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Is the Fisher Effect Nonlinear? Some Evidence for Spain, 1963-2002*

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RESUMEN
En este trabajo examinamos el papel de las no linealidades en la relación entre los tipos de interés nominales y la inflación, con objeto de analizar la evidencia generalmente desfavorable sobre la presencia de un efecto Fisher completo. El análisis se aplica al caso de España para el periodo 1963-2002, lo que nos permite reexaminar y ampliar resultados previos sobre el tema. La metodología empírica utiliza desarrollos recientes sobre umbrales de cointegración, de manera que podría esperarse la existencia de cointegración entre dos variables sólo cuando se ha alcanzado un determinado umbral.

Palabras clave: tipo de interés, efecto Fisher, umbral de cointegración, no linealidad.

ABSTRACT
In this paper we examine the role of nonlinearities in the relationship between nominal interest rates and inflation, in order to shed some additional light on the mostly unfavorable evidence on the presence of a full Fisher effect. The analysis is applied to the case of Spain for the period 1963-2002, which allows us to re-examine and extend previous results on the subject. The empirical methodology makes use of recent developments on threshold cointegration, so that cointegration between a pair of variables should be expected once a certain threshold was reached.

Keywords: Interest rate, Fisher effect, Threshold cointegration, nonlinearity.

***JEL* classification:** E43, E44.

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1 Introduction

Empirical testing of the so called "Fisher effect" (i.e., the degree in which nominal interest rates incorporate the expected evolution of the inflation rate, without affecting the real interest rate) is a habitual topic in monetary and financial economics. Such a concern lies on the fact that fulfilment of the hypotesis is highly relevant for a number of important questions in both theory and policy. So, for instance, if the Fisher effect holds, the superneutrality of money would apply, the nominal interest rate would be a good predictor of future inflation as well as a bad indicator of the kind of monetary policy followed, and this would be a necessary condition for the validity of the consumption-based capital asset pricing model or CCAPM (Haliassos and Tobin, 1990).

The hypothesis dates back to Fisher (1896, 1930), who also provided its first empirical test. It is important to notice that Fisher's own results showed that the hypothesis associated to his name would be satisfied only partially: although the interest rate responded to changes in the inflation rate in the sense suggested by the theory, it did it by a smaller amount and with a substantial delay. In addition, Fisher pointed as the ultimate reason of his results the existence of money illusion, so that the agents would be unable to distinguish changes in nominal values from changes in real values of the economic variables. Indeed, money illusion may be a rational response to systemic coordination problems, and has been traditionally invoked as the main reason behind the non-neutrality of money (Howitt, 1987). Although this hypothesis would have been mostly discredited in last years, a recent paper by Fehr and Tyran (2001) shows that a small amount of money illusion at the individual level may explain the real effects of otherwise fully anticipated nominal shocks.

The emergence of the literature on unit roots and cointegration provided an important impulse to the empirical testing of the Fisher effect. So, if the nominal interest rate and the inflation rate have stochastic trends (or, equivalently, have a unit root), the tests of the Fisher's hypothesis performed so far would be the result of spurious regressions in the sense of Granger and Newbold (1974). Following the early work of Rose (1988), a number of further contributions aimed to test for the Fisher effect using cointegration techniques have subsequently appeared, with sometimes conflicting results; a non-exhaustive list would include, among others, Moazzami (1991), Mishkin (1992), Peláez (1995), Crowder (1997), Bajo and Esteve (1998), Koustas and Serletis (1999), or Bajo, Díaz and Esteve (2003).

However, a common result to most of these studies is that nominal interest rates and inflation would not move one-for-one in the long-run, so that the Fisher effect would hold only partially; that is, confirming Fisher's initial insights. As a consequence, some authors have offered nonlinearities as a possible explanation to explain this (apparent) puzzle, using data for the U.S. So, Evans and Lewis (1995) estimate a Markov switching model with two regimes for inflation, whereas Garcia and Perron (1996) estimate univariate Markov switching autoregressive models for the real interest rate and inflation. More recently, Bierens (2000) has examined the comovement of interest rates and inflation using a nonparametric, nonlinear cotrending approach.

In this paper we analyze the possible nonlinear relationship between nominal interest rates and inflation through a different approach. In particular, given the unfavorable evidence on the presence of a full Fisher effect, a reasonable hypothesis would be guessing that the effect could be more operational (i.e., the nominal interest rate could respond more strongly to changes in inflation) only if the divergence between nominal interest rates and inflation was large enough. To this end, we make use of the new approach recently developed by Hansen and Seo (2002), based on a threshold cointegration model.

This approach will allow us to consider the possibility of a nonlinear long-run relationship between the nominal interest rate and the inflation rate, so that a mean-reverting dynamic behaviour of the *ex-post* real interest rate (or a cointegrating relationship between the nominal interest rate and the inflation rate) should be expected only once a certain threshold is reached. In the empirical application we will use Spanish data, providing further evidence on a subject previously analyzed in Bajo and Esteve (1998). In that paper, a long-run partial Fisher effect was found for the Spanish economy between 1962 and 1996, with a transmission to the nominal interest rate of roughly one third for each point increase in the inflation rate. This result, in turn, was attributed to the presence of some money illusion on the side of lenders, defined in a broad sense (specifically, as their impossibility to fully transmit to the nominal interest rate, for whatever reason, any changes in the inflation rate).

The rest of the paper is organized as follows. The empirical methodology is outlined in Section 2, the empirical tests are performed in Section 3, and the main conclusions are summarized in Section 4.

2 Methodology

The concept of threshold cointegration was introduced by Balke and Fomby (1997) as a feasible way to combine nonlinearity and cointegration. As is well known, systems in which variables are cointegrated can be characterized by an error correction model (ECM), which describes how the variables respond to deviations from the equilibrium. In this way, the ECM can be characterized as the adjustment process through which the long-run equilibrium is maintained. The traditional approach, however, assumes that such a tendency to move towards the long-run equilibrium is present every time period.

Balke and Fomby (1997) stress the possibility that this movement towards the long-run equilibrium might not occur in every time period, due to the presence of some adjustment costs on the side of economic agents. In other words, there could be a discontinuous adjustment to equilibrium so that, only when the deviation from the equilibrium exceeds a critical threshold, the benefits of adjustment are higher than the costs, and economic agents move the system back to equilibrium. Threshold cointegration characterizes this discrete adjustment as follows: the cointegrating relationship does not hold inside a certain range, but holds if the system gets 'too far' from the equilibrium; i.e., cointegration would hold only if the system exceeds a certain threshold.

In a recent contribution, Hansen and Seo (2002) provide an important new refinement into this literature, by examining the case of a unknown cointegration vector. In particular, these authors propose a vector error-correction model (VECM) with one cointegrating vector and a threshold effect based on the error-correction term, and develop a Lagrange multiplier (LM) test for the presence of a threshold effect. This will be the approach followed in this paper.

Hansen and Seo (2002) consider a two-regime threshold cointegration model, or a nonlinear VECM of order $l+1$, such as:

$$\Delta x_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t & \text{if } w_{t-1}(\beta) \le \gamma \\ A_2' X_{t-1}(\beta) + u_t & \text{if } w_{t-1}(\beta) > \gamma \end{cases} \qquad (1)$$

with

$$X_{t-1}(\beta) = \begin{pmatrix} 1 \\ w_{t-1}(\beta) \\ \Delta x_{t-1} \\ \Delta x_{t-2} \\ \vdots \\ \Delta x_{t-l} \end{pmatrix}$$

where x_t is a p-dimensional $I(1)$ time series which is cointegrated with one $p \times 1$ cointegrating vector β, $w_t(\beta) = \beta' x_t$ is the $I(0)$ error-correction term, u_t is an error term, A_1 and A_2 are coefficient matrices that describe the dynamics in each of the regimes, and γ is the threshold parameter.

As can be seen, the threshold model (1) has two regimes, defined by the value of the error-correction term. As long as deviations from the equilibrium are lower or equal than the threshold, there is no tendency for the variables x_t to revert to an equilibrium (i.e., the variables would not be cointegrated); on the contrary, if deviations from the equilibrium are greater than the threshold, there is a tendency for the variables x_t to move towards some equilibrium (i.e., the variables would be cointegrated).

Next, Hansen and Seo (2002) propose two heteroskedastic-consistent LM test statistics for the null hypothesis of linear cointegration (i.e., there is no threshold effect), against the alternative of threshold cointegration (i.e., model (1)). The first test would be used when the true cointegrating vector is known a priori, and is denoted as:

$$\sup LM^0 = \sup_{\gamma L \leq \gamma \leq \gamma U} LM(\beta_0, \gamma) \tag{2}$$

where β_0 is the known value of β (in the case analyzed below, $\beta_0 = 1$); whereas the second test would be used when the true cointegrating vector is unknown, and is denoted as:

$$\sup LM = \sup_{\gamma L \leq \gamma \leq \gamma U} LM(\tilde{\beta}, \gamma) \tag{3}$$

where $\tilde{\beta}$ is the null estimate of β. In both tests, $[\gamma_L, \gamma_U]$ is the search region set so that γ_L is the π_0 percentile of $\widetilde{w}_{t-1}$, and γ_U is the $(1 - \pi_0)$ percentile; Andrews (1993) suggests setting π_0 between 0.05 and 0.15. Finally, Hansen and Seo (2002) develop two bootstrap methods to calculate asymptotic critical values and p-values.

3 Results

In Bajo and Esteve (1998), a procedure to test for the Fisher effect was proposed as follows. The first step would be testing for the order of integration of the variables nominal interest rate, and inflation rate (where the latter would proxy the expected inflation rate, which is not observable). Next, if the nominal interest rate and the inflation rate were both I(1), the following equation would be estimated:

$$i_t = \alpha + \beta \pi_t + \eta_t \tag{4}$$

where i_t is the nominal interest rate in period t, π_t is the inflation rate from $t-1$ to t, η_t is a stationary error term, and the constant α would proxy the *ex-ante* real interest rate.

Then, if i_t and π_t were cointegrated and the estimate of β not significantly different from one, there would be a full Fisher effect so that changes in the expected inflation rate would be transmitted one-for-one to the nominal interest rate. On the other hand, if i_t and π_t were cointegrated and the estimate of β significantly lower than one, there would be a partial Fisher effect so that changes in the expected inflation rate would be transmitted in a proportion $\beta < 1$ to the nominal interest rate, due to the presence of partial money illusion. Finally, if i_t and π_t were not cointegrated, some additional variables presumably influencing the nominal interest rate should be introduced in the estimation of (4); see Bajo and Esteve (1998) for details.

Instead of estimating a linear equation like (4), in this paper we are going to analyze the relationship between nominal interest rate and inflation using a nonlinear VECM as in (1), with $w_{t-1} = i_{t-1} - \beta\pi_{t-1}$. In the empirical application we use quarterly data for Spain, obtained as averages of the original monthly data, over the period 1963:1 to 2002:4. The variables are defined as follows[1]:

- i_t: Long-run nominal interest rate (before February 1978, private bonds of electric utilities; from March 1978 to December 1992, central government bonds at more than two years; from January 1993, central government benchmark bond of 10 years).

- π_t: Inflation rate, computed as the annual percentage change (T_{12}^{12}) of the Consumer Price Index (CPI) (before December 1995, national CPI; from December 1995 to November 1996, interim indices for euro area; from December 1996, harmonised indices for euro area).

The data are taken from Bank of Spain (2003), tables 2.9 and 2.7, respectively. The time evolution of the two series is shown in Figure 1.

As a first step of the analysis, we have tested for the order of integration of the two series. To this end, we have used a modified version of the Phillips and Perron (1988) tests recently proposed by Ng and Perron (2001), which tries to solve the main problems present in the conventional tests for unit roots. Table 1 shows the results of the three tests, $\bar{M}Z_{\alpha}^{GLS}$, $\bar{M}Z_{t}^{GLS}$, and ADF^{GLS}. As shown in the table, the null hypothesis of non-stationarity for i_t and π_t cannot be rejected, independently of the test. Consequently, both series would be I(1) or integrated of first order.

Next, we have applied the tests of threshold cointegration proposed by Hansen and Seo (2002), namely, $\sup LM^0$ (for a given $\beta = 1$) and $\sup LM$ (for an estimated β). In both cases, the p-values are calculated using a parametric bootstrap method (with 5,000 simulation replications), as proposed by Hansen and Seo (2002). To select the lag length of the VAR, we have used the AIC and BIC criteria, both of them leading to $l = 1$; we also report the results for $l = 2$ for the sake of comparison. The results of the tests are reported in Table 2.

Threshold cointegration would appear at the 10% significance level when $l = 1$ and β is fixed at unity. If, instead, β is estimated freely, evidence on threshold cointegration is reinforced, since it now emerges at the 5% significance level, and the null hypothesis of linear cointegration would be more strongly rejected. In this case, the estimated cointegration vector

[1] Notice that the long-run nominal interest has been proxied by linking more than one series, since a unique, homogeneous series is not available for the period analyzed. This procedure, however, has been also applied in several other empirical studies of the Spanish economy, such as those derived from the MOISEES model elaborated at the Ministry of Economy; see, e.g., the studies included in Molinas, Sebastián and Zabalza (1991).

is $(1, -0.50)$, i.e., different to the theoretical values consistent with a full Fisher effect, $(1, -1)$. This result would indicate the presence of a partial Fisher effect in the long run, with a transmission to the nominal interest rate of 0.50 points of each point increase in the inflation rate, suggesting that lenders would have suffered some money illusion in the sense that the nominal interest rate would have not been fully adjusted to compensate them for a higher inflation.

On the other hand, the estimated threshold is $\hat{\gamma} = 0.80$, and the corresponding two-regime threshold VAR (with heteroskedasticity-consistent standard errors in parentheses) is:

$$\Delta i_t = \begin{cases} \underset{(0.01)}{0.02} - \underset{(0.03)}{0.007}\, w_{t-1} + \underset{(0.29)}{0.20}\, \Delta i_{t-1} - \underset{(0.03)}{0.02}\, \Delta\pi_{t-1} + u_{1t}, & w_{t-1} \leq 0.80 \\ \underset{(0.02)}{0.05} - \underset{(0.01)}{0.04}\, w_{t-1} + \underset{(0.06)}{0.36}\, \Delta i_{t-1} + \underset{(0.05)}{0.06}\, \Delta\pi_{t-1} + u_{2t}, & w_{t-1} > 0.80 \end{cases}$$

$$\Delta \pi_t = \begin{cases} \underset{(0.06)}{-0.59} + \underset{(0.10)}{0.99}\, w_{t-1} - \underset{(0.80)}{1.47}\, \Delta i_{t-1} + \underset{(0.08)}{1.00}\, \Delta\pi_{t-1} + u_{1t}, & w_{t-1} \leq 0.80 \\ -\underset{(0.02)}{0.02} + \underset{(0.01)}{0.02}\, w_{t-1} + \underset{(0.08)}{0.02}\, \Delta i_{t-1} + \underset{(0.07)}{0.79}\, \Delta\pi_{t-1} + u_{2t}, & w_{t-1} > 0.80 \end{cases}$$

Hence, the first regime would occur when the divergence between the nominal interest rate and the adjustment for inflation is below 0.80. This would be the relatively unusual regime, including only 9% of the observations, and corresponds to two periods (1963-65 and 1977-78) characterized by a very high inflation rate (see Figure 1). Accordingly, the associated high degree of money illusion would have been reflected in negative *ex-post* real interest rates, due to the lack of response of nominal interest rates (the estimated coefficient on the ECM is not significantly different from zero).

In turn, the second or usual regime, with 91% of the observations, would occur when the divergence between the nominal interest rate and the adjustment for inflation is above 0.80. This regime would correspond to periods of "moderate" inflation, characterized by less money illusion, and a significant response of nominal interest rates. However, such a response would be quantitatively very small (with an estimated coefficient on the ECM equal to -0.04), which would provide further support to the hypothesis that the Fisher effect would operate in the very long run.

Figure 2 plots the error-correction effect, i.e., the estimated response of the nominal interest and inflation rates to the discrepancy between the former and the adjustment for the latter, in the previous period, holding the other variables constant. It can be seen the flat, near zero, error-correction effect on the left-hand side of the threshold parameter for the nominal interest rate; and the very small, though significant, effect for both the nominal interest rate and inflation rate on the right-hand side of the threshold parameter. In contrast, for the high inflation regime, a sharp positive response of inflation appears, which tends to become negative immediately afterwards, so assuring that inflation does not increase without limit.

4 Conclusions

In this paper we have analyzed the role of nonlinearities in the relationship between nominal interest rates and inflation, in order to shed some additional light on the mostly unfavorable evidence on the presence of a full Fisher effect. Since the empirical application has been based in the case of Spain for the period 1963-2002, we have also tried to provide further evidence regarding previous results on the subject by Bajo and Esteve (1998). The empirical methodology has made use of Hansen and Seo's (2002) recent contribution, based on a threshold cointegration model that considers the possibility of a nonlinear long-run relationship between the nominal interest rate and the inflation rate, so cointegration between both variables should be expected only once a certain threshold was reached.

Our results showed that the null hypothesis of linear cointegration between the nominal interest rate and the inflation rate was rejected in favor of a two-regime threshold cointegration model, with the coefficient on inflation in the ECM estimated at 0.50. Therefore, a partial Fisher effect would emerge in the long run, with a transmission to the nominal interest rate of 0.50 points of each point increase in the inflation rate, due to the presence of some degree of money illusion.

In addition, a system of two regimes (interpreted as of high and "moderate" inflation, respectively), would seem to characterize the discontinuous or nonlinear adjustment of the nominal interest rate towards a long-run equilibrium, with the threshold parameter estimated at 0.80. So, we could expect a cointegrating relationship only when the divergence between the nominal interest rate and the adjustment for inflation is above 0.80. Such a regime would correspond to periods of "moderate" inflation, characterized by less money illusion, and a significant response of nominal interest rates; in other words, only when the deviation from the equilibrium exceeds a critical threshold, the system acts to move the variables back towards the equilibrium. However, the response of the nominal interest rate would be quantitatively very small, which would provide further support to the hypothesis that the Fisher effect would operate in the very long run.

The above results would basically confirm and extend those of Bajo and Esteve (1998), where the time period finished in 1996. Transmission to the nominal interest rate of each point increase in the inflation rate would be still incomplete (although it would have increased from 0.32 to 0.50 points); and a nonlinear response of the nominal interest rate to that divergence would have been detected, but quantitatively very small. Overall, the results would reflect the presence of some degree of money illusion in the financial markets, in the broad sense defined in Bajo and Esteve (1998), and Bajo, Díaz and Esteve (2003). Money illusion, however, would seem to have decreased when extending the time period, which would be consistent with the decrease in inflation experienced by the Spanish economy in those years.

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Table 1
Ng-Perron tests of unit roots

Case: $p = 1, \bar{c} = -13.5$				
Variable	k	$\bar{M}Z_{\alpha}^{GLS}$	$\bar{M}Z_{t}^{GLS}$	ADF^{GLS}
i_t	7	-2.29	-0.84	-0.71
π_t	6	-3.99	-1.39	-1.35

Notes:

[a] No test statistic is significant at the usual levels. The critical values are taken from Ng and Perron (2001), Table 1.

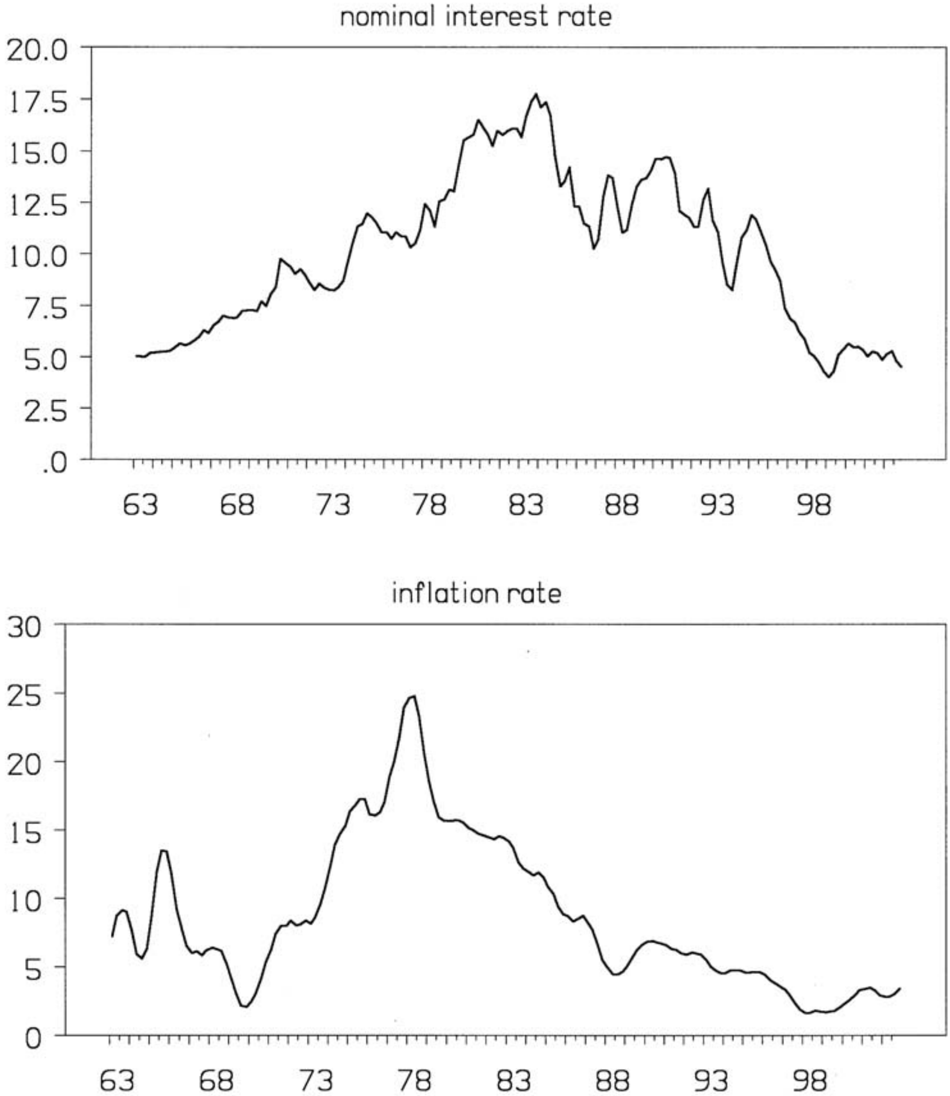
[b] The autoregressive truncation lag, k, has been selected using the $MAIC$ information criterion, as proposed by Perron and Ng (1996).

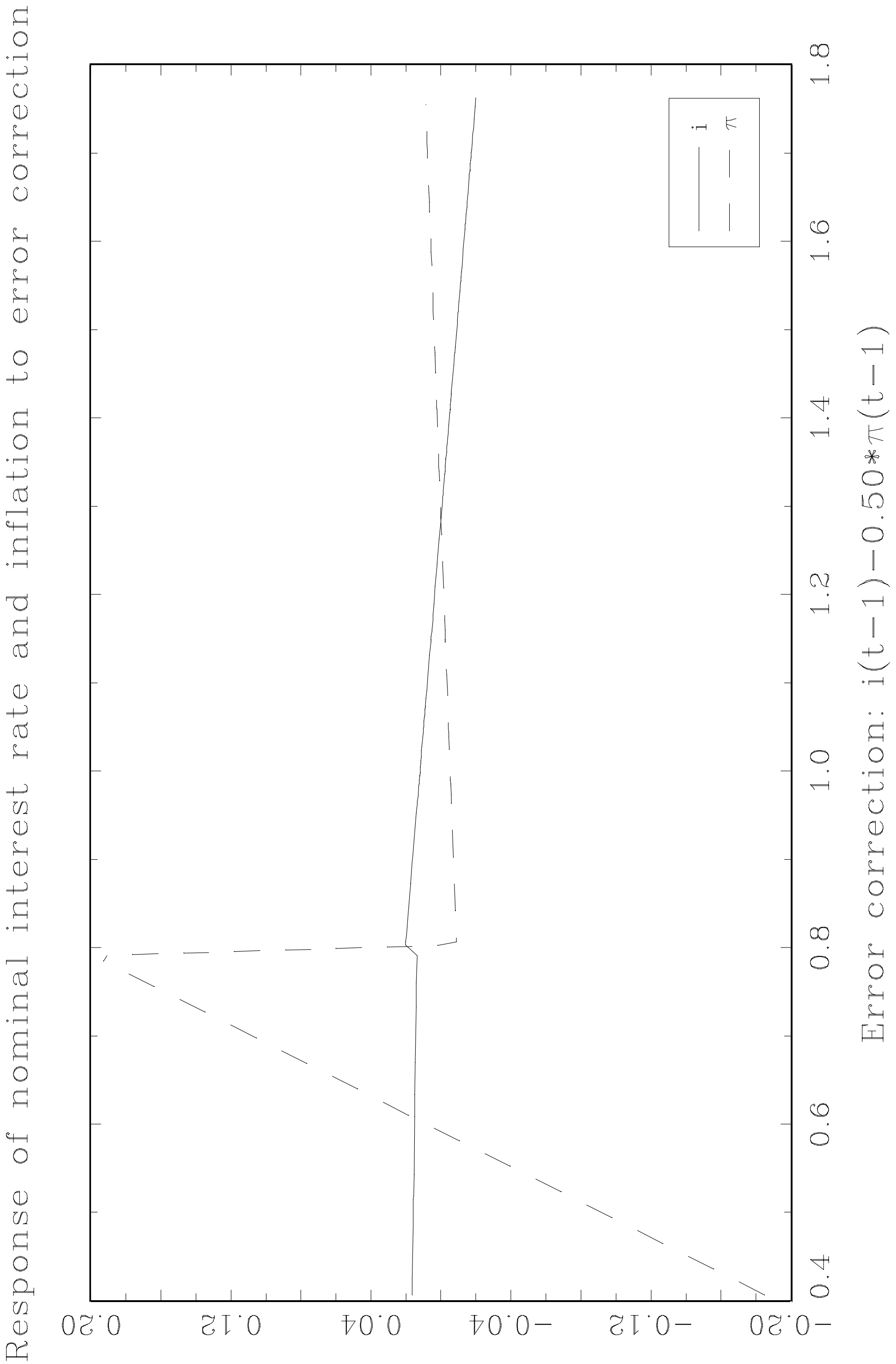
Table 2
Hansen-Seo tests of threshold cointegration

	$\sup LM^0$		$\sup LM$	
	$l = 1$	$l = 2$	$l = 1$	$l = 2$
Test statistic value	19.48	22.24	19.85	22.14
Calculated p-values	0.064*	0.176	0.046**	0.139
Threshold parameter	0.89	0.90	0.80	0.90
Estimate of the cointegrating vector	—	—	0.50	1.00

Notes:
[a] *, and ** denote significance at the 10%, and 5% levels, respectively.

Figure 1
Nominal interest rate and inflation in Spain, 1963-2002




Response of nominal interest rate and inflation to error correction
Error correction: i(t−1)−0.50*π(t−1)
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
0.20
0.12
0.04
−0.04
−0.12
−0.20
i
π

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