGLE, ROBERT F. (1982), "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of UK Inflation", *Econometrica*, 50, pp. 987–1008.
- ENGLE, ROBERT F. and CHOWDHURY MUSTAFA (1992), "Implied ARCH Models from Options Prices", *Journal of Econometrics*, 52, pp. 89–311.
- EVANS, MARTIN and RICHARD K. LYONS (2002), "Order Flow and Exchange Rate Dynamics", *Journal of Political Economy*, 110, pp. 170–180.
- FILARDO, ANDREW J. (1994), "Business Cycle Phases and their Transitional Dynamics", *Journal of Business and Economic Statistics*, 12, pp. 299–308.
- FLOOD, ROBERT P. and ANDREW K. ROSE (1995), "Fixing Exchange Rates: A Virtual Quest for Fundamentals", *Journal of Monetary Economics*, 36, pp. 3–37.
- FRANKEL, JEFFREY A. and ANDREW K. ROSE (1994), "A Survey of Empirical Research on Nominal Exchange Rates", NBER working paper 4865.
- FRIEDMAN, BENJAMIN M. and DAVID I. LAIBSON (1989), "Economic Implications of Extraordinary Movements in Stock Prices", *Brookings Papers on Economic Activity*, 2, pp. 137–189.
- GENBERG, HANS and ULRICH KOHLI (1997), "Recent Developments in Swiss Monetary Policy", in: Philippe Bachetta and Walter Wasserfallen (ed.), *Economic Policy in Switzerland*, London.
- GRANGER, CLIVE W. J. (1999), *Empirical Modelling in Economics*, Cambridge.
- GUERRA, ROGER (2003), "Nonlinear Adjustment towards Purchasing Power Parity: The Swiss Franc-German Mark Case", *Swiss Journal of Economics and Statistics*, 139, pp. 83–100.
- HAMILTON, JAMES D. (1990), "Analysis of Time Series Subject to Changes in Regime", *Journal of Econometrics*, 45, pp. 39–70.

- HAMILTON, JAMES D. and RAUL SUSMEL (1994), "Autoregressive Conditional Heteroscedasticity and Changes in Regime", *Journal of Econometrics*, 64, pp. 307–333.
- HECHLER-FAYD'HERBE, NANNETTE (1999), „Findet die ‚Free Option‘ der SNB an die Devisenmärkte ein Ende?“, *Swiss Strategy & Relative Value*, CSFB Fixed Income Research, 21, pp. 7–9.
- JOCHUM, CHRISTIAN and LAURA KODRES (1998), "Does the Introduction of Futures on Emerging Market Currencies Destabilize the Underlying Currencies?" IMF Staff Papers, 45, pp. 486–521.
- KIM, CHANG-JIN and MYUNG-JIG KIM (1996), "Transient Fads and the Crash of '87", *Journal of Applied Econometrics*, 11, pp. 41–58.
- KRUGMAN, PAUL (1991), "Target Zones and Exchange Rate Dynamics", *Quarterly Journal of Economics*, 106, pp. 669–682.
- LAMOUREUX, CHRISTOPHER G. and WILLIAM D. LASTRAPES (1990), "Forecasting Stock Return Variance: Towards an Understanding of Stochastic Implied Volatilities", *Review of Financial Studies*, 5, pp. 293–326.
- MACDONALD, RONALD and MARK P. TAYLOR (1992), "Exchange rate Economics", IMF Staff Papers, 39, pp. 1–57.
- MEESE, RICHARD and KENNETH ROGOFF (1983), "Empirical Exchange Rate Models of the Seventies", *Journal of International Economics*, 14, pp. 3–24.
- MUSSA, MICHAEL (1979), "Empirical Regularities in the Behavior of Exchange Rates and Theories of the Foreign Exchange Market", in: Karl Brunner and Alan Meltzer (ed.), *Policies for Employment, Prices, and Exchange Rates*, North-Holland, pp. 117–213.
- PEYTRIGNET, MICHEL (2000), «Politique monétaire suisse en changes flexibles: la pratique des objectifs monétaires», *La monnaie, la politique monétaire et les mécanismes de transmission*, Banque du Canada, pp. 223–251.
- TATOM, JOHN A. (1996), "Swiss Exchange Rate Appreciation and Domestic Economic Activity", *Swiss Journal of Economics and Statistics*, 132, pp. 473–494.

SUMMARY

The paper aims to describe the behavior of the Swiss Franc-Deutsch Mark exchange rate between January 1980 and December 1998. Contrary to research results provided for other currencies a random walk is not sufficient to describe the empirical characteristics of the Swiss Franc. A regime switching approach shows that changes in the spot rate levels alternate between two regimes: a

random walk and an autoregressive process. Mean reverting forces exist that "capture" the random walk within elastic bounds. Equally, we find that the volatility of the process is better described by a regime switching model and that low levels of volatility are associated with exchange rate movements close to a level of 0.80 SFR per DEM.

ZUSAMMENFASSUNG

Wir analysieren den Verlauf des Wechselkurses Schweizer Franken-Deutsche Mark von Januar 1980 bis Dezember 1998. Im Gegensatz zu Forschungsergebnissen über den Verlauf anderer Wechselkurse scheint ein Random Walk Prozess ungenügend, um das Verhalten des Schweizer Frankens zu beschreiben. Unsere Studie zeigt auf, dass die Niveauveränderungen des Wechselkurses zwischen zwei Verhaltensweisen alternieren: derjenigen eines Random Walkes und derjenigen eines autoregressiven Prozesses. Der Wechselkurs scheint aufgrund von „mean reverting“ Kräften zwischen zwei elastischen Bändern eingeschlossen zu sein. Für die Volatilität finden wir ebenfalls alternierende Verhaltensweisen. Bei einem Niveau von 0.80 SFR pro DEM weist der Wechselkurs eine geringere Volatilität auf.

RÉSUMÉ

Cet article analyse le comportement du taux de change Franc Suisse-Deutsche Mark de janvier 1980 jusqu'à décembre 1998. Contrairement aux conclusions des articles sur le comportement d'autres taux de change, nous trouvons que le comportement du taux de change Suisse est mal estimé par une marche aléatoire. Une approche «regime switching» se montre plus prometteuse et nous trouvons que le comportement des changements de niveaux du taux de change alterne entre une marche aléatoire et un processus autorégressif. Des forces «mean reverting» semblent garder le taux de change à l'intérieur de marges élastiques. La volatilité est également mieux expliquée par un modèle «regime switching» car elle est plus basse quand le taux de change s'approche d'un niveau de 0.80 SFR par DEM.