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# Fisher effect in nonlinear STAR framework: some evidence from Asia

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## Abstract

This study tests the presence of the long run Fisher effect in eight Asian economies. Using monthly data and a variety of interest rates, the paper employs a recent nonlinear methodology to capture the long run relationship between the nominal interest rate and the inflation rate. The estimation results on the basis of the new methodology are encouraging and indicate the validity of Fisher effect in almost all the examined economies.

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## 1. Introduction

The long-run Fisher hypothesis of interest postulates that a permanent change in inflation will lead to an equal change in the nominal interest rate. In other words, monetary shocks cannot affect real interest rate in the long run, where the latter is defined as the difference between the nominal interest rate and the expected inflation rate. If this hypothesis holds, short-term interest rate variations do not imply a long-term tightening or loosening of monetary policy as eventually it leads to a rise in expected inflation only.

The monetary neutrality entails that an increase in the growth rate of money has no impact on real economic activity. The holding of the Fisher effect in its strong form indicates that money is super neutral and fully anticipated inflation does not have an effect on the real interest rate. Many believe that in the short-run, especially during the time of fluctuations, the Fisher effect may not hold fully. Rather it is likely to prevail in longer time horizons.

Due to its many far reaching implications, various studies have tried to test the presence of the Fisher effect in several developed countries, while few have modeled the Fisher effect in developing economies. Some of the studies on the topic are Atkins (1989), MacDonald and Murphy (1989), Dutt and Ghosh (1995), Crowder and Hoffman (1996), Crowder (1997), Kousstas and Serletis (1999), Atkins and Coe (2002), Granville and Mallick (2004) and Johnson (2006). A comprehensive survey on the subject is given in Bullard (1999) and Cooray (2003). The results of these studies are mixed. Some have concluded the absence of a long term relationship between expected inflation and nominal interest rate, while others have demonstrated the existence of this effect.

In an important study KSS (Kapetanious *et al*. (2003)) have tested the Fisher effect by examining the stationarity of the real interest rate in a nonlinear smooth transition autoregressive (STAR) framework[1]. They used the data of 10 developed countries including Australia, Canada, France, Germany, Italy, Japan, Netherlands, New Zealand, Spain and UK. They found that the STAR framework was successful in finding Fisher effect in more countries compared to simple linear tests which could detect the existence of Fisher effect in fewer countries. This indicates the possibility of a nonlinear long term relationship between the nominal interest rate and the inflation rate.

The present study extends the work of KSS to developing economies by testing for the presence of the Fisher effect in China, Hong Kong, Indonesia, Korea, Malaysia, Philippine, Singapore and Thailand by checking the stationarity of real interest and employing the methodology given by KSS. There is no other study which has used this methodology to test for the Fisher effect in these countries and this study therefore represents a contribution to this literature. Ling *et al.* (2007) have tested for the Fisher effect in East Asian economies using a panel unit root approach and found that real interest rates are stationary by the panel.

For a better assessment, this study incorporates a variety of interest rates in the analysis by using monthly data. The selection of these rates is mostly affected by

[1] Johnson (2006) argues that cointegration of the nominal interest rate and the inflation rate is not a sufficient condition for the Fisher effect to hold and, at best, mildly explains the usefulness of Fisher's theory.

their availability. These rates may be classified into short-term, medium-term, and long-term interest rates. Generally the data covers the period from 1980M1 to 2007M2; due to unavailability, some of the interest rate series' starting dates may differ slightly. The data series are taken from IFS.
The KSS methodology is presented in section 2, while estimation results are given in section 3. Section 4 concludes the study.

## 2. Methodology

The standard ADF test is used to check the stationarity of a series under the null hypothesis that the series is linearly non-stationary, while the alternative hypothesis tests the absence of a unit root. However, there is a growing consensus that many time series such as exchange rates, inflation, and interest parity follow nonlinear patterns and some alternative processes are needed to incorporate these movements. The literature offers several methodologies to model nonlinearity in financial time series, such as Neural Network approaches, the class of Generalized Autoregressive Conditional Heteroscedasticity models, and more recently Smooth Transition Autoregressive (STAR) class models[1]. An earlier version of the STAR framework can be seen in the Threshold Autoregressive (TAR) model. This model allows the series to behave differently under different state spaces. These behaviors are modeled linearly in different pieces by introducing different thresholds[2]. However, it is often argued that there is no guarantee that the SETAR (Self-excited TAR) model performs better than the linear AR model, as the impractical fixed threshold in the SETAR model makes it inefficient. In the STAR structure, a time series is allowed to move within two different state spaces. The transition of the series from one time space to other, however, occurs smoothly. In our case this smooth transition is due to varied activities of money market participants. The STAR model allows the interest rate movements to adjust symmetrically at every point, but the speed of adjustment varies with the amount of interest rate deviation. The STAR framework is helpful in tracing the nonlinear variation in nominal interest rates and inflation where the interest rate is assumed globally mean reverting or stable, as it moves to its long run equilibrium value, although locally it may be non-mean reverting (non stationary locally). A nonlinear test proposed by KSS (2003) under the null hypothesis tests the series as non stationary; the alternative hypothesis however is that the series is nonlinear but globally stationary. This test is based upon the following exponential smooth transition autoregressive process:

$$\Delta y_t = \gamma y_{t-1}\left[1-\exp\left(-\theta y^2{}_{t-1}\right)\right]+\varepsilon_t \qquad (1)$$

where $y_t$ is the de-meaned or de-trended series of interest and $\varepsilon_t$ is an i.i.d. error with zero mean and constant variance and $\left[1-\exp\left(-\theta y^2{}_{t-1}\right)\right]$ is the exponential transition function used to present the nonlinear adjustment. The null hypothesis $H_0$: $\theta = 0$ implies that $\Delta y_t = \varepsilon_t$ as $\left[1-\exp\left(-\theta y^2{}_{t-1}\right)\right]= 0$ while the alternative hypothesis that series is nonlinear but globally stationary process entails that $\theta>0$, where $\theta$

[1] Some of the earlier studies which have used above methodologies include, Azali *et al*. (2001), Liew *et al*. (2002), and Sarno (2000),

[2] Self-excited TAR or SETAR model is an example of TAR model.

determines the speed of mean reversion. The null hypothesis $H_0$: $\theta = 0$ cannot be directly tested as $\gamma$ in above equation under the null is not identified. KSS has re-parameterized equation 1 based on first-order Taylor series approximation to equation 1 to obtain the auxiliary regression specified as:

$$\Delta y_t = \theta {y^3}_{t-1} + \text{ error} \qquad (2)$$

To correct for the serially correlated errors in equation 2, the above equation can be written as:

$$\Delta y_t = \sum_{j=1}^{p} \rho_j \Delta y_{t-j} + \theta {y^3}_{t-1} + \text{ error} \qquad (3)$$

The null hypothesis in equation 1 or 2 to be tested is $H_0$: $\theta = 0$ while the alternative hypothesis is $H_1$: $\theta < 0$. The KSS show that the t-statistics for $\theta = 0$ against $\theta < 0$, denoted by $t_{NL,}$ does not have an asymptotic standard normal distribution. KSS (2003:364) perform simulations with 5000 replications and 1000 observations to get asymptotic critical values of the *t* statistics. The present study uses these critical values and the relevant statistics are reported at the end of table 1.

On the basis of equation 3, we have estimated two values of $t_{NL}$, i.e., $t_{NL1}$ and $t_{NL2}$ where the former is the de-meaned and the latter is the de-trended data. These data series are obtained by first regressing each series on a constant or on both a constant and a time trend and then saving the residuals.

The lag length for the ADF test (reported in table 1) has been selected on the basis of Akaike Information Criteria while the autoregressive order in the KSS test is allowed to vary from 1 to 12, as it is considered that fixing this order weakens the power of the test.

## 3. Estimation

Table 1 presents the estimation results on the basis of the KSS methodology. The ex-post real interest rate has been used in the estimation, since the difference between ex-ante and ex-post real interest rate is a forecast error. Under rational expectations, this forecast error is a white noise component and hence the ex-ante and ex-post real interest rates have the same long run properties. Besides presenting nonlinear KSS test results, Table 1 also reports conventional linear ADF test results for a variety of interest rate series. The $t_{ADF1}$ and $t_{ADF2}$ show the standard augmented Dickey Fuller test statistics with the null of nonstationarity of a variable without ($t_{ADF1}$) and with trend ($t_{ADF2}$). On the other hand, $t_{NL1}$ and $t_{NL2}$ indicate the test statistics for the de-meaned and de-trended data, respectively.

At this point some discussion of stationarity and trend stationarity is warranted. Any process is said to be stationary if its statistical properties do not change with time. On the other hand, processes are trend stationary if they are linear combination of a stationary process and one or more processes display a trend. In our case, the real interest rate is stationary if the linear combination of the nominal interest rate and the actual inflation is stationary. This is possible if both the nominal interest rate and the actual inflation rate are I(0) or both are I(1). The real interest rate is trend stationary if any linear combination of the nominal interest rate and the actual inflation rate is stationary and either one or both of them exhibit a trend. It is important to note that in our method of finding the stationarity of a real interest rate,

we impose a cointegrating vector (1, -1) between the nominal interest rate and the actual inflation rate. Studies which estimate the cointegrating vector between the nominal interest rate and the actual inflation may come up with the cointegrating coefficient less than or more than one (in the presence of tax effects). In that case, the cointegration between the nominal interest rate and the actual inflation does not imply the stationarity of a real interest rate (Neely and Rapach, 2008).

Comparing the results for China, the ADF test indicates the presence of a long term relationship between the nominal interest rate and the inflation rate when stationarity of a real interest rate (bank rate) is observed. The KSS test results also indicate the presence of a long run relation between the two variables of interest. However, neither test could detect the Stationarity of a real interest rate when real lending rate was used.

For Hong Kong the superiority of the KSS test is clearly visible where it detects the presence of the Fisher effect on the basis of three real interest rates i.e., the Treasury bill rate, the money market rate and the lending rate. On the other hand, ADF finds the presence of Fisher effect in one series only.

A similar pattern can be found when comparing the results for other countries. There is stronger evidence for the presence of a long run relationship between interest rate and inflation rate on the basis of the KSS test compared to the traditional ADF test. Moreover, the KSS test has detected the presence of the Fisher effect in 22 series of real interest rates in all the countries, compared to the ADF that detects 18 series to be stationary. Table 1 also provides a loose categorization of various interest rates into short term (S), medium term (M), and long term (L). Table A1 provides the definitions of various interest rates used, which help in above categorization. There are four series which belong to the long term interest rate (L) category. All of the four series are found to be stationary on the basis of both types of tests. The remaining series either fall in the (S) or (S,M) category and the stationarity of the various interest rate series is mixed on the basis of these categories.

By using various series of interest rates it can be confidently concluded that Fisher effect exists in all the countries studied. The slightly weak case is China where out of two available real interest rate series, only the bank rate is found to be stationary at 10 per cent significance level.

**Table 1. Unit Root Test Results for Real Interest Rates**

| Country | ADF | | KSS | |
|---|---|---|---|---|
| | $t_{ADF(c)}$ | $t_{ADF(c+t)}$ | $t_{KSS(c)}$ | $t_{KSS(c+t)}$ |
| **China** | | | | |
| Bank Rate (1990M3-2007M12) (S) | -2.67* | -2.99 | -2.65* | -2.16 |
| Lending Rate (1980M1-2007M12) (S,M)) | -1.14 | -1.37 | -2.01 | -2.48 |
| **Hong Kong** | | | | |
| Treasury Bill Rate (1993M12-2007M12) (S) | -3.91** | -3.64** | -4.40** | -4.51** |
| Money Market Rate (1993M12-2007M12) (S) | -1.90 | -1.56 | -4.01** | -4.57** |
| Discount Rate (1992M6-2007M12) (S) | -1.95 | -1.64 | -1.32 | -2.46 |
| Lending Rate (1990M12-2007M12) (S,M) | -1.32 | -1.24 | -3.04** | -2.90 |

| | | | | |
|---|---|---|---|---|
| **Indonesia** | | | | |
| Deposit Rate (1980M1-2007M12) (S) | -3.73** | -3.72** | -4.25** | -4.18** |
| Discount Rate (1990M1-2007M12) (S) | -2.65* | -3.14* | -5.79** | -5.90** |
| **Korea** | | | | |
| Money Market Rate (1980M1-2007M12) (S) | -4.17** | -5.40** | -3.16** | -6.19** |
| Discount Rate (1980M1-2007M12) (S) | -5.36** | -5.56** | -6.51** | -6.42** |
| Bonds Rate (1980M1-2007M12) (L) | -3.40** | -5.37** | -2.31 | -4.34** |
| Lending Rate (1980M6-2007M12) (S,M) | -4.00** | -4.24** | -2.67* | -2.56 |
| **Malaysia** | | | | |
| Money Market Rate (1980M1-2007M12) (S) | -2.55 | -2.69 | -5.32** | -5.34** |
| Treasure Bill Rate (1980M1-2007M12) (S) | -3.12** | -2.90 | -2.78* | -2.67 |
| Government Bonds Rate (1992M6-2007M12) (L) | -2.80* | -2.98 | -2.96** | -2.75 |
| Lending Rate (1986M12-2007M12) (S,M) | -2.09 | -2.46 | -2.67* | -3.42** |
| **Philippine** | | | | |
| Treasury Bill Rate (1980M1-2007M12) (S) | -4.05** | -4.01** | -4.15** | -4.35** |
| Money Market Rate (1980M1-2007M12) (S) | -2.52 | -2.99 | -2.05 | -2.30 |
| Lending Rate (1980M1-2007M12) (S,M) | -3.91** | -3.40* | -4.84** | -4.94** |
| **Singapore** | | | | |
| Treasury Bill Rate (1980M1-2007M12) (S) | -3.01** | -3.02 | -2.66* | -3.10 |
| Lending Rate (1980M1-2007M12) (L) | -2.85* | -3.04 | -5.72** | -4.62** |
| Deposit Rate (1980M1-2007M12) (S,M) | -2.50 | -3.22* | -4.64** | -4.99** |
| **Thailand** | | | | |
| Money Market Rate (1980M1-2007M12) (S) | -2.66* | -4.52** | -2.76* | -4.50** |
| Government Bond Rate (1980M1-2007M12) (L) | -3.11** | -4.05** | -3.05** | -3.33* |
| Lending Rate (1980M1-2007M12) (S,M) | -2.46 | -4.41** | -4.84** | -5.84** |

**Notes:** $t_{ADF(c)}$ and $t_{ADF(c+t)}$ are the standard ADF test statistics for the null of nonstationary of the variable in the study without and with a trend, respectively, in the model for testing. $t_{KSS(c)}$ and $t_{KSS(c+t)}$ are the KSS test statistics for the de-meaned and the de-trended dada, respectively, using the models with augmentation. The 10% and 5% asymptotic critical values are -2.57 and -2.86 for $t_{ADF(c)}$ respectively, and are -3.12 and -3.41 for $t_{ADF(c+t)}$ respectively. The 10% and 5% asymptotic critical values for $t_{KSS(c)}$ are -2.66 and -2.93 respectively and those for $t_{KSS(c+t)}$ are -3.313 and -3.40 respectively, taken from Kapetanios et al. (2003, p.364). * and ** denote rejection of the null hypothesis at the 10% and 5% significance levels, respectively.

## 4. Conclusion

There has been a revival in testing the long term relationship between the nominal interest rate and the inflation rate after the emergence of modern econometric techniques. The earlier studies' results for the existence of the Fisher effect are mixed. The nonlinear cointegration techniques are more successful in detecting long term relationships between two or more variables. This study has been an effort to test the validity of the Fisher effect in Asian economies using a nonlinear unit root methodology. This new technique is more successful in establishing the long term relationship between the nominal interest rate and the inflation rate in these economies. This result is consistent with other similar studies. It can be concluded

that the real interest rates in these economies are stationary and monetary policy is not very successful in influencing this rate in the long run.

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**Table A1**
**Interest Rates and Definition**

| Interest Rate | Definition |
|---|---|
| **China**<br>1. Bank Rate<br>2. Lending Rate | 1. Also termed as Discount rate represents average cost of funds for Banks. This is the rate at which the central banks lend or discount eligible papers for deposit money banks. (S)<br>2. The rate which usually meets the short and medium term financing needs of the private sector (S,M) |
| **Hong Kong**<br>1. Treasury Bill Rate<br>2. Money Market Rate<br>3. Discount Rate<br>4. Lending Rate | 1. The rate at which short term government securities are issued or traded in the market (S)<br>2. Rate on short term lending between financial institutions (S)<br>3. Same as discount rate defined above (S)<br>4. Same as above (S,M) |
| **Indonesia**<br>1. Deposit Rate<br>2. Discount Rate | 1. Rate offered to resident customers for demand, time or saving deposits. For Indonesia, it is 3 months deposit rate (S)<br>2. Same as defined above (S) |
| **Korea**<br>1. Money Market Rate<br>2. Discount Rate<br>3. Bonds Rate<br>4. Lending Rate | 1. Same as defined above (S)<br>2. Same as Above (S)<br>3. Series representing yields to maturity of government bonds or other bonds that would indicate longer term rates. For Korea, its long term rate. (L)<br>4. Same as above (S,M) |
| **Malaysia**<br>1. Money Market Rate<br>2. Treasury Bill Rate<br>3. Government Bonds Rate<br>4. Lending Rate | 1. Same as above (S)<br>2. 3 months treasury bill rate (S)<br>3. Five year bond rate (L)<br>4. Average lending rate (S,M) |
| **Philippine**<br>1. Treasury Bill Rate<br>2. Money Market Rate<br>3. Lending Rate | 1. 3 months T-bill rate (S)<br>2. Same as above (S)<br>3. Average lending rate (S,M) |
| **Singapore**<br>1. Treasury Bill Rate<br>2. Lending Rate<br>3. Deposit Rate | 1. Same as above (S)<br>2. Maximum lending rate (S,M)<br>3. Time deposit rate (L) |
| **Thailand**<br>1. Money Market Rate<br>2. Government Bond Rate<br>3. Lending Rate | 1. Same as above (S)<br>2. Long Term rate (L)<br>3. same as defined above (S,M) |