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# Does the Term Structure of Interest Rates Hold True for East-Asian Countries? More Powerful Nonlinear Cointegration Tests

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**Abstract:** The expectations hypothesis of the term structure (EHTS) of interest rates is one of the cornerstones of financial theory and macroeconomic theory. It's vital for predicting future interest rate changes, analyzing monetary policy, and developing macroeconomic models. This study evaluates the effectiveness of the EHTS of interest rates for seven East Asian countries from January 2011 to November 2021, using the nonlinear smooth transfer error correction model (ST-ECM) established by Kapetanios et al. (2006). Compared to the traditional linear ECM, the ST-ECM is more powerful in detecting the cointegration relationship between economic variables in the presence of policy interventions and transaction costs. The empirical results indicate that the EHTS of interest rates stands true for all the East-Asian nations under study, with the exception of Singapore and Thailand, and the adjustment towards the EHTS of interest rates is found to be nonlinear for the majority of the East-Asian nations. These research findings have significant policy implications for East-Asian countries.

**Keywords:** term structure of interest rates; East-Asian countries; smooth transition error correction model

**JEL Classification:** C32; E43

## 1. Introduction

The expectations hypothesis of the term structure (hereafter, EHTS) of interest rates has always been an important proposition in macroeconomics and financial research. This hypothesis points out that the long-term interest rate equals the mean of current and predicted future short-term interest rates, adding the risk premium. And the establishment and adjustment mechanism of the EHTS has important economic implications: firstly, the EHTS reflects the validity of information in the bond market, revealing whether there are arbitrage opportunities in the bond market; secondly, the EHTS implies that long-term rates are decided by short-term rates, and policy makers can regulate long-term rates via operating short-term rates and thus affect economic operation; thirdly, the spread between long-term and short-term rates can provide valuable information about inflation rates and future interest rates. Therefore, it is critical to study this topic not only for theoretical research but also for policy implications.

Empirical research on the EHTS of interest rates is luxuriant but far from unequivocal so far. In the related studies, the conventional linear model and threshold model are frequently employed to analyze the EHTS of interest rates, such as Campbell and Shiller (1978a,1991b), Quiros-Romero and Sosvilla-Rivero (1997), Enders and Granger (1998), Camarero and Tamarit (2002), Sarno et al. (2007), Suardi (2010), Esteve et al. (2013) and Muzindutsi and Mposelwa (2021) et al. Recently, a growing agreement has emerged that the EHTS of interest rates demonstrates nonlinear adjustment, for example, Bachmeier and Li (2002), Maki (2006), Haug and Siklos (2007), Sun and Lai-Lei (2012), Guney (2013), Huang and Wang (2014), Grisse (2015), Zhu and Rahman (2015), Cai and Wang (2017), Song et al. (2017), Bekiros et al. (2018), Liu et al. (2020) and Mineo et al. (2020) et al. Consequently, the conventional cointegration tests, such as the Engle-Granger (EG) test, have low power in detecting the cointegration relationship in the EHTS of interest rates. As a result, nonlinear cointegration tests must be used. All of the above studies offered in-depth information on the EHTS of interest rates from both theoretical and empirical aspects.To our knowledge, however, no research has been conducted that uses nonlinear econometric techniques to examine the EHTS of interest rates in East-Asian nations.

This empirical study enriches this line of research by evaluating whether the EHTS of interest rates holds true in a sample of seven East Asian nations, and whether the adjustment towards their equilibrium takes place in a nonlinear manner. Economic integration appears to be increasing in Asia, and Asia is now playing a significant role in the globe as well. The Asian nations are progressively establishing themselves as major players in global marketplaces as a result of their rapid economic expansion. We test the nonlinear cointegration association of the long-term and short-term rates in seven East Asian nations based on the simple and powerful nonlinear cointegration approach of Kapetanios et al. (2006). The major advantage of this approach is that it can analyze the inherent nonlinear adjustments resulting from market friction, such as structural changes in monetary policy (Mankiw and Miron, 1986), time-varying risk premiums (Fama, 1990), transaction costs (Anderson, 1997) and institutional transfer behavior (Bekaert et al., 1997). Thus, the current research aims to fill a gap in the existing research. This is, to our knowledge, the first study to employ the nonlinear Smooth Transition Error Correction Model (hereinafter, ST-ECM) cointegration test on seven East-Asian EHTS interest rates. We find that the ST-ECM cointegration test strongly rejects the null hypothesis that EHTS of interest rates doesn't hold true for all the countries examined except Singapore and Thailand, indicating that EHTS of interest rates holds true for five of the seven East-Asian countries. Additionally, the adjustment process towards equilibrium is nonlinear for the majority of these East-Asian nations.

The rest of this article is arranged in this way: Section II expounds the EHTS of interest rates and outlines the ST-ECM for nonlinear cointegration tests. Section III introduces the data and empirical findings, and Section IV concludes this article.

## 2. EHTS of Interest Rates and Methodology

### *2.1. The EHTS of Interest Rates*

The EHTS of interest rates connects long-term rates to present and predicted short-term rates, and is defined by Campbell and Shiller (1991) as follows :

$$i_t^{(n)} = \frac{1}{q}\sum_{i=0}^{q-1} E_t i_{t+mk}^{(m)} + c(n,m) \tag{1}$$

where $q = n/m$ and $i_t^{(n)}$ contains a weighted mean of current and predicted short-term rates, $i_t^{(m)}$ and a continuous risk premium, $c(n,m)$.

To evaluate the effectiveness of the expectation theory conveniently, empirical researches on the EHTS of interest rates have frequently utilized a linear model such as:

$$i_t^{(n)} = \alpha + \beta i_t^{(m)} + \mu_t \tag{2}$$

where $\alpha$ is a constant, $\beta$ is a cointegration vector, and $\mu_t$ is the residual difference. Considering the long-run equilibrium relation is not always one-to-one proportional, therefore, it's more crucial to assess the above long-run relation using a flexible modality instead of the pre-specified cointegrating vector as Campbell and Shiller (1991) claimed.

### *2.2. Kapetanios et al's. (2006) Nonlinear Cointegration Test*

This study applies Kapetanios et al's. (2006) ST-ECM for nonlinear cointegration approach to examine the EHTS with nonlinear adjustments for seven East-Asian nations. Following Kapetanios et al. (2006), the ST-ECM is expressed as follows:

$$\Delta y_t = \phi u_{t-1} + \gamma u_{t-1}(1 - e^{-\theta(u_{t-1}-c)^2}) + \omega'\Delta x_t + \sum_{i=1}^{p}\psi_i'\Delta z_{t-i} + e_t \tag{3}$$

$$\Delta x_t = \sum_{i=1}^{p}\Gamma_{xi}\Delta z_{t-i} + \varepsilon_{xt} \tag{4}$$

where $t = 1,2,\ldots,T$, $z_t = (y_t, x_t)$, $\theta \geq 0$ is the ST-ECM model's transition parameter that controls the rate at which transitions occur, $c$ is the threshold parameter that may be understood as the transition point between the two states, $\omega' = \sum_{xx}^{-1}\sigma_{xy}$, $\psi_i' = \gamma_{yi} - \omega'\Gamma_{xi}$, $i = 1,2,\ldots,p$, and

$$u_t = y_t - \beta_x' x_t \tag{5}$$

$\beta_x'$ is a $k \times 1$ vector of cointegration parameters. The obvious difference from the traditional linear ECM is the transition function $(1 - e^{-\theta(u_{t-1}-c)^2})$, which is dynamic and changes with the deviations $u_t$. According to Kapetanios et al. (2006), there is no nonlinear cointegration if $\theta = 0$, so the null and alternative hypotheses for nonlinear cointegration are as follows:

$$H_0: \theta = 0 \quad H_1: \theta > 0 \tag{6}$$

Nevertheless, it is impractical to test the null hypothesis straightly because the parameter $\gamma$ is unidentifiable. In order to solve this issue, they approximate (3) using a Taylor series of first order around $\theta = 0$ approximation to $(1 - e^{-\theta(u_{t-1}-c)^2})$, under the condition of $\phi \neq 0$, they acquire the ancillary testing regression as follows:

$$\Delta y_t = \delta_1 \hat{u}_{t-1} + \delta_2 \hat{u}_{t-1}{}^2 + \delta_3 \hat{u}_{t-1}{}^3 + \omega' \Delta x_t + \sum_{i=1}^{p} \psi_i' \Delta z_{t-i} + \varepsilon_t \quad (7)$$

Based on the above considerations, the null hypothesis $\theta = 0$ in (6) is converted to $\delta_1 = \delta_2 = \delta_3 = 0$. And the $F_{NEC}$ test statistic is put forward for the null hypothesis of $\delta_1 = \delta_2 = \delta_3 = 0$ against they are not all equal to zero, which is expressed as follows:

$$F_{NEC} = \frac{(SSR_0 - SSR_1)/3}{SSR_0/(T-4-p)} \quad (8)$$

where $SSR_0$ and $SSR_1$ are the sums of squared residuals derived from the specification with and without the constraints $\delta_1 = \delta_2 = \delta_3 = 0$ in (7), correspondingly.

There are previous theoretical justifications for limiting the threshold parameter in model (3) to zero in a large number of financial and economic applications in the ST-ECM, which results in the following constrained auxiliary testing regression:

$$\Delta y_t = \delta_1 \hat{u}_{t-1} + \delta_3 \hat{u}_{t-1}{}^3 + \omega' \Delta x_t + \sum_{i=1}^{p} \psi_i' \Delta z_{t-i} + \varepsilon_t \quad (9)$$

The $F_{NEC}^{*}$ test is presented according to the test statistic for $\delta_1 = \delta_3 = 0$ against they are not both equal to zero, and is given as follows:

$$F_{NEC}^{*} = \frac{(SSR_0 - SSR_1)/2}{SSR_0/(T-3-p)} \quad (10)$$

Under the condition of $\phi = 0$ and considering $c = 0$, model (7) can be simplified as the following model (10):

$$\Delta y_t = \delta_3 \hat{u}_{t-1}{}^3 + \omega' \Delta x_t + \sum_{i=1}^{p} \psi_i' \Delta z_{t-i} + \varepsilon_t \quad (11)$$

The $t_{NEC}$ test is presented to test $\delta_3 = 0$ and expressed as follows:

$$t_{NEC} = \frac{\hat{\delta}_3}{se(\hat{\delta}_3)} \quad (12)$$

where $\hat{\delta}_3$ is the OLS estimate of $\delta_3$ and $se(\hat{\delta}_3)$ is the standard error of $\hat{\delta}_3$.

They presented the above three statistics' asymptotic distributions and simulated their critical values respectively, and for more details see Kapetanios et al. (2006).

## 3. Data and Empirical Results

### *3.1. Data*

This research includes seven East Asian nations: China, Japan, Korea, the Philippines, Singapore, Thailand, and Indonesia. And our empirical analysis uses monthly data and covers the period from January 2011 to November 2021. All the data is taken from the Wind Database. Table 1 summarizes the names of each country, the sample period, and the indicators of the long-term and short-term rates in this research.

Table 2 shows the statistical characteristics of the interest rate indicators in seven East Asian countries. As can be seen from Table 2, the digital characteristics of two interest rates indicators vary greatly among nations due to the monetary policies, economic development environment and economic development period. Compared to other nations, Indonesia has the highest short-term and long-term interest rates, with averages of 5.894 and 7.230, respectively.

**Table 1.** Sample interval and variable selection

| Nation | Sample Interval | Long-term rate | Short-term rate |
|---|---|---|---|
| China | 2011.01-2021.11 | 10-year GBY | 1-year TBR |
| Japan | 2011.01-2021.11 | 10-year GBY | 1-year TBR |
| Korea | 2011.01-2021.11 | 10-year GBY | 1-year TBR |
| Philippines | 2011.01-2021.11 | 1-year GBY | 3-month TBR |
| Singapore | 2011.01-2021.11 | 10-year GBY | 1-year TBR |
| Thailand | 2011.01-2021.11 | 10-year GBY | 1-year TBR |
| Indonesia | 2011.01-2021.11 | 10-year GBY | 1-year TBR |

Note: GBY denotes Government Bond Yield and TBR denotes Treasury Bill Rate.

These rates are 2-4 times higher than those of other countries owing to Indonesia's long-term high inflation rate. Japan has the lowest short-term and long-term interest rates, with the mean of long-term interest rate being 0.377, far lower than those of other countries, owing to the Japanese government's long-standing zero interest rate policy. Moreover, the mean of short-term interest rates in Japan is -0.059, owing to its policy of negative interest rates to stimulate economic growth recently. By observing the JB statistics of the short and long interest rates, it is obvious that both the two interest rates of almost all nations do not obey the normal distribution, which fully demonstrates the characteristics of the non-normal distribution of the peak and thick tail of financial time series.

**Table 2**. Descriptive statistics

| Country | Index | Observations | Mean | Max. | Min. | S.D. | JB statistics |
|---|---|---|---|---|---|---|---|
| China | S-Rate | 130 | 2.814 | 4.220 | 1.150 | 0.556 | 0.453 |
| | L-Rate | | 3.439 | 4.550 | 2.540 | 0.445 | 3.059 |
| Japan | S-Rate | 131 | -0.059 | 0.167 | -0.344 | 0.138 | 8.569** |
| | L-Rate | | 0.337 | 1.290 | -0.259 | 0.408 | 13.537*** |
| Korea | S-Rate | 131 | 1.953 | 3.590 | 0.611 | 0.837 | 7.165** |
| | L-Rate | | 2.568 | 4.760 | 1.254 | 0.859 | 9.114** |
| Philippines | S-Rate | 119 | 1.936 | 5.754 | 0.001 | 1.310 | 32.090*** |
| | L-Rate | | 2.528 | 6.546 | 0.190 | 1.414 | 28.705*** |
| Singapore | S-Rate | 130 | 0.827 | 2.050 | 0.180 | 0.598 | 15.427*** |
| | L-Rate | | 1.959 | 2.850 | 0.810 | 0.500 | 8.959** |
| Thailand | S-Rate | 131 | 1.804 | 3.600 | 0.420 | 0.840 | 3.510 |
| | L-Rate | | 2.728 | 4.210 | 1.170 | 0.842 | 6.775** |
| Indonesia | S-Rate | 131 | 5.894 | 8.819 | 2.944 | 1.289 | 5.075* |
| | L-Rate | | 7.230 | 9.624 | 5.167 | 0.952 | 2.582 |

Note: S-Rate stands for short-term rate and L-Rate stands for long-term rate.* signifies a 1% significance level, ** a 5% significance level, and *** a 10% significance level.

### *3.2. Empirical Results*

To avoid spurious regression, the variables' stationarity should be examined by the Augmented Dickey-Fuller test before conducting a cointegration test. As the interest rates have no obvious trend over time and the raw data is not zero mean, all tests involve simply a constant term and determine the lag period with the SC criterion. Table 3 summarizes the

results of the Augmented Dickey-Fuller (ADF) unit root tests on both interest rates. The unit root hypotheses for the short-term and long-term rates in level are not rejected for all countries at the significance level of 5%, while these hypotheses are rejected in their first difference for all countries. Therefore, all the series are I(1). On the basis of these findings, we conduct a cointegration test.

**Table 3.** Dickey-Fuller unit root tests results

| Country | Long term rate | | Short term rate | |
|---|---|---|---|---|
| | Level | First difference | Level | First difference |
| China | -1.784[0] | -9.837[0]*** | -2.461[0] | -9.722[0]*** |
| Thailand | -1.246[0] | -9.863[0]*** | -0.600[1] | -6.600[0]*** |
| Japan | -2.398[2] | -8.498[1]*** | -1.614[0] | -12.209[0]*** |
| Korea | -2.736[1]* | -8.341[0]*** | -1.983[1] | -7.509[0]*** |
| Philippines | -1.096[1] | -7.867[1]*** | -1.361[1] | -4.774[3]*** |
| Singapore | -2.269[0] | -10.807[0]*** | -1.452[2] | -9.916[0]*** |
| Indonesia | -0.903[0] | -11.175[0]*** | -0.907[0] | -12.376[0]*** |

Note: Each cell displays the ADF test statistic. The digit in parentheses is the appropriate lag order determined by the Schwarz Info Criterion (SC). * signifies a 1% significance level, ** a 5% significance level, and *** a 10% significance level.

For the sake of comparison, we also incorporate the linear $EG$ cointegration test put forward by Engle and Granger (1987) and $t_{NEG}$ test raised by Kapetanios et al. (2006) into our study. Table 4 displays the results of the cointegration test. Since the EHTS theory of interest rates does not allow for a tendency, all of the tests involve simply a constant term and the appropriate lag duration for each test is determined by the SC criteria. As shown in Table 4, the $EG$ tests can only figure out the linear cointegration relationship of China and Philippines. Besides, the $t_{NEG}$ and $t_{NEC}$ tests confirm the nonlinear cointegration relationship for China, Indonesia and Korea at the level of 5% significance. Compared with the $t_{NEC}$ tests, the cointegration relationship is also found in Singapore according to the $t_{NEG}$ test. On the other hand, the $F_{NEC}$ tests provide clear evidence of nonlinear cointegration relationship for China, Indonesia ,Philippines and Japan at the level of 5% significance as reported in Table 4. The nonlinear cointegration relationship is also found in Korea at the level of 10% significance both according to the $F_{NEC}$ and $F^{*}_{NEC}$ statistic, which reveals that the prior restriction of the switch point c to be zero is reasonable. Although the $EG$ test and $F^{*}_{NEC}$ test of China and the Philippines are both valid, according to the significance, the evidence of linear cointegration relationship for China is more significant, and the evidence of nonlinear cointegration relationship for Philippines is more significant. The results imply that differences from long term equilibrium for Indonesia, Korea, Japan, and the Philippines may be inherently nonlinear. All of these suggest that the EHTS of interest rates stands true for all nations with the exception of Singapore and Thailand. What's more, the adjustment towards the EHTS of interest rates is linear in China, but nonlinear in Indonesia, Japan, Korea and Philippines. The linear adjustment mechanism for China may be due to the government's strong regulation of the financial market. However, the reasons for the nonlinear adjustment mechanisms are very complex, most likely due to the transaction costs of investors, time-

varying risk premiums, regional transfer behavior, and structural changes of the monetary policy in various countries.

**Table 4.** Cointegration test results

| Country | EG[a] | $t_{NEG}$[b] | $t_{NEC}$[c] | $F_{NEC}$*[d] | $F_{NEC}$[e] |
|---|---|---|---|---|---|
| China | -4.667*** | -3.905*** | -3.344** | 8.143** | 6.000*** |
| Indonesia | -1.289 | -3.956*** | -3.478** | 8.193*** | 5.990*** |
| Japan | -2.351 | -1.395 | -2.876 | 2.473 | 5.700** |
| Korea | -2.116 | -3.948 *** | -4.531*** | 5.908* | 4.064* |
| Singapore | -2.553 | -3.161* | -2.528 | 2.855 | 2.293 |
| Philippines | -3.797** | -2.162 | -1.995 | 8.470*** | 6.444*** |
| Thailand | -2.733 | -2.470 | -2.010 | 2.569 | 1.822 |

Note: * signifies a 1% significance level, ** a 5% significance level, and *** a 10% significance level. a critical values of 10%, 5%, and 1% are -3.06, -3.36, and -3.91, respectively ,proposed by Phillips and Ouliaris (1990). b and c critical values of 10%, 5%, and 1% determined from Kapetanios et al. (2006) are -2.98, -3.28, -3.84 and -2.92, -3.22, -3.78, respectively. d and e critical values are equivalent to 4.99, 5.96, 8.17 and 3.81, 4.47, 5.94, respectively, based on Kapetanios et al. (2006).

## 4. Conclusions

This study evaluates the applicability of the EHTS for interest rates in seven East Asian countries from January 2011 to November 2021, based on the Kapetanios et al. (2006)'s ST-ECM for nonlinear cointegration approach. ST-ECM is more effective at detecting the co-integration relationship in the presence of policy interventions and transaction costs. The empirical findings reveal that the EHTS of interest rates stands true for all nations, with the exception of Singapore and Thailand, and that the adjustment toward the EHTS is nonlinear for the majority of East-Asian nations.

Our findings have significant policy implications for East Asian nations. Firstly, the EHTS reflects the information effectiveness of the bond market. The empirical results in this paper indicate that there is no arbitrage chance in the bond markets of most East Asian countries except Singapore and Thailand. Secondly, the major idea behind the EHTS is that long-term and short-term rates in the bond market have a stable cointegration connection. As the cointegration test indicates, most of East-Asian countries' central banks can control long-term rates by operating the short-term rates to affect the actual economic variables except Singapore and Thailand. Finally, the difference between long-term interest rates and short-term interest rates, according to the EHTS of interest rates, reflects the market's anticipation of future interest rate changes, therefore it can provide valuable information about inflation rate, future interest rate and economic operation. Our empirical results imply that the term structure of interest rates of banks will become an important information indicator within the monetary policy framework, as an important input variable in macroeconomic models and monetary policy evaluation, providing decision support for monetary policy makers in most of East-Asian countries.

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## References


Anderson, H. M. (1997). Transaction costs and nonlinear adjustment towards equilibrium in the US Treasury Bill market. *Oxford Bulletin of Economics and Statistics, 59*(4), 465-484. https://doi.org/10.1111/1468-0084.00078

Bachmeier, L., & Li, Q. (2002). Is the term structure nonlinear? A semiparametric investigation. *Applied Economics Letters, 9,* 151-153. https://doi.org/10.1080/13504850110053275

Bekaert, G., Hodrick, R. J., & Marshall, D. A. (1997). On biases in tests of the expectations hypothesis of the term structure of interest rates. *Journal of Financial Economics*, *44*(3),309-348. https://doi.org/10.1016/S0304-405X(97)00007-X

Bekiros, S., Avdoulas, C., & Hassapis, C. (2018). Nonlinear equilibrium adjustment dynamics and predictability of the term structure of interest rates. *International Review of Financial Analysis, 55*,140-155. https://doi.org/10.1016/j.irfa.2017.11.009

Cai, Z. Z., & Wang, X. B. (2017). Analysis of expected hypothesis of term structure of interest rate based on threshold return model. *Financial Theory & Practice, 10*, 46-51.

Camarero, M., & Tamarit, C. (2002). Instability tests in cointegration relationships. An application to the term structure of interest rates. *Economic Modelling, 19,* 783-799. https://doi.org/10.1016/S0264-9993(01)00079-7

Campbell, J. Y., & Shiller, R. J. (1987). Cointegration and tests of present value models. *Journal of Political Economy, 95,* 1062-1088. https://doi.org/10.3386/w1885

Campbell, J. Y., & Shiller, R. J. (1991). Yield spreads and interest rate movements: a bird's eye view. *Review of Economic Studies, 58,* 495-514. https://doi.org/10.2307/2298008

Enders, W., & Granger, C. W. G. (1998). Unit-Root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates. *Journal of Business and Economic Statistics, 16*(3), 304-311. https://doi.org/10.1080/07350015.1998.10524769

Engle R. F., & Granger, C. W. J. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica,* 55(2), 251-276. https://doi.org/10.2307/1913236

Esteve, V., Navarro-Ibanez, M., & Prats, M. A. (2013). The Spanish term structure of interest rates revisited: Cointegration with multiple structural breaks, 1974-2010. *International Review of Economics and Finance, 25,* 24-34. https://doi.org/10.1016/j.iref.2012.04.007

Fama, E. F. (1990). Stock returns, expected returns, and real activity. *The journal of finance, 45(4),* 1089-1108. https://doi.org/10.1111/j.1540-6261.1990.tb02428.x

Grisse, C. (2015). The zero lower bound and movements in the term structure of interest rates. *Economics Letters, 131,* 66-69. https://doi.org/10.1016/j.econlet.2015.03.039

Guney, P. O. (2013). The Term Structure of Interest Rates: A Cointegration Analysis in the Non-Linear STAR Framework. *Journal of Economics and Behavioral Studies, 12,* 851-860. https://doi.org/10.22610/jebs.v5i12.458

Haug, A. A., & Siklos, P. L. (2007). The behavior of short-term interest rates: international evidence of non-linear adjustment. *Studies in Nonlinear Dynamics & Econometrics, 10*(4), 1276-1276. https://doi.org/10.2202/1558-3708.1276

Huang, R. F., & Wang, H. (2014). Nonlinear mean recovery characteristics of China's term structure of interest rates. *Statistics and decision, 05,* 31-34.

Kapetanios ,G., Shin, Y., & Snell, A. (2006).Testing for cointegration in nonlinear smooth transition error correction models. *Econometric Theory*, *22*(2), 279-303. https://doi.org/10.1017/S0266466606060129

Liu, X., Li, X., Zheng, S., & Qian, H. (2020). PMCMC for Term Structure of Interest Rates under Markov Regime Switching and Jumps. *Journal of Systems Science and Information, 8*(2), 159-169. https://doi.org/10.21078/JSSI-2020-159-11

Maki, D. (2006). Non-linear Adjustment in the Term Structure of Interest Rates: a Cointegration Analysis in the Non-Linear STAR framework. *Applied Financial Economics, 16,* 1301-1307. https://doi.org/10.1080/09603100500426572

Mankiw, N. G., & Miron, J. A. (1986).The changing behavior of the term structure of interest rates. *The Quarterly Journal of Economics, 101*(2), 211-228. https://doi.org/10.2307/1891113

Mineo, E., Alencar, A. P., Moura, M., & Fabris, A. E. (2020). Forecasting the term structure of interest rates with dynamic constrained smoothing b-splines. *Journal of Risk and Financial Management, 13*(4), 65. https://doi.org/10.3390/jrfm13040065

Muzindutsi, P. F., & Mposelwa, S. (2021). A Comparative Analysis of the Expectations Hypothesis of the Term Structure of Interest Rates between the BRICS and G7 Countries. *Comparative Economic Research. Central and Eastern Europe, 24(2)*, 87-102.

Phillips, P. C. B., & Ouliaris, S. (1990). Asymptotic Properties of Residual Based Tests for Cointegration. *Econometrica, 58*, 165-193. https://doi.org/10.2307/2938339

Quiros-Romero, G., & Sosvilla-Rivero, S. (1997). Do short-term interest rates influence long-term interest rates? Empirical evidence from some EMS countries. *Applied Economics Letters, 4*, 449-451. https://doi.org/10.1080/135048597355249

Sarno, L., Thornton, D. L., & Valente, G. (2007). The empirical failure of the expectations hypothesis of the term structure of bond yields. *Journal of Financial and Quantitative Analysis, 42*, 81-100. https://doi.org/10.1017/S0022109000002192

Song, P. P., Sun, H., & Zhang, L. L.(2017). Research on information of monetary policy rules in Term structure of Interest rate in China. *Modern Economic Information, 17*, 248-249+251.

Suardi, S. (2010). Nonstationarity, cointegration and structural breaks in the Australian term structure of interest rates. *Applied Economics, 42*, 2865-2879. https://doi.org/10.1080/00036840801964625

Sun, H., & Lai-Lei, Y. U. (2012). The nonlinear dynamic adjustment of China's interest rate term structure: a study based on MS-VECM model. *Contemporary Finance & Economics, 25*(01), 85-91.

Zhu, X. N., & Rahman, S. (2015). A regime-switching Nelson–Siegel term structure model of the macroeconomy. *Journal of Macroeconomics, 44*, 1-17. https://doi.org/10.1016/j.jmacro.2014.12.007