INTEREST RATE, EXPECTATIONS AND THE CREDIBILITY OF THE BANK OF SPAIN*

Francisco J. Goerlich, Joaquín Maudos and Javier Quesada**

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ABSTRACT

This paper tries to precisely date the change of monetary policy regime occurred in Spain along the year 1984 moving away from controlling monetary aggregates into interest rate targeting. The most likely date for the change is estimated and, surprisingly, there is evidence that agents learn quite rapidly about the new intermediate target. A week after the change, the term structure of interest rates shows how market agents attribute much more informational content to interest rate changes than they did before. Two types of transitions are tried, namely, using a one step and a gradual logistic switching function.

KEYWORDS: Monetary control, expectations, credibility.

RESUMEN

Este documento pretende establecer la fecha exacta del cambio en la política monetaria -del control de agregados monetarios al control de tipos de interés- que tuvo lugar en España a lo largo del año 1984. Se determina la fecha más probable del cambio, y se observa que, sorprendentemente, los agentes asimilan rápidamente este nuevo objetivo. Alrededor de una semana después del cambio, la estructura de los tipos de interés muestra como los agentes de mercado atribuyen mucho más contenido informacional a los cambios en los tipos de interés que anteriormente. Se suponen dos tipos de transición: un ajuste instantáneo y otro gradual según una función logística.

PALABRAS CLAVE: Control monetario, expectativas, credibilidad.

1.- INTRODUCTION.

Since the beginning of the seventies Spanish monetary policy was conducted controlling, basically, monetary aggregates (M3 and ALP's[1]). Sometime in 1984 a shift towards interest rates -credit conditions- was carried out. It was fairly clear by then the prospective of a future integration into the European Monetary System (EMS), which favored the replacement of the intermediate target by a policy variable more compatible with the eventual targeting of the exchange rate. As a result, the quantity of money was expected to acquire a higher degree of endogeneity and, hence, would be less controllable by the central bank. A smooth entrance into the EMS would require first, a previous gradual adoption by monetary policy of the features required by full membership; namely, the targeting of the exchange rate through the use of interest rate control. Second, to catch markets by surprise not announcing the exact membership date.

This study attempts to establish the exact date on which the change of regime in monetary policy took place. We know that it was around 1984 when the Central Bank of Spain decided to emphasize short term interest rate control, abandoning the strict monitoring of monetary aggregates, and shifting aggregate targeting from the very short to the medium term. This point was raised by Escrivá (1989) and Escrivá and Santos (1991) and was explained in the context of the Spanish monetary policy in Escrivá and Malo de Molina (1991)[2].

More specifically, this paper provides further evidence -from a different perspective- on this change in regime in the operation of monetary policy. In particular:

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[1]ALP stands for "activos líquidos en manos del público", short term liquid assets, excluding private assets.

[2]A summary of monetary control in Spain may be found in Ayuso, J. & Escrivá, J.L. (1993).

(1) Empirical evidence on the change in the stochastic process for the short rate is shown, confirming a break down around 1984.

(2) An exercise establishing the exact timing of such change is done, so that it can be interpreted as the exact change of monetary policy.

(3) The consequence of the new monetary policy on expectations may be explored by looking at the term structure of interest rates.

(4) The change of monetary regime provides us with a good case to test the degree and speed of adjustment of expectations to the new form of conducting monetary policy. Once a more stable path for interest rates is perceived agents will consider any variation of interest rates a more permanent change of the current condition, attributing to it now, more informational content.

This study, inspired in Escrivá (1989), follows Mankiw et al (1987) using additional tools, namely, unit root and co-integration theory. The paper is organized as follows: section 2 summarizes the Spanish monetary policy main institutional changes occurred during the period under analysis, section 3 describes the data set, section 4 studies the stochastic process followed by the short rate, section 5 considers the exact timing for the change of regime, section 6 discusses the relationship between short and long rates, section 7 dwells into the term structure for evidence on the timing for the change of regime, and, finally, section 8 draws conclusions and makes suggestions for further research.

2.- MONETARY POLICY IN SPAIN: THE INSTITUTIONAL ANALYSIS.

Since the beginning of the seventies, the central bank of Spain established a new framework for conducting monetary policy. Based upon the control of monetary aggregates it was, initially, merely an internal reference for the central bank to become, only after 1978, a publicly announced target. Every year after, once the government proposed a target for nominal GDP growth, the monetary authorities designed a compatible monetary policy that would not jeopardize the aimed goals of real growth and inflation. More specifically, a growth rate for a particular definition of money was announced, allowing a range of deviation around the central path of $\pm2\%$ (later $\pm1.5\%$). The monetary aggregate chosen as an intermediate target was M3 (currency + demand + savings + time + certificates of deposits), which showed a very stable relationship with nominal GDP until 1984. Financial innovations and the massive arrival of short term public debt brought instability to the M3 aggregate, making more convenient the shift in 1984 of intermediate targeting towards a broader definition of money, namely, ALP (basically, M3 + short term public debt + other liquid assets).

It was also around 1984 when the monetary authorities decided to conduct a monetary policy more in accordance to the eventual integration of Spain into the European Monetary System. EMS membership required a much stronger commitment to target exchange rates -within a more or less flexible interval of fluctuation-, meaning a certain loss of control over monetary aggregates. Hence, any aggregate targeting should be compatible with exchange rate stability, at least in the medium and long run, and interest rate control was to become the appropriate instrument to manage exchange rates, inducing compensating currency appreciations or depreciations through international capital movements.

Money multipliers -relationships between different definitions of money and bank reserves- became also much less stable, making aggregate control much more difficult and much less reliable, particularly in the short run. The causes behind such multiplier instability were twofold: the unexpected changes in household and firm portfolio decisions, and the unforeseen alterations in bank liability management. Initially, identified deviations of monetary aggregates away from the desired path imposed continuous adjustments of bank reserves, introducing too much noise into money markets. The central bank decided to follow -in the very short run- a loser control of monetary aggregates and a smoother path for interest rates. A few years later this new policy would develop into a double action on interest rates: first, their use as a reference rate for central bank loan policy and their management as indicators of the orientation of monetary policy, changing them only when the bank wants to announce a policy decision. Second, a daily control of very short term (one day) interest rates in inter bank loans, through the increasing use of conventional open market operations (repurchase agreements on public debt or certificates of deposit of the central bank), letting market expectations determine longer term interest rates.

The process which ended up in such policy framework started in 1984 when the bank, trying to reduce interest rate volatility, began a more flexible management of bank reserves. Under the new framework for monetary policy, pursuing higher interest rate stability meant giving up the strict control over monetary aggregates, if only in the short run. Aggregate targeting was, still, the basic tool for monetary programming and medium run targets were maintained as a guideline. Nevertheless, short run deviations in the ten-day bank reserve growth target increased quite clearly after the change of regime. Along the following years, also the speed of reaction towards such deviations decreased, trying to avoid over reactions to small observed divergences between planned and realized levels of bank reserves. A base drift procedure was adopted in which any unexpected deviation was accepted as permanent and no intention to remove it was pursued thereafter.

In sum, active monetary policy in Spain, born in 1973, was defined in terms of aggregate control until 1984 when a shift towards interest rate control took place. It is the objective of this paper to explore the data to time this change of regime, so we move to explain the data used in the analysis.

3.- DATA.

Two different interest rate series were used[3]. A short run (one day) interest rate (SR): the marginal rate of the "Préstamos de regulación monetaria" (TM) (central bank loans to banks offered in auctions). A long run (one month) interest rate (LR): the prevailing rate in the "Mercado interbancario" (TI) (inter bank loan market) in operations done for a period between 27 and 33 days.

The sample period spans between 1/1/1980 and 12/31/1988. Although later data were available we decided to limit the sample period at such date for the following reasons: (i) Escriva's (1989) analysis ended up at the same date and we wanted to discuss his results; (ii) Spain became a member of the EMS in June 1989 possibly implying another change of regime; and (iii) after May 1990 central bank loan auctions were set at ten day intervals, becoming the rates ten day-rates thereafter.

Using the original data, eight different data sets were constructed and used later in empirical work, according to two criteria; (i) the treatment of missing values and (ii) the treatment of saturdays, since the inter bank market operated six days per week during the first part of the sample and only five days during the second part. More specifically, with respect to the treatment of missing values, we defined four different sets of data: a) we used for every non available (na) observation the value of the preceding observation; b) we dropped all observations for which there was any missing value; c) & d) we dropped the observation when there was a missing value in one of the series (SR or LR) independently of whether the other variable had a realized value for such date or was a missing value, in which case the value of the preceding observation was repeated. (Data sets c) & d) are intermediate cases between cases a) and b)). Similarly, another four data sets were created with the same definitions, but eliminating all observations for saturdays. The use of eight data sets presumably improves the robustness of our findings. In

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[3]Data were kindly provided by the Statistical Office of the Central Bank of Spain.

the next sections we provide results obtained from the first set of data, using observations for saturdays and repeating the former value whenever there is a missing value. The use of the alternative data sets does not change significantly our results either quantitatively or qualitatively, so that we may consider them quite robust.

4.- THE STOCHASTIC PROCESS OF THE SHORT RATE (SR).

Since informal arguments date a change of monetary control around the first half of 1984, we looked for evidence of a change in the stochastic process of the series for SR along that year. A higher control of the very short rate should show up in a reduction of the variance of the series sometime around that year. This section offers (1) descriptive statistics that show a change in behavior of the SR, (2) a univariate model for this variable.

We split the whole sample (1/1/1980-12/31/1988) into two sub-samples dropping a year in between: (i) 1/1/1980-9/30/1983 and (ii) 10/1/1984-12/31/1988. Main statistics are reported in table 1 for both sub-samples: sample mean, standard error, and auto correlations (1-30) for both levels and first differences.

When we compare corresponding statistics for the two sub-samples we find evidence of a different population lying behind. Comparing statistics for the variable -measured in levels- we find that the sample mean is 4.60 basis points higher for the first sub-sample, and so is the standard error 3.17 *versus* 2.27. That is to say, we find interest rates fluctuating more around a higher mean in the first sub-sample. Looking at the first difference in SR we also find a higher sample mean and a higher standard error for the first sub-sample; in fact we cannot reject the hypothesis that the sample mean is zero in any of the sub-samples, although the degree of significance is higher in the second sub-sample. Graph 1 shows two different measures of variability:

TABLE 1: DESCRIPTIVE STATISTICS OF THE SHORT TERM INTEREST RATE (TM)

Sub-sample: 1/1/1980-9/30/1983 (T=1174)

	Level	Difference
Sample Mean	17.3628	0.0098
Standard Error	3.1714	0.6018
t-Statistic	187.5849	0.5579
Signif. Level (Mean=0)	0.0000	0.5769

CORRELATIONS OF SERIES TM (SR)-LEVEL
Autocorrelations

1:	0.9797	0.9567	0.9366	0.9178	0.8988	0.8802
7:	0.8653	0.8533	0.8403	0.8227	0.8047	0.7898
13:	0.7771	0.7634	0.7501	0.7383	0.7266	0.7121
19:	0.6934	0.6739	0.6540	0.6348	0.6157	0.5972
25:	0.5824	0.5700	0.5570	0.5442	0.5316	0.5202

CORRELATIONS OF SERIES TM (SR) - DIFFERENCES
Autocorrelations

1:	0.0460	-0.0570	-0.0373	0.0052	-0.0103	-0.0992
7:	-0.0804	0.0249	0.1305	0.0087	-0.0849	-0.0627
13:	0.0301	-0.0128	-0.0420	-0.0004	0.0791	0.1169
19:	0.0219	0.0097	-0.0264	-0.0011	-0.0160	-0.1174
25:	-0.0642	0.0159	-0.0087	-0.0015	-0.0438	0.0166

Note: Aproximated standard errors for autocorrelations are 0.03

UNIT ROOT TEST

DF = -3.3289

ADF

Lags	
10	-3.0883
15	-2.6829
30	-2.7511

Non-Parametric Corrections

Window Size	
10	-3.2197
15	-3.2651
30	-3.3521

Critical Values

	10%	5%	3%	1%
t(rho-1)	-2.5700	-2.8600	-3.1200	-3.4300

COCHRANE'S (1988) MEASURE OF PERSISTENCE: Vk

Window Size	Vk	Asympt.SD
10	0.8520	0.0952
15	0.7907	0.1359
30	0.6758	0.1627
75	0.5832	0.1714
100	0.4152	0.1407
125	0.2634	0.0997
150	0.1667	0.0690
200	0.1714	0.0819

TABLE 1: DESCRIPTIVE STATISTICS OF THE SHORT TERM INTEREST RATE (TM)

(Continuation)

Sub-sample: 10/1/1984–12/31/1988 (T=1332)

	Level	Difference
Sample Mean	12.7718	–0.0004
Standard Error	2.2677	0.1377
t–Statistic	205.5514	–0.1193
Signif. Level (Mean=0)	0.0000	0.9049

CORRELATIONS OF SERIES TM (SR) – LEVEL

Autocorrelations

1:	0.9981	0.9960	0.9938	0.9916	0.9894	0.9871
7:	0.9846	0.9822	0.9793	0.9760	0.9726	0.9691
13:	0.9656	0.9620	0.9584	0.9548	0.9511	0.9473
19:	0.9433	0.9394	0.9354	0.9313	0.9270	0.9227
25:	0.9184	0.9138	0.9091	0.9042	0.8992	0.8942

CORRELATIONS OF SERIES TM (SR) – DIFFERENCES

Autocorrelations

1:	0.0569	0.0405	0.0008	–0.0062	0.0374	0.0198
7:	0.0089	0.1063	0.1329	0.0105	0.0349	0.0179
13:	0.0052	0.0049	0.0082	0.0055	0.0343	0.0244
19:	0.0027	0.0076	0.0556	0.0126	0.0273	0.0109
25:	0.0651	0.0673	0.0159	0.0300	0.0092	0.0097

Note: Aproximated standard errors for autocorrelations are 0.03

UNIT ROOT TEST

DF =–1.1035

ADF

Lags	
10	–1.5909
30	–1.6520
60	–2.0810

Non–Parametric Corrections

Window Size	
10	–1.2814
30	–1.5420
60	–1.7815

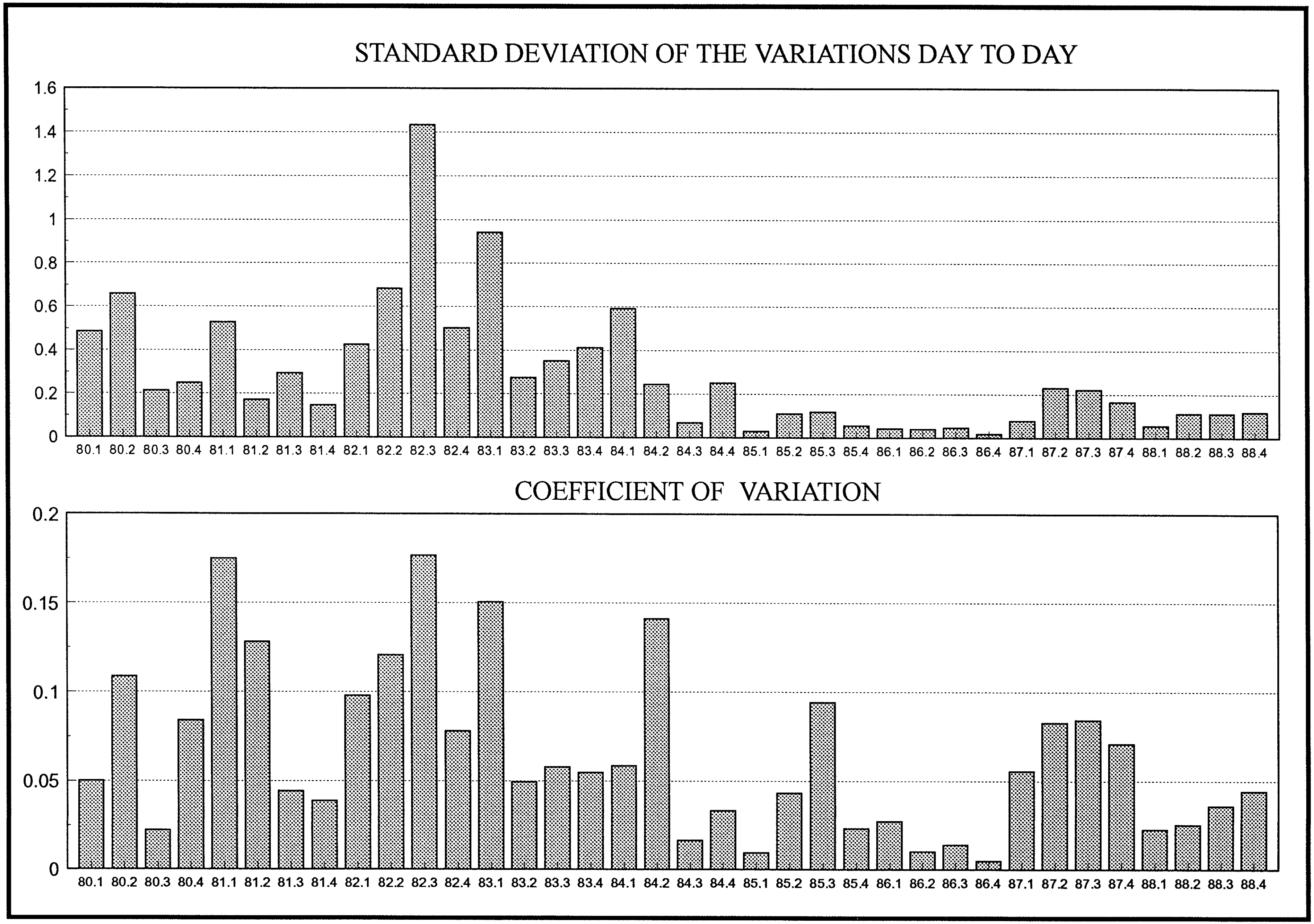
Critical Values

	10%	5%	3%	1%
t(rho–1)	–2.5700	–2.8600	–3.1200	–3.4300

COCHRANE'S (1988) MEASURE OF PERSISTENCE: Vk

Window Size	VK	Asympt.SD
10	1.3481	0.1415
25	1.8152	0.2929
50	2.4509	0.5539
75	2.9580	0.8162
100	3.3344	1.0606
125	3.6312	1.4900
150	3.8137	1.6013
200	3.7112	1.6660

GRAPH 1: VARIABILITY OF THE SR (TM).



namely, the standard deviation of the S.R. day to day variation and the coefficient of variation of the S.R. levels. Again, the series shows a lower variability for the second sub-sample.

According to Escrivá (1989) and looking into the auto correlation functions we find less persistence in the first sub-sample -smaller coefficients in levels and more negative values in the correlation coefficients on first differences-, probably meaning that changes in interest rates during the first part of the period were less permanent than in the second part, when monetary authorities let interest rates change only when the movement was considered convenient for the objectives of monetary policy. Negative values in the auto correlation coefficients for the first difference of the variable indicate a mean reverting process, where movements in one direction tend to generate compensating movements in the future that take away inertia from the series.

Unit roots tests were run (Dickey-Fuller (1979), Dickey-Fuller (1981) and Phillips-Perron (1988)), not being able to reject a unit root for the first sub-sample (the unit roots statistics are just between 5% and 1% significance levels) and clearly rejecting a second unit root for the same period. During the second half of the sample a unit root is clearly accepted and a second unit root is clearly rejected as well. So, the unit root is barely accepted in the first sample but clearly accepted in the second. A measure of persistence (Cochrane (1988)) shows a smaller degree for the SR in the first sub-sample.

Table 2 offers a univariate model for the SR. Given the unit root statistics reported in table 1 we estimate a model in differences. Using the criterion AIC[4] for simple AR models for first differences of SR, an AR(9) (not reported) was initially selected and estimated.[5]

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[4]We take 10 as the maximum possible lag.

[5]Other estimated models were AR(2) and AR(20), an under- and an over-parameterized model; for our purposes they produce, essentially the same results.

TABLE 2: UNIVARIATE PROCESS FOR THE SHORT TERM INTEREST RATE (TM)

Sub-sample: 1/1/1980 – 9/30/1983 (T=1174)

A general ARMA

Dep. Variable: DTM
Usable Obs.: 1164
SEE: 0.585
SSR: 395.867
D.W.: 2.004
Q(36): 26.270
Sig. Level of Q: 0.393

Variable	Coeff.	T-Stat.	Signif.
DTM(1)	0.034	1.167	0.244
DTM(2)	−0.050	−1.711	0.087
DTM(6)	−0.083	−2.836	0.005
DTM(7)	−0.055	−1.858	0.063
DTM(8)	0.024	0.805	0.421
DTM(9)	0.113	3.874	0.000
MA(12)	−0.078	−2.664	0.008
MA(24)	−0.100	−3.402	0.001
MA(25)	−0.066	−2.261	0.024
MA(26)	−0.006	−0.193	0.847
MA(35)	0.117	4.011	0.000

Persistence measure implied by the ARMA = 0.853

Sub-sample: 10/1/1984 – 12/31/1988 (T=1332)

A general ARMA

Dep. Variable: DTM
Usable Obs.: 1332
SEE: 0.135
SSR: 24.298
D.W.: 1.996
Q(36): 10.331
Sig. Level of Q: 0.995

Variable	Coeff.	T-Stat.	Signif.
DTM(1)	0.037	1.363	0.173
DTM(2)	0.033	1.227	0.220
DTM(6)	0.015	0.544	0.587
DTM(7)	−0.005	−0.200	0.842
DTM(8)	0.096	3.542	0.000
DTM(9)	0.120	4.378	0.000
MA(12)	0.012	0.434	0.665
MA(24)	−0.006	−0.216	0.829
MA(25)	0.056	1.998	0.049
MA(26)	0.054	1.917	0.055
MA(35)	0.017	0.618	0.537

Persistence measure implied by the ARMA = 1.609

Since we found some auto correlation left in the estimated model for the first sub-sample ($Q(36) = 68.38$), we estimated a general ARMA (table 2) on the SR differences model for both sub-samples. This model reduced the degree of auto correlation ($Q(36) = 26.27$) for the whole sample and showed again a higher persistence for the second half of the sample, meaning a higher tendency of any variation to stay permanently.

Although the ARMA models improve the simple AR models we can hardly use them any further when we want to find the exact timing of the change of regime.

5.- WAS IT REALLY A CHANGE IN REGIME?

This section offers statistical evidence on the effect of the change in the monetary regime on the stochastic process for the SR. It also tries to pin down the exact time in which the regime occurred. To do this we begin by determining the most likely date for the change to occur, conditional on the assumption that the change took place all at once.

5.1.- Step switching.

Assume that the process for SR obeyed the following general ARMA(p,q) process in first differences

$$\begin{aligned} \theta_o (L)\, \Delta SR_t &= \phi_o(L)\, \varepsilon_{ot} \qquad && t = 1,\ldots,T_S \\ \theta_n (L)\, \Delta SR_t &= \phi_n(L)\, \varepsilon_{nt} \qquad && t = T_S+1,\ldots,T \end{aligned} \tag{1}$$

where $\theta_i(L) = 1 - \theta_{i1}L - \theta_{i2} L^2 - ... - \theta_{iP} L^P$, and $\phi_i(L) = 1 - \phi_{i1}L - \phi_{i2} L^2 - ... - \phi_{iq} L^q$, $i = 0,n$; and T_S is the switch date, the last period of the old regime.

This model is known as *deterministic switching on the basis of time.* The goal is to find an estimate of T_S so that such particular date is the most likely date for the entire transition to take place. We use a maximum likelihood (ML) procedure suggested by Goldfeld and Quandt (1976).

Assuming normal errors, the (approximated) log-likelihood for model (1) is,

$$\text{Log } \Phi = - \frac{T}{2}.\ \log(2\pi) - \frac{T_S}{2}.\ \log \sigma_0^2 - \frac{T-T_S}{2}.\ \log \sigma_n^2 - \frac{1}{2}.\sum_{t=1}^{T_s} \frac{\varepsilon_t^2}{\sigma_0^2} - \frac{1}{2}.\sum_{t=T_s+1}^{T} \frac{\varepsilon_t^2}{\sigma_n^2} \tag{2}$$

where σ_0^2 and σ_n^2 are the error variances in the old and new regime respectively, which are allowed to differ. We can determine the ML value for T_S by computing the ML estimates of the parameters for all possible T_S's and then choosing the value of the T_S with the maximum likelihood; we call this date the *most likely switching date* (MLSD).[6]

Table 3 shows the maximized log-likelihood of various possible switch dates around the MLSD.[7]

To judge the degree of confidence one should have on these point estimates, we calculate the *posterior odds ratio* for alternative switch dates. If we start from diffuse priors, which means that we consider all possible switch dates equally likely, then the ratio of the likelihood values for

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[6]Note that T is an integer, so standard regularity conditions on ML estimates don't apply.

[7]The search was done from 1/1/1983 until 12/31/1984, even if only results for the first half of 1984 are reported. A RATS procedure was developed to perform the calculations and is available from the authors, upon request.

different switch dates relative to the maximal likelihoods produces the posterior odds ratio. The posterior odds ratio is the ratio of subjective probabilities of different switch dates conditioned on the data. A useful interpretation of the posterior odds ratio is as a simple metric for judging how flat or steep the likelihood function is.[8]

TABLE 3: SWITCH DATE FOR THE STOCHASTIC PROCESS OF THE SHORT INTEREST RATE (TM)

Process: ARMA

Date	Log-Likelihood	Posterior Odds Ratio
3/2/1984	3680.2	0.15970
3/3/1984	3681.3	0.45778
3/5/1984	3679.9	0.11120
3/6/1984	3678.5	0.02655
3/7/1984	3677.0	0.00638
3/8/1984	3675.6	0.00153
3/9/1984	3674.2	0.00033
3/10/1984	3673.6	0.00021
3/12/1984	3671.8	0.00003
6/4/1984	**3682.1**	**1.00000**
6/5/1984	3680.3	0.26488
6/6/1984	3679.3	0.06485
6/7/1984	3677.9	0.01507
6/8/1984	3676.4	0.00351
6/9/1984	3675.0	0.00082
6/10/1984	3673.5	0.00018
6/12/1984	3672.0	0.00004
6/13/1984	3671.080	0.00001

Maximum Value of Likelihood is 3682.1 at 6/4/1984 (This is the most probably date of the end of the old regime)
Likelihood ratio of the hypothesis of no-switching (This is a test conditional on a known date for the switching) Chi-Squared(12)= 2338.990 with significance level 0.000

Note: Log-likelihood is the log of the likelihood function. The posterior odds ratio is the probability that the switch occured at that date relative to the probability with the highest likelihood; this calculation is based on the estimated likelihood value and difffuse priors.

[8]Note that for each possible switch date, the remaining parameters are chosen to maximize the likelihood function. An alternative calculation, still more in the Bayesian spirit, would be to posit a prior joint distribution over all the parameters, to use the likelihood function to yield a posterior joint distribution over all the parameters, and then to integrate out the remaining parameters to produce the posterior marginal distribution for the switch date. (Holbert (1982)). It's difficult to say if this would produce the same results but it would certainly complicate the numerical analysis; our guess is that it would all depend on the priors (as always happens with Bayesian analysis) but since our prior from the literature is that the switch date occurs along the first half of 1984, it does not seem too unfair to consider all days along this period equally likely.

Table 3 also shows, for a range of possible switch dates, the posterior odds ratio of that date as a switch date compared to the ML date, and a likelihood ratio of the hypothesis of no-switching conditional on a known date for the switching, which we take to be the MLSD. A graph of the posterior odds ratio (graph 2) offers a visual impression of these results. They appear quite robust since we obtained similar (quantitative and qualitative) conclusions with different ARMA and AR models.

The change of regime is detected around the beginning of June 1984. The peculiar fact however is, that data reveal an extremely fast change; more precisely, a complete change in **one** single day, i.e. we face a very steep likelihood function (in fact, too steep to be believable!). These results are similar to those reported in Mankiw et al. (1987) dealing with the change of regime implied by the birth of the Federal Reserve System in the US. However we recognize their use of quarterly data, making a complete change experienced in one period a more acceptable outcome. In daily frequencies more probability mass around the MLSD should be expected, rather than concentrated completely in one single day. Since some evidence of a change appears at the beginning of March and concentrates during the first weeks of June one could loosely interpret this result as a change of regime that started in March and was completed by mid June 1984, a question that can be investigated with a gradual switching technique, where a logistic transition function is estimated, allowing for a much more flexible transit between different regimes.

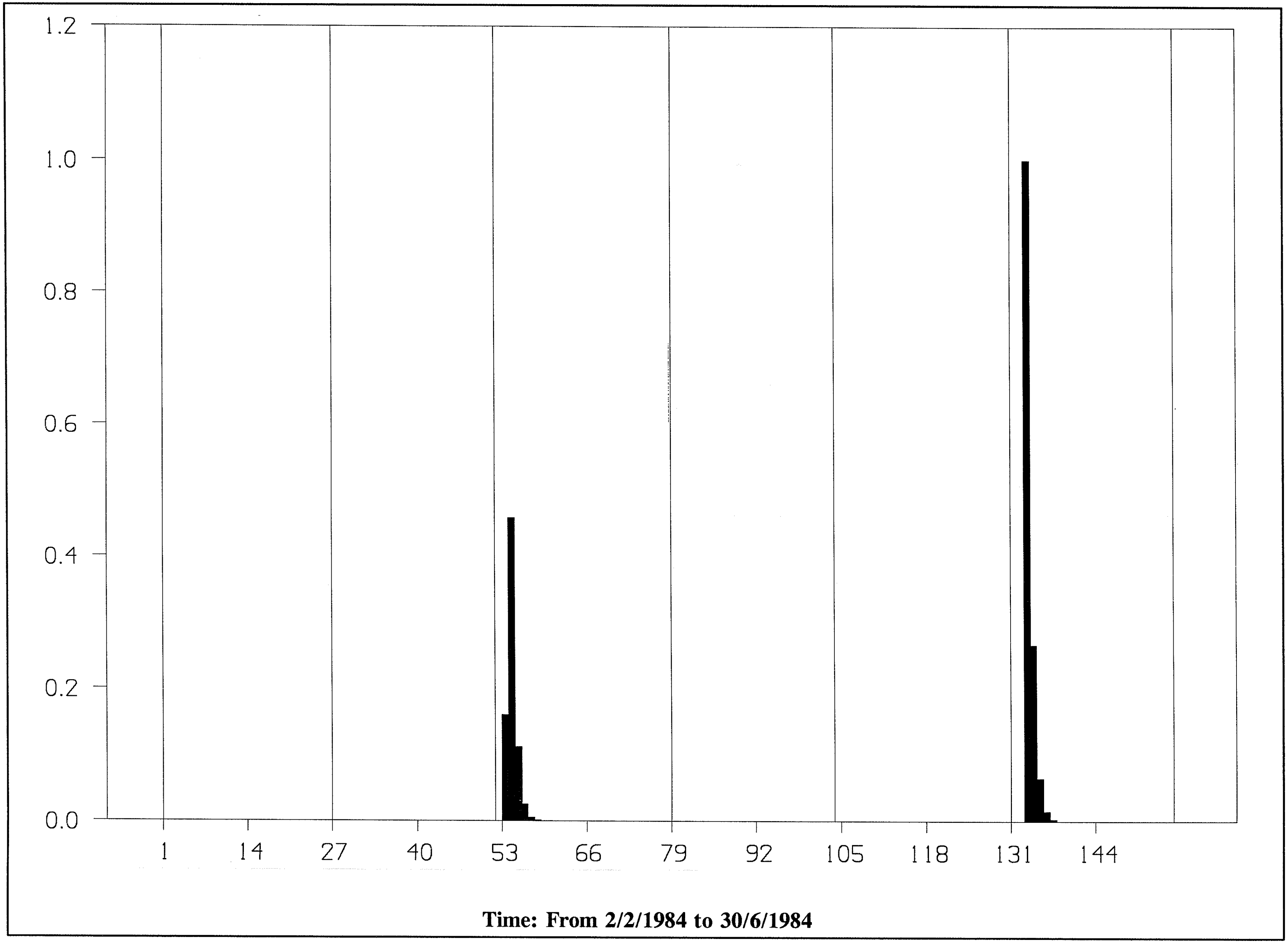
5.2.- Gradual switching.

Consider now the possibility that the change in regime occurred gradually over time.

Assume that the process for the short rate obeys the following time-varying ARMA(p,q) process in first differences in which the coefficients are allowed to change gradually over time, rather than moving instantaneously

GRAPH 2: POSTERIOR ODDS RATIO

Univariate Process for the SR Interest Rate - ARMA Model



from the old to the new regime values as in the step switching above.[9]

$$\theta_t(L)\Delta SR_t = \phi_t(L)\varepsilon_t \qquad t = 1,....,T$$

where

$$\theta_t(L) = 1 - \theta_{t1}L - \theta_{t2}L^2 - ... - \theta_{tp} L^p , \tag{3}$$
$$\phi_t(L) = 1 + \phi_{t1}L + \phi_{t2}L + ... + \phi_{tq} L^q .$$

The parameters for this process change as

$$\theta_{ti} = (1-L_t)\theta_{oi} + L_t\theta_{ni} , \qquad i = 1,...,p$$

$$\phi_{ti} = (1-L_t)\phi_{oi} + L_t\phi_{ni} , \qquad i = 1,...,q$$

$$\sigma^2_t = (1-L_t)^2 . \sigma^2_o + L^2_t . \sigma^2_n$$

where "o" represents the old regime, "n" the new one and

$$L_t = \frac{e^{\alpha+\delta t}}{1 + e^{\alpha+\delta t}}$$

is a logistic trend.

Together all the parameters of the short rate process adjust continuously. Parameters α and δ determine when the change in regime occurred; α is a location parameter and δ is a slope parameter that indicates the speed of adjustment from the old to the new regime. Note that as $\delta \Rightarrow \infty$, L_t becomes a step function, so this time-varying parameter model includes the step switching as an extreme limiting case. (Full details of the behavior of the logistic trend are given in the appendix).

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[9]This process can be obtained just multiplying the first equation in (1) by $(1-L_t)$, the second by L_t and adding.

In particular, it is not difficult to show that at $t = -\alpha/\delta$, $L_t = 1/2$ and the logistic curve is at its inflexion point. At such moment of time, the short rate process is an equal mix of the old and the new regimes. To judge the speed of the change in regime we define implicitly the dates at which $L_{t_0} = 1/4$ and $L_{t_1} = 3/4$, so $t_1 - t_0$ is the time it takes for the parameters to make one half of the adjustment symmetrically around the inflexion point, (i.e. from one-fourth to three-fourths into the new regime). Straightforward algebra shows that $t_1 - t_0 = \ln(9)/\delta$. (see appendix).

This model could be called *deterministic logistic switching on the basis of time.*

Parameters were estimated using a ML method (Goldfeld and Quandt (1976)).[10] Assuming normal errors the (approximated) log-likelihood function for model (3) is

$$\text{Log } \Phi = -\frac{T}{2}.\log(2\pi) - \frac{1}{2}\sum_{t=1}^{T} \log\left[(1-L_t)^2.\sigma_o^2 + L_t^2.\sigma_n^2\right] - \frac{1}{2}\sum_{t=1}^{T} \frac{\varepsilon_t^2}{(1-L_t)^2.\sigma_o^2 + L_t^2.\sigma_n^2} \tag{4}$$

where ε_t is given by (3).

To avoid the possibility to converge to a local maxima we used a sufficiently wide range of values of α and δ, choosing the remaining parameters to maximize the likelihood function (4)[11]. For different rates of

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[10]Calculations for the *logistic* part of the paper were done with TSP using a double algorithm. Given initial values, the BHHH algorithm was used until the model converged or, alternatively, after 20 iterations, whatever happened first; and then the Newton-Rapson algorithm was used afterwards until final convergence was achieved.

[11]Another reason to do this is that α and δ, although continuous in our formulation, are discrete parameters in nature (they are the equivalent to T_s in the previous section), so it makes sense to consider only integer values in

adjustment (δ), we present the maximum likelihood switch date, interpreted in this case as $L_{T_s} = 1/2$; the maximum likelihood value achievable with that rate of adjustment and switching date; and the posterior odds ratio for those values of the switching date and δ relative to the maximal likelihood.[12]

Results are presented in table 4. Graph 3 offers a visual impression of the results.

TABLE 4: LOGISTIC SWITCHING FOR THE SHORT INTEREST RATE PROCESS (TM)

Date	Days for 1/2 of switch	Log-Likelihood	Posterior Odds Ratio	Date	Days for 1/2 of switch	Log-Likelihood	Posterior Odds Ratio
4/2/1984	75	3658.8	0.31849	5/11/1984	75	3659.7	0.78222
4/2/1984	81	3659.1	0.43219	5/11/1984	76	3659.7	0.71712
5/2/1984	69	3658.6	0.25427	5/11/1984	80	3659.2	0.45540
5/2/1984	75	3659.3	0.51737	5/12/1984	60	3659.4	0.55958
5/4/1984	69	3659.2	0.45979	5/12/1984	65	3659.9	0.92138
5/4/1984	75	3659.7	0.72054	5/12/1984	69	3660.0	0.98558
5/7/1984	65	3659.1	0.42254	5/12/1984	75	3659.9	0.69648
5/7/1984	69	3659.6	0.70350	5/12/1984	80	3659.0	0.37912
5/7/1984	70	3659.7	0.75995	5/14/1984	60	3659.5	0.64486
5/7/1984	75	3659.8	0.86095	5/14/1984	65	3659.9	0.94391
5/7/1984	80	3659.6	0.67643	5/14/1984	69	3659.9	0.93310
5/8/1984	65	3659.4	0.53965	5/14/1984	75	3659.5	0.59824
5/8/1984	69	3659.8	0.81730	5/14/1984	80	3658.8	0.30540
5/8/1984	75	3659.9	0.88900	5/15/1984	60	3659.6	0.70838
5/8/1984	80	3659.5	0.64511	5/15/1984	65	3659.9	0.92631
5/9/1984	60	3658.7	0.27339	5/15/1984	69	3659.8	0.84901
5/9/1984	65	3659.6	0.65920	5/15/1984	75	3659.3	0.49595
5/9/1984	69	3659.9	0.91099	5/16/1984	60	3659.7	0.74210
5/9/1984	70	3659.9	0.94326	5/16/1984	65	3659.8	0.87123
5/9/1984	75	3659.9	0.88409	5/16/1984	69	3659.7	0.74286
5/9/1984	80	3659.5	0.59432	5/16/1984	70	3659.6	0.68939
5/10/1984	60	3659.0	0.36442	5/16/1984	75	3659.1	0.39702
5/10/1984	65	3659.7	0.77026	5/17/1984	60	3659.7	0.74190
5/10/1984	69	3660.0	0.97425	5/17/1984	65	3659.7	0.78585
5/10/1984	75	3659.8	0.84707	5/17/1984	69	3659.5	0.62538
5/10/1984	80	3659.3	0.52911	5/17/1984	70	3659.4	0.57137
5/11/1984	60	3659.2	0.46268	5/17/1984	75	3658.8	0.30708
5/11/1984	65	3659.8	0.86113	5/18/1984	60	3659.6	0.70828
5/11/1984	**69**	**3660.0**	**1.00000**	5/21/1984	60	3659.4	0.56397

NOTE: Log.likelihood is the log of the likelihood function for the set of parameters that maximizes the likelihood for given values of alpha and delta. The posterior odds ratio is the probability of given values of (alpha,delta) relative to the probability of values of (alpha,delta) with the highest likelihood; this calculation is based on the estimated likelihood value and diffuse priors.

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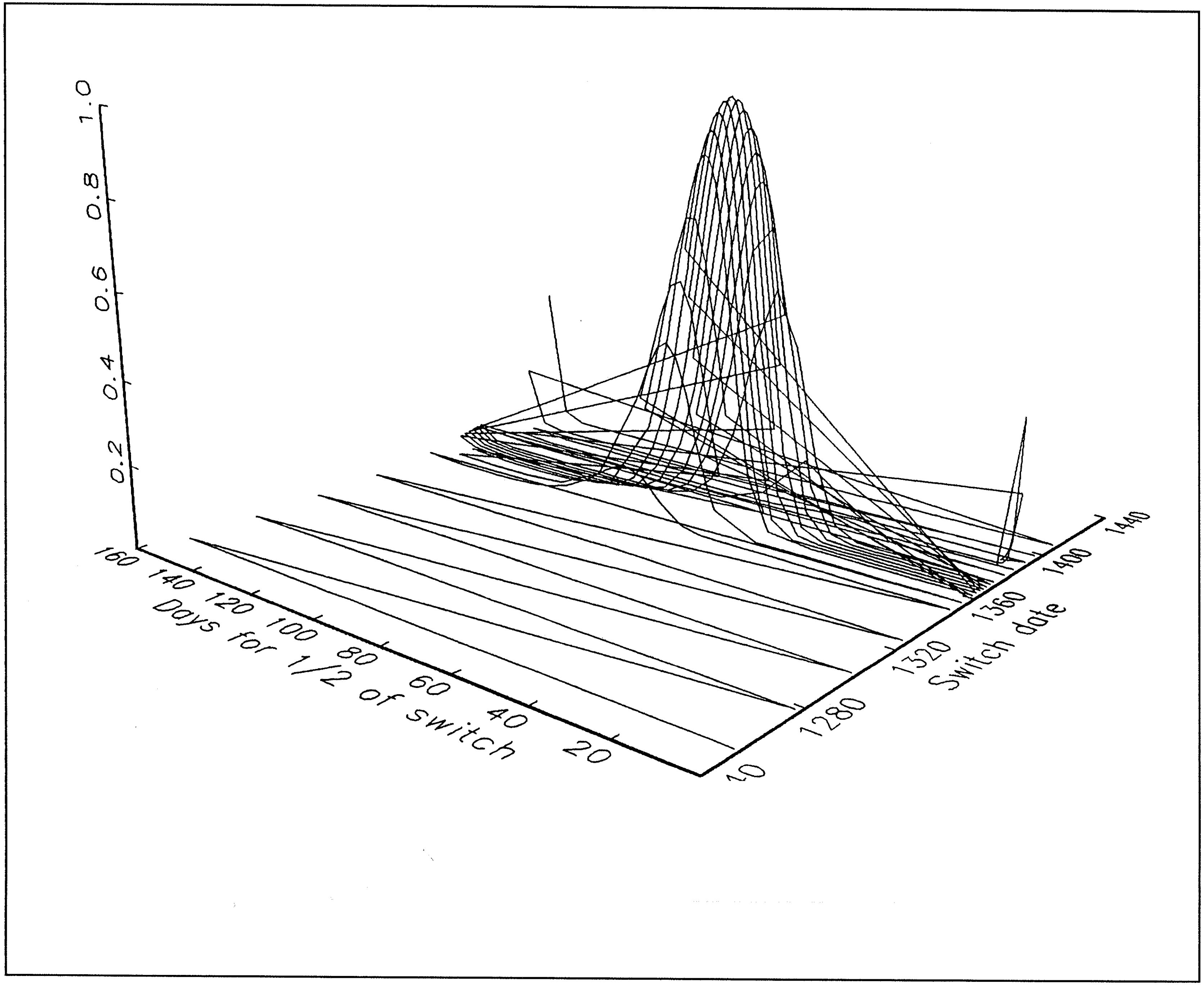
order to maximize (4). Initial values were taken from the corresponding models in table 3.

[12]Because the ARMA likelihood function was difficult to program in the logistic switching model this part of the paper was done using the AR(9) model.

GRAPH 3: POSTERIOR ODDS RATIO

Logistic Switching - AR model



Results are somewhat different from the ones obtained with the step switching model. The switch date is now located around the first half of May/1984 but, more importantly, the posterior odds ratio shows clearly that one half of the change in regime took about 3 months. One can conclude that the likelihood function is not as steep as the step switching model apparently indicated.

5.3.- Conclusions.

What can we conclude from the two sections above? Apparently they give different results, but they are, in fact, consistent witch each other.

The step switching model is forced to give us a single date for the regime switch, and therefore is forced to choose a date when the change in regime is well advanced; about 70% of the change had already occured at the beginning of June/1984 if we took as "true" the logistic curve estimated above. The univariate process for SR should be highly unstable during this period, which can justify the big changes in the likelihood function shown in table 3. It is worth noting, however, that the step switching also signals "something" at the beginning of March/1984 so we can now be confident that the change in regime occurred gradually over the second quarter of 1984[13].

[13]We should recognize that during 1983 some changes were introduced in the reserve requirements coefficient, which might have altered the functioning of the interbank loan market and hence the term structure of interest rates.

6.- THE RELATIONSHIP BETWEEN THE SHORT (SR) AND THE LONG RATE (LR).

Further evidence on the timing of the monetary policy change of regime realized in Spain in the mid eighties, can be derived from the analysis of the relationship between short and long term interest rates. More specifically, a change of regime would imply a modification of the term structure of interest rates once agents learn and adapt their behavior to the new monetary rule. As the Lucas (1976) critique suggests, one should not expect the relation between the LR rate and the SR rate to remain invariant when there is a fundamental change in the stochastic process generating the SR rate. Expectations should end up being consistent with the new informational content of interest rates, and this alters the term structure. This section shows evidence on how rapidly the Spanish market adapted to the new state, taking the complete process about a week.

According to the Expectations Theory of the Term Structure of interest rates, long rates are formed as averages of current short rates and expected future short rates. The pure version assumes that only expectations determine such structure, so that annual returns of holding short and long term assets are exactly equal. Other approaches recognize agent biases towards the short side of the market -implying the presence of a liquidity premium- or else, the existence of segmented markets with low substitutability between different term assets. For our purposes only the expectational effect, -present in all approaches in a higher or lesser degree- will be relevant, since apparently no further meaningful institutional change took place during this period. Hence, in general, long rates exceed short rates only if short rates are expected to go up in the future. Similarly, long rates are lower than short rates if short rates are expected to fall. In the first case we have a rising yield curve, while in the second case we have a downward sloping yield curve.

In general we may write,

$$LR_t = \frac{1}{k} . \sum_{j=1}^{k} E_t SR_{t+j-1} + \theta_t \tag{5}$$

where E_t denotes the expectation conditional on information available at time t, $E_t = E(°| \Omega_t)$ and θ_t denotes the term premium. We know that the pure expectations hypothesis imposes $\theta_t=0$ for all t, or at least that it follows a stationary process. Other approaches that incorporate different assumptions about this premium would still be consistent with the framework described here. We will assume, for simplicity, $\theta_t = 0$, so that it is a case of an *exact linear rational expectation model*[14].

In a stationary world, given a stochastic process for SR_t, we can obtain the process for LR_t which will contain no error term. Equation (5) -above- imposes cross-equation restrictions among the coefficients of an unrestricted bivariate VAR between SR_t and LR_t. By testing these restrictions the theory is tested in a usual fashion.[15]

In a non-stationary world, assuming SR_t and LR_t are integrated of order 1 and subtracting SR_t from both sides of equation (5) we get equation (6)

$$LR_t - SR_t = \frac{1}{k}\sum_{j=1}^{k} E_t SR_{t+j-1} - SR_t \tag{6}$$

$$= \frac{1}{k}\sum_{i=1}^{k-1}\sum_{j=1}^{i} E_t \Delta SR_{t+j}$$

The right hand side of equation [5] is a finite sum of stationary variables and hence stationary[16]. Given these conditions, it follows that the left hand side of [5] is stationary, so LR_t and SR_t are cointegrated and (1,-1)' is a cointegrating vector. It follows that expectations-based theories of the term structure imply that in a unit root world the long term and the short term rate are cointegrated with cointegrating vector (1,-1)'; i.e. the spread $S_t = LR_t-SR_t$ is stationary.[17]

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[14]See Hansen and Sargent (1991).

[15]See Sargent (1979) for a complex application in our context or Mankiw *et al* (1987) for a simple one.

[16]With $\theta_t \neq 0$ this is true as long as premia are stationary.

[17]See Campbell and Schiller (1987) and Hall *et al.* (1992).

In this non-stationary world the theory also places cross-equation restrictions among the coefficients of an unrestricted reduced form for LR_t and SR_t, but now we have to work with a VECM or with a VAR of ΔLR_t or ΔSR_t and S_t. In addition, the theory also imposes a LR restriction. (Campbell and Schiller (1987)).

Table 5 contains some descriptive statistics -for both sub-samples- regarding the behavior of long term interest rates LR. As with the SR, we find less variability and more persistence in the second than in the first sub-sample: (i) lower standard errors for levels, (ii) higher auto correlation coefficients for levels, (iii) smaller number of negative values of the corresponding coefficients when first differences are estimated and (iv) higher values of the estimated measure of persistence support this statement. Furthermore we are unable to reject a unit root in both sample periods -with more confidence for the second sub-sample-, so we are ready to look for a cointegration relationship.

For our purposes it is interesting to see how day to day changes in interest rates affect expectations and therefore move the long rate. If agents are rational and learn that the monetary authority has decided to stabilize short term interest rates and that it will only let them change when it is meant to be an indication of the future course of monetary policy -whether it will be looser or tighter-, they will expect that every movement in short rates is there to last; more so, after rather than before the change in regime. For this reason we should find a higher elasticity of expectations during the second sub-sample than during the first part of the whole period. Since expectations cannot be observed we may check whether the long rate, which incorporates them, will become more sensitive towards short rate changes during the second half of the period. This evidence would tell us that agents have learned fairly quick of the change of regime and have consequently adapted their behavior.

As mentioned in section 2, monetary authorities decided to control the very short rate letting the market freely determine the longer term rate. This means that if we find evidence of the presence of a change in the long rate elasticity with respect to the short term rate, we would be able to interpret such point in time as the moment in which people realized and assimilated this

TABLE 5: DESCRIPTIVE STATISTICS OF THE LONG INTEREST RATE (TI)

Sub-sample: 1/1/1980–9/30/1983 (T=1174)

	Level	Difference
Sample Mean	16.5335	0.0074
Standard Error	2.5798	0.4279
t-Statistic	219.5888	0.5976
Signif. Level (Mean=0)	0.0000	0.5502

CORRELATIONS OF SERIES TI (LR) – LEVEL

Autocorrelations

1:	0.9836	0.9747	0.9674	0.9576	0.9491	0.9395
7:	0.9284	0.9181	0.9064	0.8949	0.8835	0.8733
13:	0.8602	0.8481	0.8367	0.8236	0.8123	0.8013
19:	0.7886	0.7765	0.7627	0.7496	0.7638	0.7230
25:	0.7093	0.6945	0.6779	0.6615	0.6447	0.6293

CORRELATIONS OF SERIES TI (LR) – DIFFERENCES

Autocorrelations

1:	–0.2411	–0.0525	0.0814	–0.0352	0.0483	0.0602
7:	–0.0386	0.0215	–0.0286	–0.0146	–0.0490	0.1071
13:	–0.0398	–0.0205	0.0609	–0.0548	–0.0171	0.0722
19:	–0.0275	0.0533	–0.0314	–0.0072	0.0313	–0.0044
25:	0.0486	0.0564	–0.0211	0.0083	–0.0546	0.0321

Note: Aproximated standard errors for autocorrelations are 0.03

UNIT ROOT TEST

DF = –2.5979

ADF

Lags	
10	–2.0370
15	–2.1096
30	–2.8703

Non-Parametric Corrections

Window Size	
10	–2.0718
30	–2.4172
60	–2.6014

Critical Values

	10%	5%	3%	1%
t(rho–1)	–2.57	–2.86	–3.12	–3.43

COCHRANE'S (1988) MEASURE OF PERSISTENCE: Vk

Window Size	Vk	Asympt.SD
10	0.6325	0.0707
25	0.6748	0.1160
50	0.7190	0.1731
75	0.5779	0.1698
100	0.4593	0.1556
125	0.3529	0.1335
150	0.2671	0.1106
200	0.2577	0.1232

TABLE 5: DESCRIPTIVE STATISTICS OF THE LONG INTEREST RATE (TI)
(Continuation)

Sub-sample: 10/1/1984-12/31/1988 (T=1332)

	Level	Difference
Sample Mean	12.8076	0.0001
Standard Error	2.4387	0.2112
t-Statistic	191.6696	0.0116
Signif. Level (Mean=0)	0.0000	0.9906

CORRELATIONS OF SERIES TI (LR) – LEVEL
Autocorrelations

1:	0.9962	0.9930	0.9894	0.9854	0.9810	0.9759
7:	0.9706	0.9652	0.9594	0.9536	0.0948	0.9425
13:	0.9374	0.9318	0.9267	0.9220	0.9175	0.9130
19:	0.9086	0.9041	0.8997	0.8955	0.8912	0.8869
25:	0.8824	0.8782	0.8736	0.8687	0.8638	0.8585

CORRELATIONS OF SERIES TI (LR) – DIFFERENCES
Autocorrelations

1:	-0.0752	0.0612	0.0480	0.0430	0.1080	0.0241
7:	0.0023	0.0651	0.0044	-0.0630	0.0379	-0.0787
13:	0.0645	-0.0576	-0.0596	-0.0265	0.0026	-0.0080
19:	-0.0008	-0.0057	-0.0211	0.0160	-0.0067	0.0238
25:	-0.0312	0.0548	0.0242	0.0107	0.0569	0.0773

NOTE: Aproximated standard errors for autocorrelations are 0.03

UNIT ROOT TEST

DF =-1.5785 -1.5785

ADF

Lags	
10	-1.7817
15	-1.8179
30	-1.9702

Non-Parametric Corrections

Window Size	
10	-1.9139
30	-1.7189
60	-2.1866

Critical Values

	10%	5%	3%	1%
t(rho-1)	-2.57	-2.86	-3.12	-3.43

COCHRANE'S (1988) MEASURE OF PERSISTENCE: Vk

Window Size	Vk	Asympt.SD
10	1.2664	0.1329
25	1.2894	0.1914
50	1.4671	0.3316
75	1.6044	0.4427
100	1.6867	0.5365
125	1.7645	0.6269
150	1.8781	0.7304
200	1.7923	0.8042

NOTE: Calculated by Campbell & Mankiw (1987)
Calculations are biased corrected by factor: NOBS/(NOBS-K)

change of regime.

Table 6 offers evidence of cointegration between both interest rates for both sub-samples, and shows differences in the long run response of the LR rate to the SR rate variations across regimes. Dickey-Fuller and usual non-parametric corrections tests do not lead us to reject cointegration for both sample periods, and the evidence is much more clear for the second period than for the first one. It is interesting to note the smaller long run response of the LR to variations in the SR over the first sub-sample than along the second sub-sample, (0.67 *versus* 1.03). According to these estimates, over the first sub-period, if the short rate went up one percentage point forever the LR would go up only 0.67 percentage points in the long run[18], while it would be completely incorporated -1.04- in the LR in the second part of the sample period. For the first part of the sample we can reject cointegration when the number of lags in the augmented Dickey-Fuller test reaches 15. The second part of the sample shows more confidence towards not rejecting a relationship of cointegration between the LR and the SR.

The long run multiplier we obtained for the first part of the sample is significantly smaller than one, so the long run restriction is not satisfied. Note, however, that for this period of interest rate control we can still accept (marginally) the cointegration result, so a long run relation between both interest rates can still be found although without a unitary long run response.

Exactly the same kind of result is found in Hall et al. (1992) for the United States. They conclude that in periods of interest rate targeting the statistical tests support the predictions of the theory. However these relationships appear to have broken down during a period in which the Fed targeted non-borrowed reserves, letting the Federal fund market interest rate fluctuate much more widely. Over this period the authors observed a change in the cointegrating relationships between Treasury Bill yields. Yields were still cointegrated but the spreads no longer defined the cointegration

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[18]This value goes down to .48 when the estimation period runs from 1/1/1980 to 12/31/1982.

TABLE 6: COINTEGRATION BETWEEN THE LR (TI) AND SR (TM) INTEREST RATE

Sub-sample: 1/1/1980 – 9/30/1983 (T=1174)

Cointegration regression (Estimation by Least Squares)

Dep. Variable: TI
Usable Obs.: 1174
Centered R2: 0.6702
SEE: 1.4819
D.W.: 0.1507

Variable	**Coeff.**
Constant	4.9701
TM	0.6659

DICKEY-FULLER (1979) TEST

Lags	
10	–3.7300
15	–3.0505
30	–2.6780

NON PARAMETRIC CORRECTIONS

W. Size	
10	–5.8372
30	–6.9938
60	–8.3671

Sub-sample: 1/10/1984 – 31/12/1988 (T=1332)

Cointegration regression (Estimation by Least Squares)

Dep. Variable: TI
Usable Obs.: 1132
Centered R2: 0.9329
SEE: 0.6317
D.W.: 0.1437

Variable	**Coeff.**
Constant	–0.4591
TM	1.0387

DICKEY-FULLER (1979) TEST

Lags	
10	–4.9254
15	–4.2939
30	–4.3780

NON PARAMETRIC CORRECTIONS

W. Size	
10	–6.4260
30	–7.2293
60	–7.9045

Cointegration test: Uniroot statistics on the residuals – ADF – PP

Critical Values:	10%	5%	2.5%	1%
t(rho–1)	–3.0657	–3.3654	–3.642	–3.9618

relationships. They argue that during this period the term premia became non-stationary, causing a breakdown of the cointegrating relationship. However the reasons for such change remain unclear.

Table 7 offers an Error Correction Model (ECM) for both sub-samples. We proceed from a fairly general autoregresive distributed lag model and end up with a model containing 12 lags of the differences in the long rate (ΔLR), 6 lags plus the current period for the differences in the short rate (ΔSR), and, finally, the error correction term. Estimation was performed using the non-linear least squares procedure of Stock (1987)[19]. A Hausman (1978) exogeneity test for the current period of SR was run[20] according to which we could not reject exogeneity at the 5% level in both sub-samples. This last result justifies the use of single equation methods.

It should be noted that the error correction term is highly significant, a result reinforcing cointegration. Furthermore, it's worth noting that although there are some differences in the long-run response values when we estimate the static or the ECM by non-linear least squares regression (.67, .73; 1.04, .92), we find similar evidence of a change in regime having taken place between both sub-samples. After the change, long rates became more responsive in the long run to movements observed in the short rate, a possible indication of a higher information content attributed by agents to fluctuations of the short rate.

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[19]The non-linear estimation was initialized with the parameters obtained from the Engle and Granger (1987) estimation procedure.

[20]The instruments used to construct the test are 12 lags of the differences in LR, 9 lags of the differences in SR, 1 lag of LR, 1 lag of SR and a constant term.

TABLE 7: AN ECM FOR THE RELATION BETWEEN THE LR (TI) AND THE SR (TM) INTEREST RATE

Sub-sample: 1/1/1980 – 9/30/1983 (T=1174)

(1) Engle & Granger (1987): 2nd step

Estimation by Least Squares

Dep. Variable: DTI
Usable Obs.: 1161
SEE: 0.4031
SSR: 185.450
D.W.: 1.968
Q(36): 35.698
Sig. Level of Q: 0.482

Variable	Coeff.	T-stat.	Signif.
DTI(1)	−0.273	−9.123	0.000
DTI(2)	−0.132	−4.268	0.000
DTI(3)	0.023	0.735	0.463
DTI(4)	−0.002	−0.050	0.960
DTI(5)	0.057	1.839	0.066
DTI(6)	0.074	2.428	0.015
DTI(7)	−0.006	−0.198	0.843
DTI(8)	0.000	0.011	0.991
DTI(9)	−0.049	−1.613	0.107
DTI(10)	−0.043	−1.401	0.161
DTI(11)	−0.062	−2.021	0.044
DTI(12)	0.077	2.623	0.009
DTM	0.049	2.448	0.014
DTM(1)	0.051	2.500	0.013
DTM(2)	0.012	0.614	0.539
DTM(3)	0.067	3.285	0.001
DTM(4)	0.016	0.808	0.419
DTM(5)	0.027	1.349	0.178
DTM(6)	0.049	2.394	0.017
ECM1(1)	−0.028	−3.276	0.001

HAUSMAN (1978) Exogeneity test for TM
Normal Statistic = 0.5833 with Significance Level 0.5596

(2) Stock (1987): NLLS

Estimation by Nonlinear Least Squares

Dep. Variable: DTI
Usable Obs.: 1161
SEE: 0.4034
SSR: 185.3579
D.W.: 1.9966

Variable	Coeff.	T-stat.	Signif.
DTI(1)	−0.274	−9.130	0.000
DTI(2)	−0.133	−4.283	0.000
DTI(3)	0.022	0.712	0.477
DTI(4)	−0.002	−0.073	0.942
DTI(5)	0.056	1.809	0.071
DTI(6)	0.073	2.390	0.017
DTI(7)	−0.007	−0.242	0.809
DTI(8)	−0.001	−0.047	0.963
DTI(9)	−0.051	−1.666	0.096
DTI(10)	−0.045	−1.460	0.145
DTI(11)	−0.064	−2.074	0.038
DTI(12)	0.075	2.552	0.011
DTM	0.050	2.472	0.014
DTM(1)	0.050	2.428	0.015
DTM(2)	0.011	0.559	0.576
DTM(3)	0.066	3.221	0.001
DTM(4)	0.016	0.765	0.445
DTM(5)	0.027	1.307	0.191
DTM(6)	0.048	2.353	0.019
ECM	0.729	5.209	0.000
CTE	0.118	1.470	0.142
GAM	−0.029	−3.293	0.001

HAUSMAN (1978) Exogeneity test for TM
Normal Statistic = 0.6614 with Significance Level 0.5083

TABLE 7: AN ECM FOR THE RELATION BETWEEN THE LR (TI) AND THE SR (TM) INTEREST RATE
(Continuation)

Sub-sample: 10/1/1984 – 12/31/1988 (T=1332)

(1) Engle & Granger (1987): 2nd step

Estimation by Least Squares

Dep. Variable: DTI
Usable Obs.: 1331
SEE: 0.1981
SSR: 51.4600
D.W.: 1.9936
Q(36): 28.5006
Sig. Level of Q: 0.8088

Variable	Coeff.	T-stat.	Signif.
DTI(1)	–0.141	–4.917	0.000
DTI(2)	–0.014	–0.476	0.634
DTI(3)	–0.004	–0.132	0.895
DTI(4)	0.020	0.705	0.481
DTI(5)	0.099	3.516	0.000
DTI(6)	0.025	0.917	0.359
DTI(7)	0.001	0.020	0.984
DTI(8)	0.051	1.863	0.063
DTI(9)	–0.166	–0.609	0.543
DTI(10)	–0.095	–3.480	0.001
DTI(11)	–0.014	–0.530	0.596
DTI(12)	–0.092	3.404	0.001
DTM	0.237	5.728	0.000
DTM(1)	0.322	7.785	0.000
DTM(2)	0.198	4.684	0.000
DTM(3)	0.166	3.903	0.000
DTM(4)	0.076	1.808	0.071
DTM(5)	0.059	1.409	0.159
DTM(6)	0.043	1.020	0.308
ECM1(1)	–0.037	–3.139	0.002

HAUSMAN (1978) Exogeneity test for TM
Normal Statistic =–1.7235 with Significance Level 0.0847

(2) Stock (1987): NLLS

Estimation by Nonlinear Least Squares

Dep. Variable: DTI
Usable Obs.: 1332
SEE: 0.1979
SSR: 51.3519
D.W.: 1.9939

Variable	Coeff.	T-stat.	Signif.
DTI(1)	–0.144	–5.011	0.000
DTI(2)	–0.017	–0.599	0.549
DTI(3)	–0.006	–0.222	0.824
DTI(4)	0.018	0.647	0.518
DTI(5)	0.097	3.449	0.001
DTI(6)	0.024	0.863	0.388
DTI(7)	–0.000	–0.002	0.998
DTI(8)	0.051	1.860	0.063
DTI(9)	–0.017	–0.622	0.534
DTI(10)	–0.094	–3.466	0.001
DTI(11)	–0.150	–0.551	0.582
DTI(12)	–0.092	–3.413	0.001
DTM	0.235	5.698	0.000
DTM(1)	0.326	7.868	0.000
DTM(2)	0.202	4.785	0.000
DTM(3)	0.170	4.009	0.000
DTM(4)	0.081	1.907	0.057
DTM(5)	0.064	1.507	0.132
DTM(6)	0.047	1.117	0.264
ECM	0.918	11.901	0.000
CTE	0.040	1.268	0.205
GAM	–0.037	–3.115	0.002

HAUSMAN (1978) Exogeneity test for TM
Normal Statistic =–1.6758 with Significance Level 0.0937

Note: ECM is the long run response
GAM is the parameter associated to the error correction term

7.- LEARNING ABOUT THE CHANGE IN REGIME.

This section offers statistical evidence on the change in regime about the relation between the short and long term interest rates. It also tries to pin down the timing of the change, so inference about the speed at which individuals learn about changes in policy regimes can be drawn.

As in section 5 we begin by determining the most likely date for the change in regime, conditional on the assumption that the change occurred all at once. We then consider the possibility that the change in regime took place gradually over time.

7.1.- Step switching.

This section implements a *deterministic switching model on the basis of time*.

We proceed exactly as in section 5.1. but substituting the ARMA model by the ECM shown in table 7. In short, the second column in table 8 shows the maximized log-likelihood of various possible switch dates[21] and column 3 the corresponding posterior odds ratio of that date as a switch date compared to the ML date and a likelihood ratio of the hypothesis of no-switching *conditional* on a known date for the switching, which we take as the ML date. Graph 4 offers a visual impression of the result. According to the values of these ratios the most likely date for a change of regime is June/8/1984, that is to say, 4 days after the identified change of regime of section 5. This is a surprisingly short time spanning between the introduction of the new monetary policy and the moment the market reflects public awareness of such a

[21] As before, the search was done from 1/1/1983 to 12/31/1984.

TABLE 8: SWITCH DATE FOR THE STOCHASTIC RELATION BETWEEN TI (LR) AND TM (SR)

Date	Log-Likelihood	Posterior Odds Ratio
5/21/1984	3488.8	0.02552
5/22/1984	3487.8	0.01031
5/23/1984	3487.5	0.00728
5/24/1984	3489.8	0.07523
5/25/1984	3491.2	0.30154
5/26/1984	3490.3	0.12516
5/28/1984	3489.5	0.05652
5/29/1984	3488.8	0.02564
5/30/1984	3488.3	0.01574
5/31/1984	3487.5	0.00699
6/01/1984	3488.0	0.01186
6/02/1984	3487.0	0.00452
6/03/1984	3487.1	0.00481
6/04/1984	3490.5	0.14317
6/05/1984	3490.1	0.09540
6/06/1984	3490.9	0.21163
6/08/1984	**3492.4**	**1.00000**
6/09/1984	3491.7	0.46635
6/11/1984	3491.1	0.26542
6/12/1984	3491.8	0.56160
6/13/1984	3491.1	0.27575
6/14/1984	3490.6	0.15566
6/15/1984	3489.8	0.07031
6/16/1984	3489.0	0.03171
6/18/1984	3489.2	0.04176
6/19/1984	3490.6	0.16741
6/20/1984	3489.8	0.07505
6/21/1984	3489.0	0.03381
6/22/1984	3489.2	0.03980
6/23/1984	3489.0	0.03204
6/25/1984	3488.3	0.01546
6/26/1984	3487.5	0.00735
6/27/1984	3486.8	0.00359
6/28/1984	3486.0	0.00163
6/29/1984	3485.5	0.00102
6/30/1984	3484.9	0.00056

Maximum Value of Log-likelihood is 3492.4209 at 1390 (6/8/1984)
(This is the most probably date of the end of the old regime)

Likelihood ratio of the hypothesis of no-switching
(This is a test conditional on a kwon date ot the switching)
Chi-Squared (23)= 881.3037 with Significance level 0.0000

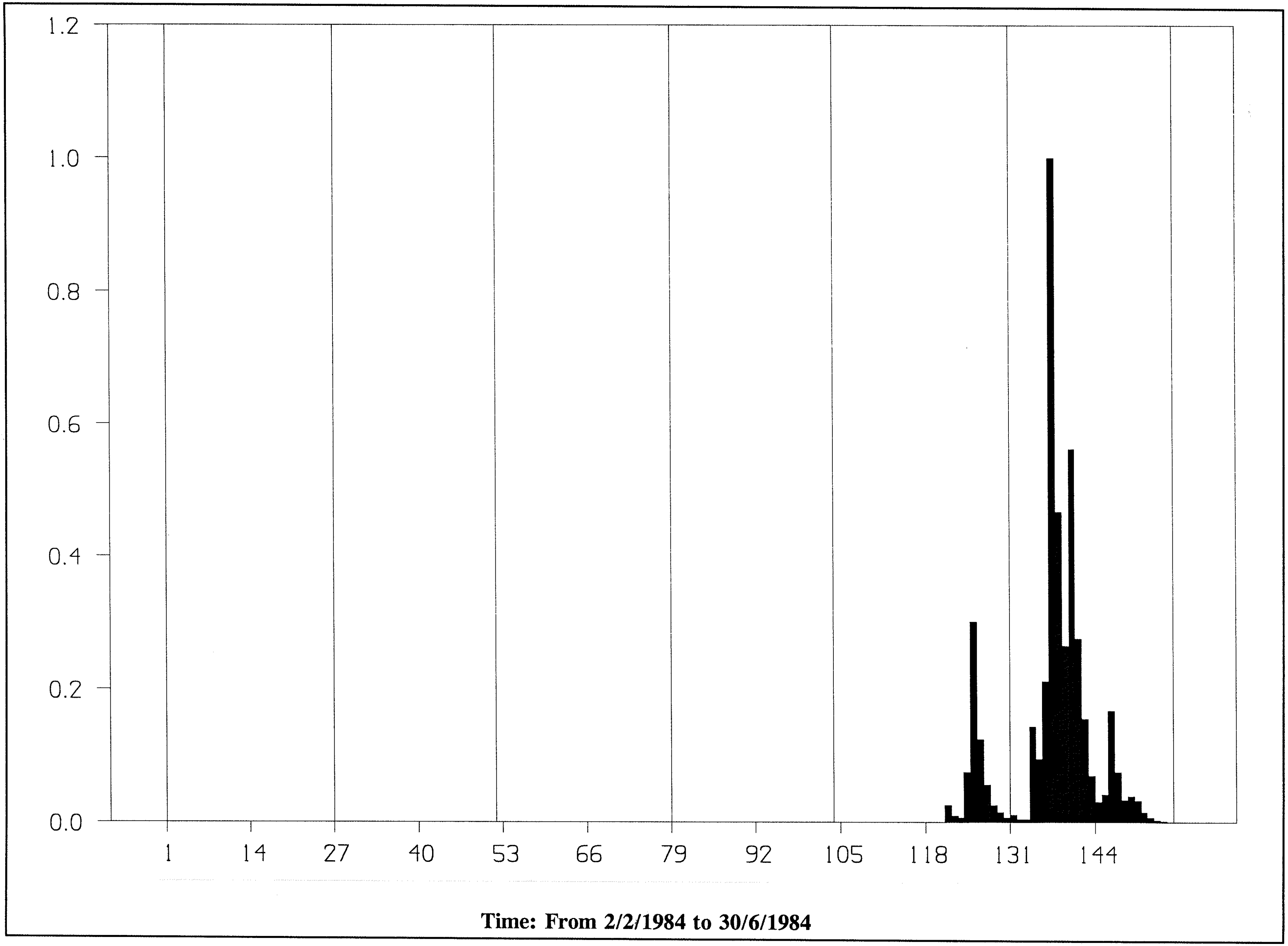
NOTE: Log-likelihood is the log of the likelihood function. The posterior odds ratio is the probability that the switch occured at that date relative to the probability with the highest likelihood; this calculation is based on the estimated likelihood value and diffuse priors.

change. In our estimates, a quite rapid learning process.

According to the values of the ratios around the most likely switching date, the change of regime might have occurred during the last week of May and the first three weeks of June. Again this result is quite similar with the evidence shown in section 5, although signs of a new regime were not present before the end of May.

GRAPH 4: POSTERIOR ODDS RATIO

ECM Model for the relation between the SR and the LR Interest Rate



7.2.- Gradual switching.

This section implements a *deterministic logistic switching model on the basis of time*. We proceed exactly as in section 5.2. but substituting the AR model by the ECM shown in table 7.[22]

Table 9 shows the same information as table 4, but now referred to the logistic ECM. We offer -for different rates of adjustment (δ)-, the maximum likelihood switch date, interpreted as $L_{T_S} = 1/2$, the maximum likelihood value achievable with that rate of adjustment and switching date; and the posterior odds ratio for those values of the switching date and δ relative to the maximal likelihood. A graph of the posterior odds ratio (graph 5) offers a visual impression of these findings.

Our results are fully consistent with those of the step switching model. The change in regime (in the term structure of interest rates) is detected around the beginning of June/1984 and the posterior odds ratios presented in Table 9 shows that an adjustment period longer than two weeks (1 week = 6 days) in not very likely.

These findings show that participants in monetary markets reacted quickly and properly to the change in monetary policy regime operated by the Bank of Spain in the second term of 1984 and confirmed the intuition given in Escrivá (1989). In particular, our results suggest that, given that the change in the policy rule was not known in advance, market participants considered that a permanent change in policy had taken place when the change was completed up to approximately a 70%. Once they consider that a change is permanent they adjust their behavior quickly to the new situation. Inspection of graphs 3 and 5 should make this point clear.

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[22]Initial values for the ML estimation were taken from the corresponding models in table 7.

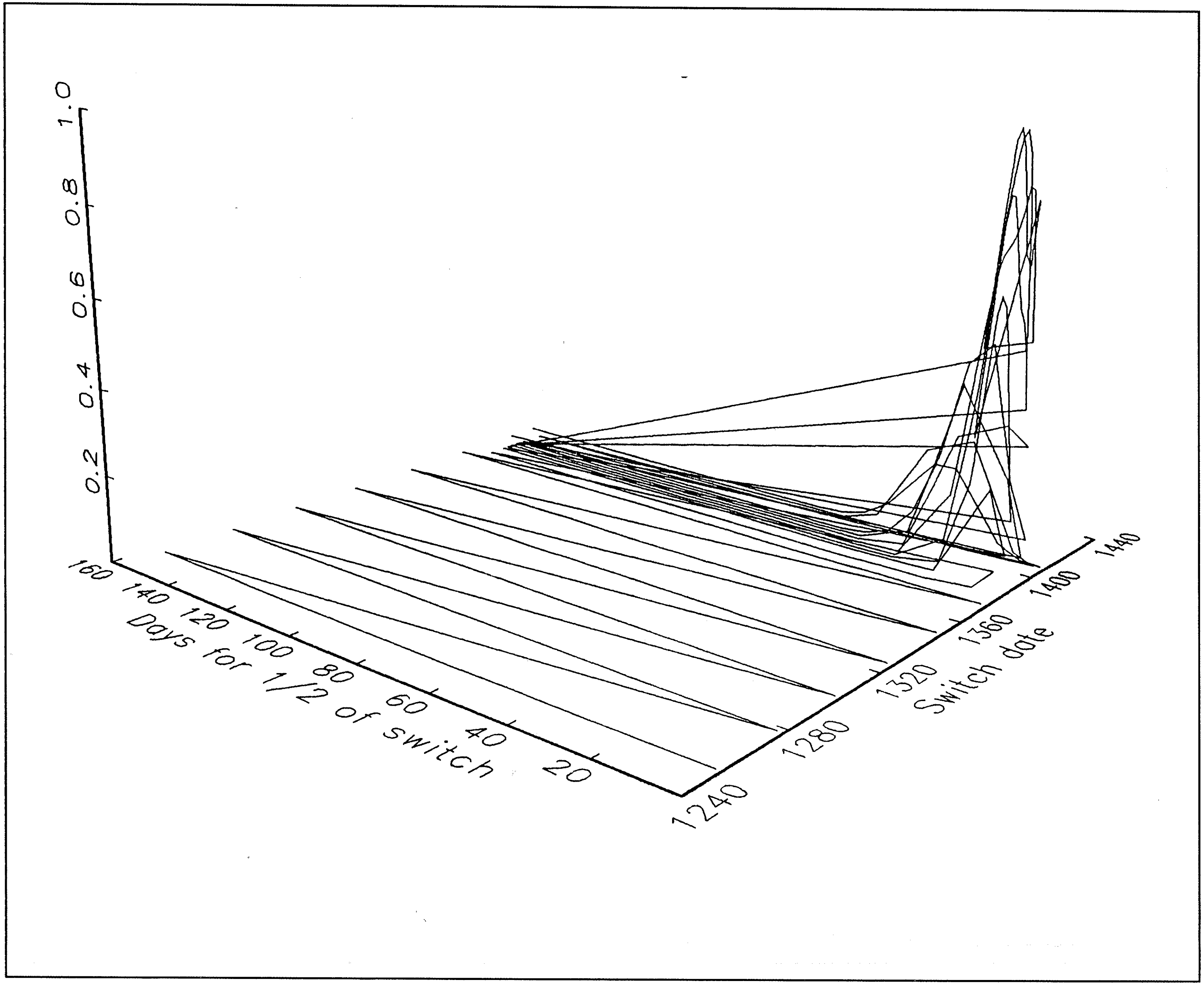
TABLE 9: LOGISTIC SWITCHING FOR THE ECM BETWEEN THE LR (TI) AND SR (TM) INTEREST RATE

Date	Days for 1/2 of switch	Log-likelihood	Posterior Odds ratio
6/6/1984	4	3491.6	0.44435
6/6/1984	6	3491.9	0.6249
6/6/1984	8	3491.9	0.60245
6/6/1984	10	3491.5	0.40657
6/7/1984	2	3491.9	0.59573
6/7/1984	4	3492.0	0.69508
6/7/1984	6	3492.2	0.85723
6/7/1984	8	3492.1	0.79388
6/7/1984	10	3491.8	0.55678
6/7/1984	12	3491.2	0.32506
6/8/1984	2	3492.0	0.71520
6/8/1984	4	3492.2	0.85946
6/8/1984	5	3492.3	0.96154
6/8/1984	**6**	**3492.4**	**1.0000**
6/8/1984	7	3492.3	0.9716
6/8/1984	8	3492.3	0.89302
6/8/1984	10	3492.0	0.66384
6/8/1984	12	3491.5	0.43143
6/9/1984	2	3491.8	0.56105
6/9/1984	4	3492.3	0.95097
6/9/1984	6	3492.3	0.97618
6/9/1984	8	3492.2	0.86348
6/9/1984	10	3492.0	0.70564
6/9/1984	12	3491.7	0.51945
6/11/1984	2	3492.1	0.75489
6/11/1984	4	3492.2	0.87781
6/11/1984	6	3492.1	0.78388
6/11/1984	8	3492.1	0.74058
6/11/1984	10	3492.0	0.69286
6/11/1984	12	3491.8	0.58234
6/13/1984	18	3491.2	0.30512
6/15/1984	18	3491.5	0.42024
6/18/1984	12	3491.7	0.51616
6/18/1984	18	3491.6	0.46436
6/25/1984	18	3491.1	0.27220

NOTE: Log-likelihood is the log of the likelihood function for the set of parameters that maximizes the likelihood for given values of alpha and delta. The posterior odds ratio is the probability of given values of (alpha,delta) relative to the probability of the values of (alpha,delta) with the highest likelihood; this calculation is based on the estimated likelihood value and diffuse priors.

GRAPH 5: POSTERIOR ODDS RATIO

Logistic Switching - ECM model



8.- CONCLUDING REMARKS AND SUGGESTIONS FOR FURTHER RESEARCH.

The decision of the Bank of Spain to change monetary policy from rigidly controlling monetary aggregates to interest rates provided us with a challenge to try to identify the exact timing of such a change. We first explored long and short rates behavior separately, confirming a significant change observed in the first half of 1984. A relationship between long and short rates through the expectational approach to the term structure of interest rates allowed us to identify again the exact moment in which short rates movements provided more informational content to the market participants, incorporating them into the long rates.

A step switching model and a gradual switching model -adjusting a logistic function- have been employed to date the timing of the change in the operation of monetary policy. According to the step switching model for the stochastic process of the short interest rate the change in regime is detected around the beginning of June/1984, and four days later for the relation between the long and short interest rate. However, if we consider that the change in regime occurs gradually over time, the switch date for the stochastic process of the short rate interest rate is located around the first half of May/1984. These results show that one half of the change in regime took about 3 months, not being as fast as the step switching model apparently indicated. For the relation between the long and short interest rate the change in regime is detected around the beginning of June/1984 and the adjustment period is not longer than 2 weeks.

To conclude, the picture that emerges from this study is that of a remarkably fast adjustment of expectations and behavior in the face of a major change in economic policy. This finding suggests that financial market participants reacted quickly to the change in monetary regime operated by the Bank of Spain during the second term of 1984.

One important caveat is however in order, by looking only at term structure data, we are able to examine only the expectations of a relatively small group of economic agents, those who operate in money markets. Indeed, it may not even be necessary that all members of this group held the correct expectations right away, since arbitrage practiced by a well-informed subset might have produced the results we find. One should be cautious then in applying our findings to situations in which the relevant expectations are those of a larger or less sophisticated group of economic agents.

Additional suggestions for further research would include the use of a longer term interbank interest rates in order to check the robustness of our results, the recognition of ARCH effects, the analysis of the Friday/Saturday effects and the over/under reaction of financial markets. None of them, we think, will alter the results reached at this time.

APPENDIX: THE LOGISTIC FUNCTION.

Let

$$y_t = \frac{e^{\alpha+\delta t}}{1 + e^{\alpha+\delta t}}$$

note that this function is always bounded between 0 and 1 since

$$\left.\begin{array}{r} e^{\alpha+\delta t} \to \infty \\ t \to \infty \end{array}\right\} \quad y_t \to 1 \quad \text{as} \quad t \to \infty$$

and

$$\left.\begin{array}{r} e^{\alpha+\delta t} \to 0 \\ t \to -\infty \end{array}\right\} \quad y_t \to 0 \quad \text{as} \quad t \to -\infty$$

and implies

$$1 - y_t = \frac{1}{1 + e^{\alpha+\delta t}}$$

so, as it is known, it is well designed to model probability outcomes. Because our logistic function only depends on time (a logistic trend) the function is appropiate to study problems of convergence from one regime to another in a time series context.

For simplicity let $e^{\alpha} = \beta$, so

$$y_t = \frac{\beta e^{\delta t}}{1 + \beta e^{\delta t}}$$

The slope at any point is given by

$$\frac{dy_t}{dt} = \frac{\beta\delta e^{\delta t}(1 + \beta e^{\delta t}) - \beta e^{\delta t}.\beta\delta e^{\delta t}}{(1 + \beta e^{\delta t})^2} =$$

$$= \frac{\beta\delta e^{\delta t}}{(1 + \beta e^{\delta t})^2} =$$

$$= \delta.\frac{y_t}{1 + \beta e^{\delta t}}$$

But since

$$1 + \beta e^{\delta t} = \frac{1}{1 - y_t}$$

Hence

$$\frac{dy_t}{dt} = \delta.y_t(1 - y_t)$$

This expression allow us to interpret the derivate of y_t as being proportional to the current level of y_t multiplied by the distance below the saturation level. The first derivative is always positive.

Note that from the above expression the growth rate of y_t is linear in y_t:

$$\frac{1}{y_t}.\frac{dy_t}{dt} = \delta.(1 - y_t)$$

Evaluating the second derivative

$$\frac{d^2y_t}{dt^2} = \delta.\frac{dy_t}{dt}.(1 - y_t) - \delta.y_t.\frac{dy_t}{dt}$$

and setting it to zero we get that at the inflexion point $y_t = 1/2$, morever this point occurs at

$$1 - 1/2 = 1/2 = \frac{1}{1 + \beta e^{\delta t}}$$

$$1 + \beta e^{\delta t} = 2 \qquad ====> \qquad \beta e^{\delta t} = 1$$

taking logarithms and since $\beta = e^{\delta t}$

$$e^{\alpha+\delta t} = 1 \qquad ===> \qquad \alpha + \delta t = 0 \qquad ===> \qquad t = -\alpha/\delta$$

So at $t = -\alpha/\delta$ we have $y_t = 1/2$.

Now let's consider the problem more generally and given a value of y_t between 0 and 1 lets obtain the corresponding t

$$1 - y_t = \frac{1}{1 + \beta e^{\delta t}}$$

since $\beta = e^{\alpha t}$ we have that $1+e^{\alpha+\delta t} = 1/(1-y_t)$, hence

$$e^{\alpha+\delta t} = \frac{1}{1 - y_t} - 1 = \frac{y_t}{1 - y_t}$$

taking logarithms $===>$ $\alpha + \delta t = \log(y_t/(1-y_t))$, so

$$t = \frac{\log\left\{\frac{y_t}{(1-y_t)}\right\} - \alpha}{\gamma\delta}$$

Now assume that we are interested in measuring the speed of adjustment, so lets see how long it takes from $y_{t_0} = 1/4$ to $y_{t_1} = 3/4$, i.e. the time that takes in doing half of the adjustment around the inflexion point.

From the above expression it follows that

$$\delta.(t_1 - t_0) = \log\left\{\frac{y_{t1}}{(1-y_{t_1})}\right\} - \log\left\{\frac{y_{t0}}{(1-y_{t_0})}\right\}$$

$$= \log\left\{\frac{y_{t_1}/(1-y_{t_1})}{y_{t_0}/(1-y_{t_0})}\right\}$$

so

$$t_1 - t_0 = \frac{\log\left\{\frac{y_{t_1}/(1-y_{t_1})}{y_{t_0}/(1-y_{t_0})}\right\}}{\delta}$$

For $y_{t_0} = 1/4$ and $y_{t_1} = 3/4$ this expression becomes

$$t_1 - t_0 = \log(9)/\delta$$

Hence the parameter δ is inversely related to the rate of adjustment from 0 to 1, and it is (obviously) not independent of the units of measurement of t. α is just a location parameter.

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