Applied Financial Economics, 2005, **15**, 849–854

Is the Fisher effect non-linear? Some evidence for Spain, 1963–2002

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In this paper the role of non-linearities in the relationship between nominal interest rates and inflation is examined, in order to shed some additional light on the mostly unfavourable 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 previous results on the subject to be re-examined and extended. The empirical methodology makes use of recent developments on threshold cointegration, so that cointegration between a pair of variables should be expected only once a certain threshold was reached.

I. 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. This is so because the fulfilment of the hypothesis would be 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 recent years, a 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),

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Applied Financial Economics ISSN 0960–3107 print/ISSN 1466–4305 online © 2005 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/09603100500123187

Bajo and Esteve (1998), Koustas and Serletis (1999), or Bajo *et al*. (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 non-linearities as a possible explanation to this (apparent) puzzle, using data for the USA. 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 non-parametric, non-linear cotrending approach.

In this paper the possible non-linear relationship between nominal interest rates and inflation is analysed through a different approach. In particular, given the unfavourable 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, use is made of the new approach recently developed by Hansen and Seo (2002), based on a threshold cointegration model.

This approach will allows the possibility of a non-linear long-run relationship between the nominal interest rate and the inflation rate to be considered, 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 Spanish data over the years 1963–2002 will be used. During this period, the Spanish economy experienced some episodes of high inflation reaching its maximum in 1977, and gradually declining since then, which eventually allowed the Spanish economy joining EMU from its start.

The rest of the paper is organized as follows. The empirical methodology is outlined in Section II, the empirical tests are performed in Section III, and the main conclusions are summarized in Section IV.

II. Methodology

The concept of threshold cointegration was introduced by Balke and Fomby (1997) as a feasible way to combine non-linearity 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 an 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 non-linear VECM of order $l+1$, such as:

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

with

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

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 (Equation 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 heteroscedastic-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 (Equation 1)). The first test would be used when the true cointegrating vector is known *a priori*, and is denoted as:

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

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

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

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 $\tilde{w}_{t-1}$ 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.

III. 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 Equation 4; see Bajo and Esteve (1998) for details.

Instead of estimating a linear equation like Equation 4, in this paper the relationship between nominal interest rate and inflation will be analysed using a non-linear VECM as in Equation 1, with $w_{t-1} = i_{t-1} - \beta\pi_{t-1}$. In the empirical application quarterly data for Spain, over the period 1963 : 1 to 2002 : 4, are used for the long-run nominal interest rate, and the inflation rate (computed as the annual percentage change of the Consumer Price Index). The data are taken from the Bank of Spain's *Statistical Bulletin*, and the time evolution of the two series is shown in Fig. 1.

As a first step of the analysis, the order of integration of the two series has been tested for. To this end, a modified version of the Phillips and Perron (1988) tests recently proposed by Ng and Perron (2001) has been used, 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 nonstationarity 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, the tests of threshold cointegration proposed by Hansen and Seo (2002) have been applied, 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 5000 simulation replications), as proposed by Hansen and Seo (2002). To select the lag length of the VAR, the AIC and BIC criteria have been used, both of them leading to $l = 1$; the results for $l = 2$ are also reported 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 is $(1, -0.50)$, i.e., different to the theoretical values consistent with a full Fisher effect $(1, -1)$. This result

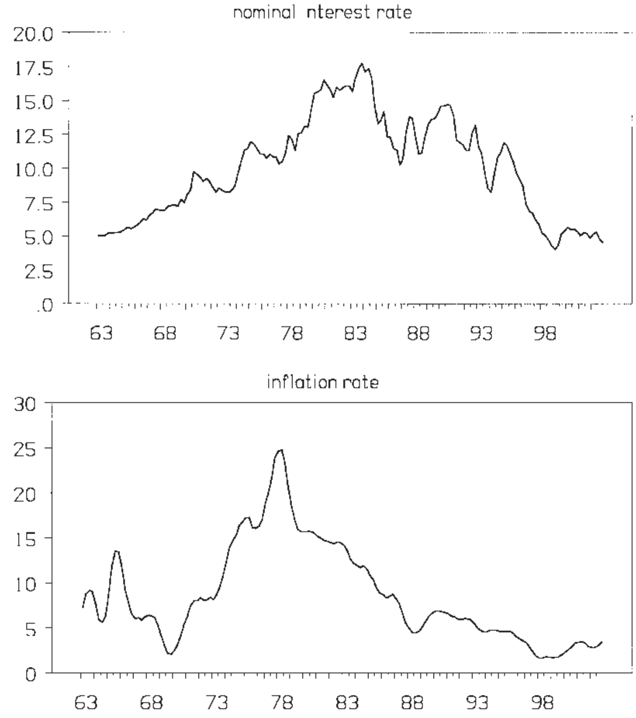

Fig. 1. Nominal interest rate and inflation in Spain, 1963–2002

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

Note: *, and ** denote significance at the 10%, and 5% levels, respectively.

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 heteroscedasticity-consistent standard errors in parentheses) is:

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

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

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%

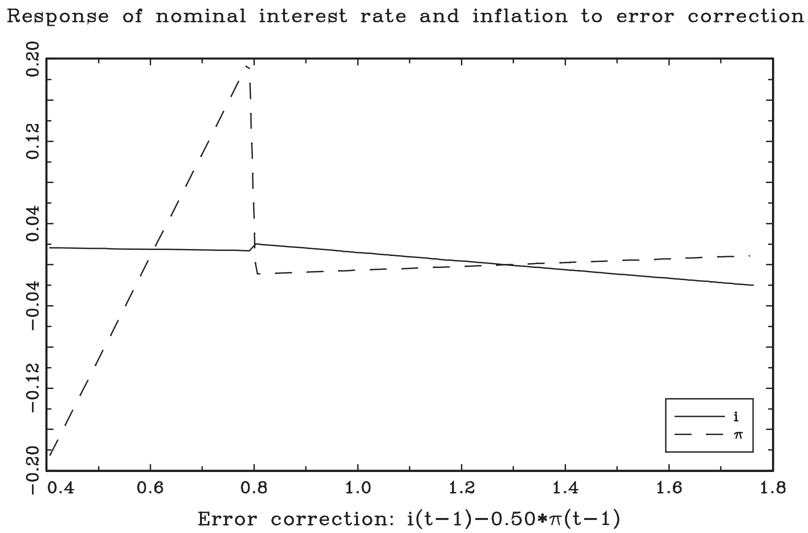

Fig. 2. Response of nominal interest rate and inflation to error correction

of the observations, and corresponds to two periods (1963–1965 and 1977–1978) characterized by a very high inflation rate (see Fig. 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.

IV. Conclusions

In this paper the role of non-linearities in the relationship between nominal interest rates and inflation has been analysed, in order to shed some additional light on the mostly unfavourable evidence on the presence of a full Fisher effect. 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 non-linear 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.

The results showed that the null hypothesis of linear cointegration between the nominal interest rate and the inflation rate was rejected in favour 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 one half 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 non-linear adjustment of the nominal interest rate towards a long-run equilibrium, with the threshold parameter estimated at 0.80. So, a cointegrating relationship could be expected 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.

Overall, the results would reflect the presence of some degree of money illusion in the financial markets, as already noticed by Fisher (1930), at least in the broad sense defined in Bajo and Esteve (1998) and Bajo *et al*. (2003). That is, the impossibility of lenders to fully transmit any changes in the inflation rate to the nominal interest rate, would mean that the Fisher effect would be observed only partially, and in the very long run.

Acknowledgements

The authors acknowledge financial support from the Spanish Ministry of Science and Technology, through the projects SEC2002-01892 (O. Bajo-Rubio and C. Díaz-Roldán) and SEC2002-03651 (V. Esteve), as well as from Fundación BBVA (O. Bajo-Rubio and C. Díaz-Roldán) and the Valencian Council of Education and Science, through the project GV01-127 (V. Esteve).

References

Andrews, D. W. K. (1993) Tests for parameter instability and structural change with unknown change point, *Econometrica*, **61**, 821–56.

Bajo-Rubio, O. and Esteve, V. (1998) Existe un efecto Fisher en el largo plazo? Evidencia para la economía española, 1962–1996, *Revista Española de Economía*, **15**, 149–66.

Bajo-Rubio, O., Díaz-Roldán, C. and Esteve, V. (2003) Testing the Fisher effect in the presence of structural change: a case study of the UK, 1961–2001, Working Paper E2003/22, Fundación Centro de Estudios Andaluces.

Balke, N. S. and Fomby, T. B. (1997) Threshold cointegration, *International Economic Review*, **38**, 627–45.

Bierens, H. J. (2000) Nonparametric nonlinear cotrending analysis, with an application to interest and inflation in the United States, *Journal of Business and Economic Statistics*, **18**, 323–37.

Crowder, W. J. (1997) The long-run Fisher relation in Canada, *Canadian Journal of Economics*, **30**, 1124–42.

Evans, M. D. D. and Lewis, K. K. (1995) Do expected shifts in inflation affect estimates of the long-run Fisher relation?, *Journal of Finance*, **50**, 225–53.

Fehr, E. and Tyran, J.-R. (2001) Does money illusion matter?, *American Economic Review*, **91**, 1239–62.

Fisher, I. (1896) Appreciation and interest, *AEA Publications*, **3**, 331–442.

Fisher, I. (1930) *The Theory of Interest*, Macmillan, New York.

Garcia, R. and Perron, P. (1996) An analysis of the real interest rate under regime shifts, *Review of Economics and Statistics*, **78**, 111–25.

Granger, C. W. J. and Newbold, P. (1974) Spurious regression in Econometrics, *Journal of Econometrics*, **2**, 111–20.

Haliassos, M. and Tobin, J. (1990) The macroeconomics of government finance, in *Handbook of Monetary Economics*, Vol. 2 (Eds) B. M. Friedman and F. H. Hahn, North-Holland, Amsterdam, pp. 889–959.

Hansen, B. E. and Seo, B. (2002) Testing for two-regime threshold cointegration in vector error-correction models, *Journal of Econometrics*, **110**, 293–318.

Howitt, P. (1987) Money illusion, in *The New Palgrave: A Dictionary of Economics*, Vol. 3 (Eds) J. Eatwell, M. Milgate and P. Newman, Macmillan, London, pp. 518–19.

Koustas, Z. and Serletis, A. (1999) On the Fisher effect, *Journal of Monetary Economics*, **44**, 105–30.

Mishkin, F. S. (1992) Is the Fisher effect for real? A re-examination of the relationship between inflation and interest rates, *Journal of Monetary Economics*, **30**, 195–215.

Moazzami, B. (1991) The Fisher equation controversy re-examined, *Applied Financial Economics*, **1**, 129–33.

Ng, S. and Perron, P. (2001) Lag length selection and the construction of unit root tests with good size and power, *Econometrica*, **69**, 1529–54.

Peláez, R. F. (1995) The Fisher effect: reprise, *Journal of Macroeconomics*, **17**, 333–46.

Perron, P. and Ng, S. (1996) Useful modifications to some unit root tests with dependent errors and their local asymptotic properties, *Review of Economic Studies*, **63**, 435–65.

Phillips, P. C. B. and Perron, P. (1988) Testing for a unit root in time series regression, *Biometrika*, **75**, 335–46.

Rose, A. K. (1988) Is the real interest rate stable?, *Journal of Finance*, **43**, 1095–12.