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Adjustment Policy of Deposit Rates in the Case of Swiss Non-maturing Savings Accounts

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Abstract

Retail banks usually apply simple linear regression models for describing the dynamics of the deposit rates of non-maturing accounts (NMA) like savings deposits. Thus, typical patterns like asymmetry or rigidity that banks follow when adjusting their deposit rates are ignored. This is insofar surprising, as the asymmetric deposit rate adjustment affects the pricing of embedded options for NMA. In this work we contribute to the elimination of these inconsistencies. Based on data for deposit rates from a representative sample of Swiss banks we provide a strong evidence for both asymmetric adjustment and rigidity pattern. Our proposed modeling approaches reveal that the strategies of Swiss banks to adjust deposit rates are regime dependent. In times of market stress, Swiss banks are tight to market rates; however, in normal regimes this is not observed.

JEL Classification numbers: G21
Keywords: non-maturing accounts; deposit rates; asymmetries; rigidity

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1 Introduction

A large percentage of the balances of retail banks consists of positions with no contractual maturity, the so-called non-maturing accounts (NMAs). This includes, for example, savings and sight deposits on the liabilities side or variable-rate mortgages on the assets side, which in Switzerland have as well no contractual maturity. The NMAs are characterized by two options: first, the retail bank is allowed to adjust the client rate[2] at any time as a matter of policy and second, the clients are allowed to withdraw their investments or to repay variable mortgages at any point in time, without penalty. Therefore, the future cash flows from the client rate payments and the volume changes of these positions due to the demand for retail products are uncertain. The importance of modeling NMAs is particularly emphasized in Basel II with respect to the uncertainty of cash-flows due to the optionalities. The regulation framework stresses the importance of finding realistic client rate models for NMA.

The high relevance of the profits generated with interest rate sensitive business in a retail bank's balance implies an important role for the measurement and control of the corresponding risks. In this context, the policy to fix client rates for the retail business plays a central role. The banks determine the client rates depending on their costs structure and on the demand for the products. It is typically observed that, for example, deposit rates are below the rates on the money market. Clients invest in deposits because they have only limited market access, or because they hold savings deposits for liquidity considerations. However, non-maturing products are in competition with other investment or financing opportunities. For the determination of the client rates, banks look at the margins of their retail products as well as at the rates for alternative savings products on the market. Therefore, the client rates on retail banking products have to be adjusted to changes in the level of market rates. It can usually be observed that this adjustment occurs only with some delay and with an asymmetric pattern.

A common practice in banks is to apply linear regression models for modeling the dynamics of the client rates. These models serve for example for

[2] By client rate it is denoted the rate payed/received by the retail banks for deposit/mortgage accounts. Often the same type of models are applied in the literature for both deposit or loan rates, as it is known that in the case of NMA they move in parallel and they show common patterns

forecasting or for valuation purposes. This way, neither the rigidity nor the asymmetry the banks follow when they adjust their client rates to changes in the observed market rates are reflected. This is insofar surprising as the asymmetric client rate adjustment forms the basis for pricing the embedded options of non-maturing accounts. In this work we contribute to the elimination of these inconsistencies.

The goal of this paper is to develop models that explain the behavior of deposit rates of NMA and to assess them from a statistical and economical point of view for finding applicability in the management of NMA. Based on data for deposit rates from a representative sample of Swiss banks we bring a strong evidence for both asymmetric adjustment and rigidity patterns and we propose modeling approaches which reflect both patterns. In this respect we extend the existing literature with a joint model for asymmetry and rigidity. Our new findings reveal that the strategies of the Swiss banks to adjust the deposit rates are regime dependent.

This paper is organized as follows: section 2 offers a detailed literature overview of the properties and model types used to describe the client rates of NMA; section 3 describes the data; section 4 includes the cointegration analysis applied to Swiss deposit rates in relation to relevant market rates; Sections 5,6,7 describe our modeling approaches employing one model in error correction form, one threshold model to describe the asymmetric adjustment of deposit rates and one rigidity model for deposit rates, respectively. Section 8 concludes.

2 Literature overview

Although various authors investigate different types of loan and deposit products in different markets, there is consensus that client rates of retail banking products typically exhibit the following characteristics:

Stickiness (or rigidity): Product rates remain stable over longer time periods and react with some delay to changes in market rates. This results from the fact that changes in product rates are associated with administrative costs, therefore banks have only an incentive for adjustments when these are smaller than the costs for not changing the rates, e.g., due to an outflow of volumes (e.g., see [31]). As a consequence, banks adjust their product rates only after larger changes in market rates and when they are convinced that these are not just temporary ([37]). Banks take also advantage from the fact that customers have no or limited information on current market conditions or competitors' product rates, or they obtain such information only with some delay (see [36]). Clients face also search and switching costs that prevents them from changing their bank connection (see [10], [34]). [19] find that the "speed of adjustment" depends also on market concentration, i.e., the (local) competition in the market for retail banking products. For liability products, one may also explain stickiness by the fact that the product rate has a natural lower bound of zero (or some slightly larger rate). If the rate dropped below this limit, clients would withdraw deposits. On the other hand, the bank will increase the product rate again not before market rates have reached a certain level.

Discrete changes: As a further consequence of the administrative costs for adjusting the product rates, banks change them (sporadically) in discrete steps, e.g., 25 bp (see [10], [28], [31]). In this way, a "disequilibrium" between the client rate and (the new level of) market rates is corrected at once.

Asymmetric adjustment: This effect describes that the timing and extent of an adjustment depend whether market rates go up or down and the current product rate is below or above its "equilibrium" ([15]). [19], [34] find that banks are slower to raise interest on deposits when market rates rise, but are faster to reduce consumer deposit rates when markets fall. The motivation is similar as for stickiness: banks exercise their market power to optimize their margins by delaying the pass-through of higher market rates to clients (see [41]).

Incomplete adjustment: Banks do not pass a change in market rates fully to clients, e.g., the difference between market and deposit rates widens when market rates increase. [23] explains this with imperfect competition that allows banks to set the product rates so that they maximize their profits.

Although not often considered in the literature, one can also suspect that individual banks have different adjustment policies for other reasons than market power. For example, [16] finds evidence that the pass-through depends on banks' asset and liability structure. It is often claimed that rates of liability (loan) products are below (above) market rates. [25] and [27] motivate this with the exclusion of arbitrage opportunities for individual investors. However, in Europe the interest rate on savings accounts may very well be higher than money market rates ([8]). This was the case in Switzerland in 2002 and 2003 when the 3 month Libor temporarily dropped below 25 bp. Furthermore variable-mortgage rates were below market rates during the early 1990ies which resulted in negative margins for many banks.

In order to reflect the diverse NMA product characteristics in different markets, a multitude of model types and econometric approaches have been suggested.

Linear models explain the product rate as a linear function of (possibly lagged) market rates of one (or more) different maturities and can be estimated with *regression analysis*. In the simplest specification, this does not allow for the consideration of asymmetric adjustments. Using this framework, [23] find a clear evidence of an incomplete adjustment of the product rate for US negotiable order of withdrawal (NOW) and money market deposit accounts (MMDA) from 200 banks. For similar products [24] obtain significant estimators and high R^2 in a regression for deposit rates on a short-term rate. [36] extends this approach by non-linear dependencies to take asymmetry into account and finds strong support for this. Particularly for German-speaking countries the "moving average method" is popular, which uses *moving averages* of current and previous rates as explanatory variables. Consultants who propagate this approach for the construction of replicating portfolios recommend that banks should change their product rates frequently by the same amount as the average portfolio rate changes in order to keep the margins on variable banking products stable ([40]). By construction, this reflects the rigidity of product rates. In a comparison of different models for data of various accounts from up to 400 German banks, [12] find higher R^2 values, in particular for typical savings deposits ("with agreed notice of 3 months") than, e.g., an asymmetric pass-through model.

Asymmetric partial adjustment models assume a long-term equilibrium between product and market rates. Although there may be temporary deviations due to frictions, the distorted product rate will adjust smoothly to the long-run equilibrium relation over time. Asymmetry of adjustments can be taken into account by different coefficients for the adjustment speed depending on the product rate being below or above the equilibrium ([34]). [6] finds strong evidence of asymmetry in an analysis of the NOW and MMDA accounts of almost 100 US banks which has also a strong impact on the estimated values and risk of the positions.

Error correction models make also the assumption of a long-term equilibrium between product and market rates which is described by a cointegration vector. The residuals of the long-term relation are used to estimate the relation of the short-term deviations from the equilibrium. Since here the first differences of product and market rates are used which are stationary, the error correction term is also stationary and the approach provides consistent estimates. Asymmetry is also incorporated by different speeds of adjustment for increases and decreases in market rates ([43]) and is empirically confirmed by [30] for deposits of Australian banks while [33] finds significant differences between different bank groups in Germany. More recent publications like [7], [18], [38] employ also models in error correction form and find evidence for asymmetric adjustment of the client rate to strictly positive/negative changes in market rates.

Threshold error correction models extend the latter framework by making the movements in client rates dependent on the interest rate regime. Technically a regime is specified by an indicator variable that is “one” if some threshold variable exceeds a threshold value and zero otherwise. This is used, e.g., by [3] to explain the interest rate pass-through to UK mortgage rates or [35] to model the asymmetry in Swiss deposit rates.

Friction models assume that changes in the client rate are non-linear functions of the spread between its lagged value and exogenous rates. The main feature of this relationship is a range of spread values for which the client rate remains unchanged, it increases (decreases) only when the spread exceeds (falls below) certain limits [13]. Obviously, this is useful to incorporate stickiness. [5], [28] model changes in the product rate as function of the accumulated margin since the last adjustment. If it crosses certain boundaries, the product rate is updated in discrete steps whose size depends on the magnitude of the current margin. A potential drawback of the approach is that it requires large samples that contain a sufficient number of "jumps" in order to obtain significant results as the client rate remains unchanged for a long time. With the different threshold values a large number of parameters need to be estimated and a rather complex non-linear optimization method is required.

Probit models are based on a similar idea: the change in the client rate as response variable can take as value the different levels of changes observed in reality (e.g., 0, ± 25 bp, ± 50 bp, ...). The product rate's propensity to change in discrete steps is represented by a latent variable which is linear in some exogenous variables. For the latter, [26] use a money market rate, the change in this rate and the spread to the product rate. In an application for Swiss savings accounts, [14] use the lagged product rate and current and previous observations of the factor of a term structure model (which represents the level of the yield curve and moves in parallel to a long-term interest). Again this suffers from the fact that long histories are needed for calibration. Logit models allow only for two states "change" and "no change". This is exploited by [31] who distinguish between strictly rising and falling rate regimes.

3 Data

Our main goal is to test and compare many econometric deposit rate models to reflect the characteristics of the NMA deposit rates representative for the Swiss market. For this purpose, we investigate the deposit rate of the Swiss deposit accounts published by the Swiss National Bank (SNB) as average over all Swiss Banks for the sample period 1988-2010 with monthly observations. The number of banks and the bank categories subject to reporting requirements, accordingly to the last statistics published by SNB are presented in Table 1.

Table 1: The number of banks in each bank category, at 31.12.2010. Source Swiss National Bank, http://www.snb.ch/en/iabout/stat/statpub/bchpub/stats/bankench

Cantonal banks	24
Big banks	2
Regional banks and savings banks	69
Raiffeisen banks	1
Stock exchange banks	47
Other banking institutions	10
Foreign-controlled banks	122
Branches of foreign banks	32
Private bankers	13
Total	325

We also extend our analysis on data sets for the deposit rates from 10 individual Swiss banks (sample 1988-2010) with monthly observations. For confidentiality reasons, in this paper neither the identity of each bank nor the category to which each bank belongs can be revealed. The market rates used in our modeling approach are provided by the SNB. We test the sensitivity of the deposit rates with respect to market rates of different maturities. Here short as well as long-term market maturities are tested.

4 Cointegration analysis

Most of the time series of the deposit rates support the statement in the literature that time series of interest rates are based on the I(1)[3] property. We apply the Augmented Dickey Fuller unit root test to check for stationarity in the deposit rates (average over all Swiss Banks as well as the deposit rates from the 10 Swiss banks) and in the market rate series (one short maturity: Libor 3m as well as one long maturity: Swap 5y). Tables 4 and 5 (Appendix) summarize the results. In all cases, we conclude non-stationarity of the analyzed series. In

[3] Integrated of order 1

this case, for most banks which model the level of deposit rates by regression analysis, depending on market rates of different maturities (or moving averages, as it is the case of Germany), the results do not reflect real causalities, but only spurious correlations (see [37], p. 104). In order to obtain consistent results it is required to conduct the regression analysis based on the first differences of the time series. An alternative would be also to derive the common trend which links the deposit rate to the market rate by the cointegration analysis and then to derive a model in error correction form.

We apply Johansen's cointegration test to see if the average deposit rate over all Swiss banks as well as the deposit rate from our 10 data sets share a long-term common trend with market rates. We include in the cointegration analysis one short maturity, the Libor 3 month rate as well as a longer maturity, the Swap 5 year rate. To compare the strength of the long-term relation we include just one market rate at one time in the cointegration relation or both of them simultaneously. The results are presented in Table 6.

Johansen's cointegration test shows overall that the deposit rate is cointegrated with market rates. The cointegrating vectors presented in the 3 panels of Table 6 represent the long-term common movement of the deposit rate with one of the included market rates or with both of them simultaneously. It helps us to obtain the "equilibrium deposit rates", or its expected value, given its common long-term trend with market rates. We include in the specification of our cointegration analysis also a constant as it is known that the deposit rate is, in general, below market rates. We observe for all data sets that the long-term relation between the deposit rate and the market rate is stronger for the longer than for the shorter maturity. The beta coefficient MR^{long} is overall higher than the coefficient of the short rate MR^{short}(panels 1 and 2 of Table 6). Thus, in 7 out of the 10 data sets, the long-term sensitivity of the deposit rate to the long-term rate is above 0.9, while the sensitivity to the short rate varies between 0.154 and 0.784. The coefficient of the long-term rate is more stable between the data sets, showing a smaller standard deviation than in the case of the short rate coefficient. While including both market rates in the cointegrating vector, the coefficients of the two market rates sum up to one only in 3 cases (data set 1, data set 4 and data set 8). For these particular cases, we can conclude that the deposit rates of the Swiss banks share a common long-term trend with both market rates, but the sensitivity to the rate of the long maturity is overall higher. We have also included in the cointegration analysis all liquid market rates, but overall the maturity with the strongest link to Swiss deposit rates is the Swap 5 year rate. The interpretation follows: as they are less volatile, changes in the longer maturity better reflect the important changes on the market and, therefore, they are used in the decisions of Swiss banks to adjust accordingly the deposit rates. This result is in line with the rigidity pattern of the deposit rates which are adjusted only when the changes in the market rates are considered stable and significant.

5 Model in error correction form

After we found that the deposit rates of Swiss banks are strongly cointegrated to the Swap 5 year rate, a natural way to model the dynamics of the rates is to derive a model in error correction form (ECM). The ECM is the most used model in the literature for client rate modeling (for both mortgage/deposit rates, see section 2). Differences between the various ECM applications come from the choice of different bank products, different market rates as explanatory variables and other exogenous explanatory factors.

The specification of our model for the deposit rates in error correction form is:

$$\Delta CR = \delta + \Gamma_1 \Delta CR_{t-1} + \Gamma_2 \Delta MR_{t-1}^{long} + \gamma EC_{t-1} + \varepsilon_t \tag{1}$$

where the EC_t is derived from the cointegrating equations derived in Table 6, panel 2. We thus take as market rate the one which showed the strongest link to the deposit rates paid by Swiss banks, i.e. the Swap 5 year rate.

We estimate equation (1) using average over the deposit rates over all Swiss banks published by the SNB as well as for the 10 data sets from individual Swiss banks. The results are presented in Table 7. The results concerning the aggregate deposit rate data are presented in the first column of Table 7.

In the case of the individual banks, we observe that individual changes in the market rates do not have a significant explanatory power for the deposit rate. However, lagged changes in the deposit rate and its deviations from the equilibrium level are significant. The model performance is displayed in Figure 2. We observe a low performance of the model to fit shocks in the deposit rate. Thus, significant drops in the deposit rates which occur between 1992-1993 (as a consequence of a significant drop in market rates) as well as the drop caused by the financial crisis (November 2008) cannot be anticipated by our ECM model. The explanation is that a change occurs in the market rates in each period, but the deposit rate does not reflect all these changes. The Ordinary-Least-Square (OLS) estimation is weak in fitting so many zero changes caused by the rigidity pattern of the deposit rate. Important characteristics like the asymmetry and the rigidity must be investigated.

Over all data sets we observe that lagged changes in the deposit rate are significant. However, the estimated coefficient for Γ_1 shows different magnitude between our data sets, varying between -0.055 and -0.250. It means that each 100 bp increase in the deposit rate in the previous month will imply, on average, a decrease at the current month varying between 5.5 bp and 25 bp over our data sets. Our results show that changes in the market rate have a low explanatory power. Only in two cases out of 10, Γ_2 is significantly positive and it has an economical interpretation: when the lagged market rate goes up, the Swiss deposit rate will be, on average, increased instantaneously, since the sign of the coefficient is positive. In two cases the coefficient is significant, but it has a negative sign, which cannot be interpreted from an economical point of view since one would expect that deposit rates follow the direction of market rates. Overall we cannot conclude a clear explanatory power of lagged market rate changes for changes in the deposit rates. This result in not surprising, given the stickiness of deposit rates. As discussed in the introduction, deposit rates remain stable over longer time periods and react with some delay to changes in market rates.

The coefficient of the error correction term is overall significant. The coefficient γ reflects the dynamics of the short-term deposit rate with respect to its equilibrium level derived in relation to market rates. Our γ coefficient varies between -0.063 and -0.136 over our data sets. The interpretation is that banks adjust the deposit rate every month, on average, with $6.3\% to 13.6\%$ from the disequilibrium of the previous period to reestablish the equilibrium spreads to market rates.

Our R^2 values show an explained variation varying between $14.9 - 68.5\%$ of the total variation. The interpretation of our low R^2 results is due to the characteristics of our model variables. We model monthly changes in deposit rates which, given the rigidity pattern, are compound of many consecutive zero changes in contrast to market rates where we have a change every month.

Our results from the error correction model show that Swiss deposit rates adjust linearly to the previous period disequilibrium level. Thus, if the deposit rate in the previous period was too high/low comparing to its equilibrium level derived in relation to market rates, banks decrease/increase it in the next period to close the gap. However, lagged individual changes in the market rates have no conclusive explanatory power for changes in the deposit rate. In other words, short-term market dynamics are not reflected in the savings rate changes.

The model in error correction form for the deposit rates, although widely used in the related literature, shows a relatively low explanatory power. This is due to the very distinct pattern of rigidity and asymmetry in the Swiss deposit rate data and, therefore, we will extend our analysis in these directions in the next chapters.

6 Modeling the asymmetries of deposit rates

6.1 Reasons for asymmetries and drivers of different types of asymmetries in the literature

Intuitively, an asymmetry in the adjustment of the deposit rates may be present if they rapidly adjust to decreasing market rates, but are slow to react when market rates rise. In this context, deposit rates are said to be "upward sticky". The literature has provided evidence that relates asymmetry of deposit rates to market rates, but a common behavioral explanation for these results is lacking.

For the definition of deposit rates, banks look at the margins of their retail products as well as at the rates for alternative savings products on the market. A change in market rates may cause a pressure on the margin that forces a bank to adjust its deposit rates. The desired minimum margin or the bank's cost structure, respectively, define a lower (upper) bound for the client rate on asset (liability) products. On the other hand, the competition on the market for retail banking products sets also limits for the client rates that a bank may fix without losing volume. Banks may exploit the leeway between these limits given by the current margin and the competitive situation to optimize their margins. This results in asymmetric adjustments of their client rates for a short term where they take advantage from customers' rigidity due to switching costs, insufficient information on bank interest rates or implicit price agreements among banks. In case market rates go up and the difference between the current client rate and its equilibrium level becomes too large, the increasing pressure from the competition requires an adjustment of product rates to avoid volume outflows. This effect is weaker the less elastic the demand for a banking product is.

The described situation does not explain asymmetries with respect to the long-term dynamics of adjustments. The banks' flexibility to achieve desired margins may be confined or extended if the elasticity of demand for a product with respect to the client rate is not stable over time. An asymmetry in the long term may therefore result if clients react in certain situations more and in other situations less sensitive. Based on these considerations, various drivers may be identified that may cause asymmetric adjustments of client rates.

Type 1. Sign of the change in market rates The bank may show a different adjustment policy depending on whether market rates go up or down. In this way, it takes advantage of customers' tardiness for the reasons given above in the short term. Often periods with a persistent trend of the interest rate evolution reflect a certain stage of the business cycle. For example, increasing market rates go along with a boom in the economy while a downswing is characterized by decreasing rates. If the business activity has an impact on the elasticity of the demand for banking products, clients may change their demand behavior in different market environments, which leads also to long-term asymmetries.

Type 2. Magnitude of market rate change Furthermore, the magnitude or speed of a change in market rates may influence banks' asymmetric adjustment behavior. Large decreases in market rates increase the pressure on the margin of liability products. It can be expected that then banks' reaction is stronger than in case of moderate changes.

Type 3. Level of market rates It can be suspected that stronger "smoothing effects" exist in periods of high or low market rates than at an average level. This results from the fact that a change in the trend of the interest rate dynamics occurs more frequently in times of extreme than of average rates. Banks do not reproduce changes in market rates up to the turning points, but try to anticipate trend changes. This results in a more rigid and incomplete adjustment for a high or low level of market rates than for an average level. Moreover, banks cannot adjust their deposit rates when interest rates are very low since the deposit rate cannot fall below zero.

Type 4. Sign of the deviation from equilibrium According to the literature [Frost/Bowden 1999], the deviation of the client rate from its equilibrium level (in the previous period) has also an effect on banks' adjustment behavior. For example, if the product rate of a deposit position is above its long-term equilibrium, the pressure on a bank's margin increases and a stronger reaction on changes in market rates can be expected than in the opposite case of a deposit rate below the equilibrium level. In the latter case, the bank resets the deposit rate to avoid a loss of volume.

6.2 Our approach versus the existing literature

[6] is the first who specifies an interesting property of the asymmetric adjustment of deposit rates. 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. [6] determines whether asymmetries exist in the adjustment of deposit rates to positive/negative disequilibrium, but he does not take into account the adjustment speed depending on the magnitude of the disequilibrium itself. In fact, clients accept low deposit rates as they benefit from other services, for example "more advantageous mortgage financing" ([25]), or because of the costs for consumers of switching banks ([1], [39]) or because of the "limited memory of depositors" ([26]). In this case, banks do not have an incentive to adjust deposit rates to each change in the more volatile short rate, but they adjust only to movements in the more stable rates of longer maturities, which better reflect the market trend.

Asymmetry is also incorporated by different speeds of adjustment for increases and decreases in market rates ([43]) and is empirically confirmed by [30] for deposits of Australian banks while [33] finds significant differences between different bank groups in Germany. More recent publications like [7], [18] employ models in error correction form and find evidence for asymmetric adjustment of the client rate to strictly positive/negative changes in the market rates or disequilibria. These models do not estimate the threshold values in the market rates or in the level of client rates disequilibria but, as in the case of [6], the threshold is fixed a priori to zero. In this way, these models reflect only the first and the fourth type of asymmetries described above. An interesting approach is that of [38], who employ a unifying empirical pass-through model that allows for thresholds, asymmetric adjustment, and structural changes over time in the interest rate pass-through in the four Common Monetary Area (CMA) countries of the South African Customs Union.

For modeling the deposit rate, we propose a simple threshold model to determine whether the relationship between the deposit rate of Swiss banks and market rates (represented by one short and one longer maturity) is asymmetric. We use the grid-search procedure proposed by [20] 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 effects in the short rate, in the rate of one longer maturity and in the error correction term. In this way, the asymmetric adjustment is not related to positive/negative changes in the market rate or in the disequilibria, but it depends whether the market rate changes or the disequilibria of the deposit rate are within tolerable bounds, or at extreme levels. The same approach was used by [42] for US prime rate movements.

6.3 Model

The deposit 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 the deposit rate to market rates.

$$\begin{aligned}\Delta CR_t &= \delta + \alpha_1 \Delta CR_{t-1} + \alpha_2 \Delta MR^{short}_{t-1} + \alpha_3 \Delta MR^{long}_{t-1} \\ &\quad + \alpha_4 EC_{t-1} + \varepsilon_t, \quad \omega_i \le \tau \\ \Delta CR_t &= \delta' + \alpha'_1 \Delta CR_{t-1} + \alpha'_2 \Delta MR^{short}_{t-1} + \alpha'_3 \Delta MR^{long}_{t-1} \\ &\quad + \alpha'_4 EC_{t-1} + \varepsilon_t, \quad \omega_i > \tau\end{aligned} \tag{2}$$

where ΔCR_t is the change in the deposit rate, ΔMR^{short}_{t-1} is the lagged change in the Libor 3 months rate and ΔMR^{long}_{t-1} represents the lagged change in the Swap 5 years rate, EC_{t-1} is the lagged error-correction term derived from the estimated cointegration vector (Table 6, panel 2), 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 deposit rate adjustment to market rates changes. The factor EC shows the deviations of the deposit rate from its equilibrium level. ω_i is the threshold variable which is used to split the sample into two regimes. We will test at one time for threshold significance in changes in one of the two considered market rates as well as in the error correction term. Equation (2) allows all of the regression parameters to switch between the regimes.

For simplification, our model can be rewritten:

$$y_i = \theta'_1 x_i + \varepsilon_i, \quad \omega_i \le \tau, \tag{3}$$

$$y_i = \theta'_2 x_i + \varepsilon_i, \quad \omega_i > \tau, \tag{4}$$

where ω_i is the threshold variable used to split the sample into two regimes. The random variable ε_i is a regression error.

Our observed sample is $\{y_i, x_i, \omega_i\}_{i=1}^n$, where y_i stands, in our case, for the changes in deposit rate observations as dependent variable and x_i is an m-vector of independent variables. 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[4], we define the dummy variable $d_i(\tau) = I[\omega_i \le \tau]$, where $I[\cdot]$ is the indicator function and we set $x_i(\tau) := x_i d_i(\tau)$. Furthermore, let $\lambda'_n = \theta'_2 - \theta'_1$ denote the threshold effect. Thus, equations 3 and 4 become:

[4]see Hansen (2000)

$$y_i = \theta' x_i + \lambda_n' x_i(\tau) + \varepsilon_i \tag{5}$$

In order to simplify the threshold estimation procedure (in the next section), we rewrite equation (5) in matrix notation. We define the vectors $Y \epsilon R^n$ and $\varepsilon \epsilon R^n$ by stacking the variables y_i and ε_i, and the $n \times m$ matrixes $X \epsilon R^{n \times m}$ and $X(\tau) \epsilon R^{n \times m}$ by stacking the vectors x_i' and $x_i(\tau)'$. Then (5) can be written as:

$$Y = X\theta + X(\tau)\lambda_n + \varepsilon \tag{6}$$

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

6.3.1 Hansen's grid search to locate the most likely threshold

To determine the location of the most likely threshold, we will apply Hansen's grid search. In the implementation of this threshold estimation procedure, we follow [21] and [22]. This paper develops a statistical theory for threshold estimation in the regression context. As mentioned in the previous section, the regression parameters are $(\theta, \lambda_n, \tau)$. Let

$$S_n(\theta, \lambda, \tau) = (Y - X\theta - X(\tau)\lambda)'(Y - X\theta - X(\tau)\lambda) \tag{7}$$

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 $[\underline{\tau}, \bar{\tau}] = \Omega$. The LS estimator is also the MLE when ε_i is i.i.d. $N(0, \sigma^2)$. Following [21], the computationally easiest method to obtain the LS estimates is through concentration. Conditional on τ, equation (6) is linear in θ and in λ_n, yielding the conditional OLS estimators $\hat{\theta}(\tau)$ and $\hat{\lambda}(\tau)$ by regression of Y on $X(\tau)^* = [XX(\tau)]$. The concentrated sum of squared errors function is

$$S_n(\tau) = S_n(\hat{\theta}(\tau), \hat{\lambda}(\tau), \tau) = Y'Y - Y'X(\tau)^*(X(\tau)^{*'}X(\tau)^*)^{-1}X(\tau)^{*'}Y,$$

and $\hat{\tau}$ is the value that minimizes $S_n(\tau)$, i.e.,

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

To test the hypothesis $H_0 : \tau = \tau_0$, a standard approach is to use the likelihood ratio statistic under the auxiliary assumption that ε_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 $LR_n(\tau_0)$. Using the $LR_n(\tau)$ function, asymptotic p-values for the likelihood ratio test are derived:

$$p_n = 1 - \left(1 - \exp(-1/2 \cdot LR_n(\tau_0)^2)\right)^2.$$

6.4 Results

We get the first insights into the asymmetric adjustment considering the average of the deposit rates paid by all Swiss banks (source SNB). Afterwards we extend our analysis to our 10 individual banks data sets for the deposit rates. 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 [20]. Since the threshold ω is not identified under the null hypothesis of no threshold effect, the p-values are computed by a bootstrap analog. 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 5y) and the error correction term were significant at 0.048 and 0.016, respectively. Figures 4 and 5 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 $\hat{\omega}_{long} = \tau_{long} = -0.520$ and $\hat{\omega}_{EC} = \tau_{EC} = 1.027$, respectively.

Since no significant threshold was found in the changes in the short market rate, we display only the estimation results for the other two cases, when the threshold variable is either changes in the Swap 5 year rate or the error correction term. Following the specification of the threshold model in equations (3) and (4), we estimate the model allowing all variables to switch between regimes. Using the coefficients shown in Table 8, we obtain the fitted values for the deposit rate model for each of the two estimated versions (see Figures

6 and 7). The estimated deposit rates fit well the observed data, in both cases. In an inspection of the residuals, the standard deviations of the residuals show no big difference between the two situations (see Figure 8).

To test if the calibrated model is realistic, we perform an out-of-sample test by re-estimating the model using historical observations of the deposit rate from January 1988 up to January 1998. A second (non-overlapping) historical period (February 1998 to July 2010) is designated as the out-of-sample testing period. Figure 9, Appendix summarizes the out-of-sample performance in case of the model with threshold variable in changes in the Swap 5 year rate. The performance of the model based on regimes in the error correction (EC) term is displayed in Figure 10, Appendix. Table 9 shows the model estimates.

The deposit rate model produces meaningful values for the out-of-sample testing period. In Figure 11 we can observe that over a long-term out-of-sample period, the residuals in the case of the model with threshold in the EC term have with 25% a smaller volatility than in the case of the model based on regimes in the Swap 5 year rate changes.

We would like to see the out-of-sample performance of our threshold models over a shorter time horizon. Thus, we re-estimate the model using historical observations of the deposit rate from January 1988 up to December 2005. A second (non-overlapping) historical period (January 2006 to July 2010) is designated as the out-of-sample testing period.

The deposit rate model based on the Swap 5 year rate regimes produces meaningful values for the out-of-sample testing period, January 2006 to July 2010. It is able to forecast the drop in the Swiss deposit rates in the financial crisis (Figure 12). Overall, as shown in Figure 14, the threshold model based on market rate regimes performs better to reflect the extreme the market rates shocks in the deposit rate adjustments than the EC regimes-based model.

6.5 Interpretation of results

Beginning with the error-correction model that uses changes in the Libor 3 month rate as threshold variable, we found the threshold parameter to be statistically insignificant. This implies that deposit rates of Swiss Banks 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 deposit rates in banks (the deposit rates do not follow closely short rate movements).

With changes in the 5 years Swap rate as threshold variable, we find that the threshold is significant (Table 8). A threshold exists when the change in the Swap rate equals -52 basis points (bp). Furthermore, for every negative shock of 100 bp below -52 bp in the Swap 5 year rate, the deposit rate will be adjusted, on average, by a 59 bp drop per month. In the second regime, the coefficient of the Swap 5 year rate is not significantly different from zero. The threshold model results help us to conclude that changes in the Swap 5 year rate are reflected in changes in the Swiss deposit rates only in case of large changes in the market rate. As a consequence, Swiss banks adjust their product rates only after larger changes in market rates and when they are convinced that these are not just temporary ([37], [p. 38]). These results allow us to conclude a strong asymmetric relationship between the deposit rate and the changes in the rates of longer maturities. The delimitation of the two market rates regimes helps us to focus on that what is noteworthy: in case of a large drop in market rates, the deposit rate will be adjusted accordingly. Thus, the threshold model is able to explain important drops which occurred in the deposit rate history, including the drop occurred in the period of the financial crisis. In Nov. 2008 a very large drop in the market rates occurred (104 bp drop in Swap 5 year rate). We have a threshold at -0.52 bp in the Swap rate. When the Swap rate drops more than 0.52 bp in the previous period, our model has a large speed of adjustment to the Swap rate in this extreme regime. In December 2008 banks decreased also considerably the deposit rates and our model can reflect this change. This works also out-of-sample, when we split the sample in December 2005 and recalculate out-of-sample the financial crisis period. In the same way the threshold model is able to explain the drop in Swiss deposit rates which occurred between 1992 and 1993 as a consequence of the significant decrease in the market rates from this period.

With the error-correction term as threshold variable, we also find that the threshold is significant. A threshold exists when the deposit rate is 1.027% (102.7 bp) above its equilibrium level. For every 100 bp above this departure from equilibrium, we expect the convergence back to equilibrium to be of the magnitude of a 10.9 bp drop in the deposit rate per month. Below this disequilibrium threshold, the convergence to equilibrium only occurs with a 3.9 bp 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 2.8 times larger for the more extreme disequilibrium. Looking at the model fit (Figure 7) we observe that the model fits the drop in the deposit rates from 1992 to 1993, but it is less accurate in explaining the drop in the financial crisis than in the case of the model with threshold in the Swap 5 year rate. In case of the crisis, banks are tighter to changes in the market rates, therefore in this case it is useful to use the threshold model which identifies market rates regimes.

However, over the longer time period (when we split the sample in 1998), the model which identifies regimes in the error correction term has a higher out-of-sample power than the model based on market rate regimes. This occurs because on the long-run deposit rates share a long-term equilibrium relation to the market rates, so corrections back to equilibrium are of importance to keep the system in equilibrium. By contrary, when we look out-of-sample over a shorter time period, splitting the sample in December 2005, the model with threshold in the Swap 5 year rate offers a better fit to the data, since shocks in the market rates are better reflected by the regime identified as volatile. Overall, we conclude that both asymmetry models in discussion are of importance for explaining the decisions about deposit rate adjustment in the case of the Swiss banks. Thus, if important shocks are expected on short-term in the market rates, this information can be incorporated in the deposit rate adjustment using a model with threshold in the market rate. In case of the Swiss deposit rates, the Swap 5 year rate reflects best the asymmetric adjustment of the deposit rate to market rates. However, when long-term forecasting is required, a model based on regimes in the error-correction term is able to fit better the long-run equilibrium relation between the deposit rate and market rates.

It is worth observing that our out-of-sample tests results (Tables 9 and 10) show that the location of the threshold in the error correction term is stable over the two samples. However, there are different threshold values in the two samples for changes in the Swap 5 year rate. Thus, up to 1998 the estimated threshold lies at -17 bp changes in the Swap rate, while in the sample up to 2005 the values drops to -52 bp. This reflects the fact that the Swiss banks, on average, became less risk averse and they adjust deposit rates only to significant changes in the market rates. Here by risk averse we understand the aversion of banks to losing clients. In other words, the tolerable bounds of non-adjusting the rates increased, which is in line with the strong rigidity pattern present in the deposit rates of Swiss banks.

6.6 Robustness check

We recall the specification of the error-correction model from equation (2) and check for threshold effects in changes in the market rate and in the error correction term, by investigating 10 data sets for deposit rates from individual Swiss banks.

The estimation results are presented in Table 11. In 9 out of 10 data sets, we found that a significant threshold exists in changes in the market rate. Furthermore, in 7 out of the 9 identified cases, the threshold has a positive value, varying between 4 bp and 17 bp for changes in the Swap 5 y rate. With respect to the number of observations included in each regime, we observe that in the 7 cases in discussion, the first regime (the case where the changes in the market rate fall below the threshold value) contains up to 4 times more observations than regime two. So we conclude that regime one represents the normal regime, while regime two isolates the deposit rate adjustments for more extreme changes in the market rate. To have a better understanding about the two regimes identified by the model, we display the magnitude of changes in the Swap 5 year rate over the analyzed period and mark the maximum identified threshold value (see Figure 15). We observe that regime two delimitates the cases where more extreme positive changes occur in the Swap 5 year rate.

Concerning sensitivity of the deposit rate to changes in the market rate, the coefficients show a high dispersion between the data sets and, beside this, their sign is not clearly defined. So also when we distinguish between the two identified regimes, we conclude that individual changes in the market rates are not reflected in the deposit rate adjustments.

Overall we observe that the EC coefficients are significant. Furthermore, they have a higher value in the second regime. Thus, positive changes in the Swap 5 year rate above the threshold value (more extreme) will imply a large negative disequilibrium of the deposit rate. In this case, the speed of adjustment of the deposit rate back to equilibrium in the next period is higher than in regime one, where less extreme positive changes and negative changes in the market rate occur. In other words, when the deposit rate is too low comparing to its equilibrium level, banks adjust their deposit rates with a higher speed to close the gap and to reestablish the equilibrium spread to the market rates.

In the other 2 out of 9 cases we found significant negative threshold in changes in the market rate. As it was also found in the case of the SNB in the previous section, regime one delimitates the cases where extreme negative changes in the market rate occur and, consequently, the deposit rate is too high with respect to its equilibrium level. In these cases, the speed of deposit rate adjustment back to equilibrium increases in case of more extreme positive disequilibria.

The lagged changes in the deposit rate are significant over our data sets and over the two regimes. An asymmetric adjustment can also be concluded from the fact that, in most cases, the coefficients of the lagged changes show a higher magnitude in the second regime.

Similarly, we found a significant threshold value in the error correction term in 7 cases (see results in Table 12). A positive significant threshold is found in 5 out of the 7 cases. In these situations, regime two represents the cases where the error correction term is above the threshold value, meaning that the deposit rate is too high comparing to its equilibrium level. In this case, the rate is adjusted with a significantly higher speed back to equilibrium than in regime one, where less extreme positive disequilibria or negative ones occur. Thus, the error correction term coefficient which is overall significant has a much larger magnitude in the second regime, showing evidence of strong asymmetric adjustment.

The lagged changes in the deposit rate and the error correction term are also in this case overall significant and show an asymmetric pattern between the two regimes.

Finally, in 2 out of 7 cases with significant threshold we found a negative threshold value in the EC term (data sets 4 and 6). These results confirm our previous findings that the larger the deviations from the deposit rate equilibrium value is, the larger the speed of adjustment back to equilibrium. Thus, regime one represents the more extreme negative disequilibria, and the speed of adjustment of the deposit rate to the EC term is significantly higher than in regime 2.

However, between the data sets, we obtain different locations for the threshold values. Thus, Swiss banks have different strategies in adjusting the deposit rates to market rates in the sense of different risk aversion levels in fixing the tolerable spreads of their deposit rates to the representative market rate.

7 Modeling the rigidity of deposit rates

In the literature overview section we have given the economical interpretation of the rigidity pattern of the client rates. Many of the papers cited in the literature overview apply rigidity models to describe the patterns of *mortgage* rates. However, it is known that mortgage and deposit rates in banks (named generically "'client rates") move in parallel and share the same patterns: asymmetric adjustment to market rates, discrete changes, stickiness and incomplete adjustment. Therefore the models describing prime/mortgage rates can also be applied to describe the deposit rates.

Friction models are based on the idea that a client rate adjustment is only done when the benefit of the client rate adjustment exceeds its costs. As emphasized by [13], in the presence of the strong rigidity pattern observed for client rates, the "Ordinary Least Squares estimator can no longer be used because of the temporary independence of the client rates from the market rates". This is actually the theory behind friction models. They assume that changes in the client rate are linear functions of the spread between its lagged value and exogenous rates. The main feature of this relationship is a range of spread values for which the client rate remains unchanged, it increases (decreases) only when the spread exceeds (falls below) certain limits ([13]). Obviously, this is useful to incorporate stickiness. [5] and [28] model changes in the product rate as function of the accumulated margin since the last adjustment. If it crosses certain boundaries, the product rate is updated in discrete steps, whose size depends on the magnitude of the current margin. A potential drawback of the approach is that it requires large samples that contain a sufficient number of "jumps" in order to obtain significant results as the client rate remains unchanged for a long time. With the different threshold parameters a large number of parameters need to be estimated and a computationally expensive non-linear optimization method is required.

The literature offers several models combining asymmetric and nonlinear adjustment. Recent examples are [11], [17] and [29]. However, these papers do not relate to client rates and therefore we skip here a discussion.

In this section we apply the friction model of [13] to the deposit rates from our 10 Swiss banks and we show that, accounting only for rigidity, the model is unrealistic in explaining the dynamics of Swiss deposit rates. However, we extend the original model by allowing for asymmetric adjustment and we obtain a realistic model for deposit rates.

7.1 Data

In Figure 16 we illustrate the deposit rate paid by one of our investigated Swiss Banks for deposit accounts versus Libor 3 months and Swap 5 year rate as a representative example. We observe, on the one hand, that retail banks are slow to adjust the deposit rate when market rates go up, but they follow closely the descending trend of the market. In this context, we talk about the deposit rate asymmetry: "retail banks exercise their market power to optimize their margins by delaying the pass-through of higher market rates to clients" (de Haan and Sterken 2011). On the other hand, we observe that since changes in the market rates occur each month, the deposit rate remains for longer periods unchanged. This is accounted in the literature as deposit rate "rigidity": banks have only an incentive for adjustments when the administrative costs are smaller than the costs for not changing the rates.

7.2 Initial rigidity model

The friction model specification for the deposit rate, follows [13]:

$$
\begin{aligned}
\Delta CR_t &= Y_{1t} + \varepsilon_t && \text{if } (Y_{1t} + \varepsilon_t > 0) \\
\Delta CR_t &= 0 && \text{if } (Y_{1t} + \varepsilon_t < 0) \text{ and } (Y_{2t} + \varepsilon_t > 0) \\
\Delta CR_t &= Y_{2t} + \varepsilon_t && \text{if } (Y_{2t} + \varepsilon_t < 0)
\end{aligned} \tag{8}
$$

where $Y_{1t} = a_1 + b * (CR_{t-1} - MR_t)$, $Y_{2t} = a_2 + b * (CR_{t-1} - MR_t)$ and ε_t is a random error with zero mean and variance σ^2 (CR represents the deposit rate, MR is a market rate).

The positive segment of Y_{1t} represents expected increases in the deposit rate, the negative segment of Y_{2t} expected decreases, and the difference between the intercepts a_1 and a_2 delimitates the range of no-changes. When the spread between the lagged deposit rate and the current market rate crosses these bounds, a positive or negative change occurs. In the original model of [13], the speed of adjustment is equal for upward or downward adjustments of the rate.

7.3 Estimation procedure

We estimate our model parameters using maximum likelihood. Let $y_t := \Delta CR_t$, $\phi x_{1t} := Y_{1t}$, $\phi x_{2t} := Y_{2t}$. From the model specification we have ε_t as a random error with zero mean and variance σ^2. The likelihood function for a sample of changes in the deposit rates which has p positive, r negative and q zero observations is written:

$$
\begin{aligned}
L = & \prod_{n=1}^{p} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{-\frac{1}{2}\sigma^2 (y_n - \phi x_{1n})^2\right\} \\
& \times \prod_{m=1}^{q} [F(\phi x_{2m}, \sigma^2) - F(\phi x_{1m}, \sigma^2)] \\
& \times \prod_{k=1}^{r} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{-\frac{1}{2}\sigma^2 (y_k - \phi x_{2k})^2\right\}
\end{aligned}
$$

where

$$
F(\phi x_{jt}, \sigma^2) = \int_{-\infty}^{\phi x_{jt}} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{-\frac{1}{2}(\lambda/\sigma)^2\right\} d\lambda.
$$

In the following log-likelihood function, $F(\phi x_{jt}, \sigma^2)$ will be written as F_{jt}:

$$
\begin{aligned}
\log(L) = & \sum_{m=1}^{q} \log(F_{2m} - F_{1m}) - \frac{(p+r)}{2} \log(2\pi\sigma^2) \\
& - \left(\frac{1}{2}\sigma^{-2}\right) \sum_{n=1}^{p} (y_n - \phi x_{1n})^2 - \left(\frac{1}{2}\sigma^{-2}\right) \sum_{k=1}^{r} (y_k - \phi x_{2k})^2
\end{aligned} \tag{9}
$$

We estimate the model proposed by [13], using the average deposit rate data for the Swiss savings accounts as displayed in Figure 16. We show the results with using the Swap 5 year rate as relevant market rate to calculate the spread. Also other market rates were investigated, however, the results do not change significantly. Table 2 summarizes the results. In Figure 17 we display the model fit.

Table 2: Friction model estimation results

	Coefficient	t-stat
a_1	-1.52	-10.10
a_2	-0.01	-0.40
b	-0.41	-2.74
σ	0.35	2.65
R^2	0.012	

We observe that the model leads to unrealistic results. The constant a_2 is not significant, so the bounds of the non-rejection region are not correctly delimitated. In fact, accordingly to these estimates, the modeled deposit rate stays only within the no-rejection region. That is because, as observed in Figure 18, the term Y_1 takes only once a positive value, while the Y_2 becomes only once negative, which means that the modeled deposit rate would only change twice over the investigated sample (see Figure 18). This is, of course, implausible. Our results are in line with the findings of [37].

The cause of these biased results is that the model assumes the same speed of adjustment of the deposit rate to upwards or downwards movements in the spread to market rates. In the following section we propose an extension of the [13] rigidity model specification, which takes into account different speeds of deposit rate adjustments and we show the importance of this additional assumption.

The cause of these biased results is that the model assumes the same speed of adjustment of the deposit rate to upwards or downwards movements in the spread to market rates. In the following section we propose an extension of the Forbes and Mayne 1989 rigidity model specification, which takes into account the asymmetric adjustment and we show the importance of this additional assumption.

7.4 Allowing for asymmetry

The model described above was applied by [13] for the prime rate. Their friction model assumes the same speed of adjustment of the prime rate to positive and negative changes in the market rate. That is, the model accounts for rigidity, but it does not account also for asymmetric adjustment of the deposit rate to market rates. In case of savings accounts, the importance of modeling the deposit rate asymmetry was discussed above. Therefore, we extend the specification of equation (8) by allowing for different speeds of adjustment of the deposit rate to its spread to one relevant market rate, for positive vs. negative adjustments. Thus, $Y_{1t} = a_1 + b_1 * (CR_{t-1} - MR)$, $Y_{2t} = a_2 + b_2 * (CR_{t-1} - MR)$ and ε_t is a random error with zero mean and variance σ^2. The graphical representation of the friction model assuming asymmetric adjustment is illustrated in Figure 1. The interpretation is: The larger the spread between the constant coefficients a_1 and a_2, the larger the range of no changes; the slope of negative changes is steeper than the slope of positive changes, as one would expect deposit rate to adjust with a higher speed downwards than upwards; when the spread of deposit rate to the market rate is too narrow/large (in absolute values), then a negative/positive change in the deposit rate occurs.

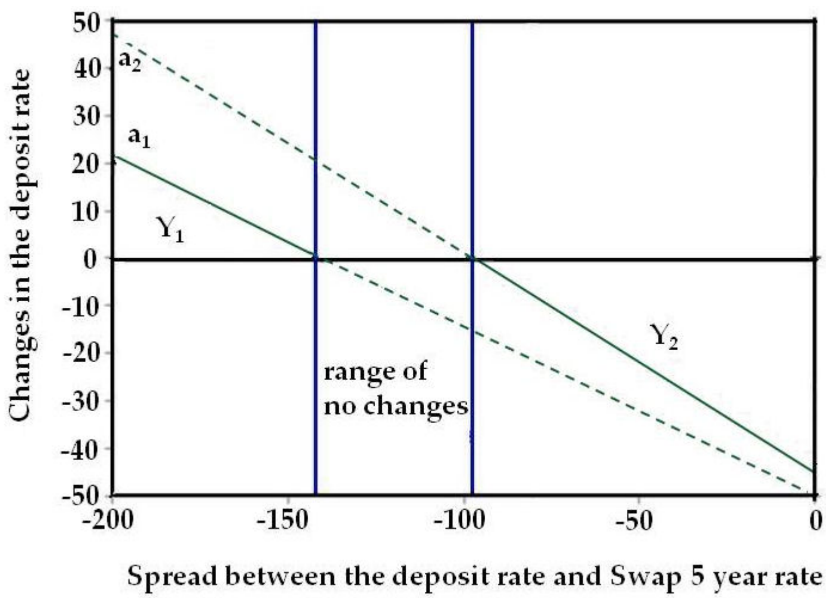

Figure 1: Hypothetical relation between changes in the deposit rate and its spread to market rates

We apply the maximum likelihood estimation procedure to obtain our model coefficients (equation 9). Table 3 summarizes the results.

Table 3: Friction model estimation results

	Coefficient	t-stat
a_1	-0.07	3.43
a_2	-0.12	12.37
b_1	-0.05	6.41
b_2	-0.08	7.31
σ	0.04	4.54
$\|a_1 - a_2\|$	0.05	3.41
R^2	0.892	

We observe that the deposit rate is adjusted with a higher speed downwards than upwards. The difference between a_1 and a_2 emphasizes the rigidity pattern of the deposit rate. The model fit is illustrated in Figure 19. We observe a realistic fit of the extended friction model to the data, while accounting for asymmetric adjustment (R^2 improved considerably, to 89% explained variation). The friction model fit for the SNB deposit rate has turned out to be the best when the spread to the Swap 5 year rate is used as explanatory variable. We investigated the goodness of the model with respect to all liquid market rates. In Figure 20 we display the rigidity model performance when the Libor 3 month is used as market rate. One can clearly see that in this case the model underperforms the realistic fit obtained with the Swap 5 year rate (Figure 19). This is due to the frequent changes in the short rate which, in reality, are not followed by changes in the deposit rate.

We have extended the analysis over all other 9 data sets and in all cases the Swap 5 year rate is the maturity which offers the best fit. In case one assumes that the Swiss deposit rates are set accordingly to the dynamics of a single swap rate, one may conclude that, in general, Swiss banks use the Swap 5 year rate as a relevant benchmark. Table 13 summarizes the results. We obtain evidence for the rigidity of deposit rates reflected in the difference between the two constant terms a_1 and a_2. The difference between a_1 and a_2 varies quite much between the data sets, namely between 1.2 bp and 8.6 bp. This diversity emphasizes the different strategies among the banks to fix their "tolerable bounds", e.g., the range of no changes for the deposit rates. We obtain clear evidence for an asymmetric adjustment of the deposit rate to its spread to the Swap 5 year rate. Overall, the speed of adjustment to the deposit rate is higher in the case of negative adjustments than for positive ones. Thus, the coefficient b_2 is overall higher in absolute value than b_1. The R^2 values vary between 75% and 90.2% and imply a good performance of the friction model to explain the deposit rate data.

One of the characteristics of the NMA deposit rates is to remain unchanged while exogenous rates fluctuate; therefore, "the usual least-square estimator, based on the assumption of linearity, is inappropriate (biased and inconsistent) in this case" (see [13]). Instead, the deposit rate must be represented as a limited dependent variable whose value is at times unrelated to exogenous rates. By modeling deposit rate rigidity with a friction model we are able to fit both short and long term dynamics of the deposit rate. On short-term horizon, the friction models reflect the non-linearity of Swiss banks' behavior in adjusting the deposit rates to exogenous rates. At the same time, the model allows deposit rates to follow in the long run the evolution of market rates. Starting from the specification of the friction model of [13], we extend the model by allowing for asymmetric adjustment of the deposit rate to market rates. Our results show that indeed the deposit rate is decreased with a higher speed to changes in market rates than it is increased. We also found evidence for the rigidity of the Swiss deposit rate, expressed by the difference between the constant terms of the two regression lines for positive and for negative changes. The friction model describes more realistically the deposit rate pattern than the other investigated models in the previous chapters. Thus, the R^2 is with up to 30% higher than in the case of the other two investigated model types. However, in the case of the two little number of ascending discrete adjustment steps in our client rate data an out of sample test for the rigidity model is difficult here.

8 Conclusion

This paper explains the adjustment policy of Swiss banks in the case of the problematic non-maturing savings accounts. To our knowledge, this is the first study in the context of the literature which refers to Swiss bank-individual client rate data, and not only to aggregate data which are publicly available. We derived and tested many econometric models and discussed their advantages and disadvantages. This study reveals different strategies of

Swiss banks to adjust their client rate in normal and stress regimes. In times of market stress, Swiss banks are tight to market rates; however, in normal regimes this is not observed. We also provide a strong evidence for both asymmetric adjustment and rigidity patterns which are typically ignored in practice by retail banks. This is insofar surprising, as the asymmetric deposit rate adjustment affects the pricing of embedded options for NMA. In this work we contribute to the elimination of these inconsistencies.

Our modeling efforts take into account essential characteristics of the savings deposits: their cash-flows uncertainty as a consequence of the embedded options that both banks and clients bear. On one hand, clients have the option to withdraw money at any time, while banks are free to adjust deposit rates at any time.

We applied cointegration analysis and show that, on long-term, the Swiss banks keep an equilibrium relation with market rates. Furthermore, we found that Swiss deposit rates are stronger cointegrated with a longer market rate than with a short rate. In fact, the strongest cointegration is found in relation to the Swap 5 year rate. Changes in the long rates are more stable (less volatile) and therefore they play a higher role for the deposit rate adjustment decision. We further derived a model in error correction form and we get the first insights that individual changes in the market rates are not reflected in the deposit rate adjustment. This result is due to the fact that linear models fail to explain the deposit rate tardiness and asymmetric patterns: a change in the market rate occurs every month, but the deposit rate is adjusted only when significant changes occur on the market. In this case, the Ordinary Least Squares estimation fails in explaining the consecutive "zero changes" which characterize real deposit rates. However, we observe that the deposit rate is sensitive to its deviations from the long-run equilibrium level derived in relation to the Swap 5 year rate.

To account for asymmetric adjustments, we derive a threshold model in error correction form and we find that the Swiss deposit rates are regime dependent. Two cases of threshold model are investigated. In the first case we identify market rates regimes, by fixing the threshold variable in the Swap 5 year rate changes. In this way, we obtain clear evidence for asymmetric adjustment of the deposit rate to changes in market rates: moderate changes in the market rates are not reflected in the deposit rates adjustment; however, when the market rates change significantly, Swiss banks adjust also the deposit rates accordingly. In other words, in times of market stress Swiss banks are tighter to market rates. Our threshold model which identifies the market rates regimes helps to explain in- and out-of-sample extreme movements in the Swiss deposit rates in the analyzed period, including the one which occurred in the financial crisis. No significant threshold is found in the Libor 3 month rate, meaning that Swiss banks adjust deposit rates linearly to the short rate. In the second case we derive regimes in the disequilibrium level of the deposit rates. This model helps us to keep in equilibrium on long-run the deposit rate and reveals the adjustment strategy of the Swiss banks in normal regimes.

We obtain a strong evidence for rigidity in the adjustment of the Swiss deposit rates. Beside this, we found that Swiss banks have different strategies to fix their "tolerable bounds", e.g., the range of no changes for the deposit rates. We obtain a model which takes into account simultaneously the two major characteristics of the deposit rate: asymmetry and rigidity. This is of major importance for banks' decision to adjust deposit rate, given the administrative costs associated with a change versus the potential loss in volume due to depositors' withdrawal option.

The different econometric models investigated help us to describe deposit rates of the Swiss banks from different perspectives. For example, the threshold model helps us to determine the limits which differentiate normal from extreme deposit rate adjustment regimes, while the friction model helps us to determine the range of no changes and to emphasize the rigidity of the deposit rates. Using the simple linear model without taking into consideration asymmetry and rigidity, we fail in explaining large shocks which occurred on the market. With the asymmetry and the rigidity on the level of an individual bank, one can derive the price of the imbedded withdrawals option that these banks' depositors bear. Moreover, threshold and friction models should form the sound basis for managing and measuring the liquidity risk associated to the NMA.

A further extension of the research would be to explore the relationship between deposit rates and volumes. A bank may offer more favorable deposit rates to attract more costumers and, thereby, increase its market share. However, this requires availability of volume data from individual banks which were not at our disposal for the current study.

9 Appendix

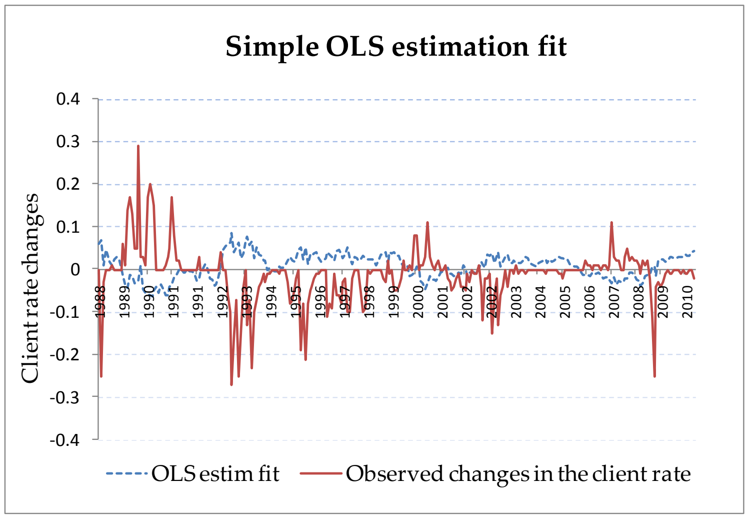

Figure 2: Model in error correction form performance

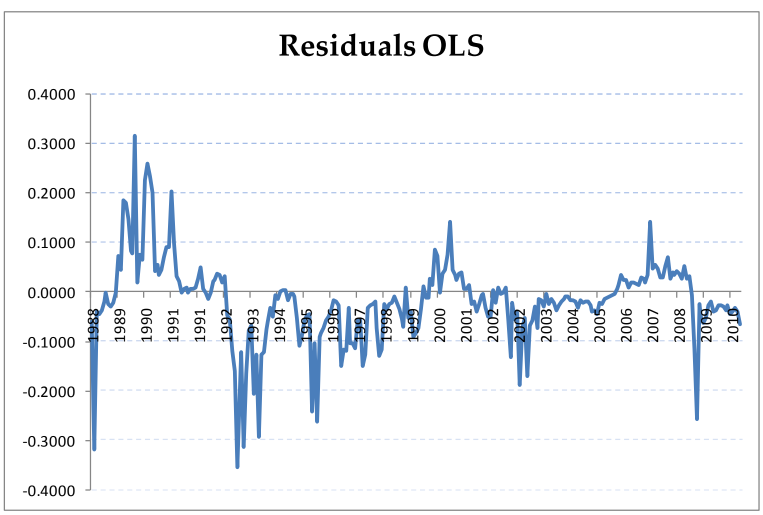

Figure 3: Model in error correction form residuals

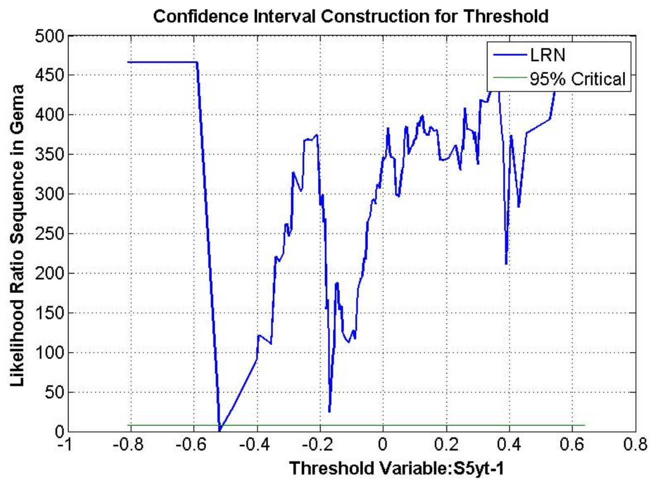

Figure 4: Sample split with threshold variable changes in Swap 5 year rate. Confidence interval construction for threshold

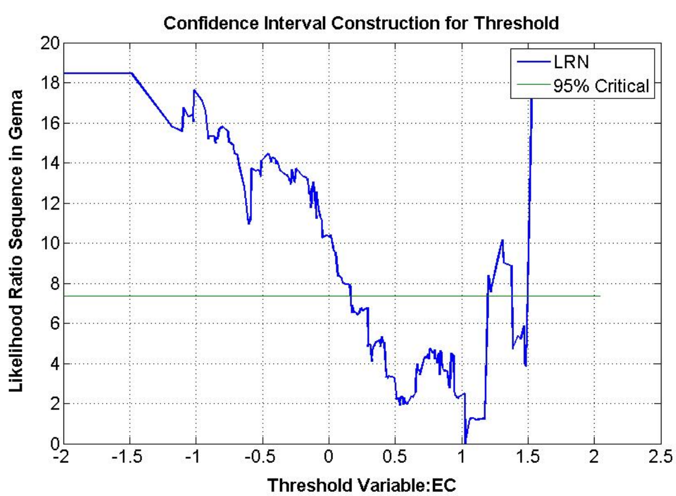

Figure 5: Sample split with threshold variable the error correction term. Confidence interval construction for threshold

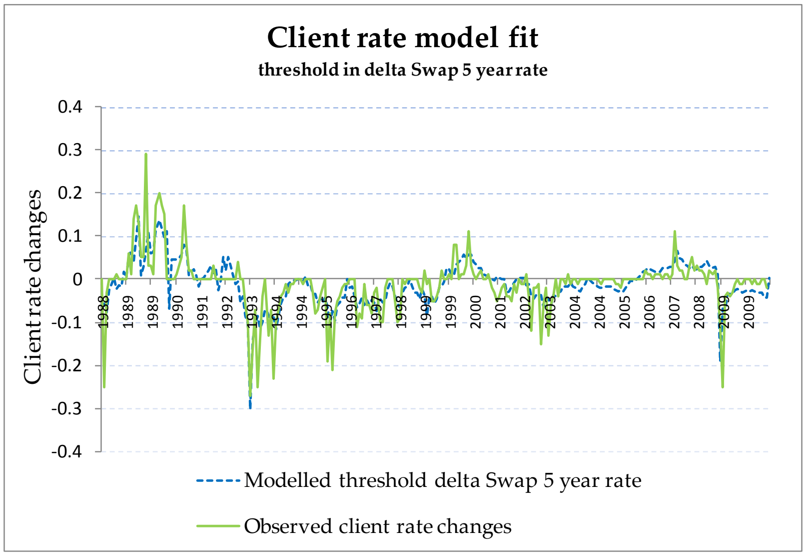

Figure 6: Model fit for changes in the deposit rate

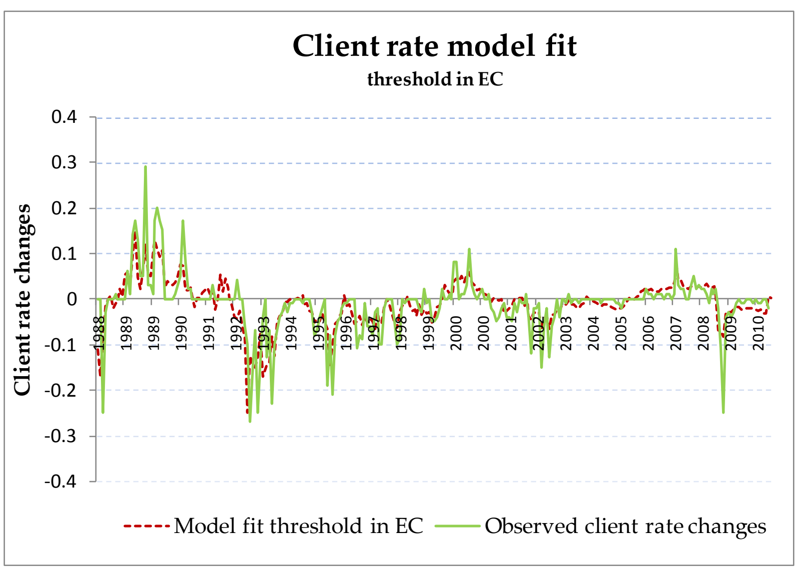

Figure 7: Model fit for changes in the deposit rate

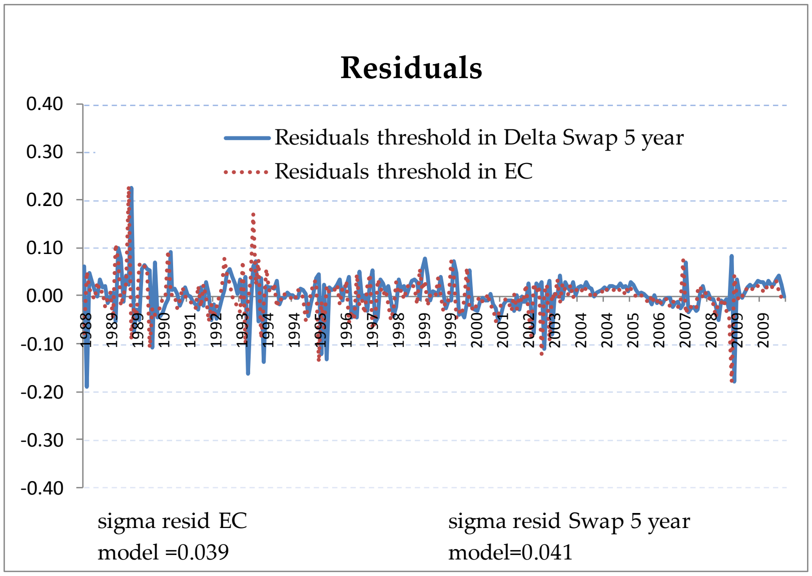

Figure 8: Threshold model residuals

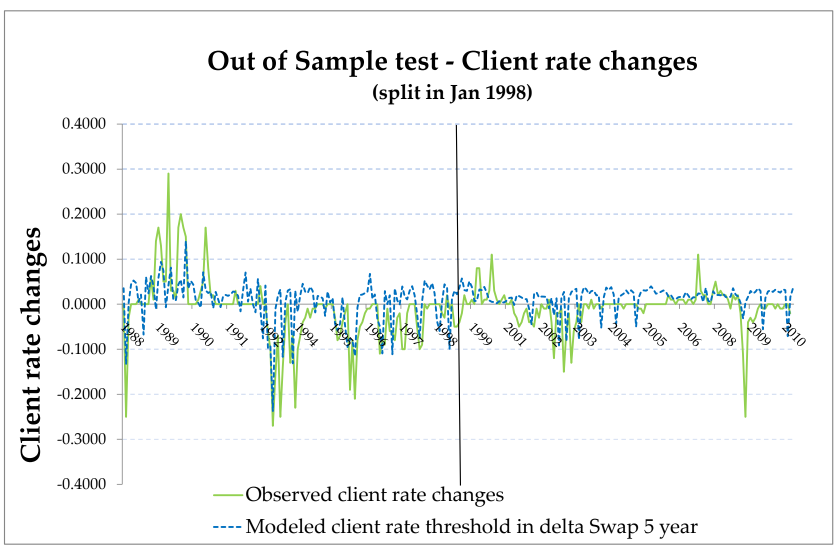

Figure 9: Deposit rate model with threshold variable changes in the Swap 5 year rate - out-of-sample test, split in Jan. 1998

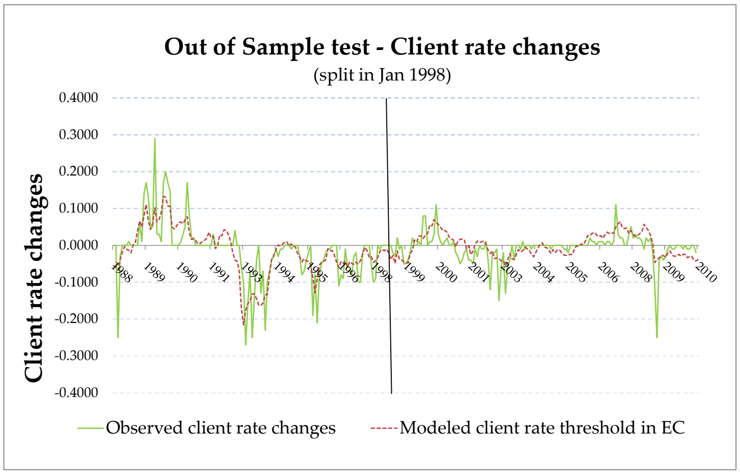

Figure 10: Deposit rate model with threshold variable EC term – out-of-sample test, split in Jan. 1998

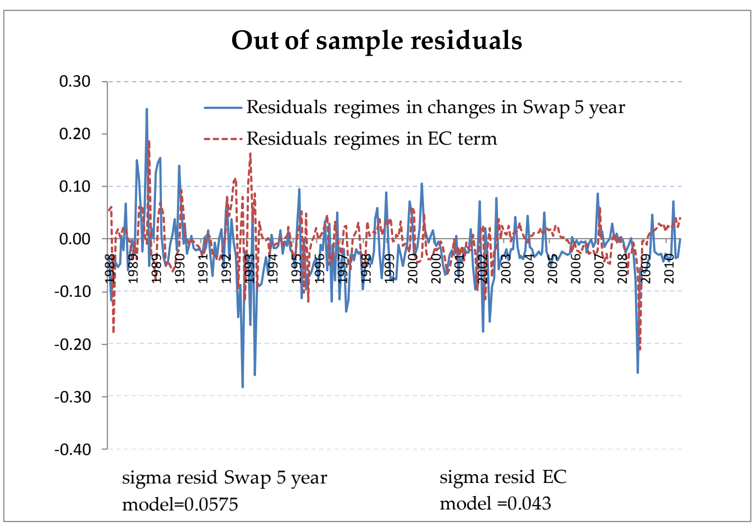

Figure 11: Residuals – out-of-sample test (split in Jan. 1998)

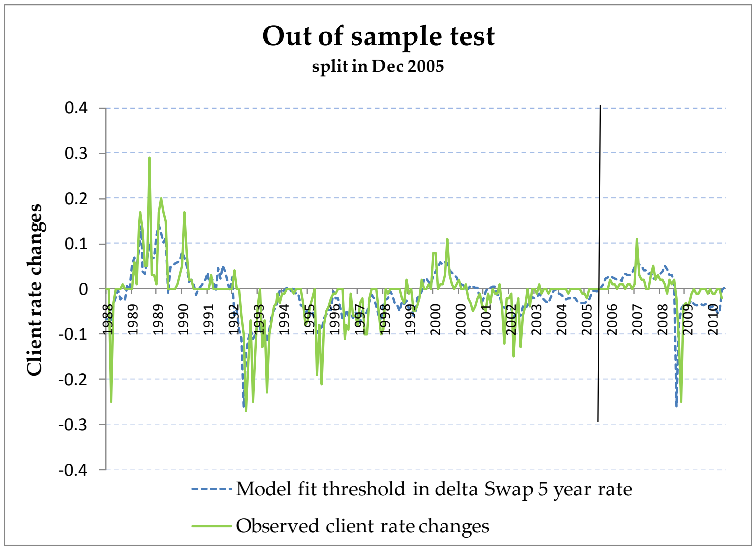

Figure 12: Deposit rate model with threshold variable changes in the Swap 5 year rate - out-of-sample test, split in Dec 2005

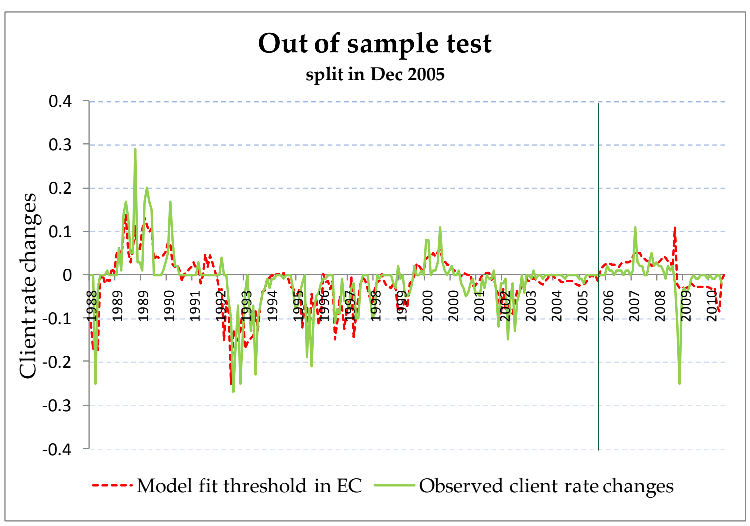

Figure 13: Deposit rate model with threshold variable EC term – out-of-sample test, split in Dec 2005

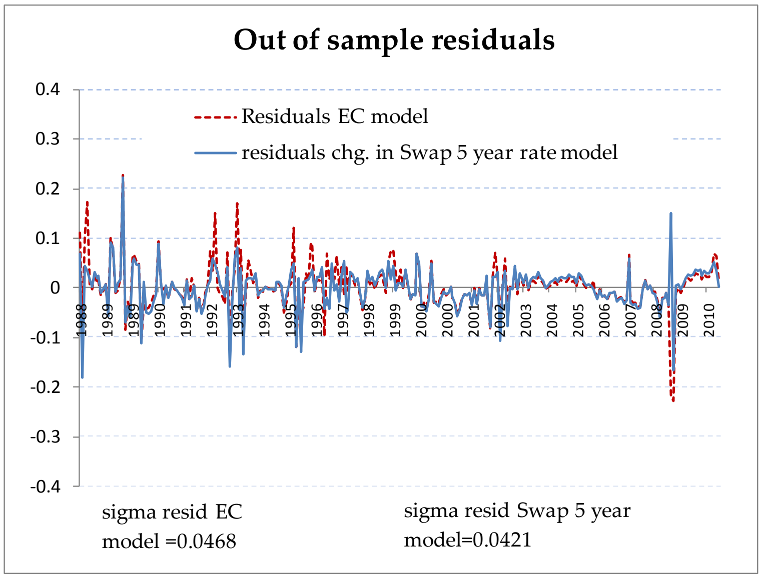

Figure 14: Residuals - out-of-sample test (split in Dec 2005)

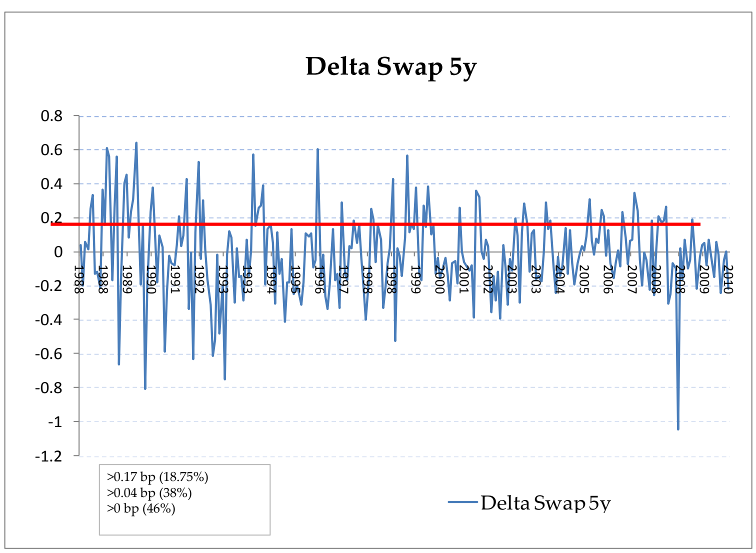

Figure 15: Threshold in the Swap 5y rate

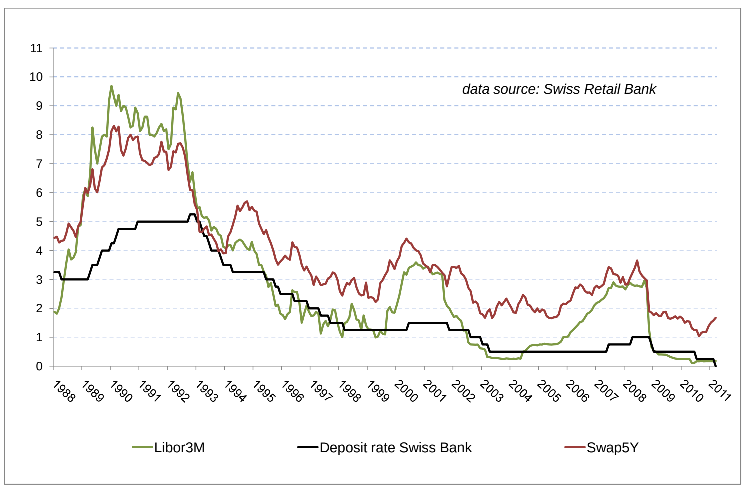

Figure 16: Client rate Swiss non-maturing savings accounts versus market rates evolution. Example from one Swiss bank

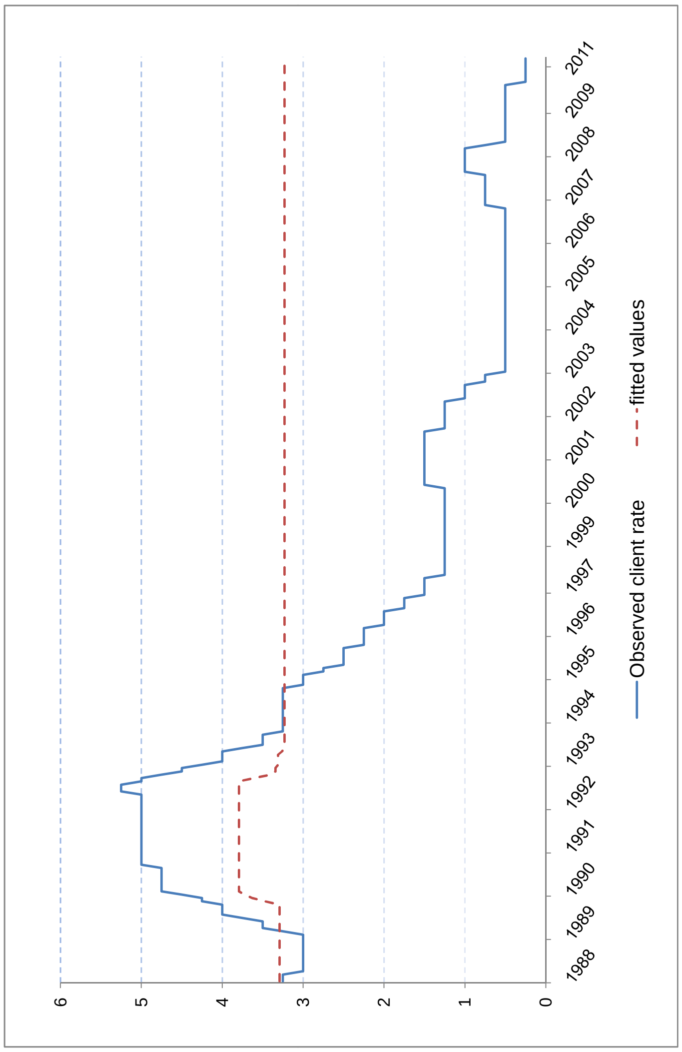

Figure 17: Forbes and Mayne (1989) friction model performance

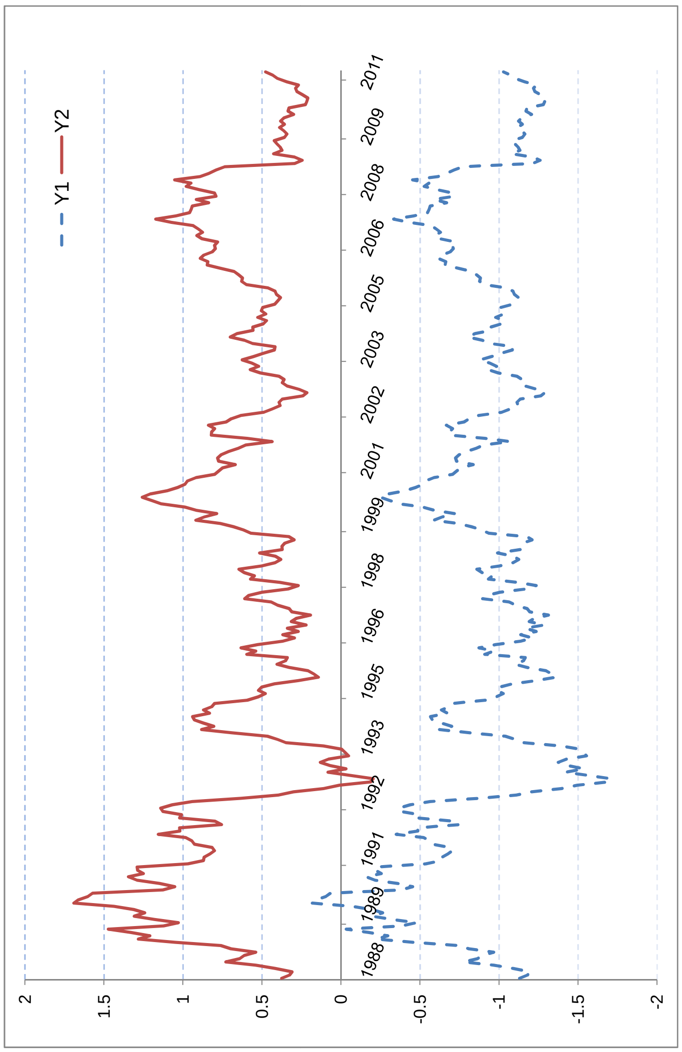

Figure 18: Calculation of Y_1 and Y_2 terms based on the estimation results

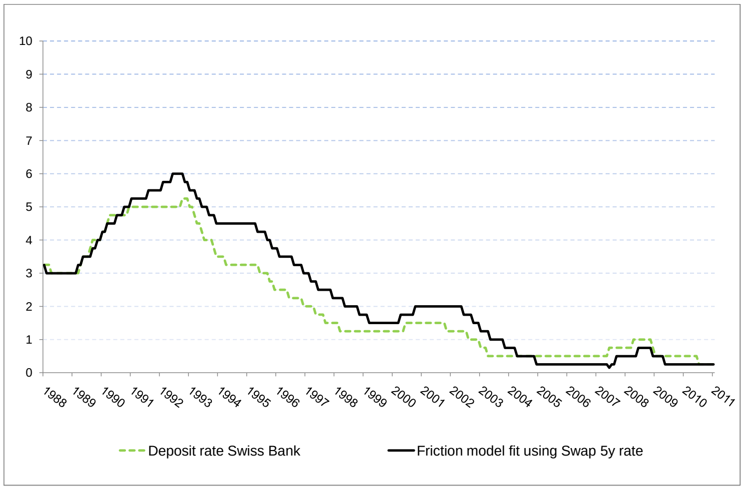

Figure 19: Friction model fit - market rate Swap 5 year rate

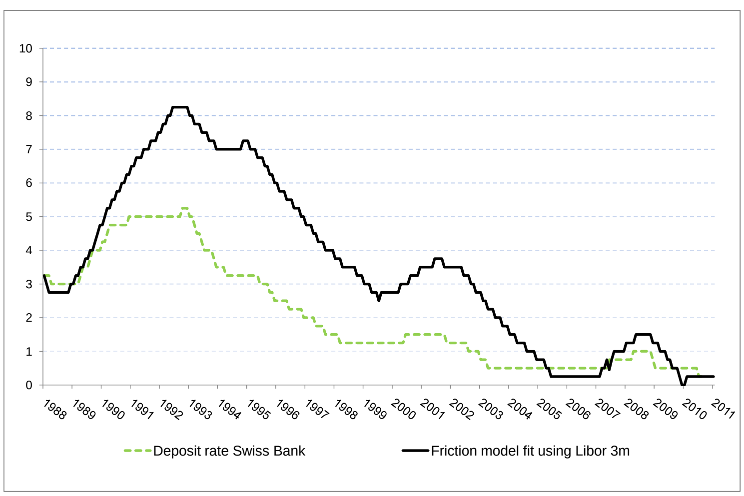

Figure 20: Friction model fit - market rate Libor 3 month rate

Table 4: Augmented Dickey-Fuller test statistic - deposit rate

ADF-test	SNB	S1	S2	S3	S4	S5
t statistic	-0.395	-0.110	-0.333	-0.426	-0.363	-1.273
1% level	-3.425	-3.435	-3.464	-3.476	-3.484	-3.459
5% level	-2.872	-2.872	-2.872	-2.873	-2.872	-2.883
10% level	-2.572	-2.572	-2.572	-2.573	-2.572	-2.578
p-values	0.907	0.947	0.918	0.894	0.918	0.659

*MacKinnon (1996) one-sided p-values.

ADF-test	S6	S7	S8	S9	S10
t statistic	-1.281	-0.121	-1.599	-0.559	-0.816
1% level	-3.499	-3.435	-3.441	-3.543	-3.967
5% level	-2.883	-2.872	-2.879	-2.902	-3.429
10% level	-2.578	-2.573	-2.576	-2.588	-3.138
p-values	0.669	0.944	0.501	0.864	0.963

*MacKinnon (1996) one-sided p-values.

Table 5: Augmented Dickey-Fuller test statistic - market rates

ADF-test	Libor 3m	Swap 5y	Libor 3m Mov.Avg.	Swap 5y Mov. Avg.
t statistic	-1.070	-0.876	-1.518	-2.857
1% level	-3.455	-3.454	-3.455	-4.002
5% level	-2.872	-2.872	-2.872	-3.431
10% level	-2.572	-2.572	-2.573	-3.139
p-values	0.728	0.795	0.523	0.179

*MacKinnon (1996) one-sided p-values.

Table 6: Cointegration analysis, cointegrating vector

	SNB	S1	S2	S3	S4	S5
Deposit rate	1	1	1	1	1	1
MR^{short}	-0.68	-0.691	-0.673	-0.681	-0.745	-0.505
(std error)	0.048	0.053	0.046	0.043	0.036	0.12
Constant	0.281	1.752	0.213	0.246	0.43	-0.036
(std error)	0.174	0.159	0.159	0.13	0.18	0.167
Deposit rate	1	1	1	1	1	1
MR^{long}	-0.977	-0.979	-0.925	-0.951	-1.007	-0.696
(std error)	0.033	0.034	0.03	0.029	0.041	0.067
Constant	1.817	1.721	1.612	1.748	1.938	1.320
(std error)	0.150	0.149	0.132	0.13	0.18	0.221
Deposit rate	1	1	1	1	1	1
MR^{short}	-0.195	0.084	-0.089	-0.165	-0.144	-0.029
(std error)	0.085	0.146	0.131	0.086	0.126	0.062
MR^{long}	-0.693	-1.108	-0.799	-0.736	-0.831	-0.671
(std error)	0.123	0.101	0.091	0.125	0.182	0.106
Constant	1.379	1.932	1.431	1.413	1.705	1.295
(std error)	0.232	0.273	0.245	0.246	0.332	0.281

	S6	S7	S8	S9	S10
Deposit rate	1	1	1	1	1.000
MR^{short}	-0.651	-0.561	-0.784	-0.154	-0.638
(std error)	0.138	0.048	0.217	0.072	0.054
Constant	0.269	-0.648	0.681	-0.435	0.249
(std error)	0.211	0.168	0.401	0.102	0.152
Deposit rate	1	1	1	1	1.000
MR^{long}	-0.887	-0.925	-0.947	-0.644	-0.935
(std error)	0.087	0.044	0.125	0.076	0.045
Constant 2.049	1.586	1.786	1.242	1.782	
(std error)	0.283	0.205	0.352	0.23	0.178
Deposit rate	1	1	1	1	1.000
MR^{short}	0.137	-0.159	0.435	-0.029	-0.123
(std error)	0.089	0.071	0.155	0.056	0.119
MR^{long}	-1.085	-0.639	-1.453	-0.512	-0.724
(std error)	0.147	0.122	0.226	0.124	0.171
Constant	2.424	0.906	2.425	0.911	1.434
(std error)	0.383	0.331	0.415	0.322	0.312

Table 7: Estimation of the EC model

	SNB_D	S1	S2	S3	S4
Constant	0.0008	-0.0003	-0.0002	-0.0007	-0.000
Std. Error	(0.004)	(0.0075)	(0.006)	(0.006)	(0.006)
ΔCR_{t-1}	0.101	-0.153	-0.190	-0.132	-0.242
	(0.078)	(0.047)	(0.041)	(0.052)	(0.053)
ΔMR_{t-1}	0.035	0.027	0.043	-0.084	0.056
	(0.014)	(0.047)	(0.029)	(0.036)	(0.023)
EC_{t-1}	-0.054	-0.087	-0.095	-0.096	-0.073
	(0.0007)	(0.024)	(0.017)	(0.019)	(0.015)
R^2	0.551	0.255	0.635	0.685	0.230

	S5	S6	S7	S8	S9	S10
Constant	-0.002	-0.013	-0.009	-0.003	-0.001	-0.005
Std. Error	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.004)
ΔCR_{t-1}	-0.068	-0.060	-0.250	-0.095	-0.055	-0.151
	(0.030)	(0.020)	(0.053)	(0.040)	(0.022)	(0.051)
ΔMR_{t-1}	-0.098	0.004	-0.017	-0.078	-0.063	-0.049
	(0.043)	(0.067)	(0.049)	(0.032)	(0.051)	(0.027)
EC_{t-1}	-0.135	-0.085	-0.076	-0.065	-0.136	-0.063
	(0.039)	(0.031)	(0.021)	(0.016)	(0.060)	(0.017)
R^2	0.299	0.151	0.286	0.149	0.286	0.252

Table 8: Threshold model in-sample performance

Case 1: $\omega = \Delta r_{t-1}^{long}$			**Case 2:** $\omega = EC_{t-1}$		
Regime1: $\Delta S5y \leq -0.520$			Regime1: $EC \leq 1.027$		
Parameter	Estimate	St Error	Parameter	Estimate	St Error
Constant	0.269	0.026	Constant	0.002	0.002
CR1	-0.286	0.129	CR1	0.236	0.081
L3m	-0.140	0.019	L3m	0.031	0.011
S5y	0.590	0.038	S5y	-0.010	0.013
EC	-0.073	0.008	EC	-0.039	0.006
Residual Variance:	0.001		Residual Variance:	0.001	
R-squared:	0.959		R-squared:	0.515	
Observations:	10%		Observations:	80%	
Regime2: $\Delta S5y > -0.520$			Regime2: $EC > 1.027$		
Constant	0.001	0.003	Constant	0.009	0.104
CR1	0.161	0.069	CR1	-0.069	0.111
L3m	0.026	0.012	L3m	-0.158	0.059
S5y	-0.008	0.021	S5y	0.044	0.067
EC	-0.050	0.007	EC	-0.109	0.062
Residual Variance:	0.002		Residual Variance:	0.006	
R-squared:	0.543		R-squared:	0.319	
Observations:	90%		Observations:	20%	

Table 9: Threshold model coefficients up to January 1998

Case 1: $\omega = \Delta r_{t-1}^{long}$			**Case 2:** $\omega = EC_{t-1}$		
Regime1: $\Delta S5y \leq -0.17$			Regime1: $EC \leq 1.2788$		
Parameter	Estimate	St Error	Parameter	Estimate	St Error
Constant	0.0155	0.0158	Constant	0.0062	0.0043
CR1	-0.0542	0.1698	CR1	0.1519	0.1000
L3m	-0.0864	0.0317	L3m	0.0255	0.0119
S5y	0.1048	0.0415	S5y	-0.0199	0.0195
EC	-0.0851	0.0164	EC	-0.0505	0.0100
Residual Variance:	0.0028		Residual Variance:	0.0020	
R-squared:	0.6927		R-squared:	0.5754	
Observations:	30%		Observations:	85%	
Regime2: $\Delta S5y > -0.17$			Regime2: $EC > 1.2788$		
Constant	0.0058	0.0054	Constant	0.0248	0.1195
CR1	0.0733	0.0917	CR1	-0.0887	0.1293
L3m	0.0390	0.0137	L3m	-0.1598	0.0583
S5y	-0.0464	0.0319	S5y	0.0358	0.0758
EC	-0.0608	0.0121	EC	-0.1218	0.0774
Residual Variance:	0.0026		Residual Variance:	0.0068	
R-squared:	0.6126		R-squared:	0.3039	
Observations:	70%		Observations:	15%	

Table 10: Threshold model coefficients up to December 2005

Case 1: $\omega = \Delta r_{t-1}^{long}$			**Case 2:** $\omega = EC_{t-1}$		
Regime1: $\Delta S5y \leq -0.520$			Regime1: $EC \leq 1.205$		
Parameter	Estimate	St Error	Parameter	Estimate	St Error
Constant	0.432	0.076	Constant	0.004	0.003
CR1	-0.569	0.167	CR1	0.204	0.086
L3m	-0.100	0.025	L3m	0.023	0.010
S5y	0.721	0.092	S5y	-0.009	0.013
EC	-0.100	0.012	EC	-0.044	0.008
Residual Variance:	0.0007		Residual Variance:	0.001	
R-squared:	0.971		R-squared:	0.531	
Observations:	10%		Observations:	90%	
Regime2: $\Delta S5y > -0.520$			Regime2: $EC > 1.205$		
Constant	0.003	0.003	Constant	0.009	0.104
CR1	0.117	0.074	CR1	-0.069	0.111
L3m	0.019	0.011	L3m	-0.158	0.059
S5y	-0.006	0.015	S5y	0.044	0.067
EC	-0.057	0.008	EC	-0.109	0.062
Residual Variance:	0.002		Residual Variance:	0.006	
R-squared:	0.564		R-squared:	0.319	
Observations:	90%		Observations:	10%	

Table 11: Sample split with threshold in changes in the market rate variable

Threshold in changes in the market rate						
	SNB	S1	S2	S3	S4	S5
Threshold value	**-0.520***	**0.040***	-0.182	**0.172***	**0.087***	**-0.582***
p value	0.049	(0.093)	(0.858)	0.088	0.058	0.073
Regime 1: $\Delta MR_{t-1} < Threshold$						
Constant	0.434*	0.020*		-0.005	0.006	0.004
Std. Error	(0.075)	(0.010)		(0.005)	(0.006)	(0.007)
ΔCR_{t-1}	-0.666*	-0.161*		-0.207*	-0.045*	-0.027
	(0.052)	(0.056)		(0.023)	(0.023)	(0.055)
ΔMR_{t-1}	0.792*	0.049		0.056*	-0.036	0.132*
	(0.093)	(0.043)		(0.029)	(0.045)	(0.032)
EC_{t-1}	-0.101*	-0.077*		-0.062*	-0.094*	-0.063*
	(0.051)	(0.025)		(0.018)	(0.039)	0.025
R^2	0.972	0.252		0.183	0.225	0.212
Nr. Obs	20%	60%		80%	70%	70%
Regime 2: $\Delta MR_{t-1} > Threshold$						
Constant	0.000	-0.023*		0.033	-0.042	0.033
Std. Error	(0.003)	(0.013)		(0.042)	(0.031)	(0.025)
ΔCR_{t-1}	0.072	-0.203*		-0.362*	-0.043*	-0.005
	(0.078)	(0.061)		(0.144)	(0.009)	(0.039)
ΔMR_{t-1}	0.035*	-0.008		-0.043	0.043	
	(0.015)	(0.065)		(0.134)	(0.160)	-0.292*
EC_{t-1}	-0.054*	-0.115*		-0.121*	-0.195*	-0.083*
	(0.008)	(0.027)		(0.045)	(0.077)	(0.030)
R^2	0.562	0.317		0.305	0.346	0.347
Nr. Obs	80%	40%		20%	30%	30%

	S6	S7	S8	S9	S10
Threshold value	**-0.582***	**0.167***	**-0.093***	**0.087***	**0.077***
p value	0.027	0.038	0.069	0.075	0.024
Regime 1: $\Delta MR_{t-1} < Threshold$					
Constant	0.364*	0.005	-0.092	0.0007	0.002
Std. Error	(0.093)	(0.006)	(0.260)	(0.006)	(0.007)
ΔCR_{t-1}	-0.212*	-0.083*	0.074*	-0.045*	-0.163*
	(0.036)	(0.029)	(0.020)	(0.017)	(0.061)
ΔMR_{t-1}	0.049		0.056*	-0.036	0.132*
	(0.105)	(0.042)	(0.095)	(0.040)	(0.097)
EC_{t-1}	-0.213*	-0.052*	-0.034	-0.076*	-0.053*
	(0.023)	(0.012)	(0.163)	(0.031)	(0.021)
R^2	0.911	0.292	0.801	0.0282	0.243
Nr. Obs	10%	83%	36%	70.5%	55.5%
Regime 2: $\Delta MR_{t-1} > Threshold$					
Constant	-0.003	-0.131*	-0.012*	-0.065	-0.033*
Std. Error	0.003	(0.036)	(0.004)	(0.041)	(0.016)
ΔCR_{t-1}	-0.322*	-0.016	-0.061*	-0.124	-0.107*
	(0.005)	(0.111)	(0.011)	(0.157)	(0.049)
ΔMR_{t-1}	-0.091*	0.273*	0.185*	0.179	0.045
	(0.039)	(0.116)	(0.016)	(0.177)	(0.061)
EC_{t-1}	-0.073*	-0.122*	-0.002	-0.295*	-0.088*
	(0.021)	(0.025)	(0.026)	(0.142)	(0.032)
R^2	0.175	0.509	0.605	0.355	0.277
Nr. Obs	90%	17%	64%	29.5%	44.5%

Table 12: Sample split with threshold in the error correction term (the threshold value for strategies 7,8,9 is not significant)

Threshold in the error correction term								
	SNB	S1	S2	S3	S4	S5	S6	S10
Threshold	**0.750***	**0.843***	**1.528***	**1.33***	**-1.415***	**0.621***	**-0.5***	**0.681***
p value	0.015	0.078	0.015	0.027	0.081	0.064	0.005	0.066
Regime 1: $EC_{t-1} < Threshold$								
Constant	0.001	-0.001	0.0002	-0.0002	-1.495*	-0.003	-0.179	0.003
	(0.002)	(0.003)	(0.006)	(0.006)	(0.162)	(0.005)	(0.109)	(0.004)
ΔCR_{t-1}	0.211*	-0.047*	-0.155*	-0.210*	-1.182*	-0.042*	-0.213*	-0.027*
	(0.108)	(0.019)	(0.038)	(0.050)	(0.101)	(0.018)	(0.098)	(0.015)
ΔMR_{t-1}	0.025*	-0.010	-0.034*	-0.075*	-0.003	0.015	-0.193*	-0.016
	(0.012)	(0.016)	(0.018)	(0.039)	(0.082)	(0.052)	(0.089)	(0.023)
EC_{t-1}	-0.037*	-0.035*	-0.084*	-0.105*	-0.982*	-0.075*	-0.237*	-0.026*
	(0.007)	(0.009)	(0.017)	(0.026)	(0.058)	(0.029)	(0.116)	(0.010)
R^2	0.522	0.279	0.349	0.256	0.736	0.305	0.533	0.253
Nr. Obs	70%	87%	90%	87%	20%	80%	20%	75%
Regime 2: $EC_{t-1} > Threshold$								
Constant	0.065	0.0005	1.873*	0.269	-0.002	-1.259*	-0.011*	-0.085*
	(0.067)	(0.083)	(0.296)	(0.183)	(0.005)	(0.478)	(0.004)	(0.027)
ΔCR_{t-1}	-0.227*	-0.375*	-0.752*	-0.695*	-0.232*	-1.775*	-0.655*	-0.217*
	(0.121)	(0.115)	(0.137)	(0.203)	(0.057)	(0.467)	(0.047)	(0.077)
ΔMR_{t-1}	0.136*	0.256*	-0.806*	-0.286*	0.050*	-0.506*	0.028	-0.175*
	(0.036)	(0.098)	(0.182)	(0.111)	(0.023)	(0.183)	(0.047)	(0.067)
EC_{t-1}	-0.145*	-0.095*	-1.28*	-0.225*	-0.069*	1.188*	-0.072*	-0.678*
	(0.050)	(0.041)	(0.187)	(0.112)	(0.014)	(0.577)	(0.020)	(0.039)
R^2	0.354	0.509	0.475	0.300	0.207	0.588	0.478	0.147
Nr. Obs	30%	13%	10%	13%	80%	20%	80%	25%

Table 13: Rigidity model - robustness test

	S1	S2	S3	S4	S5	S6	S7	S8	S9
a_1	-0.092*	-0.092*	-0.045*	-0.094*	-0.147*	-0.016*	-0.04*	-0.036*	-0.031*
(s.e.)	(0.003)	(0.005)	(0.013)	(0.023)	(0.006)	(0.008)	(0.006)	(0.008)	(0.011)
a_2	-0.121*	-0.104*	-0.082*	-0.070*	-0.119*	-0.068*	-0.08*	-0.057*	-0.117*
	(-0.022)	(-0.013)	(-0.019)	(-0.026)	(-0.011)	(-0.013)	(-0.021)	(-0.019)	(-0.031)
b_1	-0.053*	-0.051*	-0.028*	-0.032*	-0.056*	-0.023*	-0.03*	-0.028*	-0.020*
	(0.005)	(0.008)	(0.006)	(0.003)	(0.007)	(0.009)	(0.008)	(0.008)	(0.005)
b_2	-0.055*	-0.053*	-0.037*	-0.050*	-0.073*	-0.033*	-0.04*	-0.056*	-0.055*
	(0.016)	(0.018)	(0.009)	(0.015)	(0.019)	(0.013)	(0.015)	(0.019)	(0.018)
σ	0.453*	0.548*	0.186*	0.404*	0.476*	0.661$*$	0.43*	0.294*	0.501*
	(0.031)	(0.026)	(0.035)	(0.033)	(-0.019)	(0.027)	(0.031)	(0.033)	(0.028)
R^2	**0.83**	**0.75**	**0.81**	**0.865**	**0.798**	**0.81**	**0.832**	**0.765**	**0.902**
$\|a_1 - a_2\|$	0.029	0.012	0.037	0.024	0.028	0.052	0.04	0.021	0.086
	(0.001)	(0.007)	(0.015)	(0.004)	(0.005)	(0.021)	(0.002)	(0.001)	(0.031)

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