Revisiting the Fisher Hypothesis for Several Selected Developing Economies: A Quantile Cointegration Approach

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ABSTRACT

This paper reinvestigates the validity of the Fisher hypothesis, for several selected developing countries. With the quantile cointegration method proposed by Xiao (2009), we find that the long-run coefficients between nominal interest rates and inflation can be affected by the shocks and, therefore, may vary over time. More specifically, in the upper quantiles there is one-to-one relationship between the two variables, supporting the Fisher effect, while in the lower quantiles, the nominal interest rate responds by a lower percentage than the change in inflation. This is known as the Fisher effect puzzle. Thus the Engle-Granger cointegration regression may suffer from model misspecification, because of the assumption of a constant cointegrating vector. A possible explanation for such an asymmetric relationship between the two variables is provided.

1. INTRODUCTION

THE REAL INTEREST RATE IS A KEY ECONOMIC VARIABLE, in both theoretical and practical terms. In the former case, it is useful for macroeconomic modelling, such as consumption-based intertemporal models of asset prices (Hansen and Singleton 1983) and the neoclassical growth model (Solow 1956). In the latter, real interest rate can be regarded as a policy variable, because it has a great impact on saving and investment decisions, and it therefore influences economic growth.

The Fisher hypothesis relates nominal interest rate and expected inflation in a way that sees changes in the latter fully reflected in adjustments in the former, which implies long-run neutrality and no money illusion. It also means that the current nominal interest rate could be a good indicator of inflationary expectations and future inflation. For the validity of the Fisher hypothesis the real interest rate, obtained from the nominal interest rate minus expected inflation, should display mean reverting behaviour. In other words, these two variables must be cointegrated in the long run with a unity cointegrating coefficient, provided that all series contain a unit root.

Since the pioneering work of Rose (1988), a voluminous literature has attempted to establish empirically the validity of the Fisher hypothesis, either by unit-root testing methods or cointegration techniques. However, the empirical results are still mixed. For example, by using the ADF test, King *et al* (1991) and Gali (1992) failed to find evidence supporting stationary US real interest rates. Similar results are also found by, for example, Lai (1997), Rapach and Weber (2004). However, by taking into account possible structural breaks, Lai (2008) found strong evidence in favour of the Fisher hypothesis for several selected countries.

Mishkin and Simon (1995), by applying the Engle-Granger (EG) cointegration test, found that Australia's nominal interest rate and inflation are not cointegrated. Similar results were found by Koustas and Serletis (1999); Rapach (2003); and Sun and Phillips (2004). Nevertheless, Bierens (2000) provides evidence of nonlinear cotrending between the nominal interest rate and inflation for US data, supporting the Fisher effect. Allowing for a time-varying cointegrating vector, Christopoulos and León-Ledesma (2007) showed that the two variables co-move in the long run for the US. It is important to note that almost all of the aforementioned literature concentrates on the US and OECD countries only. Studies of developing countries, to the best of our knowledge, remain limited.

The aim of this paper is to explore empirically the Fisher hypothesis in several selected developing countries (Indonesia, Malaysia, Russia, and South Africa), by employing the newly developed quantile cointegration technique proposed by Xiao (2009). The novelty of the methodology can be stated as follows. First, it allows us to quantify directly the size of a shock that hits the nominal interest rate. In other words, the magnitude of the shock is determined endogenously by the data themselves.

Second, instead of focusing on a single measure of conditional central tendency relationship between nominal interest rate and inflation, which is the key to conventional cointegration frameworks, this method is able to explore the counterpart across a range of conditional quantiles of the shock. To be precise, the value of the cointegrating coefficient may be influenced by the shock, and therefore, can vary over the shock quantile.

Third, the testing procedure can be used not only to investigate whether or not the nominal interest rate and inflation constitute a long-run relationship in a quantile sense, but also to examine carefully if the interest rate reacts less than proportionately to changes in inflation: the Fisher effect puzzle. Finally, by using this technique, we are capable of elaborating on how the sign and size of the shock influences the long-run coefficient between the two variables.

Compared with conventional linear cointegration techniques, such as Engle-Granger (EG) or Johansen, imposing constant cointegrating vectors, the quantile cointegration approach allows the long-run coefficients to vary with various quantiles, and can be affected by the sign and size of the shocks as determined endogenously by the data. Although Hansen and Seo (2002) develop the threshold cointegration model, their methodology only allows two different values of the short-run dynamic parameters which are determined by the threshold. They still assume that the cointegrating vector is time-invariant. Also, their method can only distinguish between threshold cointegration and linear cointegration assuming cointegration as a maintained hypothesis. In contrast, the quantile cointegration approach is able to test cointegration *per se* against non-cointegration. Undoubtedly, the latter is more suitable for our empirical study.

Our empirical results of quantile cointegration reveal that the nominal interest rate and inflation move together in the long run for our selected countries, in sharp contrast to the counterparts obtained from the EG method. Moreover, the cointegrating vectors are different across quantiles, as determined by the interest rate shock. Specifically, their long-run relationship is asymmetric in a way that in the upper quantiles, when the interest rate is hit by positive large shocks, there is one-to-one relationship between the two variables, supporting the Fisher hypothesis. On the other hand, in the lower quantiles with small negative shocks, the less than proportional reaction of the interest rate to changes of inflation, the Fisher effect puzzle, is evident.

The remainder of our paper is organised as follows. Section 2 briefly describes the empirical methodology. Data information and some preliminary results are provided in Section 3. Section 4 presents empirical results for quantile cointegration. Finally, concluding remarks are summarised in Section 5.

2. Empirical methodology

In this section, we review briefly the quantile cointegration model and its related estimation and inference procedures proposed by Xiao (2009), which is employed in the following empirical study. Compared with the conventional cointegration model, where the long-run cointegrating coefficients are constant, the unique feature of the methodology is that the counterparts are allowed to be affected by the shocks in each period, and therefore may vary over time.

Consider the following cointegration model:

$$y_t = \beta_t x_t + \sum_{i=-K}^{K} \gamma_{it} \Delta x_{t-i} + \varepsilon_t, \quad t = 1, 2, ..., n, \tag{1}$$

where $y_t = R_t - \bar{R}$, $x_t = \pi_t - \bar{\pi}$, with R_t and π_t denoting the nominal interest rate and inflation rate, respectively; $\bar{R}$ and $\bar{\pi}$ represent their sample means. ε_t is the zero mean stationary innovation (shock). The leads and lags of Δx_t

are included to deal with the endogeneity problem. It is important to note that the long-run coefficient β_t and parameters γ_{it} may be dependent on t, which are functions of the innovation ε_t as assumed in Xiao (2009). Then the τ_{th} quantile of y_t conditional on $\Im_t$, the information up to t, can be written as:

$$Q_{y_t}(\tau \mid \Im_t) = \alpha(\tau) + \beta(\tau)x_t + \sum_{i=-K}^{K} \gamma_i(\tau)\Delta x_{t-i}, \tag{2}$$

where $\alpha(\tau)$ denotes the τ-th quantile of the shock ε_t related to the nominal interest rate, and $\beta(\tau)$, the cointegrating coefficient measuring the long-run relationship between the nominal interest rate and inflation rate, can be affected by the magnitude of the shock, and hence may vary over the innovation quantile.

Given τ, all the parameters in Eq. (2) can be consistently estimated by:

$$\min \sum_{t=1}^{n} (\tau - I(y_t < z_t'\phi(\tau))) \, |y_t - z_t'\phi(\tau)|, \tag{3}$$

where $z_t' = (1, x_t, \Delta x_{t+K}, ..., \Delta x_{t-K})$, $\phi(\tau) = (\alpha(\tau), \beta(\tau), \gamma_{-K}(\tau), ..., \gamma_K(\tau))'$, and I denotes an indicator function, that is I = 1 if $y_t < z'_t\ \phi(\tau)$, and I = 0, otherwise. Under some regular conditions, as shown in Xiao (2009), $\hat{\phi}(\tau)$, the estimator for $\phi(\tau)$ obtained from Eq. (3) is mixture normal distributed. Moreover, we can investigate the validity of the Fisher effect by testing the null hypothesis of H_0: β (τ), meaning that the reaction of the interest rate is exactly proportional to changes in inflation in the τ–th quantile, with the following Wald test statistic:

$$W(\tau) = \frac{\hat{f}_{\varepsilon}^{2}(F_{\varepsilon}^{-1}(\tau))}{\hat{\omega}_{\psi}^{*2}} (\hat{\beta}(\tau) - 1)^2 \sum_{t=1}^{n} (x_t - \bar{x})^2 , \tag{4}$$

where $\hat{f}_{\varepsilon}(F_{\varepsilon}^{-1}(\tau))$ is a consistent estimator of $f(F_{\varepsilon}^{-1}(\tau))$ with f and F signifying the density and distribution function of ε_t in Eq. (1); $\hat{\omega}_{\psi}^{*2}$ is an estimator for ω_{ψ}^{*2}, the long-run variance of $\psi_\tau(\varepsilon_{t\tau}) = \tau - I(\varepsilon_{t\tau} < 0)$, with $\varepsilon_{t\tau} = \varepsilon_t - F_{\varepsilon}^{-1}(\tau)$.[2] In addition, $\bar{x}$ is the sample mean of x_t. In a large sample, the Wald test is chi-square distributed with one degree of freedom.

In addition to the aforementioned testing procedure, we can investigate whether the cointegrating coefficients are constant across quantiles, that is $H_0: \beta(\tau) = \beta$ for τ over Γ. In practice, β is unknown, and an appropriate estimate for β is needed. As in Xiao (2009), we set $\beta = \hat{\beta}$, the least squares (LS) estimate for the coefficient associated with x_t, by running y_t on x_t, and $\Delta x_{t+K}, ..., \Delta x_{t-K}$, and test the null by using $\sup|\hat{V}_n(\tau)|$ with $\hat{V}_n(\tau) = n(\hat{\beta}(\tau) - \hat{\beta})$. In the following empirical study, we choose $\Gamma = \{0.1, 0.2, ..., 0.9\}$, and the statistic is the maximum value of $\hat{V}_n(\tau)$ over Γ. The asymptotic distribution of $\sup|\hat{V}_n(\tau)|$

is nonstandard, and Xiao (2009) suggests using the bootstrap procedure to approximate its *p*-values, which is summarised briefly as follows.

(1) Obtain the LS and quantile estimates $\hat{\beta}$ and $\hat{\beta}(\tau)$, respectively, based on:

$$y_t = \beta x_t + \sum_{i=-K}^{K} \gamma_i \Delta x_{t-i} + \varepsilon_t \tag{5}$$

Compute $\hat{V}_n(\tau) = n(\hat{\beta}(\tau) - \hat{\beta})$ and $\hat{u}_t = y_t - \hat{\beta} x_t$ for t = 1,2,...,n.

(2) Perform the VAR estimation on $\hat{w}_t = (\hat{v}_t, \hat{u}_t)'$ with $\hat{v}_t = \Delta x_t$ and obtain the residuals as follows: $\hat{e}_t = \hat{w}_t - \sum_{j=1}^{q} \hat{B}_j \hat{w}_{t-j}$ (6)

where the lag length q is selected with BIC in the following empirical application.

(3) Centre the residual $\{\hat{e}_t\}$ by:

$$\overline{e}_t = \hat{e}_t - \frac{1}{n-q} \sum_{t=q+1}^{n} \hat{e}_t \tag{7}$$

(4) A random sample of $\{\overline{e}_t^*\}_{t=q+1}^{n}$ is taken from the empirical distribution that puts mass $1/(n\text{-}q)$ on each of the centred residuals $\overline{e}_t$.

(5) Generate $\hat{w}_t = (\hat{v}_t, \hat{u}_t)'$ with $\overline{e}_t$ by using the following estimated VAR model:

$$w_t^* = \sum_{j=1}^{q} \hat{B} w_{t-j}^* + \overline{e}_t^* \tag{8}$$

with $\hat{B}_j$ being the estimate in Eq. (6), and $w_t^* = \hat{w}_t$ for t =1,2,...,q

(6) Generate the bootstrap sample y_t^* based on

$$y_t^* = \hat{\beta} x_t^* + u_t^*, \tag{9}$$

where $x^* = x_{t-1}^* + v_t$ with $x_1^* = x_1$, and $\hat{\beta}$ is the LS estimate in step 1.

(7) Based on y_t^* and x_t^* compute the bootstrap version of $\hat{V}_n(\tau)$, denoted by $\hat{V}_n^*(\tau)$. Specifically, obtain $\hat{\beta}^*(\tau)$ and $\hat{\beta}(\tau)$ from quantile and LS estimation based on:

$$y_t^* = \hat{\beta} x_t^* + \sum_{i=-K}^{K} \gamma_i \Delta x_{t-i}^* + \varepsilon_t^* \tag{10}$$

Then construct $\hat{V}_n^*(\tau)$ = $n(\hat{\beta}^*(\tau) - \hat{\beta}^*)$, and therefore obtain sup $|\hat{V}_n^*(\tau)|$.

(8) Repeat steps (4) to (7) NB times, with NB=1000.

(9) Compute the empirical distribution function (edf) of NB values for sup $|\hat{V}_n^*(\tau)|$, and use this empirical distribution function as an approximation to the cumulative distribution function (cdf) of the bootstrap null distribution.

(10) Make inference based on the bootstrap *p*-value.

Additionally, based on the fluctuation of the residuals obtained from the quantile cointegration regression, Xiao (2009) also developed a quantile cointegration test, denoted by $|Y_n|$, to investigate the null hypothesis of quantile cointegration.[3] This test statistic is useful for the confirmation of the validity of quantile-varying cointegration models.

3. Data and preliminary results

This study examines the validity of the Fisher effect for several selected developing countries: Indonesia, Malaysia, Russia, and South Africa. Indonesia and Malaysia are two founding members of the Association of South East Asian Nations (ASEAN), and they are the largest and the third largest economies in Southeast Asia, respectively. Also, Malaysia's economic performance is among the best in Asia, with GDP growing an average 6.5 per cent for almost 50 years. According to the World Bank, South Africa is ranked as an upper-middle income economy, and its economy is the largest and most developed in Africa. Further, South Africa and Russia are two of the BRICS.

Different nominal interest rates are used because of limited data availability. To be specific, call money data are selected for Indonesia, and interbank overnight rates are chosen for Malaysia. Money market rates are used for Russia and South Africa. Annualised inflation data for these countries are based on consumer price indices (CPI). All the monthly data are retrieved from the International Monetary Fund's IFS database, covering the sample period from January 1995 to June 2011.

Table 1a: Descriptive statistics for nominal interest rates

Country	*Mean*	*S.D.*	*Skewness*	*Kurtosis*	*JB stat. (p-vlue)*
Indonesia	14.677	15.614	2.562	8.772	459.227 (0.000)
Malaysia	3.814	2.069	1.780	5.228	135.935 (0.000)
Russia	12.626	18.129	3.595	19.796	2572.944 (0.000)
South Africa	10.375	3.647	0.757	2.815	17.926 (0.000)

Notes: JB stat. denotes the Jarque-Bera normality test, which is $\chi^2(2)$ distributed asymptotically.

Tables 1a and 1b present the preliminary descriptive statistics for nominal interest rates and inflation rates, respectively. For nominal interest rates, the mean for Indonesia is the largest (14.677), the smallest for Malaysia (3.814). The sample standard deviation for Russia is 18.129, meaning that the nominal rates are subject to considerable variation. However, the counterparts for Malaysia are relatively stable.

Table 1b: Descriptive statistics for inflation rates

Country	*Mean*	*S.D.*	*Skewness*	*Kurtosis*	*JB stat. (p-vlue)*
Indonesia	10.811	11.581	2.871	11.031	751.201 (0.000)
Malaysia	2.490	1.644	0.638	5.486	60.205 (0.000)
Russia	18.280	16.620	2.439	8.156	388.322 (0.000)
South Africa	5.969	2.763	0.116	2.552	1.957 (0.376)

Notes: see table 1a

In addition, their distributions are skewed and leptokurtic, and all the values of the Jarque-Bera normality tests are large (*p*-values are quite small), strongly suggesting that they are non-Gaussian, which is consistent with the literature (see Koenker and Xiao 2004). It is important to note that, analytically, efficiency gains can be achieved from the quantile cointegration analysis in the presence of non-normal distributed data. Similarly, inflation rates also exhibit heavy-tailed, except for the case of South Africa.

Table 2a: Results for univariate unit root tests on nominal interest rates

Country	MZ_α–*GLS*	*DF-GLS*	*p*
Indonesia	-6.27	-1.75	2
Malaysia	-2.61	-0.90	5
Russia	-1.10	-0.67	3
South Africa	-4.00	-1.77	2

Notes: *p* denotes the optimal lag selected by MAIC with maximum lag set at 16. The 5% critical values for the MZ_α–*GLS* and DF-GLS test are -8.1 and -1.98, respectively.

Table 2b: Results for univariate unit root tests on inflation rates

Country	MZ_α–*GLS*	*DF-GLS*	*p*
Indonesia	-6.05	-1.91	12
Malaysia	-7.17	-1.91	12
Russia	-0.36	-0.14	12
South Africa	0.08	0.03	13

Notes: *p* denotes the optimal lag selected by MAIC with maximum lag set at 16. The 5% critical values for the MZ_α–*GLS* and DF-GLS test are -8.1 and -1.98, respectively.

Tables 2a and 2b report the results of unit root testing on nominal interest rates and inflation rates, respectively. The MZ_α–GLS and *DF-GLS* tests proposed by Ng and Perron (2001) are used, as they not only deliver high power properties, but also maintain robust type I errors. Moreover, the lag length p for these tests are selected by MAIC (see also Ng and Perron 2001) with the maximum lag set at 16, as suggested in Tsong and Lee (2010, 2011). According to these results, all the nominal interest rates and inflation rates for the countries considered exhibit unit-root behaviour, since the two tests uniformly fail to reject the null hypothesis of non-stationarity. Note also that the optimal lag orders for inflation rates are much larger than those for nominal interest rates, revealing that inflation rates may be described by moving average (MA) processes with a large negative root. This is consistent with findings which are well-documented in the literature (see, for example, Lee and Tsong 2013; Ng and Perron 2001; Schwert 1987).

Table 3 Results for the Engle-Granger cointegration test

Country	*ADF*	β
Indonesia	-2.807	1.060
Malaysia	-1.875	0.596
Russia	-3.456**	0.439
South Africa	-1.657	0.753

Notes: The 5% and 10% critical values for the ADF test are -3.37 and -3.07, respectively, retrieved from Table B.9 in Hamilton (1994). β denotes the cointegrating coefficient. ** indicates significance at the 5% level.

Since the two time-series behave like a unit-root process, we take a further step, turning our attention to the results of EG cointegration test, shown in Table 3. Note that such a cointegration test relies on a single measure of conditional central tendency, and a constant cointegrating vector for the sample period considered. These are more restrictive than the quantile cointegration inference, allowing researchers to explore various possible long-run relationships between variables across different quantiles of shocks, as explained in Section 3. As shown in Table 3, the nominal rate and inflation are cointegrated only for Russia. Even for Russia, however, the value of the cointegrating coefficient is much less than unity (0.439), revealing strong evidence that the interest rate reacts less than proportionately to changes in inflation: the Fisher effect puzzle. The Fisher effect puzzle can also be found for the remaining countries, except for Indonesia. The absence of cointegration between the interest rate and inflation, and the less than proportionate reaction obtained from the EG test, provide very weak evidence in supportive of the Fisher hypothesis.

These results are in line with, for example, Koustas and Serletis (1999), Rapach (2003) and Mishkin and Simon (1995). One explanation for these empirical results may be the presence of a varying cointegrating vector. In other words, the coefficient measuring the long-run equilibrium relationship could vary over time, though the interest rate and inflation still move together in the long run. These issues can be elaborated on by using quantile cointegration as shown in the following section.

4. Results for quantile cointegration

Table 4 presents the quantile cointegration results, including the estimated magnitudes of shocks across quantiles ($\hat{\alpha}(\tau)$), the long-run equilibrium coefficients for various quantiles ($\hat{\beta}(\tau)$), the values of Wald statistic for testing the null of unity cointegrating coefficient, the values of $\sup|\hat{V}_n(\tau)|$ and *p*-values testing the null of constant cointegrating coefficient, as well as the values of $|Y_n|$ and *p*-values investigating the null of existing quantile cointegration.

In sharp contrast with the results in Table 3, where the EG test fails to corroborate the presence of cointegration, the sup $|Y_n|$ test provides strong support for the hypothesis that interest rates and inflation rates constitute a long-run equilibrium relationship for all countries in a quantile sense, since the -values of the statistic are large enough that there is no evidence to reject the null of quantile cointegration.

The sizes of shock associated with the interest rate, represented by $\hat{\beta}(\tau)$, are different across quantiles. Negative shocks are in the lower quantiles, while positive shocks are in the upper quantiles. The distribution for Russia's interest rate shock is the most dispersive, ranging from -9.653 to 8.127, while the counterpart for Malaysia is the most concentrated, ranging from -1.226 to 2.503. These results conform to the results shown in Table 1, where Russia has the largest interest rate standard deviation , Malaysia the smallest.

The most noticeable feature is the value of cointegrating vectors across different quantiles. Obviously they are not fixed, compared with those in Table 3, and can vary across quantiles. To be precise, they are much smaller than unity in the lower quantiles, and in general, get larger in the upper quantiles. Taking Malaysia as an example, at the 10% quantile, the coefficient is only 0.19, but at 90% quantile it can be up to 1.222. For easy comparison, the cointegrating coefficients in Table 3, and the quantile-varying counterparts are plotted in Figure 1.

Table 4 Quantile cointegration results for nominal interest rates and inflation rates

Country	τ	*0.1*	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*
Indonesia	$\hat{\alpha}(\tau)$	-7.178**	-5.882**	-4.294**	-2.655**	-1.266**	-0.350	1.837**	4.078**	7.975**
	p-value	0.000	0.000	0.000	0.000	0.000	0.317	0.000	0.000	0.000
	$\hat{\beta}(\tau)$	0.559	0.728	1.006	1.076	1.142	1.139	1.191	1.203	1.207
	Wald test	186.093**	10.021**	0.003	0.503	1.479	1.282	1.625	0.812	0.321
	p-value	0.000	0.002	0.954	0.478	0.224	0.258	0.202	0.368	0.571
	$\sup\lvert\hat{V}_n(\tau)\rvert$ (p-value): 10562.06 (0.000)						$\sup\lvert Y_n\rvert$ (p-value): 0.162 (0.874)			
Malaysia	$\hat{\alpha}(\tau)$	-1.226**	-1.128**	-1.037**	-0.915**	-0.765**	-0.426*	0.143	1.341**	2.503**
	p-value	0.000	0.000	0.000	0.000	0.000	0.086	0.588	0.000	0.000
	$\hat{\beta}(\tau)$	0.190	0.201	0.192	0.229	0.271	0.528	0.795	1.374	1.222
	Wald test	283.077**	271.604**	148.488**	42.182**	17.989**	1.756	0.191	0.308	0.221
	p-value	0.000	0.000	0.000	0.000	0.000	0.185	0.662	0.579	0.638
	$\sup\lvert\hat{V}_n(\tau)\rvert$ (p-value): 16667.32 (0.000)						$\sup\lvert Y_n\rvert$ (p-value): 0.169 (0.860)			

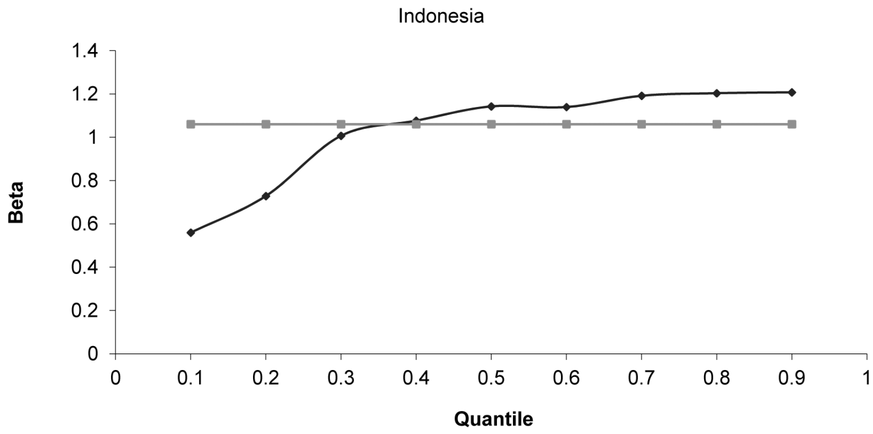
Notes: The null of zero is tested for $\beta_0(\tau)$ with student-t test. Wald test examines the null of unity cointegrating coefficient. sup $\lvert V_n\rvert$ and $\lvert Y_n\rvert$ test the null of constant cointegrating coefficient and the existence of quantile cointegration, respectively. ** denotes significance at 5% level.

Table 4 (Continued) Quantile cointegration results for nominal interest rates and inflation rates

Country	τ	*0.1*	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*
Russia	$\hat{\alpha}(\tau)$	-9.653**	-8.774**	-7.456**	-6.134**	-4.899**	-3.096**	-0.810	3.786**	8.127**
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.176	0.000	0.000
	$\hat{\beta}(\tau)$	0.559	0.728	1.006	1.076	1.142	1.139	1.191	1.203	1.207
	Wald test	186.093**	10.021**	0.003	0.503	1.479	1.282	1.625	0.812	0.321
	p-value	0.000	0.002	0.954	0.478	0.224	0.258	0.202	0.368	0.571
	$\sup\lvert\hat{V}_n(\tau)\rvert$ (p-value): 78821.15 (0.000)					$\sup\ \lvert Y_n\rvert$ (p-value): 0.136 (0.894)				
South Africa	$\hat{\alpha}(\tau)$	-1.226**	-2.378**	-1.909**	-1.529**	-1.051**	-0.227	1.141**	2.987**	4.327**
	p-value	0.000	0.000	0.000	0.000	0.030	0.665	0.038	0.000	0.000
	$\hat{\beta}(\tau)$	0.190	0.667	0.702	0.662	0.595	0.558	0.810	1.102	1.189
	Wald test	283.077**	2.962*	2.196	1.754	0.601	0.483	0.064	0.032	0.367
	p-value	0.000	0.085	0.138	0.185	0.438	0.487	0.801	0.858	0.544
	$\sup\lvert\hat{V}_n(\tau)\rvert$ (p -value): 5393.24 (0.026)					$\sup\ \lvert Y_n\rvert$ (p-value): 0.173 (0.864)				

Notes: The null of zero is tested for $\beta_0(\tau)$ with student-t test. Wald test examines the null of unity cointegrating coefficient. sup $\lvert V_n\rvert$ and $\lvert Y_n\rvert$ test the null of constant cointegrating coefficient and the existence of quantile cointegration, respectively. ** denotes significance at 5% level.

Figure 1: Cointegration coefficients between nominal interest rate and inflation rate. The diamonds and squares denote quantile and EG coefficients, respectively.



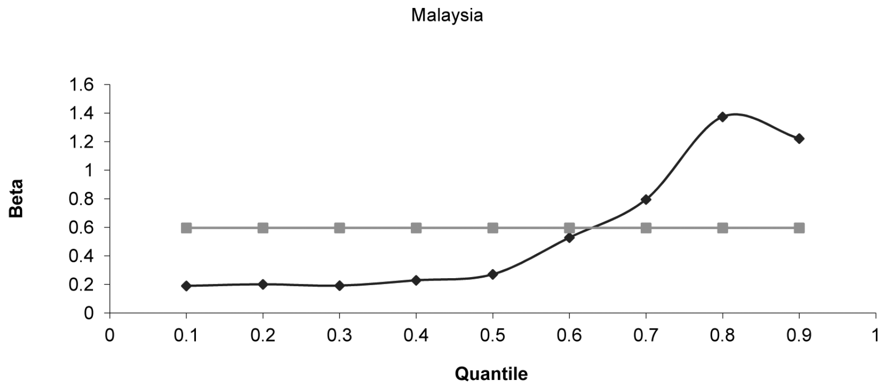


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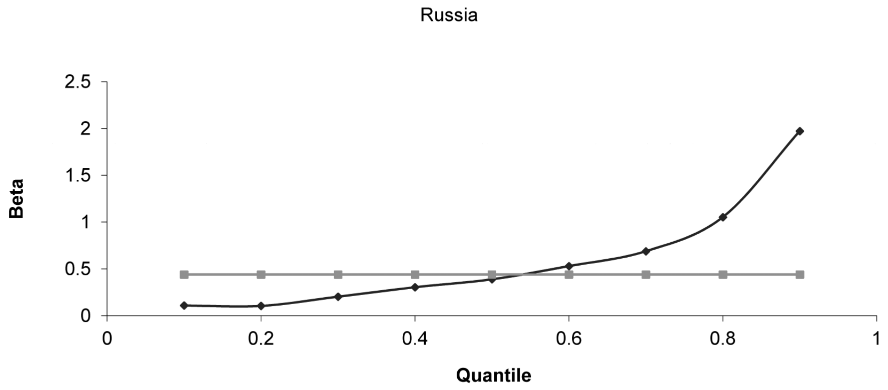
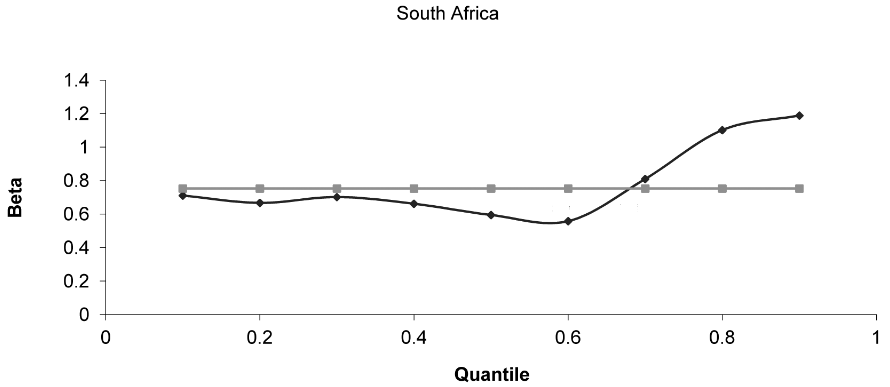
Figure 1: *...cont*





Turning to the Wald test, we find that in the lower quantiles, with small coefficients, the statistic overwhelmingly reject the null of a unity coefficient, indicating the existence of the Fisher effect puzzle. However, the Wald test cannot reject the unity null, as the coefficients increase with quantiles. Taking Malaysia as an example again, below the 60% quantile, the small values of the coefficient result in large Wald test values, (283.077, 148.488, and 17.989, at the 10%, 30%, and 50% quantiles, respectively) and have small *p*-values (around zero). However, the coefficients become large with increasing quantiles. We can see that above the 50% quantile, the corresponding *p*-values are larger than 0.05 (0.185, 0.662, 0.579, and 0.638 at the 60%, 70%, 80%, and 90% quantiles, respectively), strongly supporting the Fisher effect.

Such a asymmetric, nonlinear long-run relationship between interest rate and inflation rate is interesting, and cannot be revealed by conventional cointegration techniques such as the EG method. These results are similar to the counterparts in Christopoulos and León-Ledesma (2007), in which the LSTAR-type long-run relationship is evident for the US, with data spanning

1979 to 2004. Combining the estimated magnitudes of shock and the quantile-varying long-run coefficient, one possible explanation for such an asymmetric relationship is as follows. For policymakers, monetary policies can be implemented through the nominal interest rate, and hence this influences the equilibrium relationship between interest rate and inflation. Specifically, the main goal of monetary authorities is to keep the price level stable, and they are able to determine the short-term rate to bring inflation under control.

Our results imply that when inflation is high, they would raise nominal interest rate more aggressively to bring down inflation, thus preventing high inflation from hurting the economy. Such action leads to a one-to-one relationship between the two variables, and supports the Fisher effect. For emerging markets, the risk of inflation is heightened by weak institutions, poor regulations (Mishkin 2008) and high growth rates (Henderson 2005). On the other hand, when inflationary pressure is mild, the nominal interest rate could be increased less than the inflation change, bringing about the Fisher effect puzzle. Furthermore, when inflation is low, for example during an economic downturn, the monetary authorities would lower the interest rate to stimulate the economy. However, worrying about the resurgence of high inflation, they reduce the rate less than proportionately to the desired decrease in inflation. The partial adjustments of the nominal interest rate in the above two cases, undoubtedly, result in the Fisher effect puzzle.

5. Conclusions

In this paper, we have re-examined empirically the Fisher hypothesis, in several selected developing economies: Indonesia, Malaysia, Russia, and South Africa. By using the recently developed quantile cointegration technique of Xiao (2009), we find that a long-run equilibrium relationship between interest rate and inflation does exist, in sharp contrast with results obtained by EG cointegration tests. Moreover, the cointegrating coefficients are not constant; they are affected by shocks and, hence, may vary over time. More importantly, strong evidence has been revealed that the cointegration relationship exhibits asymmetry. In the upper quantiles, the nominal interest rate results in one-to-one changes in inflation, supporting the Fisher hypothesis; while in the lower quantiles, a less than proportional inflation reaction is evident, showing the presence of the Fisher effect puzzle. Such results may be attributed to asymmetric monetary policy.

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Endnotes

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2. The computation of $\hat{f}$ and $\hat{\omega}_{\psi}^{*2}$ are omitted for space conservation. Please refer to Xiao (2009) for further information.

3. The procedure for sup $|Y_n|$ is omitted for brevity. For detailed discuss, please refer to Xiao (2009).

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