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Modeling client rate and volumes of non-maturing accounts

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Abstract

In this paper we develop models for the client rate and the volumes of non-maturing accounts[2]. We test the hypothesis that movements in the client rate[3] are dependent upon the market rates regime. We find that the responsiveness of the client rate is symmetric to changes in the short rate, but asymmetric to changes in the longer market rates. Furthermore, the speed of adjustment of the client rate is faster when there is substantial deviation from the equilibrium relationship linking client rate and market rates. We also show that volumes can be explained by the spread between the client rate and the market rates.

[2] Accounts without a fix maturity; our analysis will focus on savings accounts (non-maturity deposits which have no specific maturity and individual depositors can freely add or subtract balances as they wish);

[3] We will use this term for the rate paid by banks to their depositors.

Introduction

An important issue for the risk management of non-maturing account positions is, in addition to the exposure to interest rate risk, the uncertainty in the timing and amount of future cash flows. A rigorous analysis of the client rate as well as of the volumes are required for liquidity risk management (cash-flow forecast), as well as for pricing the non-maturing accounts using valuation models (Jarrow van Deventer (1998), O'Brien(2000)) . The objective of this paper is to find realistic models for the client rate and for the volumes of non-maturing accounts which could be integrated in the framework of the multistage stochastic programming model proposed by Frauendorfer and Schürle (2007) for dynamic replicating portfolio of non-maturing accounts.

Intuitively, an asymmetry in the adjustment of the client rates may be present if they rapidly adjust to decreasing market rates, but are slow to react when market rates rise, as banks are less willing to pay higher interest rates. In this context, deposit rates are said to be "upward sticky". The banking literature has provided evidence relating asymmetry of the deposit rates to market rates, but a consensus behavioral explanation for these results is lacking.

Hannan and Berger (1991) emphasize difficulties in explaining asymmetric behavior in terms of standard models of imperfect competition. Sharpe (1997) provides a model for deposit rents[4] based on consumer search costs for optimal investment opportunities. Sharpe's model provides some basis for forecasting market structure factors that will have predictable effects on the level of deposit rents. However, the analysis is static and does not account for deposit rigidity or asymmetry in response to market rate changes. Ausubel (1992) offers one of the few choice-theoretic explanations for asymmetric adjustment. He suggests limited information on market investment alternatives and search costs that lead to the type of rigidity and asymmetry in deposit rate setting that are observed. However, his model also predicts a high probability of losing deposits when deposit rates are low and spreads between client rate and market rates are narrow. This is, actually, contrary to existing evidence. Dueker (2000) offers further explanations for asymmetric adjustment in the context of loan rates.

O'Brien (2000) is the first who specifies an interesting property of the asymmetric client rate adjustment. He derives an equilibrium deposit rate conditional on the short market rate, and states that under asymmetric deposit rate adjustment, the unconditional expected deposit rate will be different from the expected equilibrium rate. O'Brien determines whether asymmetries

[4] The value of the bank's rent from issuing deposits is the present value of the future cash flows (marginal revenue from investing the deposits minus costs with interest rates payment and costs for managing the deposits accounts).

exist in the adjustment of deposit rates to positive/negative disequilibrium, but he does not count for the adjustment speed depending on the magnitude of the disequilibrium itself. Furthermore, we add additional observations about the idea of "equilibrium deposit rate" emphasized by the author in the description of the client rate model. Supporting our arguments on empirical results provided by papers related to client (depositor) behavior (Nyström (2008)), we find the equilibrium deposit rate inadequately related to a short term interest rate. This specification would make sense in the case when the depositors were concerned with opportunity costs. In this case, if banks do not raise deposit rates in response to an increase in the market rates, depositors might withdraw their balances or part of them to invest their funds at the higher market rates. But, as explained below, the client behavior studies show that "depositors are more concerned with service and convenience than with opportunity costs" (Dewachter, Lyrio and Maes, (2006)). The clients accept low deposit rates as they benefit from other services, for example "more advantageous mortgage financing" (Jarrow and Van Deventer (1998)), costs for consumers of switching banks (Ausubel (1992), Sharpe (1997)) and "limited memory of depositors" (Kahn, Pennacchi, Sopranzetti (1999)).

For modeling the client rate, we propose a simple threshold model to determine whether the relationship between the deposit rate and the market rates (including a short and a longer maturity) is asymmetric. The present paper study differs from previous work in two respects. First, we derive the "equilibrium" by studying the common trend of the client rate and market rates, instead of linking the client rate to a short maturity. Second, we use the grid-search procedure proposed by Hansen (1996) to locate the most likely threshold level, and simulate the appropriate asymptotic distribution in order to test the hypothesis of asymmetry. This is necessary when the threshold level is unknown a priori and chosen endogenously. We test for threshold effect in the short rate, a longer maturity and in the error correction term. The results emphasize a strong asymmetric relation between the client rate and the rate of longer maturity (5 years Swap rate). Furthermore, we show that the speed of adjustment of deposit rates depends on the magnitude of disequilibrium with respect to market rates.

For the estimation of the model, we will use, in a first step, aggregated data, the final goal being to create realistic client rate and volume models which could be applied for the individual banks non-maturing accounts. For the client rate and for the volumes we will use monthly data published by the Swiss National Bank computed at an aggregate level (average over all banks) starting with January 1988 up to present. As proxy for the market rates, we will include in the estimation one short and one longer maturity.

Considering the models for the non-maturing accounts volumes, a common factor in the majority of studies is the formulation of the volume equations as autoregressive distributed lag models. Thus, Selvaggio (1996), O'Brien (2000), de Jong and Wielhouver (2001), Dewachter, Lyrio and Maes (2006) find the previous period (log) volume as being significant. Another commonly used explanatory variable for the volumes is represented by the market rates (or a proxy for the market rates, taking into account both shorter and longer maturities), see e.g. Hutchison and Pennacchi (1996), Bardenhewer (2007). Interesting approaches in modeling the client rate are offered by O'Brien (2000) and de Jong and Wiellhouwer (2001) who, instead of the level of the market rates, introduce an "opportunity cost" (spread between the considered market rate and the client rate). Among the most recent suggestions on modeling the NMLs are the volume models presented by Bardenhewer (2007), which introduces as explanatory variable the level of the client rate relative to a long term average as well as the level of various market rates relative to their long-term mean. Most of the existing volume models introduce a linear time trend in order to capture macroeconomic influence factors that cannot be specified further or observed directly. An exception, in this sense, is O'Brien (2000), who incorporates the income to measure regional macroeconomic effects on the volumes level.

In the specification of the volumes model, we take into account a time trend (to check for macroeconomic influences), the lagged values of the volumes and the spread between the client rate and market rates. We find that depositors are sensitive to an increase in market rates. The volumes fluctuations reflect the effects of changing spreads between market rates and the client rate.

To test if the calibrated model produces realistic client rates, we conduct an out of sample test which shows a good performance of the models in predicting the future values. These results show that the models are tractable and can be integrated in the general framework of non-maturing accounts dynamic replicating portfolio approach or could serve for valuation models.

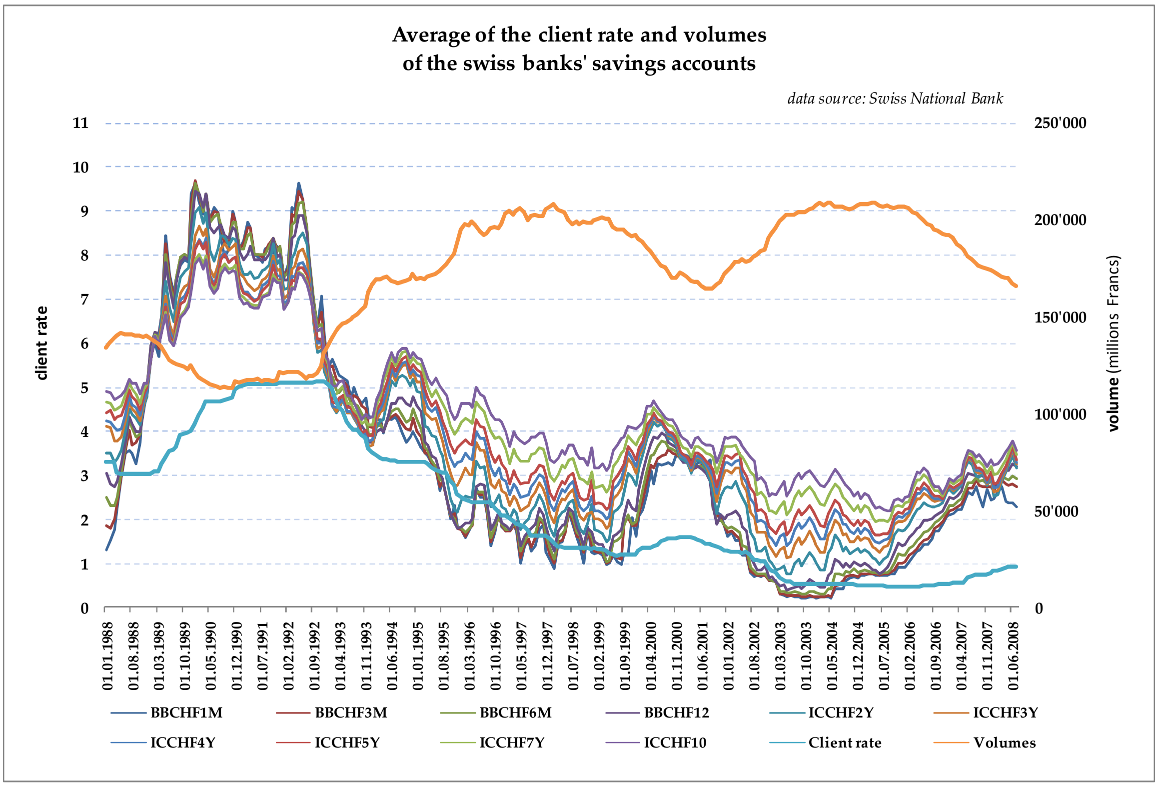
This paper is organized as follows: we describe in two major sections the models that we suggest for the client rate and for the volumes, describing the methodology used for their estimation and interpreting the results; in the last section we conclude and we briefly discuss future possible extensions.

Modeling client rate of savings accounts

Preliminaries

An asymmetry in the adjustment of the client rates may be present if they rapidly adjust to decreasing market rates, but are slow to react when market rates rise, as banks are less willing to pay higher interest rates. In this context, deposit rates are said to be "upward sticky" (as illustrated in *Figure 1* below). The client rate model presented in this paper will have the objective to determine whether there are asymmetries between market rates and the deposit rate in the form of a threshold effect. The threshold model is useful and intuitive in this context, since it allows the parameter on the market rates to differ when they are above or below some estimated threshold.

Figure 1 *shows the client rate and volumes evolution, on average, over all Swiss banks savings accounts and the market rates evolution over a 20 years horizon.*



Since the client rates should respond to policy actions, we assume in our analysis that the direction of causality is from market rates to deposit rates. Both market rates (Libor 3 months as short rate and Swap 5 years as longer maturity) and the client rate time series were found to be I(1)[5] using three different unit root tests (Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin). Thus, we may proceed with a model in error-correction form if the two series are cointegrated, which is confirmed using Johansen's (1988) maximum likelihood procedure (as shown in *Table 1,* subsection below).

Theoretical background

Johansen cointegration test

The finding that many macro time series may contain a unit root has spurred the development of the theory of non-stationary time series analysis. Engle and Granger (1987) pointed out that if a linear combination exists, the non-stationary time series are said to be *cointegrated*. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables.

The purpose of the cointegration test is to determine whether a group of non-stationary series are cointegrated or not. As explained below, the presence of a cointegrating relation forms the basis of the VEC (vector error correction) specification. The methodology developed by Johansen (1991, 1995a) considers a VAR (vector autoregression) of order p:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \varepsilon_t \qquad (1)$$

where y_t is a k-vector of non-stationary variables, x_t is a d-vector of deterministic variables, and $\mathcal{E}_t$ is a vector of innovations. We may rewrite this VAR model as:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_{\mathrm{i}} \, \Delta y_{t-i} + B x_t + \varepsilon_t \qquad (2)$$

where:

$$\Pi = \sum_{i=1}^{p} A_i - I, \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j \qquad (3)$$

Granger's representation theorem asserts that if the coefficient matrix Π has reduced rank $z < k$, then there exist $k \times z$ matrices α and ζ each with rank z such that $\Pi = \alpha\zeta'$ and $\zeta' y_t$ is I(0)[6]. z is

[5] Integrated of order one.

[6] Integrated of order 0, e.g. stationary

the number of cointegrating relations (the *cointegrating rank*) and each column of ζ is the cointegrating vector. Johansen's method helps us to estimate the Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π.

The cointegration test results show that the client rate and the 5 years Swap rate are cointegrated:

Table 1: Johansen cointegration test results

System	Vector	Eigen value	Trace statistic	Lags
Client rate	**1.000**	**0.158**	**58.477**	**4**
Swap 5y	**-0.97**			
	(0.033)			
Constant	**1.807**			
	(0.15)			

The lags for the VAR were chosen by minimizing the Schwartz Criterion. The critical value for rejecting the null of no cointegration is 35.17 at the 95% level.

Client rate model

A common practice in the literature is to explain client rate by a short maturity. Jarrow and van Deventer (1998) propose an arbitrage-free approach for valuation and hedging of non-maturing accounts. They obtain an analytic valuation formula in a simple one-factor model with deposit rates and volumes given by deterministic functions of the short rate. O'Brien (2000) derives equilibrium client rates as a function of the short rate.

Practically, the short rate is more volatile than the longer maturity. Thus, one would expect banks to react to changes in a shorter maturity only if clients were concerned with opportunity costs. In this context, banks should follow closely the market movement to avoid losing clients. However, a recent study of Nystrom (2008) shows that depositors were not concerned with opportunity costs. Kalkbrener and Willing (2003) argue that "deposit rates are heavily influenced by market rates, but rates of different types of depositors differ significantly. In particular, sensitivities to interest rate changes vary." Thus, the authors propose a more flexible model for the deposit rates, where market rates of different maturities can be used as arguments. We would like to follow this idea, by introducing in our client rate model a short (3 month Libor), as well as a longer maturity (5 years Swap) as explanatory variables. Intuitively, it is more likely that changes in the longer maturity, as less volatile market rate, have a higher impact in determining banks to adjust client rates.

Hutchison and Pennacchi (1996), Jarrow and van Deventer (1998), G. Tkacz (2000) recognize higher order or more complex lag dependencies of the client rate on market rates. We model changes in the client rate by taking into consideration lagged changes in the chosen market rates, as it is known that banks adjust client rate with a certain delay, imposed by the decision making mechanism (Forbes, Mayne (1988)).

After studying the cointegration between the client rate and the market rates and after deriving the error correction term (EC), we can estimate a threshold model to determine whether the movements in the client rate depend upon the interest rate regimes. Our observed sample is $\{y, x_i, \omega_i\}_{i=1}^{n}$, where y_i stands for the changes in client rate observations and x_i is a vector of independent variables (lagged change in the client rate, lagged error-correction term and the lagged change in the market rates). The *threshold variable* ω_i may be an element of x_i and is assumed to have a continuous distribution. To write the model in a single equation[7], we define the dummy variable $d_i(\tau) = [\omega_i \leq \tau]$, where $I[\cdot]$ is the indicator function and we set $x_i(\tau) = x_i d_i(\tau)$. Thus, the general specification of the threshold regression model is:

$$y_i = \theta' x_i + \lambda_n' x_i(\tau) + \varepsilon_i \qquad (4)$$

The equation above allows all of the regression parameters to switch between the regimes. We will estimate the model in both cases: when all variables switch between regimes or when only the threshold variable switches between regimes.

In order to simplify the threshold estimation procedure (in the next section), we transform equation (1) in matrix notation. We define $n \times 1$ vectors Y and ε stacking the variables y_i and ε_i, and the $n \times m$ matrixes X and X_τ by stacking the vectors x_i' and $x_i(\tau)'$. Then (4) can be written as

$$Y = X\theta + X_\tau \lambda_n + \varepsilon \qquad (5)$$

The client rate model that we specify helps us to determine whether there are asymmetries between market rates and the deposit rate in the form of a threshold effect. We will test for a threshold effect in the 3 month rate, 5 years rate and in the deviations from the equilibrium which links client rate to market rates. The specification of our model is the following:

$$\Delta R_t = \alpha + \beta_1 \Delta R_{t-1} + \beta_2 \Delta r_{t-1}^{short} + \beta_3 \Delta r_{t-1}^{long} + \delta EC_{t-1} + \gamma \varpi_{t-1} + \varepsilon_t \qquad (6)$$

[7] see Hansen (2000)

where ΔR_t is the change in the deposit rate, Δr_{t-1}^{short} is the lagged change in the 3 months Libor rate and Δr_{t-1}^{long} represents the lagged change in the 5 years Swap rate, EC_{t-1} is the lagged error-correction term derived from the estimated cointegration vector, and ε is a random i.i.d. disturbance. We introduce lagged values of the explanatory variables as it is known that there is a delay in the client rate adjustment to market rates changes. The factor EC shows the deviations of the client rate from its equilibrium level. The variable $\varpi_{t-1} = \omega_{t-1} I\left[\omega_{t-1} \le \tau\right]$ captures the threshold effect where ω is the threshold variable, τ is the threshold unknown variable and the indicator function $I\left[\cdot\right]$ is defined as:

$$I\left[\omega_{t-1} \le \tau\right] = \begin{Bmatrix} 0 \;\; for \;\; \omega_{t-1} > \tau \\ 1 \;\; for \;\; \omega_{t-1} \le \tau \end{Bmatrix}$$

Considering the form of the indicator function, the parameter on ϖ_{t-1} is added to the estimated parameter on the threshold variable. For example, if we use the change in the 3 months market rate as the threshold variable ($\omega = \Delta r_{t-1}^{short}$), the magnitude of the impact of a change in this variable on ΔR will be ($\beta_2 + \gamma$) when the change in the market rate is below the estimated threshold τ, and simply β_2 when it is above it.

Another interesting approach to determine whether asymmetries exist in adjustments of the deposit rate to a disequilibrium would be to use the error-correction term as the threshold variable ($\omega = \Delta EC$). In this case, the speed of adjustment as response to a disequilibrium is allowed to depend on the magnitude of the disequilibrium itself. Using the error correction term as the threshold helps us to estimate the spread between the client rate and its equilibrium level that banks can keep without the risk of losing clients (in case the client rate is too low comparing to its equilibrium level, the depositors might be interested to invest on the money market, for a considerably more attractive rate). Intuitively, if a large disequilibrium occurs due to a large unforeseen negative money market shock, one may suspect that since the market rate is sharply decreased, the deposit rate will respond more quickly to close the gap (as banks are interested in lowering the rates).

Methodology and results

In determining the location of the most likely threshold, we will apply Hansen's grid search. In the implementation of this threshold estimation procedure, we will follow Hansen (2000). This paper develops a statistical theory for threshold estimation in the regression context.

Threshold estimation:

Following equation (4), the regression parameters are $(\theta, \lambda_n, \tau)$, and the natural estimator is least squares (LS). Let

$$S_n(\theta, \lambda, \tau) = (R - X\theta - X_\tau\lambda)'(R - X\theta - X_\tau\lambda) \qquad (7)$$

be the sum of squared errors function. Then, by definition, the LS estimators $\hat{\theta}, \hat{\lambda}, \hat{\tau}$ jointly minimize (7). For this minimization, τ is assumed to be restricted to a bounded set $[\underline{\tau}, \overline{\tau}]$=Γ. The LS estimator is also the MLE when ε_i is i.i.d. $N(0, \sigma^2)$.

Following Hansen (2000), the computationally easiest method to obtain the LS estimates is through concentration. Conditional on τ, equation (5) is linear in θ and λ_n, yielding the conditional OLS estimators $\hat{\theta}(\tau)$ and $\hat{\lambda}(\tau)$ by regression of R on $X_\tau^* = [X\ X_\tau]$. The concentrated sum of squared errors function is

$$S_n(\tau) = S_n\big(\hat{\theta}(\tau), \hat{\lambda}(\tau), \tau\big) = R'R - R'X_\tau^*(X_\tau^{*\prime}X_\tau^*)^{-1}X_\tau^{*\prime}R, \qquad (8)$$

and $\hat{\boldsymbol{\tau}}$ is the value that minimizes $S_n(\tau)$. Since $S_n(\tau)$ takes on less than *n* distinct values, $\hat{\boldsymbol{\tau}}$ can be defined uniquely as

$$\hat{\tau} = argmin\, S_n(\tau)$$

To test the hypothesis $H_0\colon \tau = \tau_0$, a standard approach is to use the likelihood ratio statistic under the auxiliary assumption that $\boldsymbol{\varepsilon_i}$ is i.i.d. $N(0, \sigma^2)$. Let

$$LR_n(\tau) = n\frac{S_n(\tau) - S_n(\hat{\tau})}{S_n(\hat{\tau})}.$$

The likelihood ratio test of H_0 is to reject for large values of $LR_n(\tau_0)$.[8]

Since the distribution function is available in a simple closed form, it is easy to generate *p*-values for observed test statistics. Thus,

$$p_n = 1 - (1 - exp\,(-1/2LR_n(\tau_0)^2))^2$$

is the asymptotic *p*-value for the likelihood ratio test.

[8] see Hansen (2000) for more technical details concerning the asymptotic distribution of $LR_n(\tau_0)$.

Our threshold variable will be, at one time, either the short rate, the long rate or the error correction term. We verify if there is evidence for a threshold effect in each case by employing the heteroskedasticity-consistent Lagrange multiplier (LM) test for a threshold introduced by Hansen (1996). Since the threshold ω is not identified under the null hypothesis of no threshold effect, the p-values are computed by a bootstrap analog (see Hansen (1996)). Using 1000 bootstrap replications, the p-value for the threshold model using the short rate (Libor 3m rate) was insignificant at 0.262, while that for the threshold model using the long rate (Swap 5 years) and the error correction term were significant at 0.048 and 0.016, respectively (see Table 2). Figures 2 and 3 display a graph of the normalized likelihood ratio sequence $LR_n^*(\omega)$ as a function of the threshold in the long rate, and in the error correction term variables respectively. The LS estimates of ω is, in each case, the value that minimizes this graph, which occurs at $\widehat{\omega}_{long} = -0.520$ and $\widehat{\omega}_{EC} = 1.027$ respectively.

Figure 2: Sample split with threshold variable the long rate (Swap 5 years). Confidence interval construction for threshold.

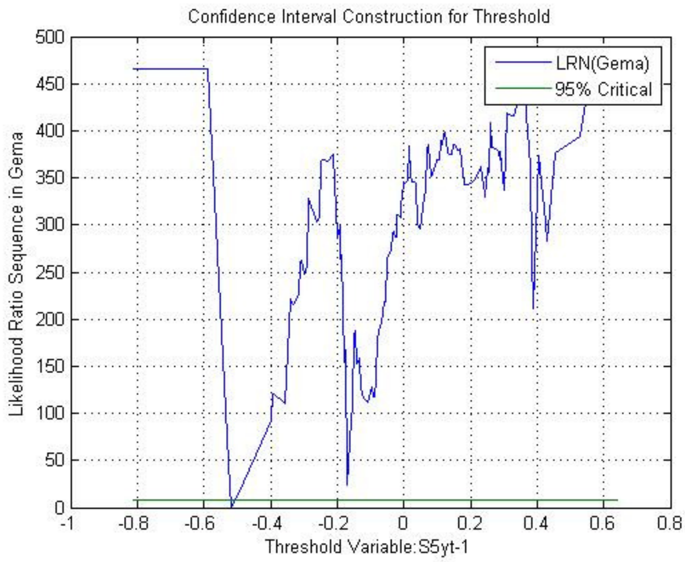
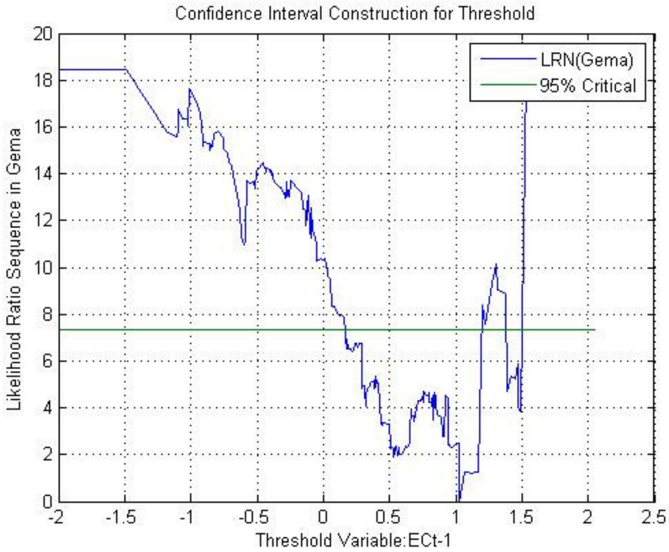
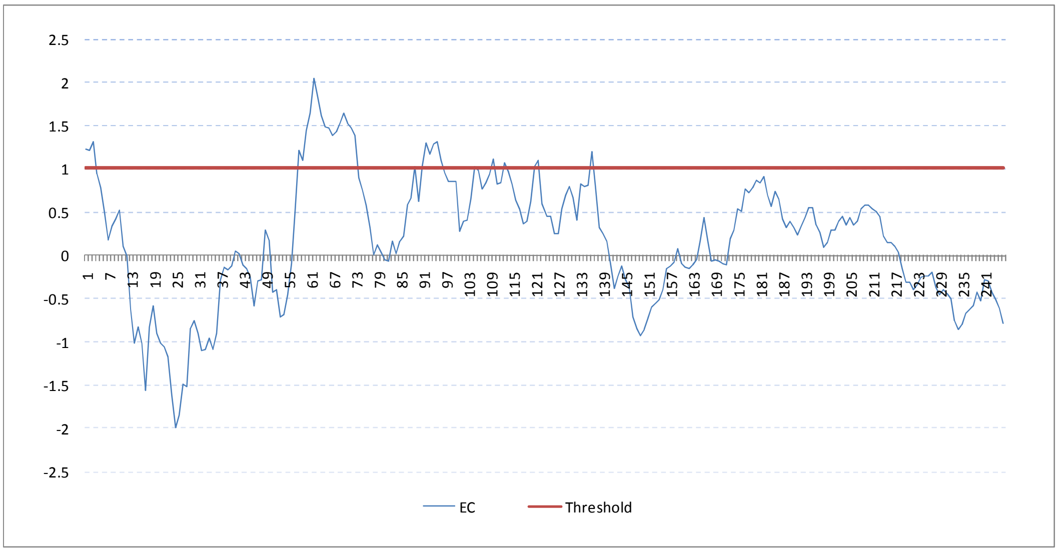


Figure 3: Sample split with threshold variable the error correction term. Confidence interval construction for threshold.



Since the confidence interval for $\hat{\omega}_{long}$ might seem rather tight by viewing *Figure 2*, it is important to know that only 3% of the interest rates sample fall in the 95% confidence interval, so 97% of the sample can be decisively classified into the first or second regime. Thus, we have considerable certainty about the estimated value for the threshold. Similarly 10% of the sample fall in the 95% confidence interval for the $\hat{\omega}_{EC}$ estimated value, which gives us certainty about the location of the threshold in the case of the error correction term. Approximately 10% of the error correction term values are above the estimated threshold values:

Figure 4: Threshold in Error correction term



After estimating the threshold in each case, we estimate the client rate model using Newey-West hetero/serial consistent estimates, allowing only the threshold variables, at a time, to switch between regimes. The results are summarized in *Table 2*.

Table 2: Threshold model

Parameters	**Libor 3m threshold** $(\boldsymbol{\omega} = \boldsymbol{\Delta r_{t-1}^{short}})$	**Swap 5Y threshold** $(\boldsymbol{\omega} = \boldsymbol{\Delta r_{t-1}^{long}})$	**Error-correction threshold** $(\boldsymbol{\omega} = \mathbf{EC})$
α	**0.056** (2.41)	**0.0008** (0.275)	**-0.027** (-3.028)
β_1	**0.098** (1.245)	**0.101** (1.287)	**0.070** (0.887)
β_2	**-0.062** (1.216)	**0.020** (1.679)	**0.020** (1.785)
β_3	**-0.043** (-3.35)	**0.034** (2.27)	**0.042** (3.328)
δ	**-0.053** (-7.35)	**-0.053** (-6.799)	**-0.140** (2.592)
λ	**0.057** (3.47)	**0.756** (7.63)	**0.101** (1.983)
$\overline{R^2}$	**0.592**	**0.551**	**0.563**
Durbin-Watson stat.	2.01	1.98	2.0005
Threshold	**0.468**	**-0.520**	**1.027**
Sup-LM	10.53	8.958	13.78
p-value	**0.262**	**0.048**	**0.016**

t Statistics are in parenthesis. *Threshold* is the value of the nuisance parameter associated with the *sup-LM* statistic to locate the most likely threshold. the *p*-value associated with sup-LM is also presented, and is obtained by simulating the asymptotic distribution (1000 replications) of the test statistic using the method proposed by Hansen (1996).

Following the specification of the threshold model (*Equation 3*), we estimate also the model allowing all variables to switch between regimes when our threshold variables is, at a time, the long rate or the error correction term. The results are presented in *Table 3.*

Table 3:Threshold model estimation allowing all variables to switch between regimes

Case 1: $\omega = \Delta r_{t-1}^{long}$		
Regime 1: $\Delta r_{t-1}^{long} \leq -0.52$		
Parameters	**Estimate**	**t-statistics**
α	0.432	5.76
β_1	-0.668	-3.88
β_2	-0.08	-3.07
$\beta_3 + \gamma$	0.79	7.97
δ	-0.10	-8.33
$\overline{R^2}$	0.971	
Regime 2: $\Delta r_{t-1}^{long} > -0.52$		
Parameters	**Estimate**	**t-statistics**
α	0.00022	0.1
β_1	0.074	0.94
β_2	0.029	2.95
β_3	0.034	2.26
δ	-0.053	6.625
$\overline{R^2}$	0.561	
Case 2: $\omega = \mathrm{EC}_{t-1}$		
Regime 1: $\mathrm{EC}_{t-1} \leq 0.75$		
Parameters	**Estimate**	**t-statistics**
α	0.001	0.5
β_1	0.210	2
β_2	0.031	3
β_3	0.020	1.87
$\delta + \gamma$	-0.039	-5.57
$\overline{R^2}$	0.522	

Regime 2: $\mathbf{EC_{t-1}} > 0.75$		
Parameters	**Estimate**	**t-statistics**
α	0.065	0.970
β_1	-0.225	-1.78
β_2	-0.079	-1.88
β_3	0.138	3.83
δ	-0.140	-2.8
$\overline{R^2}$	0.354	

Using the coefficients shown in *Table 3*, we obtain the fitted values for the client rate model:

Figure 5: Model fit for changes in the client rate

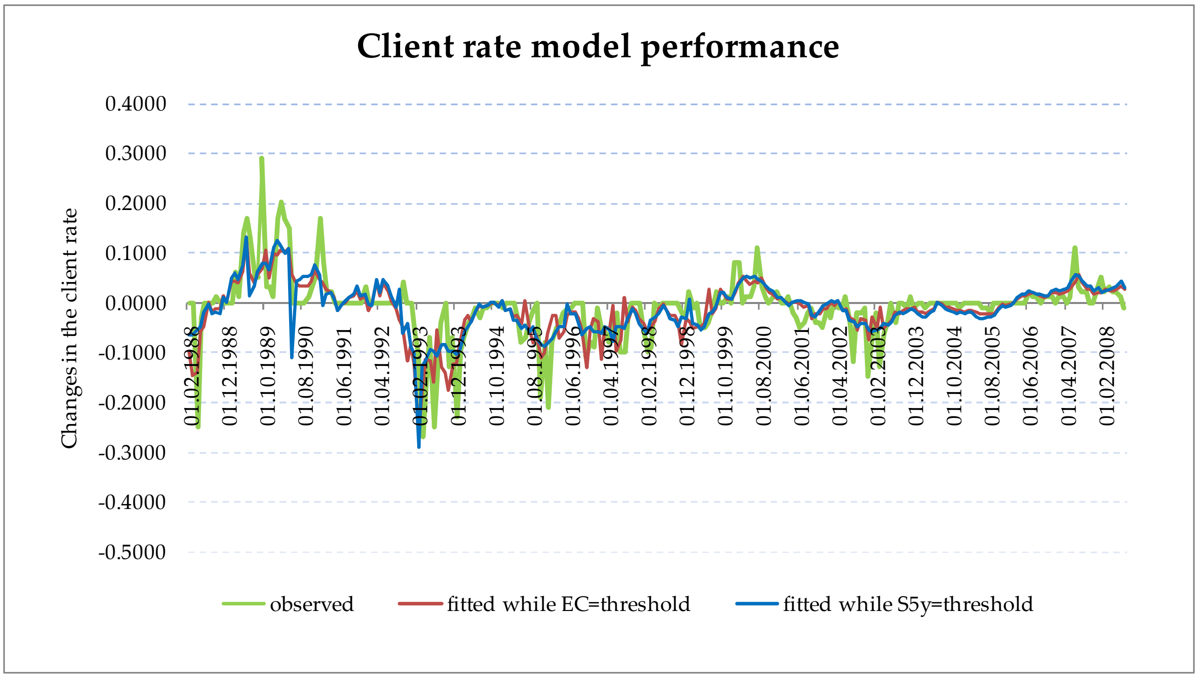
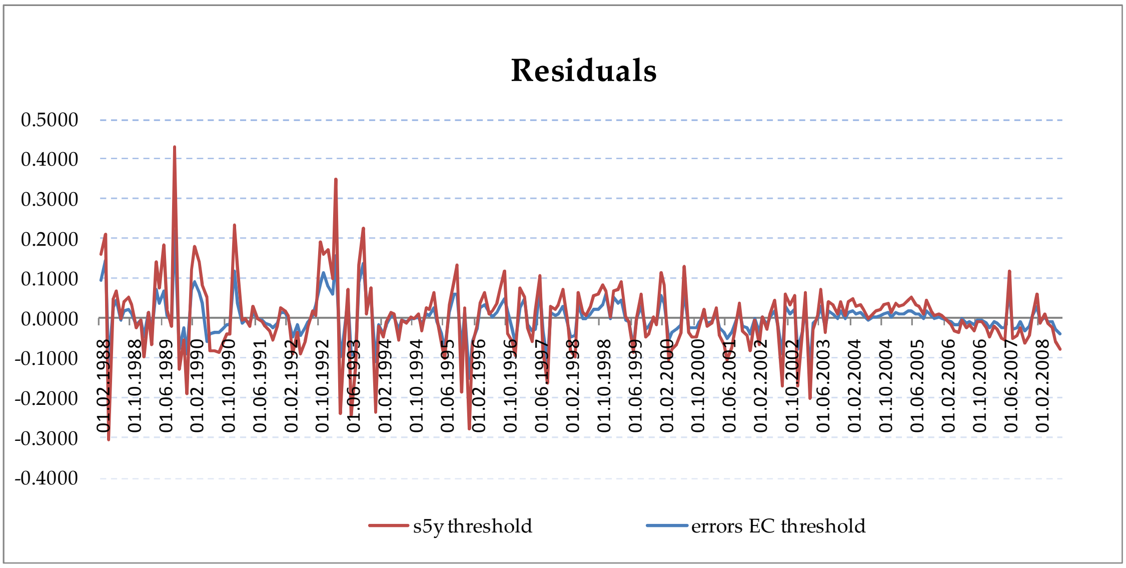


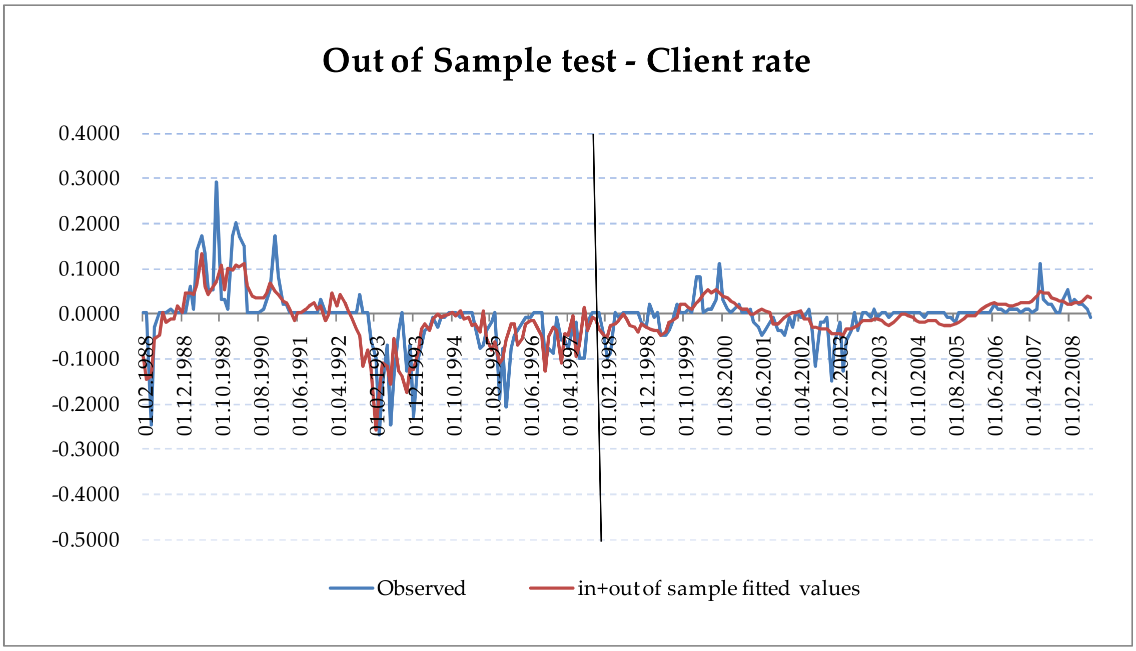
Figure 5 shows that the estimated client rates fit well the observed data. Inspecting the residuals, we can conclude that the best fit is obtained while using the error correction term as threshold variable:

Figure 6: Residuals while considering estimated model using the long rate or the EC term as threshold variables



To test if the calibrated model produces realistic client rates, we do an out of sample test, by reestimating the model using historical observations of the client rate from January 1988 up to January 1998. A second (non-overlapping) historical period (February 1998 to July 2008) is designated as the out-of-sample testing period.

Figure 7: Client rate model - out of sample test



The client rate model produces meaningful values for the out-of-sample testing period.

Interpretation of results

Beginning with the error-correction model that uses changes in the Libor 3 months rate as the threshold variable, we find the threshold parameter to be statistically insignificant. This implies that deposit rates respond in a linear fashion to the short rate. In fact, we expect that: since the short rate is more volatile, it does not have a major impact on the adjustment of the client rates in banks (the deposit rates do not follow closely the short rates movement).

When using the changes in the 5 years Swap rate as the threshold variable, we now find that the threshold is significant. We find that a threshold exists when the change in the Swap rate equals -52 basis points (b.p.). Furthermore, for every negative shock of 100 b.p. below -52 b.p. in the Swap 5 year rate, the client rate will be adjusted by a 79 b.p. drop per month. On the other hand, for every 100 b.p. increase in the market rate above -52 b.p. level, the client rate will increase by only 3.4 b.p. per month. These results allow us to conclude a strong asymmetric relationship between the client rate and the changes in the longer rates maturities.

When using the error-correction term as threshold variable, we also find in that the threshold is significant. A threshold exists when the client rate is 1.027% (102.7 b.p.) above its equilibrium level. For every 100 b.p. above this departure from equilibrium, we expect the convergence back to equilibrium to be of the magnitude of a 14.06 b.p. drop in the client rate per month. Below this disequilibrium threshold, the convergence to equilibrium only occurs with a 3.9 b.p. drop. Hence, as suspected, the greater the magnitude of the disequilibrium, the greater the speed of adjustment towards equilibrium. The speed of adjustment would be approximately 4.5 times greater for the more extreme disequilibrium.

Modeling volumes of savings accounts

Volumes model specification

The model that we suggest for the volumes of non-maturing accounts is the following:

$$D_t = \beta_1 + \beta_2 t + \beta_3 D_{t-1} + \beta_4\left[R_{t-3} - \left\{\delta r_{t-3}^{short} + (1-\delta) r_{t-3}^{long}\right\}\right] + \varepsilon_t$$

where t represents the time trend; D_{t-1} is the lagged value of the deposits volumes; the fourth explanatory variable is the spread between the client rate R_{t-3} and a proxy for the market rates, where a short and a long maturity are considered. As observed in case of the savings accounts, a longer maturity influences more the volumes dynamics, as it is less volatile and its changes might have a higher impact on the client behavior. Therefore, we will use higher weights for the long rate in the proxy for the market rates (in this analysis we fix $\delta = 0.33$).

Methodology and results

In the first step, we estimate the parameters by using a top down approach for variable selection applying Newey-West hetero/serial consistent estimates. *Table 3* summarizes the results. The time trend is not significant and Durbin Watson statistics show serial correlation in our variables. Thus, in the next step we eliminate the time trend from the model and check for serial correlation by estimating an AR(1) model. The results are summarized in *Table 4*.

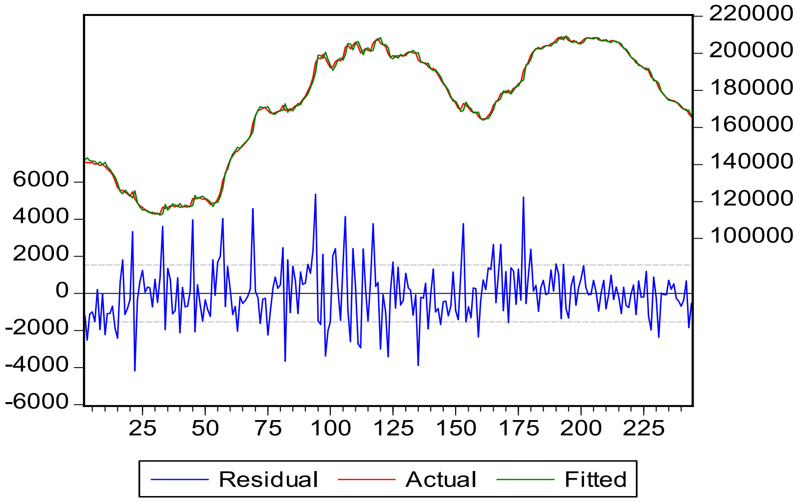
Table 3: *Step one: OLS covariance matrix obtained with Newey West estimator*

Variable	Coefficient	t-statistic	t-probability
beta1	8850	5.00	0.000001
beta2	4.60	1.20	0.231164
beta3	0.96	100.12	0.000000
beta4	1486	5.81	0.000000
Rbar-squared	0.9971		
Durbin-Watson	1.1740		

Table 4: Results estimating the volumes model in AR(1) form excluding the time trend from the estimation:

Variable	Coefficient	t-statistic	t-probability
beta1	7884	4.179615	0.0000
beta3	0.96	115.3435	0.0000
beta4	1360	4.895730	0.0000
AR(1)	0.42	7.016911	0.0000
Rbar-squared	0.99		
Durbin-Watson	2.04		

Figure 8: Volumes model performance

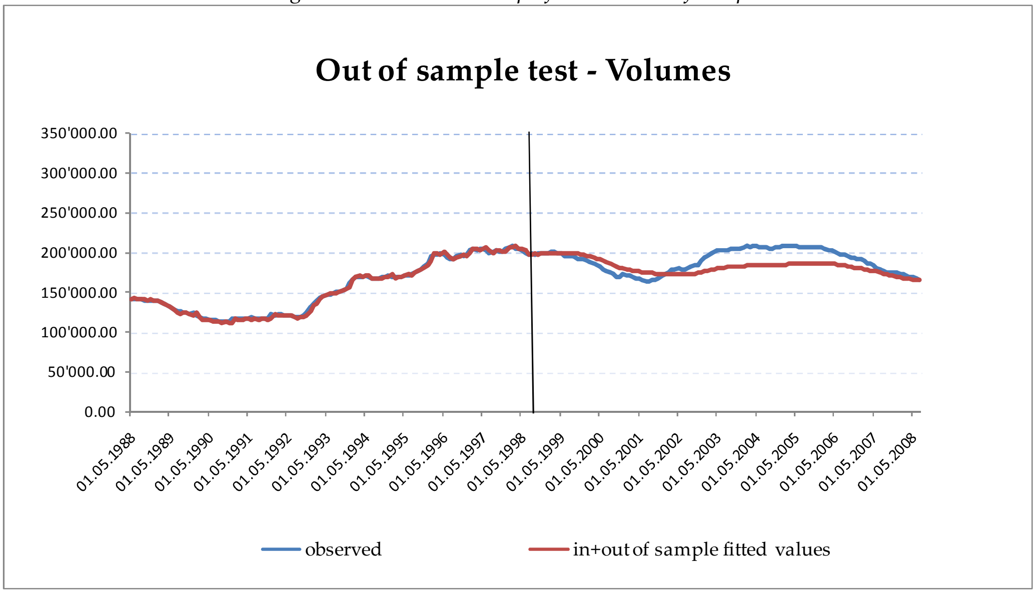


We repeat the procedure for the out-of-sample test, this time for the volumes model using historical observations of the client rate from January 1988 up to December 1998. The model coefficients are significant and the model offers a good fit to the observed data also when we reestimate it using a shorter data sample (see *Table 5*). Furthermore, the out of sample test shows that the model predicts the tendency correctly (see *Figure 9*).

Table 5: Reestimation of the model parameters using sample period: January 1988 up to December 1998

Variable	Coefficient	t-statistic	t-probability
beta1	6893	3.02	0.0000
beta3	0.97	82.94	0.0000
beta4	1169	3.50	0.0000
AR(1)	0.41	4.88	0.0000
Rbar-squared	0.99		
Durbin-Watson	2.00		

Figure 9: Volumes model performance out of sample



Interpretation of results

The results above show that the lagged deposits and the spread between deposits-market rates have important explanatory power for deposit balances. The coefficient of the lagged deposits show us that the volumes series is stationary. The time trend is not significant to explain the volumes evolution.

The spread between the client rate and the market rates is expected to be negative (as banks pay below the market rates). If the market rates go up with 100 basis points (e.g. 100 basis points decrease in the spread), this would determine 1360 millions CHF drop in the volumes value. This can be explained by the fact that the depositors are sensitive to market rates increase. So we can conclude that the fluctuations in balances that one can observe in *Figure 1* reflect the effects of changing market-to-deposit rate spreads on the deposit balances.

Conclusion and outlook

This paper develops models for the client rate and volumes of non-maturing accounts. We take into account data at an aggregate level over all Swiss banks.

Our results concerning the client rate aim at contributing to a better understanding of the asymmetric adjustment to market rates. We found that deposit rates and markets rates are cointegrated. This result allowed us to relate the idea of equilibrium client rates to their common trend with the market rates and, further, to formulate a model in error-correction form. This approach is new in the context of deposit rates modeling related literature. Testing a simple threshold model, we found a strong asymmetric adjustment of client rates to the 5 years Swap rate. Explicitly, banks adjust deposit rates with significantly higher speed in case of negative changes in the market rate, but the speed of adjustment is significantly lower in case of positive changes in the Swap rate. We further found that deposit rates adjusts in a linear fashion to the short rate changes. Testing for a threshold effect in the error-correction term, we found that the greater the magnitude of client rate's disequilibrium, the greater the speed of adjustment back to equilibrium.

Modeling the volumes, we can conclude that the depositors are sensitive to market rates changes: market-to-deposit rates spreads are reflected in changes in deposit balances.

We also present an out-of-sample test and we conclude a good prediction power in case of both models suggested in this paper, which makes them useful for cash-flows forecast or for pricing non-maturing accounts.

Our suggested models perform well with data at an aggregate level, However. our goal is to create models to be applied successfully at the level of individual banks. It is often observed that banks adjust their deposit rates with a certain delay to the market rates; we talk, in this sense, about "rigidity" of client rates. In this context, it would be interesting, as further research, to implement "friction models" and to compare the performance with our threshold model for individual banks data.

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