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An Empirical Examination of the Fisher Hypothesis in Sri Lanka

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An Empirical Examination of the Fisher Hypothesis in Sri Lanka

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Abstract

Maintaining a low rate of inflation is very important to achieve sustainable economic growth but is a challenging task for policy makers. Interest rates are one of the main channels through which monetary policy changes can be used to achieve this goal of low inflation. Thus, a significant relationship between interest rates and inflation reveals the effectiveness of monetary policy in controlling inflation. The “Fisher hypothesis” provides a theoretical basis for this relationship. This hypothesis states the nominal interest rate rises one-for-one with inflationary expectations, maintaining, other things being constant, a constant real interest rate.

The aim of this study is to test the Fisher hypothesis in Sri Lanka with the aid of recently introduced econometric tools for the period January 1986 to December 1995, using monthly data. Even though the current inflation rate in Sri Lanka is not as high as in most developing countries, maintaining a low inflation rate receives a high priority in the Sri Lankan Government’s policy agenda.

The results suggest that Sri Lankan nominal interest rates do not fully adjust to expected inflation which in turn indicates that real variables are not completely insulated from monetary changes. Therefore, changes in monetary instruments do not appear to be completely effective in meeting the goal of low inflation.
Introduction

The ‘Fisher hypothesis’, widely accepted as the cornerstone of interest rate theory, suggests that the nominal interest rate fully adjusts to anticipated inflation, allowing real interest rates to be constant over time. Although this is intuitively appealing, the empirical evidence is inconclusive. For example, Atikens (1989), using Engle and Granger’s cointegration technique, found that the Fisher effect is valid for US and Australian data whereas Inder and Silvapulle (1993), using Australian data, did not find support for the hypothesis. Mishkin and Simon (1995), using US and Australian data, and Olekalns (1996), using Australian data, provided evidence to support the latter findings when they tested the Fisher hypothesis using similar techniques. However, using a modified test statistic, Mishkin and Simon (1995) document evidence favouring the Fisher effect in the US and Australia and, using a method of estimation involving vector autoregressive innovations, Olekalns (1995) supports Mishkin and Simon’s (1995) findings in the Australian case. Hewarathna and Silvapulle’s (1997) Australian study likewise provides strong evidence of the validity of the Fisher hypothesis using Gregory and Hansen’s (1996) procedure for testing cointegration in the presence of a structural break.

A careful analysis of these studies and many others on this topic indicate that the inconsistency of results is mainly due to differences in the methodologies used. Furthermore, these and other studies testing the Fisher hypothesis focus on developed countries such as USA and Australia. Due to the differences between developed and developing countries, the findings from above studies may not apply in developing countries.

The lack of research on this issue for developing countries and the conflicting results of existing studies are the main issues motivating this paper. Thus, the purpose of this study is to examine, using recent econometric techniques, the validity of Fisher hypothesis for the Sri Lankan economy. Sri Lanka, like many other developing countries, is a small country with deep-rooted economic problems such as a high unemployment rate and ever-
increasing inequality in income distribution. Inflation is low in comparison to other developing countries (Central Bank of Sri Lanka, 1995). With respect to income levels, it has been labelled a ‘low income’ country for a long period, but has recently been classified as a ‘lower middle income’ country by the World Bank (Central Bank of Sri Lanka, 1998). Testing the Fisher effect for a developing country like Sri Lanka may give different and interesting results which certainly have implications for policy makers. Furthermore, the conflicting results on testing for the Fisher hypothesis are mainly due to different methodologies and here we use recent econometric tools which are capable of capturing seasonal features of the data series. When modelling economic relations using time series data, it is important to consider seasonalities in them. To avoid the problem of seasonality, some researchers use seasonally adjusted data, but seasonal adjustment can severely distort the properties of time series (Wallis, 1974), and thus we use seasonal series in this study.

Using monthly data from January 1986 to December 1995, we test for two forms of Fisher hypothesis, strong form and weak form. The strong form of the Fisher hypothesis states that the nominal rate of interest fully adjusts to anticipated inflation, whereas the weak form claims that the nominal interest rate either over-adjusts or under-adjusts to anticipated inflation. The results support only the weak form, which indicates that real interest rates are not completely insulated from monetary policy changes.

The paper is organised as follows: the second section provides a brief description of the Fisher hypothesis; section three provides a description of the econometric tools used; section four presents a description of the data series and analysis of empirical findings; and section five concludes the paper with some directions for possible future research.
2. **Methodology of testing for Fisher Hypothesis**

The Fisher effect states that in long run equilibrium a change in the rate of growth of the money supply leads to a fully perceived change in inflation and a concomitant adjustment in nominal interest rates, leaving the real interest rate constant, *ceteris paribus*. This is described by the following well-known Fisher identity:\(^1\)

\[
R_t = r_t^e + \pi_t^e
\]

(1)

where \(R_t\) represents the nominal interest rate, \(r_t^e\) the *ex ante* real interest rate and \(\pi_t^e\) the expected inflation rate. Under the rational expectations hypothesis the inflation rate is given by:

\[
\pi_t = \pi_t^e + u_t
\]

(2)

where \(u_t\) has a zero mean, a constant variance \(\sigma^2\) and is serially uncorrelated. \(\pi_t\) is the observed inflation rate at time \(t\) for the period \(t\) to \(t+1\). Combining equations (1) and (2) yields the following equation:

\[
r_t^e = R_t - \pi_t + u_t
\]

(3)

Rearranging equation (3) yields the following estimating equation:\(^2\)

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\(^1\) Tax effects are ignored here as many researchers found a minimal difference in the results when testing the Fisher hypothesis using pre-tax and post-tax nominal interest rates. See Atkins (1989) and Inder and Silvepulle (1993) for more details.

\(^2\) See Fama (1975) for more details of this model.
\[ \pi_t = \alpha + \beta R_t + \xi_t \] \tag{4}

The Fisher hypothesis can be examined by testing the significance of the coefficient $\beta$.\(^3\) Estimating this model is a straightforward task, but the results are not reliable if unit roots are present in the data. If interest rates and inflation series have unit roots, a more reliable way to test the Fisher effect is to examine the cointegrating relations between them. Thus, the cointegration test of Engle and Granger (1987) is used to examine the Fisher effect in this study. An explanation of econometric tools is given next.

3. **Econometric Tools**

(a) **Unit Root Tests**

The appropriate distribution theory for estimators and test statistics for non-stationary series is different from that for the stationary series. Thus, it is the general practice to test for stationarity of the time series prior to any estimations. We explain here the tests that are used to analyse the stationarity of the data series as well as to examine the Fisher effect.

Two testing procedures, Augmented Dickey Fuller (ADF) test and Beaulieu and Miron’s (1993) seasonal unit root test, are used to examine the stationary properties. The ADF test is a commonly used test in many economic and econometric studies and therefore it does not require explanation. However, the Beaulieu and Miron’s (1993) test is a fairly recent test which needs explanation.

\(^3\) The Fisher effect is in fact the relationship between expected inflation and nominal interest rate as follows: \[ \pi_t^e = \alpha + \beta R_t + \xi_t, \] (4a). Since the expectations are based on the rational expectations hypothesis, and under this assumption, the Ordinary Least Square (OLS) estimate of $\beta$ in equation (4) is a consistent estimate of $\beta$ in equation (4a), a test of the correlation of interest rates and future inflation is also a test for the correlation of interest rates and expected inflation (see Mishkin and Simon (1995)).
The ADF test and many other unit root tests are based on the assumptions that the unit root of interest has a modulus of one, and that there are no other unit roots in the system. But, as many economic time series exhibit substantial seasonality, it is possible to have unit roots at other frequencies such as the seasonals. Hylleberg, Engle, Granger and Yoo (HEGY, 1990) have developed a procedure to test seasonal unit roots in a quarterly time series. Beaulieu and Miron (1993) have extended their work to monthly series using the following regression:

$$\Delta_{12}x_t = \beta_0 + \beta_1 t + \sum_{k=1}^{12} \pi_k x_{k,t-1} + \sum_{k=1}^{11} \gamma_k D_{k,t} + \sum_{i=1}^{m} \phi_i \Delta_{12}x_{t-i} + \epsilon_t, \tag{5}$$

where $\Delta_{12}x_t = x_t - x_{t-12}$; $t$ is a deterministic time trend and $D_{k,t}$ is the dummy variable for month $k$. The $x_{k,t}$s ($x_{1t}, x_{2t}, \ldots x_{12t}$) are defined in the appendix.

For monthly data, the seasonal unit roots are: $-1; \pm \iota; -1/2(1 \pm \sqrt{3} \iota); 1/2(1 \pm \sqrt{3} \iota); -1/2(\sqrt{3} \pm \iota); 1/2(\sqrt{3} \pm \iota),$ corresponding to 6, 3, 9, 8, 4, 2, 10, 7, 5, 1 and 11 cycles per year, respectively. The corresponding frequencies of these roots are $\pi; \pm \pi/2; \mp 2\pi/3; \pm \pi/3; \mp 5\pi/6$ and $\pm \pi/6$, respectively. The $m$ is a number of lags of the dynamic term included to whiten the noise term. In order to test the hypotheses of various seasonal roots, equation (5) is estimated by OLS and then the relevant $t$- and $F$-statistics of the parameter restrictions of interest are compared with the corresponding finite sample critical values tabulated in Beaulieu and Miron (1993). To test for unit roots at 0 and $\pi$ frequencies, the $H_0: \pi_k = 0$ should be tested against the $H_1: \pi_k < 0$ using the relevant $t$-statistics. For those at other frequencies, the null that $\pi_k = 0$ should be tested against the two-sided alternative. If there are unit roots at all frequencies, the following
conditions should hold: $\pi_1 = 0$, $\pi_2 = 0$ and $\pi_{k-1} = \pi_k = 0$ for $k = 4, 6, 8, 10, 12$. The joint restrictions that $\pi_{k-1} = \pi_k = 0$ can be tested using the F-statistic. The presence of a unit root at a particular frequency is established if the relevant test statistic is less than the corresponding tabulated critical value given in Beaulieu and Miron (1993). The critical values change depending on whether the regression contains an intercept term, a time trend and seasonal dummies.

(b) Cointegration

If the variables are integrated of the same order, say I(1), they can be tested for cointegration using the following OLS regression:

$$Y_t = \alpha + \beta X_t + \epsilon_t$$

$Y_t$ and $X_t$ are the two data series. The residuals ($\epsilon_t$) are then tested for stationarity (I(0)) using the following equation (Engle and Granger (1987)):

$$\Delta \hat{\epsilon}_t = -\phi \hat{\epsilon}_{t-1} + \sum_{j=1}^{m} \delta_j \Delta \hat{\epsilon}_{t-j}$$

The null hypothesis of this test is $H_0: \phi = 0$ and the alternative is $H_1: \phi < 0$. The t-statistic of $\hat{\phi}$ is used to test the null of non-cointegration. The critical values for this test are given in Engle and Granger (1987).
In the next section the time series properties of the data series are reported. As the methodology of testing the Fisher effect is premised upon the stationarity of the data series, knowing about the time series properties of the data is important. If the data series are I(0) (stationary), then equation (4) can be estimated and the significance of the coefficient $\beta$ determines the existence or otherwise of the Fisher effect for the sample. But if they are I(1) (non-stationary), which is common with many economic series, the OLS results of estimating equation (4) will give spurious results. In that case the strong form of the Fisher effect can be tested by testing for unit root in $R_t - \pi_t$ series (real interest rates). The weak form of the Fisher effect can be tested by examining the cointegration relations between $R_t$ and $\pi_t$, which is a residual-based test.

4. Empirical Evidence

In this study the monthly Colombo Consumers’ Price Index (CCPI) is used to derive the inflation rate, and Treasury bill rates are used as nominal interest rates. The sample starts from January 1986 and runs up to December 1995.⁴ The CCPI has limitations and weaknesses as an overall price indicator. The most appropriate indicator to measure the change in the general price level in Sri Lanka is the Gross National Product Implicit Price Deflator (GNDP) (Central Bank of Sri Lanka, 1995). But GNDP is available only once a year. CCPI is used to measure inflation in Sri Lanka by the Government, private sector and trade unions for all practical and policy purposes. To represent interest rates we use Treasury bill rates,⁵ since the yield rates determined at the weekly Treasury bill auctions serve as benchmark rates in the determination of other interest rates. The graphical representations of the inflation series derived from CCPI and the Treasury bill rates are shown in Figure 1 and 2 respectively. High volatility is a prominent feature of the inflation series which may be due to interaction of seasonal and random variation. In Figure 2, Treasury bill rates show marginal volatilities and a moderately increasing trend.

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⁴ The data series are extracted from the Central Bank Annual Reports and inflation is derived using CCPI as follows: $\pi_{t+1} = 1200^* (\log(ccpi_{t+1}) - \log(ccpi))$.

⁵ These are secondary market discount rates.
As the inflation series has a seasonal pattern, we use Beaulieu and Miron’s (1993) seasonal unit root test for monthly data to examine the time series properties of the series. Initially the deterministic seasonality was investigated and the results are reported in Table 1. These results explain the following. The $R^2$ of the model with inflation as the dependent variable is fairly high, suggesting significant deterministic seasonality in that series. We do not give much emphasis to the estimated coefficients or the related t-values because of the inclusion of lagged terms of the dependent variable to eliminate serial correlation. Therefore, the values of the coefficients do not give a clear meaning of the seasonality. However, according to Central Bank reports, seasonality is fairly high in price series mainly due to the seasonality in agricultural production. This can be seen in the actual data series. In many years CCPI declines in February and March (Maha harvest) and again in August and September (Yala harvest) and the deterministic seasonality we found can be attributed to this. In contrast, the $R^2$ is very low in the model with the nominal interest rate as the dependent variable, suggesting that the percentage of variation in the detrended interest series due to deterministic seasonal variation is very low. The $R^2$ of the model with the real interest rate as the dependent variable suggests that the deterministic seasonality is significant in that series. These findings are useful for us to specify correct models in testing for seasonal unit roots.

The above test examines only deterministic seasonality. To examine the existence of stochastic seasonality, we use Beaulieu and Miron’s (1993) test. We can use different model specifications in testing for unit roots: a model with a constant term; with a constant term and a time trend; with a constant term and seasonal dummies; and with a constant term, a time trend and seasonal dummies. The results are sensitive to the model specification. From the graphical representations of the two series and from testing for deterministic seasonality of each series it is confirmed that inflation has fairly high deterministic seasonality and that the time trend is significant in interest rate series. Considering these findings, we tested seasonal unit roots in the inflation series using a model with a constant and seasonal dummies. The interest rate series is similarly tested using a model with a constant and a time trend. Lagged values of the dependent variable
are included in the models to remove the serial correlation and the optimal lag lengths are determined using the Akaike’s information criterion (AIC). The results for the models considered as correctly specified are reported in Table 2. They indicate that both inflation and interest rate series have unit roots only at zero frequency. No unit roots were found in the seasonal frequencies. Conventional unit root tests (ADF and Phillips-Perron (PP) tests) gave the same results in the interest rate series. However, when considering inflation, the results were different. The reason for this is that the inflation series has high seasonal variations and the conventional tests are not suitable in such a situation. When using Beaulieu and Miron’s (1993) test, seasonal dummies can be included in the model, and this captures the deterministic seasonality. If there is stochastic seasonality, the test itself captures them. This indicates that inadequate modelling of seasonality leads to misleading inferences.

The unit root test results suggest that both inflation and interest rates are integrated at the same order and the next step is to test for the Fisher effect, in both its strong and weak form. Testing for the strong form of the Fisher effect is a test of whether inflation and interest rates move one-for-one in the long run. This is examined by testing for unit roots in $\pi_t - i_t$ (real interest rate) series. Stationarity of this series implies the validity of the strong form of the Fisher hypothesis. Stationarity of real interest rates is investigated using Beaulieu and Miron’s (1993) test, because deterministic seasonality is significant in that series (see Table 1). The test results for Beaulieu and Miron’s (1993) procedure is reported in Table 2. Results suggest that the real interest rate is stationary at seasonal frequencies but non-stationary at the zero frequency. These findings do not support the strong form of the Fisher effect for the data series used in this study.

The next step is to test for the weak form of the Fisher effect. This is examined by testing for cointegration between interest rates and inflation series. Results of two tests of the null hypothesis of no cointegration are reported in Table 3. These are the Cointegrating Regression Durbin-Watson test (CRDW), used by Granger and Engle (1987) and derived from Sargan and Bhargava (1983), which is a quick test of cointegration; and the ADF test based on the cointegration regression residuals. Both these test results reject the null
hypothesis of no cointegration. Therefore, the cointegration results in this study support the weak form of the Fisher effect for Sri Lanka.

Overall, then the results support only the weak form of the Fisher hypothesis. A possible explanation for this finding is that due to the rigid behaviour of markets, the nominal interest rates do not fully reflect expected inflation. However, the results suggest that even though expected inflation and interest rates diverge in the short run, they move together in the long run.

5. Conclusions

This paper has investigated two forms of the Fisher hypothesis for Sri Lanka using some recent econometric tools which give attention to the seasonal behaviour of the data series. The results do not support the one-for-one adjustment of nominal interest rates and inflation, which we named as the strong form of the Fisher effect. However, cointegration tests confirm the validity of the weak form of the Fisher effect for the period from 1986 to 1998.

The results of a study of this nature have implications for the transmission mechanism of monetary policy. If the strong form of the Fisher effect is true, then the real interest rate remains constant over time, which would be a strong support for the proposition that monetary policy does not affect the real side of economic activity. Our results do not support this. Evidence for the weak form of the Fisher hypothesis suggests partial adjustment of the nominal interest rate to anticipated inflation during the sample period in Sri Lanka. This is a valid set of information for policy-makers because this states that the real interest rate is not insulated from monetary changes. The findings also indicate that the level of nominal interest rates can be used as an indicator for the trend of expected inflation, but it is not possible to use them as perfect predictors for future inflation probably due to the market rigidity.
In this study we only tested the validity of the Fisher effect for Sri Lanka for 1986 to 1995. There are, indeed, more issues for research in this area. We can test the causality between interest rates and inflation which may give us more insight into the relationship between these two variables. Furthermore, this study gives us only the existence of the relationship between interest rates and inflation. Since we know that these two variables are cointegrated, a model which suits the data – an error correction model – can be selected and the magnitude of the relationship can be examined. Knowing the magnitudes of relationships will provide more information for policy makers.
References


Appendix

The definition of $X_t$ variables

\[
X_{1t} = X_t + X_{t-1} + X_{t-2} + X_{t-3} + X_{t-4} + X_{t-5} + X_{t-6} + X_{t-7} + X_{t-8} + X_{t-9} + X_{t-10} + X_{t-11}
\]

\[
X_{2t} = -(X_t - X_{t-1} + X_{t-2} - X_{t-3} + X_{t-4} - X_{t-5} + X_{t-6} - X_{t-7} + X_{t-8} - X_{t-9} + X_{t-10} - X_{t-11})
\]

\[
X_{3t} = -(X_t - X_{t-1} + X_{t-5} - X_{t-7} + X_{t-9} - X_{t-11})
\]

\[
X_{4t} = -(X_t - X_{t-2} + X_{t-4} - X_{t-6} + X_{t-8} - X_{t-10})
\]

\[
X_{5t} = -\frac{1}{2}(X_t + X_{t-1} - 2X_{t-2} + X_{t-3} + X_{t-4} - 2X_{t-5} + X_{t-6} + X_{t-7} - 2X_{t-8} + X_{t-9} + X_{t-10} - 2X_{t-11})
\]

\[
X_{6t} = \frac{\sqrt{3}}{2}(X_t - X_{t-1} + X_{t-3} - X_{t-4} + X_{t-6} - X_{t-7} + X_{t-9} - X_{t-10})
\]

\[
X_{7t} = \frac{1}{2}(X_t - X_{t-1} - 2X_{t-2} - X_{t-3} + X_{t-4} + 2X_{t-5} + X_{t-6} - X_{t-7} - 2X_{t-8} - X_{t-9} + X_{t-10} + 2X_{t-11})
\]

\[
X_{8t} = -\frac{\sqrt{3}}{2}(X_t + X_{t-1} - X_{t-3} - X_{t-4} + X_{t-6} + X_{t-7} - X_{t-9} - X_{t-10})
\]

\[
X_{9t} = -\frac{1}{2}(\sqrt{3}X_t - X_{t-1} + X_{t-3} - \sqrt{3}X_{t-4} + 2X_{t-5} - \sqrt{3}X_{t-6} + X_{t-7} - X_{t-9} + \sqrt{3}X_{t-10} - 2X_{t-11})
\]

\[
X_{10t} = \frac{1}{2}(X_t - \sqrt{3}X_{t-1} + 2X_{t-2} - \sqrt{3}X_{t-3} + X_{t-4} - X_{t-6} + \sqrt{3}X_{t-7} + 2X_{t-8} + \sqrt{3}X_{t-9} - X_{t-10})
\]

\[
X_{11t} = \frac{1}{2}(\sqrt{3}X_t + X_{t-1} - X_{t-3} - \sqrt{3}X_{t-4} - 2X_{t-5} - \sqrt{3}X_{t-6} - X_{t-7} + X_{t-9} + \sqrt{3}X_{t-10} + 2X_{t-11})
\]

\[
X_{12t} = -\frac{1}{2}(X_t + \sqrt{3}X_{t-1} + 2X_{t-2} + \sqrt{3}X_{t-3} + X_{t-4} - X_{t-6} - \sqrt{3}X_{t-7} - 2X_{t-8} - \sqrt{3}X_{t-9} - X_{t-10})
\]
Table 1: The estimates of parameters for testing for deterministic seasonality

Equation: $\Delta X_t = \sum_{k=1}^{12} \gamma_k D_{kt} + \sum_{i=1}^{m} \phi_i \Delta X_{t-i} + \xi_t$

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Series: Inflation</th>
<th>Nominal interest rate</th>
<th>Real interest rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_1$</td>
<td>7.22 (1.22)</td>
<td>-1.14* (-2.77)</td>
<td>0.32 (0.05)</td>
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<td>$\gamma_2$</td>
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<td>-0.26 (-0.64)</td>
<td>7.20 (1.21)</td>
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<td>$\gamma_3$</td>
<td>5.54 (0.96)</td>
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<td>$\gamma_4$</td>
<td>-1.18 (-0.21)</td>
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<td>$\gamma_5$</td>
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<td>$\gamma_6$</td>
<td>12.78* (2.51)</td>
<td>0.63 (1.63)</td>
<td>7.26 (-0.98)</td>
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<td>$\gamma_7$</td>
<td>0.71 (0.14)</td>
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<td>13.93* (2.71)</td>
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<td>$\gamma_8$</td>
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<td>0.15 (0.39)</td>
<td>1.87 (0.22)</td>
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<td>$\gamma_9$</td>
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<td>13.17* (2.48)</td>
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<td>$\gamma_{10}$</td>
<td>-25.68* (-4.81)</td>
<td>-0.23 (-0.07)</td>
<td>-0.49 (-0.89)</td>
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<td>$\gamma_{11}$</td>
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<td>-0.03 (-0.06)</td>
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<td>$\gamma_{12}$</td>
<td>0.29 (0.05)</td>
<td>0.70 (1.70)</td>
<td>-13.97* (-2.29)</td>
</tr>
</tbody>
</table>

$SE = 22.05$, $R^2 = 0.51$

Notes:  

a) $\Delta X_t$ = 1st difference of the series,  

$D_{kt}$ = dummy variable for month k,  

$m$ = number of lags of the dynamic term included to whiten the noise term.

b) The t-statistics are in parentheses.

c) * indicates the statistic is significant at the 5 per cent level.
Table 2: The t- and F- statistics of unit roots at zero and seasonal frequencies

Equation: $\Delta_{12} X_t = \beta_0 + \beta_1 t + \sum_{k=1}^{12} \pi_k X_{t,k-1} + \sum_{k=1}^{11} \gamma_k D_{k,t} + \sum_{i=1}^{m} \phi_i \Delta_{12} X_{t-i} + \epsilon_t$

<table>
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<th>Inflation</th>
<th>Nominal interest rate</th>
<th>Real Interest rate</th>
</tr>
</thead>
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<tr>
<td>$t : \pi_1$</td>
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<td>-0.86</td>
<td>-1.93</td>
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<td>$t : \pi_2$</td>
<td>-2.24*</td>
<td>-2.39*</td>
<td>-2.99*</td>
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<tr>
<td>F: $\pi_3 \cap \pi_4$</td>
<td>11.66*</td>
<td>10.23*</td>
<td>12.05*</td>
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<tr>
<td>F: $\pi_5 \cap \pi_6$</td>
<td>12.59*</td>
<td>5.89*</td>
<td>12.14*</td>
</tr>
<tr>
<td>F: $\pi_7 \cap \pi_8$</td>
<td>7.11*</td>
<td>12.87*</td>
<td>8.64*</td>
</tr>
<tr>
<td>F: $\pi_9 \cap \pi_{10}$</td>
<td>10.12*</td>
<td>3.06*</td>
<td>10.73*</td>
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<tr>
<td>F: $\pi_{11} \cap \pi_{12}$</td>
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<tr>
<td>lag length</td>
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<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: 

a) $\Delta_{12} X_t = X_t - X_{t-12}$. Derivatives of $X_{kt}$ are given in the Appendix. $D_k$ is the dummy variable for month $k$. 

b) The 5 per cent critical values are as follows:

**A model with a constant and seasonal dummies:**
(Seasonal unit roots in Inflation and real interest series are examined using a model similar to this.)

- t-statistics of $H_0: \pi_1 = 0$, and $H_0: \pi_2 = 0$ are -3.28 and -2.75 respectively.
- F-statistic of $H_0: \pi_k = \pi_{k-1}$ is 6.23.

**A model with a constant and a time trend:**
(Seasonal unit roots in nominal interest series are examined using a model similar to this.)

- t-statistics of $H_0: \pi_1 = 0$, and $H_0: \pi_2 = 0$ are -3.32 and -1.88 respectively.
- F-statistic of $H_0: \pi_k = \pi_{k-1}$ is 2.97.

See footnotes for Table 1.
### Table 3. Cointegration tests

<table>
<thead>
<tr>
<th>Variables</th>
<th>CRDW</th>
<th>ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation and nominal Interest rates</td>
<td>1.43*</td>
<td>-8.62*</td>
</tr>
</tbody>
</table>

Notes:

The 5 per cent CRDW and ADF critical values are 0.30 and -3.21 respectively. See also footnotes for Table 1.