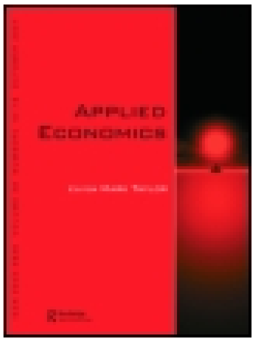

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The Fisher hypothesis: a multi-country analysis

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This paper tests whether the Fisher hypothesis holds for a sample of 26 countries by assessing the long run relationship between nominal interest rates and inflation rates taking into consideration the short run dynamics of interest rates. The empirical evidence supports the hypothesis that there is a one-to-one relationship between the interest rate and inflation for more than half of the countries under study.

I. INTRODUCTION

The Fisher hypothesis suggests that there is a positive relationship between interest rates and expected inflation. Boudoukh and Richardson (1993) argue that this positive relationship exists at all horizon lengths. In contrast, Mishkin (1992) reported the presence of this relationship for the long-run, but he could not detect the presence of the Fisher effect in the short-run for the USA. Moreover, Yuhn (1996) reported that the Fisher effect is strong over long horizons, and the presence of the Fisher effect can be seen in the short-run for Germany. Therefore, the results obtained by testing for the Fisher hypothesis might be influenced by the time horizon that has been selected. This study tests the Fisher hypothesis within the framework suggested by Moazzami (1989), which allows a direct estimate of the long-run relationship between interest rates and expected inflation by taking into consideration the short-run dynamics of the interest rates for 26 developed and developing countries.

The contribution of this paper to the literature can be highlighted within the following four headings. First, to the best of the authors' knowledge, this study is the most extensive study testing the Fisher hypothesis as far as the number of the countries that are incorporated is concerned.[1] Second, the sample includes both developed and developing economies, hence this allows one to assess the presence of the Fisher hypothesis for two types of economies. Third, studies that attempt to extract the long-term effect by applying methods similar to this utilized annual data (see Carmichael and Stebbing, 1983; Moazzami and Gupta, 1995), while this study uses monthly data. This is important because using annual data may lead to the aggregation biased problem suggested by Rossana and Seater (1995), whereas using monthly data may avoid that problem. Lastly, to the best of the authors' knowledge, this paper reports the most comprehensive robustness tests among the studies on the Fisher hypothesis testing. The next section introduces the basic model that is used to test the Fisher hypothesis, Section III presents the empirical evidence and Section IV summarizes the conclusions.

II. THE BASIC MODEL

The basic equation that has been used to test the Fisher hypothesis is

$$i_t = \alpha + \beta\pi_t^e \tag{1}$$

Where i_t is the nominal interest rate and π_t^e is the expected inflation for the period t. Here, β is expected to be one as there is a one-to-one relationship between interest rates and the expected inflation – the strong form of the Fisher hypothesis. However, β is positive but not equal to one in its weak form. Tobin (1965) suggests that if money and capital are the only forms of wealth, when the opportunity cost of holding money increases due to higher inflation, money holding decreases and capital stock increases.

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[1] Engsted (1995) and Koustas and Sertelis (1999) are the most comprehensive studies as far as the number of countries are concerned. These studies consider 13 and 11 OECD countries, respectively, for the testing of the Fisher hypothesis.

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Under decreasing return to scale economies, then interest rate decreases with lower levels of marginal productivity of capital. Therefore, in Tobin's world, β should be positive and less than one – the weak form of the Fisher hypothesis. On the other hand, tax-effect suggests that β is greater than one. Darby (1975) notes that when the nominal interest rate is taxed, the Fisher relationship implies that the change in the nominal interest rates is greater than the change in expected inflation so as to maintain the constant ex-ante real interest rate (see Crowder and Wodar, 1999). Nevertheless, all forms of Fisher hypothesis specifications suggest that β is positive.

In order to test the Fisher hypothesis, Moazzami (1989) assumes that the economy is in a steady state equilibrium and there is no deviation from its long-run equilibrium path in the short run. Here, ignoring the short-run dynamics and simply regressing nominal interest rates against the current rate of inflation suffers from misspecification, which manifests itself in residual autocorrelation. In fact, the estimated results reported by Equation 1 are associated with a common characteristic that is displayed in a low Durbin–Watson statistic, which can be regarded as a specific error due to the omission of the short-run dynamics. Some studies have addressed this issue by using the Cochrane–Orcutt procedure: e.g. Tanzi (1980) and Carmichael and Stebbing (1983). Others have attempted to minimize the effects of shorter-term fluctuations in the data, performing several transformations to reflect only the long-run tendencies of the data: e.g. Lucas (1980) and Lothian (1985). However, by using these transformations, all the information on the short-run dynamics could be lost.

In order to incorporate the short-run dynamics of interest rates, Moazzami (1989) allows for the presence of lags of interest rates on the right hand side of the equation. Hence, Equation 1 is respecified as:

$$i_t = \alpha + \sum_{i=1}^{m} \theta_i i_{t-i} + \beta\pi_t^e + \varepsilon_t \tag{2}$$

In order to estimate Equation 2, the expected inflation rate π_t^e must be specified. Gordon (1971) and Lahiri (1976) suggest that the expected inflation rate, which is unobservable, may be systematically related to past rates of inflation.[2] Hence, using the distributed lag of past rates of inflation as a proxy for the expected rate of inflation, Equation 2 can be written as:

$$i_t = \alpha + \sum_{i=1}^{m} \theta_i i_{t-i} + \sum_{i=0}^{n} \lambda_i \pi_{t-i} + e_t \tag{3}$$

Moazzami (1989) argues that the coefficients of the lagged variables are, in general, significantly different from zero in estimating Equation 3. In fact, if the coefficients of all lagged variables in Equation 3 are set to be equal to zero, then the conventional Fisher equation estimation is obtained under the implicit assumption of a steady state equilibrium in which all expectations are realized and the actual and expected rates of inflation are identical. In order to measure the expected inflation rate, an auxiliary equation can be used. However, using a distributed lag of the actual inflation rates as a proxy for the expected rate has the advantage of avoiding the problems associated with the use of generated regressors. Under the assumption of no autocorrelation, Equation 3 can be estimated by using the Ordinary Least Squares (OLS) method. The estimates then give the long-run response coefficient of the interest rate to the rate of inflation. This is expressed as follows:

$$\Gamma = \frac{\sum_{i=0}^{n} \lambda_i}{1 - \sum_{i=1}^{m} \theta_i} \tag{4}$$

In order to calculate the variance of Γ estimate, the transformation first proposed by Bewley (1979) and then modified by Wickens and Breusch (1988) was used. The method first subtracts $(\sum_{i=1}^{m} \theta_i) i_t$ from each side of Equation 3 and rearranges the terms such that it yields:

$$i_t = \alpha - \Theta \sum_{i=0}^{m-1} \left(\sum_{j=i+1}^{m} \theta_j \right) \Delta i_{t-i} + \Theta \left(\sum_{i=0}^{n} \lambda_i \right) \pi_t - \Theta \sum_{i=0}^{n-1} \left(\sum_{j=i+1}^{n} \lambda_j \right) \Delta\pi_{t-i} + \Theta e_t \tag{5}$$

where

$$\Delta X_{t-i} = X_{t-i} - X_{t-i-1}$$
$$\Theta = \frac{1}{1 - \sum_{i=1}^{m} \theta_i}$$

Here, the coefficient of π_t is the long-run multiplier of the Fisher equation, Γ, as defined in Equation 4. The long-run adjustment coefficient for the interest rate, as well as the other coefficients of Equation 5, can be estimated using the instrumental variable method. Wickens and Breusch (1988) showed that the estimate of the long-run multiplier obtained by estimating the transformed model, Equation 5 via instrumental variables is numerically identical to the one calculated from the OLS estimates of Equation 3, provided that all the predetermined variables of the original Equation 3 are used as instruments. Hence, this paper estimates the form of Equation 5 with the instrumental vari-

[2] In addition to using the autoregressive specification of the inflation equation, other specifications are tried, such as including the lag and (or) current values of money growths to form the expectations of the inflation for some of the countries. When these alternative specifications are used, the basic results of the study were robust.

able technique in order to test the basic implication of the Fisher hypothesis.

III. RESULTS

This section presents the basic empirical evidence for testing the Fisher hypothesis. The next sub-section introduces the data, the second sub-section reports the estimates of the model, the third sub-section is for the robustness analyses.

Data

Interest data is either treasury bill rates, if available, or the lending rate. The lending rate, rather than other interest rates, is used when the treasury bill rate is not available because it is believed that the lending rate is the most risk free measure of interest rates after treasury bill rates. The inflation rate is measured by the logarithmic first difference of the consumer price index. The countries that were examined, the definition of the interest rate that was used and the data sample are reported in Table 1. All the data are from the International Monetary Fund–International Financial Statistics tape and the sample size is the largest monthly sample that is available from the tape. The specific definitions of treasury bill and lending rates for each country are also available from the tape.

Table 1. *List of countries studied*

Country	Interest rate used	Sample period
	Developed countries	
Belgium	Treasury bill rate	1957:04 1998:05
Canada	Treasury bill rate	1957:08 1998:05
Denmark	Treasury bill rate	1981:06 1988:12
Finland	Lending rate	1978:03 1998:04
France	Treasury bill rate	1966:03 1998:05
Germany	Treasury bill rate	1975:10 1998:05
Italy	Treasury bill rate	1977:07 1998:04
Japan	Lending rate	1957:05 1998:05
Korea	Lending rate	1981:01 1998:03
Switzerland	Treasury bill rate	1980:05 1998:05
UK	Treasury bill rate	1964:07 1998:05
USA	Treasury bill rate	1964:04 1998:05
	Developing countries	
Brazil	Treasury bill rate	1995:05 1998:03
Chile	Lending rate	1978:01 1998:05
Costa Rica	Lending rate	1982:05 1998:05
Egypt	Lending rate	1976:03 1998:04
Greece	Lending rate	1957:05 1998:05
India	Lending rate	1979:04 1998:01
Kuwait	Treasury bill rate	1979:08 1996:07
Mexico	Treasury bill rate	1978:04 1998:05
Morocco	Treasury bill rate	1978:08 1991:12
Philippines	Treasury bill rate	1982:01 1998:04
Turkey	Treasury bill rate	1985:12 1995:08
Uruguay	Lending rate	1980:04 1998:05
Venezuela	Lending rate	1984:07 1998:04
Zambia	Treasury bill rate	1985:02 1998:01

Estimates and basic results

In order to estimate Equation 5, the optimum lag orders of the interest rate and inflation are determined from Equation 3. In order to determine the optimum lag orders for lagged values of both inflation and interest rates, the Final Prediction Error Criteria suggested by Hsiao (1979) is used. His method determines the optimum lag order such that the residual term is no longer autocorrelated. Once the optimum lag length is determined, these lag orders are used as the lag orders of those two variables in Equation 5.

In order to assess the short- and long-run dynamics of interest rates, Equation 5 is estimated via the instrumental variable method, where the predetermined variables of Equation 3 are used as instruments [parallel to those proposed by Wickens and Breusch (1988)]. This method allows one to estimate the long-run adjustment coefficient, Γ, for the interest rate to the rate of inflation directly. The estimates of the model for the developed countries under study are reported in Table 2, and Table 3 reports the estimates for developing countries.

For the 26 countries examined, except for Brazil and Costa Rica, positive coefficients are estimated for Γ. The null hypothesis that Γ is one – the strong version of the Fisher hypothesis – is also tested. The test statistics could not reject the null hypothesis for 16 out of 26 countries. Among the developed countries, no evidence was found to reject the strong version of the Fisher hypothesis for 9 out of 12 countries; these countries are Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, Switzerland and the USA. However, the estimated coefficients of Γ for Belgium and Finland are not statistically significantly different from zero. The results in the strong form of the Fisher hypothesis are in line with those reported by Moazzami and Gupta (1995) for Canada, Germany, Italy, the UK and the USA. The only result of the study conflicting with that of Moazzami and Gupta (1995) is in the case of France. One possible reason for the difference is that they used annual data from 1953 to 1989 and this study used monthly data from 1966:03 to 1998:05. For the twelve developed countries that have been examined in this study, the authors tested whether the coefficient of the inflation, Γ, is positive and statistically significant among the countries where the strong form of the Fisher hypothesis is rejected. Only the null hypothesis that Γ is zero, the weak form of the Fisher hypothesis, for France is rejected. Only for the UK is the coefficient not statistically significant.

The Fisher hypothesis is tested for the set of the developing countries and the results are reported in Table 3. No statistically significant evidence was found to reject the strong version of the Fisher hypothesis for 7 out of 14 countries: Chile, Greece, Mexico, Turkey, Uruguay, Venezuela and Zambia. The empirical evidence also suggests that among the countries where the strong form of the Fisher hypothesis is not supported (Brazil, Costa Rica, Egypt, India, Kuwait, Morocco and the Philippines), the null hypothesis that Γ is zero for Brazil, Costa Rica, India, Kuwait and Morocco could not be rejected. For the Mexican case, the result is parallel with the result reported by Thornton (1996).

The short-run dynamics of the nominal interest rate to the expected inflation rate are reported in Tables 2 and 3. $\Theta\lambda_0, \Theta\lambda_1, \Theta\lambda_2, \ldots, \Theta\lambda_5$ show the response of the nominal interest rate to expected inflation in the corresponding period. Examining the countries where the strong form of the Fisher hypothesis holds, it is concluded that the short-run responses of the nominal interest rate to expected inflation do not display a consistent pattern. In fact, the adjustment process differs from one country to another. However, an interesting point is that for some of the developing countries, the short-run adjustment of the nominal interest rate to expected inflation is more than proportional, in particular for the Chilean, Mexican and Venezuelan cases. In contrast, for the developed countries, the short-run adjustment of the nominal rate to expected inflation is always less than proportional.

Robustness analyses

It is possible that the regression analyses performed in the last section give spurious regression results. Hence, in this section various robustness tests are performed. First, the errors of the model are tested for autocorrelation. These

Table 2. *Long-term effect of inflationary expectatons on the nominal interest rate: developed countries*

Country	Belgium^t	Canada^t	Denmark^t	Finland^l	France^t	Germany^t
Period	1957:04	1957:08	1981:06	1978:03	1966:03	1975:10
	1998:05	1998:05	1988:12	1998:04	1998:05	1998:05
Constant	0.392	0.225	0.339	0.275	0.218	0.264
	(0.143)	(0.135)	(0.180)	(0.286)	(0.030)	(0.087)
π_t	0.620*	0.98*	1.302*	0.963*	0.465	0.814*
	(0.339)	(0.401)	(0.325)	(0.626)	(0.075)	(0.362)
Δi_t	−77.131	−36.305	−12.024	−112.579	−25.445	−33.545
	(37.853)	(13.693)	(5.955)	(87.420)	(8.662)	(16.820)
Δi_{t-1}	13.066	12.650	–	10.412	−1.925	8.613
	(8.168)	(5.441)		(15.147)	(1.283)	(4.268)
Δi_{t-2}	–	0.440	–	23.684	–	4.183
		(2.995)		(17.888)		(4.418)
Δi_{t-3}	–	−1.319	–	–	–	–
		(1.894)				
Δi_{t-4}	–	−0.322	–	–	–	–
		(2.157)				
Δi_{t-5}	–	1.722	–	–	–	–
		(2.376)				
Δi_{t-6}	–	−4.245	–	–	–	–
		(2.940)				
$\Delta\pi_t$	−0.268	−0.663	−1.288	−1.159	−0.306	−0.429
	(0.293)	(0.328)	(0.301)	(0.857)	(0.132)	(0.287)
$\Delta\pi_{t-1}$	0.373	–	−1.079	−0.882	−0.366	−0.127
	(0.384)		(0.276)	(0.632)	(0.095)	(0.211)
$\Delta\pi_{t-2}$	–	–	−0.829	–	−0.321	0.271
			(0.215)		(0.110)	(0.226)
$\Delta\pi_{t-3}$	–	–	−0.483	–	–	
			(0.168)			
$\Delta\pi_{t-4}$	–	–	−0.306	–	–	–
			(0.168)			
$\Theta\lambda_0$	0.352	0.315	0.015	−0.197	0.159	0.385
$\Theta\lambda_1$	0.641	0.663	0.209	0.277	−0.060	0.302
$\Theta\lambda_2$	−0.373	–	0.249	0.882	0.045	0.398
$\Theta\lambda_3$	–	–	0.337	–	0.321	−0.271
$\Theta\lambda_4$	–	–	0.187	–	–	–
$\Theta\lambda_5$	–	–	0.305	–	–	–
DW	1.99	2.00	1.87	2.00	2.00	1.99
R^2	0.99	0.98	0.98	0.98	0.99	0.98

Table 2. *(continued)*

Country	Italy[t]	Japan[l]	Korea[l]	Switzerland[t]	UK[t]	USA[t]
Period	1977:07	1957:05	1981:01	1980:05	1964:07	1964:04
	1998:04	1998:05	1998:03	1998:05	1998:05	1998:05
Constant	0.470	0.352	0.729	0.189	0.686	0.276
	(0.180)	(0.196)	(0.070)	(0.068)	(0.101)	(0.127)
π_t	0.744*	0.430*	0.339	0.661*	0.113	0.663*
	(0.223)	(0.302)	(0.204)	(0.306)	(0.124)	(0.401)
Δi_t	−27.378	−262.474	−21.695	−18.979	−34.903	−23.106
	(13.104)	(173.425)	(9.419)	(7.930)	(11.997)	(12.678)
Δi_{t-1}	−0.152	177.103	3.561	1.069	13.819	8.274
	(2.467)	(116.483)	(3.542)	(1.725)	(5.542)	(5.527)
Δi_{t-2}	3.469	−57.148	−1.084	1.730	−1.023	−5.331
	(2.838)	(51.079)	(1.373)	(1.697)	(2.125)	(4.323)
Δi_{t-3}	0.369	79.175	6.111	2.775	−0.351	–
	(2.199)	(47.731)	(3.488)	(2.067)	(2.273)	
Δi_{t-4}	–	–	0.517	–	0.021	–
			(1.581)		(2.294)	
Δi_{t-5}	–	–	–	–	2.507	–
					(2.187)	
$\Delta \pi_t$	−0.974	−0.210	–	−0.770	−0.253	0.081
	(0.397)	(0.161)		(0.295)	(0.119)	(0.413)
$\Delta \pi_{t-1}$	–	–	–	−0.269	−0.203	0.396
				(0.184)	(0.106)	(0.417)
$\Delta \pi_{t-2}$	–	–	–	–	–	−0.173
						(0.307)
$\Delta \pi_{t-3}$	–	–	–	–	–	0.049
						(0.356)
$\Delta \pi_{t-4}$	–	–	–	–	–	−0.909
						(0.483)
$\Theta\lambda_0$	−0.230	0.220	0.339	−0.109	−0.140	0.744
$\Theta\lambda_1$	0.974	0.210	–	0.501	0.049	0.315
$\Theta\lambda_2$	–	–	–	0.269	0.203	−0.569
$\Theta\lambda_3$	–	–	–	–	–	0.222
$\Theta\lambda_4$	–	–	–	–	–	−0.959
$\Theta\lambda_5$	–	–	–	–	− 0.909	
DW	2.02	1.99	1.99	2.02	1.99	2.00
R^2	0.97	0.99	0.96	0.96	0.97	0.96

Standard deviations are given in parentheses.
Standard deviations are corrected for heteroscedasticity with White (1980).
* Do not reject the null hypothesis: $\Gamma = 1$ at the 5% significance level.
[t] Treasury bill rate is used to model the interest rate.
[l] Lending rate is used to model the interest rate.

error terms are then tested for the autoregressive conditional heteroscedasticity (ARCH) by using the ARCH-LM test suggested by Engle (1982). Lastly, stability tests using Chow's test are performed.

Tables 4 and 5 report the Ljung-Box Q statistics for serial correlations for different lag orders for all the countries under study. Table 4 suggests that the autocorrelation problem is not present for any of the developed countries except for the USA. The Fisher hypothesis estimates for the USA are addressed later in the paper. Table 5 reports the Q-statistics for the developing countries under study. The null hypothesis of no autocorrelation is rejected only in the Zambia case for the 15th and 18th lags and in the Chile case for the 12th lag. The autocorrelation problem for those two developing economies exists only in high orders; therefore, it is assumed that the autocorrelation problem does not exist for these countries.

As a second test of robustness, ARCH-LM tests are performed in order to check for the presence of the ARCH effect. Therefore, the model's squared residuals are regressed on its lagged squared residuals in different lag orders and the constant term in order to test the null hypothesis that the coefficient of the lagged squared residuals are all zero. Table 6 and Table 7 report the calculated F-statistics for each country under study and for the different number of squared residual lags. Table 6 reports the ARCH-LM test for the developed economies in the sample. The test statistics could not reject the null hypothesis that

Table 3. *Long-term effect of inflationary expectations on the nominal interest rate: developing countries*

Country	Brazil[l]	Chile[l]	Costa Rica[l]	Egypt[l]	Greece[l]	India[l]
Period	1995:05	1978:01	1982:05	1976:03	1957:05	1979:04
	1998:03	1998:05	1998:05	1998:04	1998:05	1998:01
Constant	2.408	0.888	2.267	0.857	0.632	1.345
	(0.664)	(0.445)	(0.305)	(0.203)	(0.201)	(0.048)
π_t	−0.381	1.385*	−0.012	0.453	1.01*	0.007
	(0.677)	(0.358)	(0.133)	(0.185)	(0.329)	(0.059)
Δi_t	−3.495	−5.877	−35.831	−49.742	−141.359	−21.683
	(1.519)	(2.028)	(16.956)	(18.256)	(62.129)	(17.043)
Δi_{t-1}	-1.151	0.942	10.569	−9.458	−0.928	0.335
	(0.672)	(0.510)	(5.280)	(4.700)	(5.223)	(0.486)
Δi_{t-2}	−0.169	−1.063	4.401	–	5.786	1.746
	(0.321)	(0.611)	(3.525)		(7.333)	(1.241)
Δi_{t-3}	0.569	−0.154	4.927	–	21.988	5.939
	(0.305)	(0.474)	(3.060)		(15.333)	(5.133)
Δi_{t-4}	–	−0.776	–	–	–	–
		(0.452)				
$\Delta \pi_t$	–	−0.824	−0.092	−0.454	−0.955	−0.095
		(0.411)	(0.223)	(0.197)	(0.399)	(0.072)
$\Delta \pi_{t-1}$	–	2.527	−0.415	−0.357	−0.919	–
		(1.07)	(0.324)	(0.138)	(0.358)	
$\Delta \pi_{t-2}$	–	–	–	−0.225	−0.548	–
				(0.084)	(0.260)	
$\Delta \pi_{t-3}$	–	–	–	−0.097	–	–
				(0.045)		
$\Theta\lambda_0$	−0.381	0.561	−0.104	−0.001	0.059	−0.088
$\Theta\lambda_1$	–	3.351	−0.324	0.097	0.036	0.095
$\Theta\lambda_2$	–	−2.527	0.415	0.132	0.371	–
$\Theta\lambda_3$	–	–	–	0.128	0.548	–
$\Theta\lambda_4$	–	–	–	0.097	–	–
DW	1.80	1.99	1.99	1.99	2.00	1.94
R^2	0.87	0.92	0.97	0.99	0.99	0.93

there is no ARCH effect for Canada, Denmark, France, Germany and Korea. For the Belgian, Finnish, Italian and Swiss specifications, autoregressive conditional heteroscedasticity is detected only for one lag of the squared residuals. However, for the USA and Japan, autoregressive conditional heteroscedasticity is detected for most of the lags of the squared residuals included. Table 7 reports the ARCH-LM tests for the set of developing countries. The test statistics cannot reject the null hypothesis that there is no autoregressive conditional heteroscedasticity for any of the countries in the sample except for the cases of Chile, Turkey and Venezuela. In the case of Turkey, the ARCH process is detected only when one lag of the squared residuals is included. For Chile and Venezuela, however, the ARCH process is detected when one and three lags of the squared residuals are included. To sum up, of all the country models that were estimated, the ARCH effect has been defected only for Belgium, Chile, Finland, Italy, Japan, Switzerland, Turkey, the UK, the USA and Venezuela out of the 26 countries in the sample. In this study, the presence of the ARCH effect may indicate the presence of the misspecification as well as the presence of the time varying risk in the interest rates. Further research is needed to elaborate upon this issue; hence, it is left for a further study.

As a third robustness test in addition to testing the models for any serial autocorrelation and for the ARCH effect, models were tested for possible structural changes. The empirical evidence suggests that none of the countries except for the USA indicate structural change at the conventional 5% level (results are not reported here, but are available from the authors upon request).

In order to address the structural change for the US specification, the model is reestimated for different subsamples as suggested by the Chow break-point tests. The estimates are provided in Table 8. Even if none of the coefficients of the inflation are statistically significant, the Fisher hypothesis in its strong form could not be rejected for any of the sub-periods. Moreover, the latter models do not show any serial autocorrelation. While the ARCH process is detected for the first two sample periods, it could not be observed in a statistically significant fashion for the third sub-periods. The detailed results for the Q-statistic test and the ARCH-LM tests are provided in Table 9.

Lastly, it could be argued that if interest rates and inflation are nonstationary series, then the Fisher hypothesis

Table 3. *(continued)*

Kuwait	Mexico[t]	Morocco[t]	Philippines[t]	Turkey[t]	Uruguay[l]	Venezuela[l]	Zambia[t]
1979:08	1978:04	1978:08	1982:01	1985:12	1980:04	1984:07	1985:02
1996:07	1998:05	1991:12	1998:04	1995:08	1998:05	1998:04	1998:01
0.535	0.991	0.816	0.918	3.072	2.514	1.167	0.092
(0.035)	(0.493)	(0.108)	(0.173)	(4.057)	(1.269)	(1.274)	(2.128)
0.062	0.810*	0.219	0.515	0.608*	1.586*	0.451*	0.727*
(0.069)	(0.221)	(0.130)	(0.200)	(1.102)	(0.374)	(0.550)	(0.644)
−24.442	−10.902	−88.815	−9.601	−20.182	−17.463	−34.325	−22.876
(16.327)	(5.437)	(66.772)	(3.983)	(23.375)	(5.287)	(20.481)	(15.817)
−0.424	4.671	–	3.076	2.331	1.940	2.433	10.286
(2.398)	(2.729)		(1.583)	(4.433)	(1.438)	(6.471)	(5.505)
1.415	−2.789	–	–	−0.899	3.417	1.463	5.012
(2.973)	(1.619)			(1.676)	(1.851)	(3.899)	(6.39)
6.528	–	–	–	–	–	−3.199	−5.921
(3.560)							
–	–	–	–	–	–	–	–
−0.077	0.877	−0.402	−0.311	−0.494	−0.733	0.849	–
(0.062)	(0.649)	(0.255)	(0.158)	(0.926)	(0.317)	(0.678)	
–	1.049	–	−0.322	−0.101	−0.332	–	–
	(0.699)		(0.205)	(0.680)	(0.274)	–	–
–	0.534	–	−0.287	0.474	–	–	–
	(0.496)		(0.107)	(0.746)			
–	–	–	–	0.169	–	–	–
				(0.617)			
–	–	–	–	0.942	–		
				(1.151)			
−0.016	1.680	−0.183	0.205	0.115	0.854	1.300	0.727
0.077	0.172	0.402	−0.010	0.392	0.401	−0.849	–
–	−0.516	–	0.035	0.576	0.332	–	–
–	−0.533	–	0.287	−0.305	–	–	–
–	–	–	–	0.773	–	–	–
–	–	–	–	−0.942	–	–	–
1.94	2.02	2.04	1.98	2.09	2.01	2.02	2.04
0.94	0.97	0.98	0.93	0.89	0.98	0.96	0.96

Standard deviations are given in parentheses.
Standard deviations are corrected for heteroscedasticity with White (1980).
* Do not reject the null hypothesis: $\Gamma = 1$ at the 5% significance level.
[t] Treasury bill rate is used to model the interest rate.
[l] Lending rate is used to model the interest rate.

Table 4. *Ljung-Box Q-statistics: F-values for developed countries*

	Number of lags						
Country	1	3	6	9	12	15	18
Belgium	0.017	1.042	4.080	5.556	14.059	14.967	15.353
Canada	0.001	0.116	0.165	9.120	11.826	14.329	18.887
Denmark	0.391	0.893	3.619	5.743	13.577	17.018	18.138
Finland	0.005	0.962	1.347	7.110	7.175	7.896	9.019
France	0.000	2.686	3.826	5.416	12.002	13.455	13.805
Germany	0.000	0.235	5.053	8.896	16.362	20.499	20.933
Italy	0.033	0.259	0.395	3.874	6.127	12.648	16.431
Japan	0.013	1.219	9.337	11.831	15.717	20.083	20.875
Korea	0.000	0.027	1.356	1.780	3.625	4.113	10.754
Switzerland	0.056	0.126	0.919	4.282	9.565	11.173	22.214
UK	0.000	0.007	0.049	0.541	5.991	18.885	19.077
USA	0.000	1.443	23.346*	43.149*	47.808*	92.129*	95.513*
Critical χ^2 Values	3.84	7.81	12.6	16.9	21.0	25.0	28.9

* Rejects the null that there is no autocorrelation at the 5% significance level.

Table 5. *Ljung-Box Q-statistics: F-values for developing countries*

	Number of Lags						
Country	1	3	6	9	12	15	18
Brazil	0.264	2.027	2.917	3.346	3.430	3.601	–
Chile	0.000	1.246	4.406	8.516	22.252*	22.641	23.403
Costa Rica	0.002	0.301	3.942	4.923	10.390	13.285	15.064
Egypt	0.007	0.092	2.915	4.320	8.603	9.660	11.630
Greece	0.000	0.213	1.409	1.716	12.107	21.421	21.898
India	0.008	0.013	2.633	8.574	8.713	11.326	13.688
Kuwait	0.159	0.202	6.042	15.337	16.678	17.199	17.865
Mexico	0.034	0.297	7.662	9.691	16.003	19.002	23.897
Morocco	0.034	0.128	1.200	2.145	2.490	2.732	6.543
Philippines	0.010	1.391	7.410	9.992	12.114	15.320	19.084
Turkey	0.428	1.851	4.371	7.706	10.341	16.744	20.341
Uruguay	0.006	1.691	2.172	6.776	8.462	10.034	14.630
Venezuela	0.021	0.167	5.466	6.310	10.924	14.569	17.139
Zambia	0.081	0.623	8.319	9.880	17.001	27.287*	30.441*
Critical χ^2 Values	3.84	7.81	12.6	16.9	21.0	25.0	28.9

* Rejects the null that there is no autocorrelation at the 5% significance level.

Table 6. *ARCH-LM test: F-values for developed countries*

	Number of Lags						
Country	1	3	6	9	12	15	18
Belgium	8.063*	5.496	3.068	2.086	1.648	1.302	1.084
Canada	3.819	4.932	2.843	14.880	12.615	10.500	9.104
Denmark	0.000	0.129	0.106	0.267	0.246	0.375	0.359
Finland	9.560*	4.088	2.455	2.264	1.833	1.478	1.410
France	0.002	0.080	0.089	0.122	2.727	2.158	1.775
Germany	0.130	3.083	2.400	2.764	2.384	2.006	1.713
Italy	8.904*	3.627	2.072	1.401	1.077	1.170	1.145
Japan	87.936*	65.615*	50.008*	34.458*	26.031*	20.586	16.965
Korea	3.703	3.063	1.563	1.027	0.763	0.606	2.026
Switzerland	10.298*	6.572	5.885	4.736	5.227	4.628	3.969
UK	34.777*	13.643*	8.275	5.652	4.239	3.407	2.858
US	118.858*	49.505*	33.056*	22.708*	18.832	15.486	13.795
Critical χ^2 Values	3.84	7.81	12.6	16.9	21.0	25.0	28.9

* Rejects the null that there is no ARCH at the 5% significance level.

Table 7. *ARCH-LM test: F-values for developing countries*

	Number of Lags						
Country	1	3	6	9	12	15	18
Brazil	0.004	0.041	0.042	0.048	0.045	1.335	–
Chile	9.776*	15.159*	3.868	5.754	2.873	2.493	2.079
Costa Rica	0.075	0.456	0.612	0.510	0.532	0.500	0.599
Egypt	0.295	0.109	0.108	0.231	0.201	0.209	0.218
Greece	0.038	1.048	0.560	0.393	2.077	3.102	2.594
India	0.140	0.875	3.042	4.492	3.800	2.967	2.631
Kuwait	0.122	0.862	5.501	4.339	3.101	2.443	1.937
Mexico	0.688	1.505	1.077	0.683	0.525	0.978	1.488
Morocco	0.040	0.043	0.040	0.043	0.047	0.052	0.071
Philippines	3.629	1.257	1.099	0.935	0.934	1.930	1.598
Turkey	11.754*	3.912	3.958	0.726	0.614	0.653	1.814
Uruguay	0.839	1.086	3.167	2.151	1.681	1.435	1.301
Venezuela	46.176*	16.723*	8.592	5.530	4.020	3.129	2.530
Zambia	0.011	0.201	8.298	6.057	6.479	5.445	4.352
Critical χ^2 Values	3.84	7.81	12.6	16.9	21.0	25.0	28.9

* Rejects the null that there is no ARCH at the 5% significance level.

suggests these two variables must be cointegrated. Therefore, first the unit root tests of the interest rate, inflation and their first differences are reported in Table 10. The presence of unit roots in interest rates cannot be rejected for any countries except for Chile at the conventional 5% level of significance. However, their presence in inflation can be rejected for all the countries except for Italy, the USA, Chile, Costa Rica, Mexico, Venezuela and Zambia. (Engsted, 1995, also finds similar results for some of the countries in his sample.) Therefore, the empirical evidence presented in the table may suggest that there is no long-run relationship between these variables; and the real interest rate may include a unit root. This is not what most of the macroeconomic models suggest even if King *et al.* (1991) imply that the real interest rate is nonstationary for the USA within the real business cycles framework. Another reason could be that even if one cannot reject the unit root in interest rates, they are in fact stationary through near-integration.

In order to see if there is a spurious relationship between the interest rates and inflation, the Engle and Granger (1987) type of cointegration test was performed. After regressing the interest rate on a constant term and inflation. Column I of Table 11 reports the ADF tests statistics of the residuals. One can reject the null of unit root in 17 out of 26 cases at the 5% level of significance. This specification does not account for the short-run dynamics of the interest rates. The unit root of the residuals for Equation 5 is also tested. The ADF tests are reported in column II of Table 11. One can reject the unit root for all the countries in the sample. Hence, there is a long-run relationship between the interest rate and inflation, and the results reported in Tables 2 and 3 are not spurious.[3]

Table 8. *Adjusted models for US data*

	USA		
Period	1974:01 1981:01	1981:01 1990:01	1990:01 1998:05
Constant	0.222	0.429	0.402
	(0.775)	(0.164)	(0.169)
π_t	0.777*	0.5734*	−0.132*
	(1.377)	(0.488)	(0.765)
Δi_t	−34.477	−11.924	−46.964
	(91.934)	(5.225)	(31.276)
Δi_{t-1}	20.754	1.203	20.303
	(53.653)	(1.463)	(12.562)
Δi_{t-2}	−16.775	−2.108	5.986
	(44.550)	(2.169)	(6.600)
Δi_{t-3}	–	1.208	–
		(1.755)	
Δi_{t-4}	–	−2.914	–
		(2.159)	
Δi_{t-5}	–	3.348	–
		(2.304)	
$\Delta \pi_t$	1.145	0.305	−0.009
	(3.898)	(0.526)	(0.614)
$\Delta \pi_{t-1}$	1.743	0.103	0.433
	(5.249)	(0.451)	(0.717)
$\Delta \pi_{t-2}$	0.767	−0.102	0.698
	(2.904)	(0.337)	(0.835)
$\Delta \pi_{t-3}$	0.606	−0.241	0.087
	(2.574)	(0.326)	(0.461)
$\Delta \pi_{t-4}$	−2.719	−0.801	0.089
	(6.626)	(0.403)	(0.320)
$\Theta\lambda_0$	1.922	0.879	-0.141
$\Theta\lambda_1$	0.597	−0.203	0.442
$\Theta\lambda_2$	−0.975	−0.204	0.264
$\Theta\lambda_3$	−0.161	−0.139	−0.611
$\Theta\lambda_4$	−3.326	−0.560	0.003
$\Theta\lambda_5$	2.719	0.802	−0.089
DW	1.95	1.88	2.04
R^2	0.94	0.96	0.99

Standard deviations are given in parentheses.
Standard deviations are corrected for heteroscedasticity with White (1980).
* Do not reject the null hypothesis. $\Gamma = 1$ at the 5% significance level.

Table 9. *Robustness analysis for US adjusted models*

		United States		
	Period	1974:01 1981:01	1981:01 1990:01	1990:01 1998:05
Lags	Critical χ^2 values		Q-statistics F-values	
1	3.84	0.034*	0.359*	0.084*
3	7.81	0.254*	1.054*	4.097*
6	12.6	4.929*	8.206*	6.633*
9	16.9	8.785*	12.458*	13.755*
12	21.0	10.761*	13.909*	13.970*
15	25.0	16.803*	19.438*	20.566*
18	28.9	18.221*	20.897*	22.405*
			ARCH-LM test F-values	
1	3.84	45.693	5.908	0.000°
3	7.81	18.704	12.451	1.341°
6	12.6	9.169°	23.312	2.13°
9	16.9	6.369°	14.882	1.388°
12	21.0	5.155°	7.392°	1.494°
15	25.0	3.947°	5.469°	1.165°
18	28.9	3.494°	5.787°	0.998°

* Does not reject that all of the autocorrelations are zero at the 5% significance level.
° Does not reject that there is no ARCH at the 5% significance level.

[3] An alternative to Wickens and Breush's (1988) method could be Pesaran and Shin's (1999) cointegration implication of the Autoregressive Distributed Lag modelling. However, the latter model requires both the interest rate and inflation to be $I(1)$. Since Table 10 suggests that inflation is $I(0)$, the Pesaran and Shin (1999) approach has been avoided in this study.

Table 10. *Stationarity test for the interest rate and the inflation rate*

	ADF test statistics			
	Interest rate		Inflation rate	
Country	i_t	Δi_t	π_t	$\Delta\pi_t$
Belgium	−1.16	−10.01**	−4.86**	−18.44**
Canada	−2.24	−9.75**	−4.48*	−14.87**
Denmark	−1.69	−4.45*	−6.68**	−20.46**
Finland	−0.87	−5.53**	−5.21**	−16.99**
France	−1.23	−8.52**	−5.09**	−15.46**
Germany	−1.99	−5.68**	−8.79**	−16.33**
Italy	−0.80	−6.18**	−4.08	−15.54**
Japan	−1.05	−5.30**	−7.12**	−20.06**
Korea	−2.32	−4.19	−5.28**	−13.41**
Switzerland	−1.86	−5.63**	−7.62**	−19.45**
UK	−2.75	−7.94**	−5.70**	−19.18**
USA	−2.39	−8.91**	−4.12	−14.96**
Brazil	−1.53	−5.05**	−2.87**	−7.58**
Chile	−5.13**	−10.13**	−3.43	−15.17**
Costa Rica	−2.15	−5.71**	−4.26	−16.99**
Egypt	−2.59	−6.08**	−9.37**	−19.02**
Greece	−1.05	−8.40**	−7.47**	−32.99**
India	−2.84	−5.95**	−10.46**	−12.58**
Kuwait	−1.50	−5.71**	−6.02**	−13.77**
Mexico	−2.36	−8.19**	−3.45	−13.10**
Morocco	−1.36	−5.49**	−10.36**	−18.18**
Philippines	−2.92	−7.54**	−6.07**	−16.72**
Turkey	−0.69	−7.15**	−5.32**	−16.34**
Uruguay	−1.49	−5.80**	−5.46**	−19.95**
Venezuela	−1.33	−4.40	−4.03	−15.51**
Zambia	−2.41	−7.33**	−3.88	−8.73**

The critical values are −5.24, −4.70, and −4.42 for a sample size of 480, at the 1% , 5% , and 10% significance levels, respectively (MacKinnon, 1991). A constant and 4 lags are included in the test regression.
** Reject the null hypothesis of the unit root at the 5% significance level.
* Reject the null hypothesis of the unit root at the 10% significance level.

IV. CONCLUSION

There is a long tradition of testing the Fisher hypothesis in economics literature. In this study, the available literature have been extended by examining the Fisher hypothesis for a sample of 26 countries using a method that allows one to observe the long-run relationship between interest rates and inflation by abstracting from the short-run dynamics of interest rates. In this work, attention was focused on testing the strong version of the Fisher hypothesis: Does the nominal interest rate rise point-for-point with the expected inflation?

This study finds supporting evidence for the strong version of the Fisher hypothesis in 16 out of 26 countries. It is also likely that the Fisher hypothesis holds more for the developed countries than the developing ones in the sample. The strong version of the Fisher hypothesis could not be rejected for 9 out of 12 developed countries and for 7 out of 14 developing countries.

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Table 11. *Test on the linear relationship*

Country	I Statistic	II Statistic
Belgium	−1.70*	−10.55***
Canada	−2.69***	−9.30***
Denmark	−1.67*	−4.76***
Finland	−0.59	−6.91***
France	−2.21**	−9.54***
Germany	−2.18**	−6.79***
Italy	−2.16**	−7.40***
Japan	−0.07	−9.73***
Korea	−1.66*	−6.15***
Switzerland	−2.20**	−6.00***
UK	−2.91***	−8.94***
USA	−8.29***	−8.29***
Brazil	−2.49**	−2.22**
Chile	−1.68*	−5.95***
Costa Rica	−5.54***	−6.55***
Egypt	−2.18**	−6.75***
Greece	−2.54**	−10.17***
India	−1.98**	−7.04***
Kuwait	−2.23**	−6.29***
Mexico	−1.66*	−7.51***
Morocco	−3.30***	−5.25***
Philippines	−1.32	−7.38***
Turkey	−2.32**	−5.09***
Uruguay	−2.31**	−6.38***
Venezuela	−1.66*	−4.38***
Zambia	−2.50**	−5.06***

The critical values are −2.57, −1.94, and −1.62 at the 1%, 5%, and 10% significance levels, respectively (MacKinnon, 1991).
No intercept, no trend and 4 lags are included in the test regression, except for Denmark 2, Greece 2, Turkey 3 and Venezuela 2.
*** Reject the null hypothesis of the unit root at 1% significance level.
** Reject the null hypothesis of the unit root at the 5% significance level.
* Reject the null hypothesis of the unit root at the 10% significance level.

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