Does Fisher hypothesis hold for the East Asian Economies? an application of panel unit root tests

Ling, Tai-Hu and Venus, Khim-Sen Liew and Syed Khalid Wafa, Syed Azizi Wafa

Universiti Malaysia Sabah, Universiti Malaysia Sarawak, Universiti Malaysia Sabah

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Tai-Hu Ling
Labuan School of International Business and Finance,
Universiti Malaysia Sabah,
Jalan Sungai Pagar, 87000 Labuan, Malaysia.

Venus Khim-Sen Liew
Department of Economics, Faculty of Economics and Business,
Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.

Syed Azizi Wafa Syed Khalid Wafa
School of Economics and Business,
Universiti Malaysia Sabah,
8899 Kota Kinabalu, Malaysia.

1. Introduction

Irving Fisher hypothesized that there should be a long-run relationship in the adjustment of nominal interest rate corresponding to changes in expected inflation. If the Fisher hypothesis holds, then short-term interest rates will be an efficient predictor of future inflation (Granville and Mallick, 2004). More importantly, the monetary authority will then be able to influence long-term interest yields in order to enhance macroeconomic stabilization. Due to its importance, the hypothesis has been subjected to rigorous research (Evans and Lewis, 1995; Daniels *et al.*, 1996; Payne and Ewing, 1997; Lee *et al.*, 1998; Koustas and Serletis, 1999; Cooray, 2002; Fahmy and Kandil, 2003; and Granville and Mallick, 2004, just to name a few). One commonly adopted method to scrutinize the hypothesis is to examine the stationarity of the real interest rates. In this respect, if the hypothesis holds, then the real interest rate should be stationary. Empirical findings obtained from this approach are abundant but inconclusive thus far; see the Cooray (2003) and Johnson (2006) who provide excellence overviews of the theoretical and empirical issues on the Fisher effect.

One well-accepted explanation of the contrasting evidence is the low power of conventional unit root tests with the relatively short span of data employed (Rapach and Wohar, 2002; Baharumshah *et al.* 2005). It is expected that with a longer span of data, the power of test could be improved, thereby yielding more reliable results. However, long data sets are normally unavailable[1].

An alternative solution to circumvent the problem is to perform panel analysis, which has higher power[2]. In this regard, most of the East Asian economies have a history of about half a century since independence. Moreover, by pooling the data, the analysis can consider cross-country financial markets interactions, which need to be appropriately dealt with in this era of increasing international markets globalization and integration. Wu and Chen (1998, 2001) and Holmes (2002), for instance, demonstrated that by exploiting the cross-country variations of the data in the estimation, panel analysis can yield higher test power than conventional unit root tests. Due to its usefulness, recent studies have adopted panel analysis to investigate the stationarity of nominal interest rates (for instance, Wu and Chen, 2001) and real interest parity (Holmes, 2002; Baharumshah *et al.*, 2005), just to mention a few. However, to the best of our awareness, panel analysis is yet

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[1] One exception is the recent work of Granville and Mallick (2004) who is able to provide evidence supportive of Fisher hypothesis by employing a century data covering from 1900 to 2000. In contrast, Rose (1988) is unable to find result in favor of the hypothesis using shorter span of data from 1892 to 1970 for the U.S.

[2] Im *et al.* (1997) demonstrated a substantial increase in power in panel unit root test, which allows for cross-sectional variation, even for fairly short time series.

to be applied in the context of the Fisher hypothesis. This study tests the long-run validity of the Fisher hypothesis using panel unit root tests. Specifically, this note aims to examine whether the Fisher hypothesis holds for the East Asian economies. East Asia is a fascinating economic region which has undergone rapid economic transformation and experienced spectacular growth over the past four decades. This study includes ASEAN-5 (Malaysia, Singapore, Taiwan, Thailand and the Philippines), China, Hong Kong and Taiwan, Japan and South Korea, which have strong trade and economic relationship. The intraregional trade shares of these economies amounted to over one-half of their total trade in 2005 (United Nations, 2008). The combined merchandise exports of these East Asian economies amounted to over three trillion USD, accounted for one-quarter of the world exports in 2005-2006. The extraordinary growths of these economies in the recent decades and the important roles they play in the international trade have put East Asia under the spotlight of economic research (see for instance, Sarel, 1996). Among others, Baharumshah *et al*. (2005) recently documented evidence of the real interest rate parity by examining the stationary of real interest rate differentials of East Asian economies. Ling (2008) argues that the existence or non-existence of the real interest rate parity in these economies can be affected by the soundness of the Fisher hypothesis. If the hypothesis does not hold, then the resultant real interest rate differentials will not reflect the actual international financial linkages. Thus, it is important to verify the validity of the Fisher hypothesis for the case of these East Asian economies. To accomplish this task, the stationarity of ten East Asian economies' real interest rates are examined using few commonly adopted panel unit root tests developed by Maddala and Wu (1999), Choi (2001), and Im, Pesaran, and Shin (2003).

The remainder of this note is structured as follows: The next section describes the data and methodology employed in this study. This is followed by results and interpretation. The final section concludes this study.

2. Data and Methodology

This study analyses the stationarity of real interest rates of ten East Asian economies, namely China, Hong Kong, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, Thailand, and the Philippines. The sample data, which are obtained from the International Financial Statistics, Asian Development Bank and Central Banks, spans from the first quarter of 1987 to the third quarter of 2006 (1987:Q1 to 2006:Q3). Various short-term interest rates are considered, depending on data availability: deposit rate (China), money market rate (India, Indonesia, South Korea, Taiwan and Thailand), and 3-Months Treasury bill rate (Japan, Malaysia and the Philippines). Following Atkins and Coe (2002), the inflation rate, π_t, is defined as the percentage change of the quarterly consumer price index multiplied by four. The expected inflation is then obtained by estimating an autoregressive model for inflation rate as shown below:

$$\pi_t^e = \alpha_0 + \sum_{t-i}^{k=3} \alpha_i \pi_{t-i} + \eta_t \tag{1}$$

whereas π_t^e is the expected inflation and π_{t-i} is the inflation rate calculated from the CPI. Expected inflation rate is defined by, $\hat{\pi}_t = \pi_t^e$.

The real interest rate for each economy, in turn, is obtained by subtracting the expected inflation rate from the nominal interest rate. For the Fisher hypothesis to hold, the resultant ex ante real interest rate should be stationary. To test for stationarity, several panel unit root tests due to Im, Pesaran, and Shin (2003), Maddala and Wu (1999) and Choi (2001) and are adopted in this study. For comparison purpose, the conventional univariate augmented Dickey-Fuller (ADF) and its improved version known as Generalized Least Squares augmented Dickey-Fuller (ADF-GLS, due to Elliot *et al.*, 1996; see also Ng and Perron, 2001) unit root tests are included in this study.

Im et al. (2003) panel unit root test

Im *et al.*(2003) proposed a $t-$bar statistic, which is based on the average of the individual cross-sectional ADF *t*-statistics, to examine the unit root hypothesis for panels[3]. In particular, the test is performed by combining individual unit root tests to derive their panel counterpart. Im *et al.* (2003) based their panel unit root test on a separate ADF test for each cross section (in our case, country) in the panel. Then the average of the *t*-statistics of individual ADF statistics is adjusted

[3] Unlike another panel unit root test advocated by Levin *et al* (2002) who imposed the restrictive assumption of homogeneity, Im *et al.* (2003) allows for heterogenity across groups and serial correlation errors across groups. Therefore, it achieves more accurate size and higher power relative to the Levin *et al.* (2002) test. By using a Monte Carlo simulation, Im *et al.,* (2003) showed better finite sample performances of Ψ_t in relation to the Levin *et al.* (2002) test.

to obtain the unit root test statistic for the panel, namely the $t-$bar statistic. For a sample of N groups observed over T time periods, the panel unit root regression of the conventional ADF test is written as:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{p_i} \gamma_{ij} \Delta y_{it-j} + e_{it}, i = 1,..., N, \quad t = 1,..., T \tag{1}$$

where y_{it} is the real interest rate, $\Delta \mathrm{y}_{\mathrm{it}} = \mathrm{y}_{\mathrm{it}} - \mathrm{y}_{\mathrm{it-1}}$, $\alpha_{i,}\beta_i$ and γ_{ij} are the parameters to be estimated, and e_{it} stands for disturbance terms.

The null hypothesis of the Im *et al*. (2003) test is characterized as:

$$H_0 : \beta_i = 0, \text{for all } i \tag{2}$$

against the alternatives that all series are stationary processes

$$H_1 : \beta_i < 0, \ i = 1,2,..., N_1; \quad \beta_i = 0, \qquad i = N_1 + 1, N_2 + 2,..., B \tag{3}$$

This alternative hypothesis allows for β_i to differ across groups and is more general than the uniform alternative hypothesis, namely $\beta_i = \beta < 0$ for all i.

To test the hypothesis, Im *et al*. (2003) proposed a standardized *t*-bar statistic given by

$$\Psi_t = \frac{\sqrt{N}\{\bar{t}_{NT} - (1/N)\sum_{i=1}^{N} E[t_i, r(p_i)]\}}{\sqrt{(N^{-1})\sum_{i=1}^{N} Var[t_i, r(p_i)]}} \rightarrow N(0,1) \quad (4)$$

where

$$\bar{t}_{NT} = N^{-1}\sum_{i=1}^{N} t_i, r(p_i, \beta_i) \quad (5)$$

and $t_i(p_i, \beta_i)$ is the individual *t*-statistic for testing $\beta_i = 0$ for all $i. E[t_i, r(p_i, 0)|\beta_i = 0]$ and $Var[t_i, T(p_i, 0)|\beta_i| = 0]$ can be found in Table 2 of Im *et al.* (2003). Since $E[t_i, T(p_i, 0)|\beta_i = 0]$ and $Var[t_i, T(p_i, 0)|\beta_i = 0]$ vary as the lag length in the ADF regression varies, in practice, we are restricted implicitly to using the same lag length in all the individual ADF regressions. Under the null hypothesis, the standardized $t-$bar statistic Ψ_t is asymptotically distributed as a standard normal distribution, $\Psi \sim N(0,1)$.

There are several advantages of using the Im *et al.* (2003) panel unit root test as compared to previously developed panel based unit root tests (Quah, 1992; 1994; Levin and Lin, 1993). First, it takes into account of heterogeneity across countries in two aspects, comprising of individual specific effects and different patterns of residual serial correlations. Secondly, the proposed *t*-bar statistics allow for residual serial correlation and heterogeneity of the dynamics and error variances across time series data. Therefore, the Im *et al.* (2003) panel unit root test is adopted here to examine the validity of the Fisher hypothesis for the East Asian economies, allowing for heterogeneity and contemporaneous serial correlations due to financial markets interactions among these economies.

Maddala and Wu (1999) panel unit root test

Maddala and Wu (1999) proposed a Fisher test statistic solely based on joining the $p-$value of the test statistic from the individual unit root tests. The test is non-parametric and is based on Fisher (1932). Similar to Im *et al.,* (1997), this test allows for different first-order autoregressive coefficients and has the same null and alternative hypothesis in the estimation procedure. The Fisher test statistic, $p(\chi)$ is written as follows:

$$p(\chi) = -2\sum_{j=1}^{N} \log(\pi_j) \tag{6}$$

where π_j is the $p-$value of the test statistic for j. The Fisher test statistic $p(\chi^2)$ is a chi-squared distribution with $2N$ degree of freedom.

As pointed out by Maddala and Wu (1999) that Fisher test has more accurate size and better power comparative to the Levin and Lin (1993). Moreover, this test provides flexibility in choosing any different lag lengths in each series of ADF regressions. Thus, the usefulness of the test is it may reduce the bias due to the lag selection (See Banerjee, 1999).

Choi (2001) panel unit root test

Choi (2001) extends the Fisher test statistics of Maddala and Wu (1999) by demonstrating that:

$$Z = \frac{1}{\sqrt{N}} \sum_{j=1}^{N} \phi^{-1}(\pi_j) \rightarrow N(0,1) \tag{7}$$

where ϕ^{-1} is the opposite of the standard collective distribution function. $\rightarrow N$ (0,1) refers to asymptotically distributed as standard normal distribution.

There are several features that distinguish the Choi (2001) test from above-mentioned panel unit root tests. First, this test is devised for finite *N* as well as for infinite *N*, where *N* denotes the number of groups. Second, it is assumed that each series has different types of nonstochastic and stochastic elements. Third, there is flexibility in the length of time series whereby each series can be appeared in different number of time series. Fourth, this test also deals problems with some groups have a unit root and the others do not. Thus, the Choi (2001) test can be used under more general assumptions than the panel unit root test of Im *et al*. (2003) and Levin and Lin (1993)[4]. Moreover, as mentioned by the author, the Choi (2001) test is superior to that of Maddala and Wu (1999) in terms of finite sample size and power.

[4] The work of Levin and Lin (1993) is published as Levin *et al*. (2002).

In sum, the fundamental element that differentiates the above three tests is that the Fisher test (Maddala and Wu, 1999 and Choi, 2001) is calculated from a combination of the significance levels of the different tests, while the Im *et al.* (2003) statistic is computed from a group of the test statistics. Therefore, the Fisher test has the flexibility of using heterogeneous lag lengths and capability of easing restrictive assumptions assumed by Im *et al.* (2003). More importantly, in terms of All these three statistics will be computed in this study based on conventional adopted ADF, as well as ADF-GLS estimation procedures[5].

3. Results and Interpretation

As a preliminary analysis, the ordinary ADF and ADF-GLS univariate unit root tests are deployed to check the stationarity of the real interest rates for the sample period of (2001:Q1 to 2006:Q3) and the results are summarized in Table 1. It is evident in Table 1 that the null hypothesis of nonstationary series can be rejected for China, Malaysia and Singapore by the ADF test[6]. This is because the probability value of the t-statistics for the three countries are all less than 0.10, implying the real interest rates concerned are stationary at 10% significance level or better. The implication of this finding is that there is a long-run relationship between nominal interest rate and inflation rate in these countries. Hence, the

[5] Choi (2001) demonstrates the use of ADF-GLS test in his proposed Fisher test. By applying the Fisher test in the study of purchasing power parity (PPP), he demonstrated the proposed test is more powerful than ADF–GLS☐ and *t*-bar test of Im *et al.* (2003).

[6] This finding may reflect the fact that these three countries share quite similar monetary policies in the sense that they had the experience of fixing their respective currencies against US dollar for the past few decades, as well as same goals to maintain low inflation and a stable exchange rate (see Bank for International Settlements, 2006). However, it is too early to base our conclusion on the finding of ADF test, in which the shortcomings of this test had been discussed earlier.

Fisher hypothesis is valid for these countries. Applying the same principle, the results suggest that Fisher hypothesis does not hold for other countries.

Table 1. Unit root test results for individual country (2001:Q1-2006:Q3)

Series	ADF			ADF-GLS		
	Lag	t-Stat	Prob.	Lag	t-Stat	Prob.
CH	1	-3.314**	0.018	5	-3.087***	0.003
HK	1	-2.012	0.281	6	-2.091**	0.041
ID	0	-2.152	0.226	0	-2.166**	0.033
JP	2	-1.104	0.710	6	-2.595**	0.012
KR	0	-1.760	0.397	2	-1.341	0.184
MS	0	-2.628*	0.092	1	-2.055**	0.043
PH	0	-1.905	0.328	4	-1.152	0.253
SG	0	-3.616***	0.008	4	-2.065**	0.043
TH	0	-2.149	0.227	0	-2.161**	0.034
TW	3	-0.723	0.834	7	-0.717	0.476

Note: In all cases, intercept has been included in the estimation. ***, ** and * denote the rejection of the null hypothesis of unit root at 1, 5 and 10% significance levels respectively. CH, HK, ID, JP, KR, MS, PH, SG, TH and TW denote China, Hong Kong, Indonesia, Japan, South Korea, Malaysia, The Philippines, Singapore, Thailand and Taiwan.

In contrast, the ADF-GLS test is able to detect more cases supportive of the Fisher effect. In particular, the null of non-stationary series can be rejected at 5% level or better for China, Hong Kong, Indonesia, Japan, Malaysia, Singapore and Thailand, implying long-run validity of Fisher hypothesis for these countries. Since the results from ADF and ADF-GLS are inconsistent, one has to rely on a more robust test for decision. In this matter, the fact that the ADF-GLS test provides evidence in favour of the Fisher effect for most countries in the sample but the ADF test does not, is in accordance with previous discussion in the literature that the ADF-GLS test has more power than the ADF test in detecting stationarity (Ng and Perron, 2001; Rapach and Wohar, 2002). As such, relying on results obtained from the ADF-GLS test, it may be noted for this moment that Fisher hypothesis hold for all countries under consideration with the exception of Korea, the Philippines and Taiwan.

It was mentioned earlier that conventional unit root test such as the ADF test has a low power when a relatively short span of data is employed. Therefore, it is possible that a longer period could improve the results[7]. For the purpose of comparison, we report the results of examining the longer sample period of data covering from 1987:Q1 to 2006:Q3 in Table 2.

Table 2. Unit root tests for individual country (1987:Q1-2006:Q3)

Series	ADF			ADF-GLS		
	Lag	t-Stat	Prob.	Lag	t-Stat	Prob.
CH	5	-3.312*	0.073	1	-3.600***	0.001
HK	1	-1.973	0.606	1	-1.806*	0.075
ID	0	-2.155	0.507	0	-2.182**	0.032
JP	4	-2.434	0.360	4	-2.364***	0.021
KR	1	-3.477**	0.049	0	-2.389**	0.019
MS	0	-3.225*	0.087	0	-2.820***	0.006
PH	0	-3.999**	0.013	0	-2.591**	0.012
SG	0	-3.851**	0.019	0	-3.832***	0.000
TH	0	-2.744	0.223	0	-2.534**	0.013
TW	0	-6.910***	0.000	4	-4.070***	0.000

Note: In all cases, intercept has been included in the estimation. ***, ** and * denote the rejection of the null hypothesis of unit root at 1, 5 and 10% significance levels respectively. CH, HK, ID, JP, KR, MS, PH, SG, TH and TW denote China, Hong Kong, Indonesia, Japan, South Korea, Malaysia, The Philippines, Singapore, Thailand and Taiwan.

[7] Analysis of the longer sample has been included at the suggestion of one of the reviewers.

Based on the ADF test, the null hypothesis of a unit root is rejected for most of the countries with an exception of Hong Kong, Indonesia, Japan and Thailand. In other words, using a longer set of data, the ADF test is able to discover more evidence favoring the Fisher hypothesis. In addition to the evidence found earlier (China, Singapore and Malaysia), this time evidence is also found for South Korea, the Philippines and Taiwan. On the other hand, the results obtained from the ADF-GLS test suggests that the non-stationary real interest rate can be rejected for all of the countries at 10% or even better significance level. All-in-all, the results from Tables 1 and 2 suggest that the Fisher hypothesis holds better at a longer set of data. This finding is in accordance to the view that univariate unit root tests can perform better if they are applied to a longer set of time series data (Rapach and Wohar, 2002; Baharumshah *et al*., 2005).

While the ADF-GLS test is more reliable than the ADF test, it does not allow for the consideration of across countries financial market interactions, which exist due to strong trade and investment relationships among these economies. To circumvent the weakness of these univariate unit root tests, panel unit root tests are employed. For this purpose, the test statistics of Im *et al*. (2003), Maddala and Wu (1999) and Choi (2001) are computed from both the ADF and ADF-GLS tests. The results for the periods 2001:Q1 to 2006:Q3 and 1987:Q1 to 2006:Q3 are presented in Tables 3 and 4 respectively. It is observed from these tables that the null hypothesis of non-stationary series can be rejected at 1% significance level regardless of the type of unit roots employed. Thus, it can be concluded that based on panel analysis which allows for the consideration of cross-country variations, all the East Asian real interest rates are stationary. Holmes (2002) points out that panel unit root tests work better than univariate unit root tests in the case of real interest parity. As such, this study concludes that, as a whole, the Fisher hypothesis holds for all the ten countries under investigation based on panel testing procedures. Recall that in the case of univariate unit root tests, we need to lengthen the sample data to reveal more evidence in favor of the Fisher hypothesis. In sharp contrast, empirical findings of the Fisher hypothesis are obtained from panel unit root tests even when a shorter sample period was used in our study and the use of a longer sample provides consistent results. Thus, our findings are in line with those who found that panel unit root tests improve over univariate unit root tests for finite data.

Table 3. Panel unit root tests of 10 countries. (2001-2006)

	Computed from		Critical Value		
Panel Unit Root Test	ADF	ADF-GLS	1%	5%	10%
Im, Pesaran and Shin (2003)	-1.9940***	-1.7213**	-1.960	-1.645	-1.282
Maddala and Wu (1999)	36.2467***	60.7641***	40.289	33.924	30.813
Choi (2001)	-7.1312***	-15.4874***	-1.960	-1.645	-1.282

Note: ***, ** and * denote the rejection of the null hypothesis of unit root at 1, 5 and 10% significance levels respectively.

Table 4. Panel unit root tests of 10 countries. (1987-2006)

	Computed from		Critical Value		
Panel Unit Root Test	ADF	ADF-GLS	1%	5%	10%
Im, Pesaran and Shin (2003)	-5.1537***	-2.7575***	-1.960	-1.645	-1.282
Maddala and Wu (1999)	72.4849***	104.9268***	40.289	33.924	30.813
Choi (2001)	-14.8187***	-24.7780***	-1.960	-1.645	-1.282

Note: ***, ** and * denote the rejection of the null hypothesis of unit root at 1, 5 and 10% significance levels respectively.

4. Conclusion

In general, a long-run relationship in between nominal interest rates and inflation rates for all the East Asian economies under investigation has been identified by the panel but not the univariate unit root tests. The finding should come as no surprise as basically, these economies share quite similar monetary policies over the past few decades.

The key implications of this finding are: First, the validation of the Fisher hypothesis in these economies will encourage borrowers to make productive investments that promote economic growth and develop better banking system (Pill and Pradhan, 1997). Second, the stationarity finding for real interest rates provides convincing foundation for the applications of various capital asset pricing models in this region (Johnson, 2006).

Third, and perhaps more importantly, monetary policy can be used as an effective tool to influence long-term interest rates in these East Asian economies (Granville and Mallick, 2004). However, considering the fact that supportive evidence of the Fisher hypothesis is only obtained when cross-country interdependence in real interest rates is incorporated in the estimation, it is expected that monetary policy will work better with regional collaboration. This would require the coordination of policy-makers from ministries of finance; the central banks and the financial market regulators of these economies to develop a shared vision in their macroeconomic goals (see Sheng and Teng, 2007). Such collaboration is especially important in combating the recent global financial crisis and economic downturn. In this respect, the authorities across East Asia economies had used an array of similar policies (such as liquidity support, deposit guarantees, and foreign exchange intervention and swap arrangements) to support their banking systems and ensure financial stability in response to the global financial turmoil. According to the Asian Development Bank (2009) these policies indeed have successfully restored public confidence in the region's financial systems, and as a result, these economies managed to make a remarkable recovery (Lipsky 2009). Nonetheless, to date, it is still early to safely conclude that crisis is over and as such, the leaders of China, Japan and South Korea recently emphasized that it is necessary to reinforce regional collaboration to face the world economic crisis (AsiaNews, 2009). Perhaps, instead of competitive interest rate reduction to boost exported-oriented industries during crisis (Ito, 2009), a more closely coordinated regional exchange rate mechanism and the establishment of an East Asian regional financial facility as proposed by the East Asian Study Group (2002) should now be seriously considered and pursued by the economies in this region to enhance financial and economic stability.

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