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The Nominal Exchange Rate and Monetary Fundamentals: Evidence from Nonlinear Unit Root Tests

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Abstract

In this paper we model the deviation of the nominal exchange rate from the long run equilibrium level predicted by monetary fundamentals in a nonlinear framework consistent with the presence of transaction costs. In contrast to standard linear methods and studies which test for linearity only, we consider a novel approach that allows for the joint testing of nonlinearity and nonstationarity. Within this approach, we employ nonlinear threshold autoregressive (TAR) unit root tests to investigate whether the deviation of the nominal exchange rate from the level predicted by monetary fundamentals for three major currencies vis−à−vis the US dollar is mean reverting. We are able to reject the null hypotheses of linearity and nonstationarity indicating nonlinear mean reversion of the deviation of the exchange rate from monetary fundamentals. Further, large deviations are found to have faster speed of mean reversion than small deviations.

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1. Introduction

The purpose of this paper is to test the validity of the monetary approach to exchange rate determination. This emerged as the dominant exchange rate approach at the start of the recent float in the early 1970s (Mussa, 1976, 1979). However, despite its intuitive appeal, empirical evidence on the validity of this approach has been largely unfavourable. For instance, Meese and Rogoff (1983 a, b) in their seminal paper employed linear econometric tests and found that a simple random walk (RW) model performed no worse than a range of competing representative time-series and structural exchange rate models. Out-of-sample forecasting power in those models was surprisingly low for various forecasting horizons (from 1 to 12 months). Even with the benefit of twenty years of hindsight, moreover, evidence that monetary models can consistently and significantly outperform a naïve random walk is still elusive and mixed (Neely and Sarno, 2002).

The major problem with the tests that have been used so far to investigate the validity of the monetary model is that they implicitly assume that adjustment of the nominal exchange rate towards the level predicted by monetary fundamentals is linear. However, there are good reasons why, if the nominal exchange rate and monetary fundamentals co-move and are linked by a cointegrating relationship, adjustment toward equilibrium may be nonlinear. For example, transaction costs and market frictions are often cited as the major sources of nonlinearities. According to Dumas (1992) transaction costs create a band of inaction within which deviations of the nominal exchange rate from the monetary fundamentals level are left uncorrected as they are not large enough to be profitable. It is only deviations that are outside the band that are arbitraged by market agents. In this framework, deviations follow a nonlinear process that is mean-reverting. Nonlinearities in the adjustment of the nominal exchange rate towards the long run equilibrium level suggested by monetary fundamentals are supported by the studies of Taylor and Peel (2000) and Kilian and Taylor (2001). However, there is no clear way of differentiating between nonlinearity and nonstationarity in the above literature. Indeed, these studies assume stationarity prior to fitting a nonlinear model and find evidence of fast mean reversion when these nonlinear models are used. However, if stationarity is not valid and the variable under study has a unit root, then tests of linearity versus a nonlinear threshold alternative will lead to incorrect inferences as these tests will have non-standard asymptotic distributions[1].

[1] For example, Taylor and Peel (2000) estimate a nonlinear error correction model of quarterly exchange rates and monetary fundamentals for the pound / dollar and deutsche mark / dollar exchange rates and find that the exponential smooth transition autoregressive (ESTAR) model parsimoniously describes nonlinearities in the deviation of the nominal exchange rate from the level predicted by monetary fundamentals. Taylor and Peel (2000) assume that the deviation series is stationary prior to fitting the nonlinear ESTAR model. However, if the deviation is realization of a unit root process, then the linearity tests used by these authors will lead to incorrect inferences and their results must be interpreted with care. In addition, Taylor and Peel (2000) do not attempt to reconcile the nonlinear adjustment they find with the unit root evidence found in previous studies. Finally, even if the deviation series is stationary then de-trending the data and subtracting the mean off, as is done in Taylor and Peel (2000), will bias the results especially if the trend and drift coefficients are different across regimes (Darba and Patel, 2001).

Essentially, results found in the above studies regarding nonlinearity and mean reversion must be interpreted cautiously as long as a proper test of unit root against a stationary nonlinear (threshold) alternative has not been performed (Bec *et al.*, 2002).

To circumvent these problems, we use a novel approach whose tests and distribution theory have recently been developed by Caner and Hansen (2001) and which allows for the joint testing of nonlinearity and nonstationarity. This approach uses a two-regime symmetric threshold autoregressive (TAR) model with an autoregressive unit root which allows for an inner no-arbitrage band for small disequilibria and captures mean-reversion in response to shocks outside the no-arbitrage band. Within this model, we study Wald tests for nonlinear adjustment and Wald and *t*-tests for nonstationarity. We also allow for general autoregressive orders and do not artificially restrict coefficients across regimes (Basci and Caner, 2002).

In this paper, we first examine the linear univariate time series properties of the deviation of the nominal exchange rate from monetary fundamentals for three major currencies mainly the UK Pound/ US Dollar, Swiss Franc / US Dollar and Japanese Yen/ Dollar exchange rates and for the recent floating exchange rate period. Unsurprisingly, we find little evidence of mean reversion in the deviations of the nominal exchange rate from the monetary fundamentals level and this is explained by the low power of the tests used. However, given nonlinear exchange rate adjustment, the dynamic relationships implicit in testing the monetary model using linear univariate tests are misspecified and it should come as no surprise that we cannot detect any mean reversion in the relationship between the nominal exchange rate and monetary fundamentals since these linear unit root tests lack power against nonlinear alternatives. Allowing for the possibility of nonlinear adjustment and using nonlinear threshold autoregressive (TAR) unit root tests, we first obtain evidence of nonlinearities in the adjustment towards equilibrium for the UK and Japan. For Switzerland, we could not reject the null of linear adjustment. Second, the Wald and *t*-test for unit root reveal that the deviation series has a unit root inside the transaction cost band and is mean reverting outside the band. Overall, the deviation series is found to be globally stationary. Finally, the estimated half-lives for deviations of the nominal exchange rate from the level predicted by monetary fundamentals indicate that adjustment outside the band is faster than inside the band.

This paper is structured as follows: section 2 provides a description of the workhorse of our analysis, namely the flexible price monetary model of exchange rate determination. Empirical methodology is described in section 3. Data and empirical results are provided in section 4. The last section concludes.

2. The Monetary Model of Exchange Rate Determination

The monetary model used in the empirical analysis is one whose starting point is the quantity theory of money relationship. Following Frankel and Rose (1995) and Taylor and Peel (2000), the empirical analysis in this paper is performed on the deviation of the nominal exchange rate from the level predicted by monetary fundamentals which is given as:

$$f_t = s_t - (m_t - m_t^*) + (y_t - y_t^*) \tag{1}$$

where s_t, m_t, and y_t represent the nominal exchange rate, money supply and the level of income and asterisks denote the foreign variables. If f_t equals zero, then the monetary model holds. For the long-run monetary model to hold the deviation of the exchange rate from the level suggested by monetary fundamentals should be stationary and not driven by permanent shocks. In addition, if the deviation series are stationary, then this represent evidence of cointegration between the nominal exchange rate and monetary fundamentals.

3. Empirical Methodology: The Caner and Hansen (2001) Threshold Autoregressive (TAR) Unit Root Test

The model suggested by Caner and Hansen (2001) is a threshold autoregressive (TAR) process of the form:

$$\Delta f_t = \theta_1' x_{t-1} 1_{\{Z_{t-1}<\lambda\}} + \theta_2' x_{t-1} 1_{\{Z_{t-1}\geq\lambda\}} + e_t \tag{2}$$

t=1,…, T, where $x_{t-1} = (f_{t-1} r_t' \Delta f_{t-1} ... \Delta f_{t-k})'$, $1_{\{.\}}$ is the indicator function, e_t is an *iid* error, $Z_t = f_t - f_{t-m-1}$ for some $m \geq 1$ and r_t is a vector of deterministic components including an intercept and possibly a linear time trend. The threshold λ is unknown. It takes on values in the interval $\lambda \in \Lambda = [\lambda_1, \lambda_2]$ where λ_1 and λ_2 are picked so that $P(Z_t \leq \lambda_1) = \pi_1 > 0$ and $P(Z_t \leq \lambda_2) = \pi_2 < 1$[2]. It is convenient to show the components of θ_1 and θ_2 as:

$$\theta_1 = \begin{pmatrix} \mu_1 \\ \beta_1 \\ \rho_1 \end{pmatrix} \text{ and } \theta_2 = \begin{pmatrix} \mu_2 \\ \beta_2 \\ \rho_2 \end{pmatrix} \tag{3}$$

The TAR model is estimated by least squares (LS):

$$\Delta f_t = \hat{\theta}_1 (\lambda) x_{t-1} 1_{\{Z_{t-1}<\lambda\}} + \hat{\theta}_2 (\lambda)' x_{t-1} 1_{\{Z_{t-1}\geq\lambda\}} + \hat{e}_t (\lambda) \tag{4}$$

Let

$$\hat{\sigma}^2 (\lambda) = T^{-1} \sum_1^T \hat{e}_t(\lambda)^2 \tag{5}$$

be the OLS estimate of σ^2 for fixed λ. The least squares estimate of the threshold λ is found by minimizing $\sigma^2(\lambda)$:

$$\hat{\lambda} = \arg\min_{\lambda \in \Lambda} \hat{\sigma}^2 (\lambda) \tag{6}$$

In model (5), an important issue is whether there is a threshold effect. The threshold effect disappears under the hypothesis that:

$$H_0: \mu_1 = \mu_2, \rho_1 = \rho_2 \tag{7}$$

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[2] Since only the magnitude of the change in the deviation that matters and not the sign, we consider the absolute value of the change as the switching variable. We, therefore, retain a symmetric threshold $\lambda_1 = -\lambda_2 = \lambda$. This makes our TAR a two-regime symmetric model.

This hypothesis is tested using a standard Wald test statistic W_T. This statistic is written as:

$$W_T = T(\hat{\sigma}_0^2 / \hat{\sigma}^2 - 1) \quad (8)$$

where $\hat{\sigma}^2$ is the residual variance from (4), and $\hat{\sigma}_0^2$ is the residual variance from OLS estimation of the null linear model. Let (9) denote the Wald statistic of hypothesis (10) for fixed threshold.

$$W_T(\lambda) = T(\hat{\sigma}_0^2 / \hat{\sigma}^2(\lambda) - 1) \quad (9)$$

Then since $W_T(\lambda)$ is a decreasing function of $\hat{\sigma}^2(\lambda)$, the Wald statistic is:

$$W_T = W_T(\hat{\lambda}) = \sup_{\lambda \in \Lambda} W_T(\lambda) \quad (10)$$

In model (2), the parameters ϱ_1 and ϱ_2 control the stationarity of the process f_t. A leading case is when f_t is a unit root process such that:

$$H_0: \rho_1 = \rho_2 = 0 \quad (11)$$

The standard test for (11) against the unrestricted alternative $\rho_1 \neq 0$ or $\rho_2 \neq 0$ is the Wald statistic:

$$R_{2T} = t_1^2 + t_2^2 \quad (12)$$

where t_1 and t_2 are t ratios for $\hat{\rho}_1$ and $\hat{\rho}_2$ from the OLS regression of the TAR model. While it is unclear how to form an optimal one-sided Wald test, Caner and Hansen (2001) recommend focusing on negative values of $\hat{\rho}_1$ and $\hat{\rho}_2$ to end up with a simple one-sided Wald test statistic:

$$R_{1T} = t_1^2 1_{\{\hat{\rho}_1 < 0\}} + t_2^2 1_{\{\hat{\rho}_2 < 0\}} \quad (13)$$

which is testing the unit root null hypothesis against the one-sided alternative $\rho_1 < 0$ or $\rho_2 < 0$. Generally, Caner and Hansen suggest examining the individual t statistics t_1 and t_2 such that an insignificant t statistic provides evidence in favour of the presence of a unit root in the TAR process. While the distributions of R_{1T} and R_{2T} have asymptotic approximations, improved finite sample inference may be conducted using a bootstrap distribution. In this paper, we obtain the exact p-values of the R_{1T} and R_{2T} statistics using 10000 bootstrap simulations.

4. Data and Empirical Results

4.1 Data (See appendix for IMF data codes)

The data utilised in this paper are obtained from the International Financial Statistics of the International Monetary Fund (IMF) CD-ROM. The data include the end-of-quarter bilateral US exchange rates relative to Japan, Switzerland and the UK and the money supply and real GDP for each country. For the US, Switzerland and Japan, money consists of money supply M1 plus quasi money. For the UK, money is M0 which is defined as coins and notes outside the banks plus bankers operational deposits with the Bank of England. The US dollar based foreign exchange rates were chosen for analysis due to the United States being a major trading partner of the countries under examination. The empirical tests are performed with data for the period spanning the first quarter of 1973 to the last quarter of 2000. The exchange rate is defined as the amount of US dollars required to buy one unit of foreign currency.

4.2. Evidence from Univariate Tests

Testing for the stationarity the deviation series provides evidence of long run co-movement between the nominal exchange rate and monetary fundamentals. Table 1 presents the values of the Augmented Dickey Fuller (ADF) and the Kwiatkowski *et al.* (KPSS) tests performed on each deviation series. The ADF test on the log levels of deviation series shows that the unit-root null hypothesis cannot be rejected for any of the currencies under investigation.

A major criticism of the ADF unit root testing procedure is that it cannot distinguish between unit root and near unit root processes especially when using short samples of data. This prompted the use of the KPSS test, where the null is of stationarity against the alternative of a unit root. This ensures that the alternative will be accepted (null rejected) only when there is strong evidence for (against) it. With critical values of 1%, 5% and 10%, the stationarity null hypothesis is rejected for all currencies and this confirms the results of the ADF test. To sum up, the results of the two linear univariate unit root and stationarity tests used here indicate that we cannot reject the null hypothesis of a unit root in the deviation series and this provides evidence against the existence of a long run relationship between the nominal exchange rate and monetary fundamentals.

4.3. Nonlinear Threshold Autoregressive (TAR) Bootstrap Tests

The major problem with the tests that we have used so far is that they implicitly assume linear adjustment. Nonlinearities can be due to a variable speed of adjustment towards a long-run equilibrium. This may arise because small deviations are not considered important by the market and the authorities, whereas for larger deviations, the pressure from the market to return the exchange rate near its equilibrium value becomes larger (Taylor and Allen, 1992; Taylor and Peel, 2000). Nonlinearities can also arise as a consequence of transaction costs and market frictions (Dumas, 1992).

To explore the deviation of the nominal exchange rate from the monetary fundamental level for potential frictions captured by nonlinearities; we employ the nonlinear threshold autoregressive (TAR) framework of Caner and Hansen (2001). The model used is a two-regime symmetric TAR model with an autoregressive root that is local-to-unity. The first step in our analysis involves testing for linearity and the appropriate test statistic for this is a Wald test. In table 2 we report the bootstrap *p*-values for threshold variables of the form $Z_t = f_t - f_{t-m-1}$ for delay parameters m from 1 to 8. However, the optimal delay parameter is chosen so that it minimises the residual variance for the TAR model of each deviation series. These delay parameters for the deviation series are 1 for the UK and Switzerland and 5 for Japan. From table 2, the

Wald statistic is significant for the UK and Japan[3]. For Switzerland the null hypothesis of linearity could not be rejected for any delay parameter even the parameter that minimises the residual variance of the TAR. Given the strong evidence of linear adjustment for Switzerland, we do not proceed to estimate the TAR model as it appears that a linear representation is enough to describe the adjustment of the nominal exchange rate towards the monetary equilibrium level. This rejection of nonlinearity for Switzerland is confirmed by the results of Baum *et al*. (2001) who could not detect a nonlinear adjustment in the Swiss Franc / US Dollar real exchange rate. Moreover, Pippenger (1993) and Baum *et al*. (2001) did not find a cointegrating relationship between the nominal exchange rate and prices for Switzerland and the USA. This lack of evidence for PPP for Switzerland suggests that one of the main building blocks or assumption of the monetary model is not satisfied.

In table 2 we report the threshold unit root t_1 and t_2 statistics for each delay parameter m from 1 to 8, and their p-values obtained using 10000 bootstrap simulations. However, the t-statistics of interest are those that correspond to the delay parameters that minimise the residual variances which are the same as those used to test the linearity null. For these delay parameters the bootstrap p-values for t_1 are 0.0110 for the UK and 0.0232 for Japan respectively. The significant t_1 statistic indicates that we are able to reject the unit root null hypothesis in favour of $\rho_1 < 0$ in the first regime (outside the band) for the UK and Japan. The bootstrap p-values for the t_2 statistic are 0.3600 for the UK and 0.5690 for Japan. In this case, p-values indicate that we are unable to reject the unit root null hypothesis in the second regime (inside the band) for both currencies.

However, we are able to settle the unit root question using the R_{1T} and R_{2T} statistics which are reported in table 2. The one-sided Wald test R_{1T}, which tests unit root against a two-regime stationary nonlinear model, strongly rejects the null for the UK and Japan with bootstrap p-values equal to 2.06% and 6.54% respectively. This is an important result since it indicates that once allowance is made for nonlinearities we are able to reject the unit root null hypothesis for the UK and Japan. This would explain why previous studies have been unable to reject the unit root null hypothesis using linear unit root testing techniques.

For the chosen delay parameter we report in table 3 the least squares estimates of the TAR models for each deviation series. For the UK, in particular, the point estimate of the threshold is – 0.0400. This value indicates that the TAR splits the regression function depending on whether the variable $|f_{t-1} - f_{t-2}|$ lies above the threshold in absolute terms. The first regime is when $Z_{t-1} < -0.0400$, which happens when the deviation series has fallen by more than 0.0400 points. 24.8% of the observations fall into this regime. The second regime is when $Z_{t-1} > -0.0400$, which happens when the deviation series has fallen by less than 0.0400 points, has stayed constant, or has risen. 75.2% of observations fall into this regime. The first regime (outside the band) behaves as a stationary process, whereas the second regime (inside the band) is essentially a random walk with a drift. Overall, the deviation series is shown to be globally stationary

[3] Unlike previous studies which uncovered evidence of nonlinearities in the deviation of the nominal exchange rate from monetary fundamentals, our results are more robust to the specification of long run trends in the deviation series as we do not impose the assumption of stationarity on the data.

since we are able to reject the unit root null for the R_{1T} statistic with a 2.06% bootstrap *p*-value. This provides strong evidence of nonlinear mean reversion of the deviation of the nominal exchange rate from the level predicted by monetary fundamentals.

In table 4 we report the half-lives of deviations of the nominal exchange rate from monetary fundamentals. The half-lives measure mean reversion and are defined as the number of quarters it takes for deviations to subside permanently below 50% in response to a unit shock in the level of the series. In the first column we report the half-lives estimated using the linear autoregressive model. It is clear from this column that the speed of mean reversion is extremely slow. The estimates of the half-lives vary from a low of 17 to 52 quarters. In the remaining columns we report the half-lives estimated for the nonlinear TAR models. The half-lives are computed for the first regime (outside the band) and the second regime (inside the band). The values of the half-lives indicate that deviations outside the band of inaction are corrected or die out very quickly and the speed of adjustment is as low as 4.6 quarters. The estimates for the half-lives outside the band are below 6 quarters and this is much faster than the values we obtained using the linear model. As for the inner regime, adjustment is extremely slow, 60 quarters for Japan. However, this is not surprising since the inner regime behaves essentially as a unit root process and its root is insignificantly different from zero so that the estimate of the half-life will tend to infinity. Overall, we find that adjustment outside the transaction cost band is much faster than the one inside the band.

5. Conclusion

In this paper, we investigate the empirical validity of the monetary model of exchange rate determination. We assume the presence of transaction costs which implies that adjustment of the nominal exchange rate towards the level predicted by monetary fundamentals is nonlinear (Dumas, 1992). Nonlinearities in the deviation of the nominal exchange rate from the monetary fundamentals level are supported by the evidence of a recent paper by Taylor and Peel (2000). However, one unresolved issue in this paper concerns the stationarity of the deviation series. This means the results in Taylor and Peel (2000) must be interpreted cautiously. To resolve this issue we use a method that allows for the joint testing of nonlinearity and nonstationarity.

Using quarterly data for three major currencies vis-à-vis the US dollar, we first find significant evidence of nonlinearity in the deviation of the nominal exchange rate from monetary fundamentals for the UK and Japan. Second, Wald and *t*-ratio tests indicate that the deviation series are stationary TAR processes. Specifically, the deviations are shown to contain a unit root when inside the transaction cost band and when outside this band the deviations are mean reverting. Moreover, the speed of adjustment is faster outside the band than inside the band.

Overall, by combining two strands that have received a lot of attention in the literature mainly the nonlinearity and nonstationarity of time series data, we have been able to uncover strong evidence of nonlinear mean reversion in the deviation of the nominal exchange rate from monetary fundamentals. Our results reinforce those of studies which detected nonlinearities in exchange rate adjustment (Taylor and Peel, 2000). However, our results are stronger since we have dealt with one of the drawbacks of these studies that is the failure to test for unit root.

6. Appendix

Sources of the data

Country	Exchange Rate	Money Supply	Income Level
USA	-	111 34…, 35…	111 99 B.C
UK	112…AG	112 59 M.C	112 99 B.C
Switzerland	146…AG	146 34…, 35…	146 99 B.C
Japan	158…AG	158 34…, 35…	158 99 B.C

Money Supply

For the US, Switzerland and Japan money supply is made up of money and quasi money. For the UK, money is M0 which is defined as coins and notes outside the banks plus bankers operational deposits with the Bank of England. The money supply series retained were seasonally unadjusted. To seasonally adjust these series, we use the method suggested by Mark (1995). This method involves the following: let m_t be money in quarter t and x_t be the seasonally adjusted money, then $x_t = (m_t + m_{t-1} + m_{t-2} + m_{t-3})/4$.

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8. Empirical Results

Table 1 ADF and KPSS tests on the deviations from monetary fundamentals.

	UK	Switzerland	Japan
ADF: Test			
Intercept	-2.4000	-2.1300	-1.0200
ρ_1	-0.0364	-0.0398	-0.0132
Half-life	18.6937	17.0668	52.1638
KPSS: Test			
Intercept			
Newey-west	0.9683***	1.0416***	1.1567***
Andrews	0.3495*	0.4057*	0.6633**

Note: The half-life is the number of quarters it takes for deviations to subside permanently below 0.5 in response to a unit shock in the level of the series. The half-life is computed as $\ln(0.5) = \ln(1+\rho_1)$, where ρ_1 is the root of the autoregressive (AR) model for each deviation series. Critical values for the ADF test with an intercept are -3.4950 (1%), -2.8897 (5%) and -2.5818 (10%). Critical values for the KPSS test with an intercept are 0.7390 (1%), 0.4630 (5%) and 0.3470 (10%). *, ** and *** indicate significance at 10%, 5% and 1%.

Table 2 Linearity and threshold unit root tests.

	m	Linearity	λ	t_1	t_2	R_{1T}	R_{2T}	ρ_1	ρ_2
UK	1	0.0531*	-0.0400	0.0110**	0.3600	0.0206**	0.0240**	-0.1140	-0.0241
								(0.0321)	(0.0162)
Switzerland	1	0.1380	-	-	-	-	-	-	-
Japan	5	0.0998*	-0.1000	0.0232**	0.5690	0.0654*	0.0798*	-0.1400	-0.0115
								(0.0489)	(0.0134)

Note: *, ** and *** indicate significance at 10%, 5% and 1%. Bootstrap *p*-values calculated from 10000 replications obtained with Gauss 3.2.

Table 3 Least Squares (LS) estimates of the Threshold Autoregressive (TAR) models.

	UK		Japan	
Regime	$Z_{t-1} < \lambda$	$Z_{t-1} > \lambda$	$Z_{t-1} < \lambda$	$Z_{t-1} > \lambda$
n (%)	24.8	75.2	13.6	86.4
Threshold	-0.0400		-0.1000	
Intercept	-0.1800	-0.0156	-1.6600	-0.1280
	(0.0459)	(0.0144)	(0.5920)	(0.1570)
	-0.1140	-0.0241	-0.1400	-0.0115
f_{t-1}	(0.0321)	(0.0162)	(0.0489)	(0.0134)
	-0.5140	-0.1540	0.4620	0.1480
Δf_{t-1}	(0.4080)	(0.1500)	(0.6420)	(0.1060)
	-0.4600	0.0075	-0.3060	-0.0081
Δf_{t-2}	(0.1770)	(0.1150)	(0.6320)	(0.1080)
	-0.1770	0.1440	-0.9100	0.2160
Δf_{t-3}	(0.2090)	(0.1080)	(0.6470)	(0.1050)
	0.0299	0.0167	-1.1900	0.1680
Δf_{t-4}	(0.1990)	(0.1080)	(0.7170)	(0.1120)
	-0.2030	-0.1070	-0.9550	-0.1200
Δf_{t-5}	(0.2020)	(0.1100)	(0.6060)	(0.1090)
	0.2130	-0.0063	-0.1440	-0.1300
Δf_{t-6}	(0.1710)	(0.1110)	(0.4200)	(0.1110)
	0.4260	0.1410	-1.1000	0.0589
Δf_{t-7}	(0.1770)	(0.1100)	(0.2790)	(0.1110)
	0.1400	0.0000	-0.0223	-0.0099
Δf_{t-8}	(0.2040)	(0.0000)	(0.5530)	(0.1070)

Note: Bootstrap p-values calculated from 10000 replications obtained with Gauss 3.2.

Table 4 Estimated half-lives of deviations in quarters.

	Linear AR	Nonlinear TAR	
		Outside	Inside
USA	18.6937	5.7266	28.4133
Switzerland	17.0668	-	-
Japan	52.1638	4.5957	59.9264

Note: The half-life is defined as the number of quarters it takes for deviations to subside permanently below 0.5 in response to a unit shock in the level of the series. All half-lives are reported in quarters.