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Testing the Fisher hypothesis: empirical evidence in Vietnam

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Abstract

The goal of the study is to test the Fisher hypothesis in Vietnam in the period 2007-2023 using the nonlinear cointegration method. Empirical evidence shows that there exists a long-term nonlinear relationship between interest rates and inflation rates, but the correlation between them is not one-for-one as suggested by the Fisher hypothesis. From the research results, it is concluded that it is possible to use monetary policy tools to influence the long-term interest rates and forecast the inflation rate using the long-term nominal interest rate.

Keywords: nonlinear cointegration, Fisher hypothesis, smooth transition regression.

JEL classification: C22, C62, E22, E43.

1. Introduction

The Fisher hypothesis is one of the most well-known economic theories regarding the relationship between the interest rates and inflation. It posits that long-term nominal interest rates are the sum of the expected inflation and ex-ante real interest rates. As a result, the long-term interest rate maintains a long-run equilibrium relationship with the inflation rate.

The Fisher hypothesis addresses the relationship between two key macroeconomic variables, which is meaningful for the policymakers. The actual inflation plays a crucial role in influencing household investment, saving behaviors and the business cycle, making it highly significant for economic growth and development (Alimi and Ofonyelu, 2013). Furthermore, if empirical evidence supports the validity of the Fisher hypothesis, it has important policy implications, as it suggests that central banks can influence long-term interest rates by managing nominal inflation rates.

Although widely accepted in theory, empirical evidence on the validity of the Fisher hypothesis remains highly debated. While numerous studies have found evidence supporting the hypothesis (Mishkin, 1992; Evans and Lewis, 1995; Thornton, 1996; Crowder and Hoffman, 1996; Atkins and Coe, 2002; Lardic and Migron, 2003; Ayub *et al*., 2004; Maghyereh and Al-Zoubi, 2006; Berument *et al*., 2007; Obi *et al*., 2009; Nusair, 2009; Ahmad, 2010a; Ahmad, 2010b; Kose *et al*., 2012; Alimi and Ofonyelu, 2013), other studies have found conflicting results, suggesting that the Fisher hypothesis does not hold (Mishkin, 1981; Barthold and Dougan, 1986; Rose, 1988; MacDonald and Murphy, 1989; Payne and Ewing, 1997; Lai, 1997; Ghazali and Ramlee, 2003; Rapach and Weber, 2008; Nusair, 2008; Ahmad, 2010b).

Various research methodologies have been used to test the Fisher hypothesis including: cointegration methods and the error correction model (ECM) (Obi *et al*., 2009), Johansen cointegration tests (Alimi and Ofonyelu, 2013), the ARDL approach (Atkins and Coe, 2002; Ahmad, 2010a), the STAR model (Ahmad, 2010b), the GARCH model (Berument *et al*., 2007), and the AFRIMA model (Ghazali and Ramlee, 2003). Among these, Weber (2004) argued that cointegration testing is a powerful approach for validating the Fisher hypothesis. However, some researchers have criticized traditional cointegration methods, highlighting their limitations, especially in countries that implement inflation-targeting policies. As a result, recent studies have shifted towards nonlinear cointegration methods, as seen in Christopoulos and Leon-Ledesma (2007), Nusair (2009), and Ahmad (2010b).

While the Fisher hypothesis has been tested in many developed and developing countries, studies on the relationship between interest rates and inflation in Vietnam remain limited. Notable research includes Nguyen (2016) and Truong (2020). Nguyen (2016) examined a relatively simple linear regression model between the State Bank of Vietnam's target interest rate and inflation from 2005 to 2013. Their findings suggest that the Fisher hypothesis holds in the short run but is not clearly reflected in the long run. Meanwhile, Truong (2020) employed the ARDL approach and found a positive correlation between the interest rates and inflation, but not a one-to-one relationship as suggested by the Fisher effect. A common limitation of these studies is their reliance on linear models to analyze the relationship between the two variables, which may lead to misleading conclusions. To date, no research has explored the nonlinear cointegration relationship between interest rates and inflation in Vietnam. This research aims to fill that gap. By testing the Fisher hypothesis, the author examines the correlation between interest rates and inflation in Vietnam and derives relevant policy implications.

This paper contributes to the existing literature in several ways. First, it tests the Fisher hypothesis in a developing Southeast Asian country that has not yet implemented an inflation-targeting policy. Second, unlike many previous studies in Vietnam and globally, this research employs a nonlinear cointegration approach. This method allows for an examination of both short-term and long-term equilibrium relationship between the interest rates and inflation while mitigating potential errors associated with unit root tests and traditional linear cointegration methods.

2. The Fisher hypothesis and methods for testing the Fisher hypothesis

According to the Fisher hypothesis, the long-term nominal interest rate (i_t) is the sum of the expected inflation rate (π_t^e) and the ex-ante real interest rate (r_t^e):

$$i_t = r_t^e + \pi_t^e \quad (1)$$

Additionally, the expected inflation rate is equal to the inflation rate plus the inflation forecast error (ε_t):

$$\pi_t^e = \pi_t + \varepsilon_t \quad (2)$$

Therefore, the long-term nominal interest rate is the sum of the inflation rate, the expected real interest rate, and the inflation forecast error.

$$i_t = \pi_t + r_t^e + \varepsilon_t \quad (3)$$

Thus, from the perspective of the Fisher hypothesis, it follows that the inflation rate and interest rate move in the same direction. Furthermore, if the inflation rate increases by 1%, the nominal interest rate also increases by 1% on average (in which case, we say they have a one-to-one relationship). Therefore, to empirically test the Fisher hypothesis, we can consider the following regression model:

$$i_t = \beta_1 + \beta_2 \pi_t + u_t \quad (4)$$

If there is sufficient statistical evidence to conclude that β_2 is statistically significant and equal to 1, then the Fisher hypothesis is empirically validated.

Another method for analyzing the relationship between interest rates (i_t) and inflation (π_t) is cointegrated. This occurs when the variables are non-stationary, but their linear combination is stationary, meaning that u_t is stationary. To examine the stationarity of a variable, a commonly used test is the Augmented Dickey-Fuller (ADF) unit root test, which is represented by the following model:

$$\Delta u_t = \alpha + \rho u_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta u_{t-j} + \varepsilon_t \quad (5)$$

with the following hypothesis $H_0 : \rho = 0$ (meaning that u_t is stationary) and $H_1 : \rho < 0$ (meaning that u_t is non-stationary).

However, in model (5), the adjustment process u_t follows a linear form. Some researchers argue that due to various factors - such as transaction costs, economic policy shifts (Balke and Fomby, 1997), inflation targeting policies (Mishkin, 2000), and the "opportunistic behavior" of central banks (Orphanides and Wilcox, 2002; Kose *et al*., 2012), u_t should be nonlinear.

Orphanides and Wilcox (2002) and Kose *et al*. (2012) describe the opportunistic behavior of central banks as interventions in the interest rates only when inflation exceeds a certain threshold. Conversely, when inflation remains at moderate levels, central banks may refrain from intervention, allowing external factors to bring inflation back to its long-term expected level. This creates a threshold zone for interest rates and inflation, dividing central bank behavior into an "action zone" and a "non-action zone". Within the non-action zone, the interest rates and inflation remain relatively stable, and the adjustment error may exhibit unit root characteristics. Outside this zone, the adjustment error continuously reverts to its mean. This suggests that the relationship between interest rates and inflation follows a nonlinear stochastic process, where the adjustment error reverts to its mean outside the threshold but behaves as a unit root process within the threshold.

Several researchers have proposed nonlinear cointegration models to study this phenomenon. One of the most widely used models is the Smooth Transition Autoregressive Model (STAR), introduced by Granger and Terasvirta (1993). A key feature of this model is that the error correction speed is not constant but varies over time. The adjustment process follows a smooth and continuous function, allowing for a gradual transition from a fast adjustment phase to a slower adjustment phase.

Suppose there are two time series y_t, x_t and u_t is the random error when regressing y_t on x_t. The general form of the Smooth Transition Autoregression (STAR) model is:

$$\Delta u_t = \alpha' + \rho' u_{t-1} + \sum_{j=1}^{p} \lambda_j^{'} \Delta u_{t-j} + \left\{ \alpha_0 + \rho_0 u_{t-1} + \sum_{j=1}^{p} \lambda_{0j} \Delta u_{t-j} \right\} F[\theta; u_{t-d}] + \varepsilon_t \quad (6)$$

where, ε_t is white noise, $F[\theta; u_{t-d}]$ is the transition function, a continuous function bounded between 0 and 1. The parameter θ determines the speed of transition between the two regimes.

There are two common types of STAR models: ESTAR model, which corresponds to the transition function $F[\theta; u_{t-d}] = 1 - \exp\left[-\theta(u_{t-d} - \mu)^2\right]$ and LSTAR model, which corresponds to the transition function $F[\theta; u_{t-d}] = \left\{1 + \exp\left[-\theta(u_{t-d} - \mu)\right]\right\}^{-1}$

3. Methodology

3.1. Data

The Fisher hypothesis focuses on two key variables: long-term interest rates (i_t) and long-term inflation (p_t). To test the Fisher hypothesis, this research utilizes one-year government bond yield data from Reuters and consumer price index (CPI) data from the IFS database of the International Monetary Fund. To ensure consistency in frequency between the two variables, the study converts daily interest rate data into monthly data. The research period spans from July 2007 to June 2023.

The CPI data is formulated as:

$$p_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}} \times 1200 \quad (7)$$

3.2. Model

To empirically test the Fisher hypothesis, this research conducts a cointegration test between the interest rate and inflation. However, a necessary condition for cointegration is that both variables must be non-stationary time series. Thus, this research first performs a unit root test on the series i_t and p_t. This research combines the Engle and Granger (1987), ECM with the STAR model to determine the most appropriate model.

The research follows these steps:

Step 1: Estimate and test model (4) to obtain the residuals u_t;

Step 2: Test the stationarity of u_t;

Step 3: Test for the existence of nonlinear cointegration and estimate the STAR model.

To implement this, it is necessary to test $H_0 : \rho = 0$ (u_t is stationary) and $H_1 : \rho < 0$ (u_t is non-stationary). However, a major challenge is accurately determining ρ. To address this, Terasvirta (1994) suggested applying a Taylor series expansion to the transition function, leading to the following proposed model:

$$u_t = a_0 + \sum_{j=1}^{p} a_j u_{t-j} + \sum_{j=1}^{p} \left(b_{1j} u_{t-j} u_{t-d} + b_{2j} u_{t-j} u_{t-d}^2 + b_{3j} u_{t-j} u_{t-d}^3\right) + e_t \quad (8)$$

Where, p is determined using the Partial Autocorrelation Function (PACF) plot of the residual series u_t. To determine the optimal lag d, different lag values are tested sequentially such that the model is appropriate. If there are many values of d are suitable, the one corresponding to the smallest p-value is selected. Consider the null hypothesis $H_0 : \beta_{1j} = \beta_{2j} = \beta_{3j} = 0, j = 1,..., p$. If H_0 is rejected using the standard F-test, there is a basis to conclude that the STAR model is appropriate.

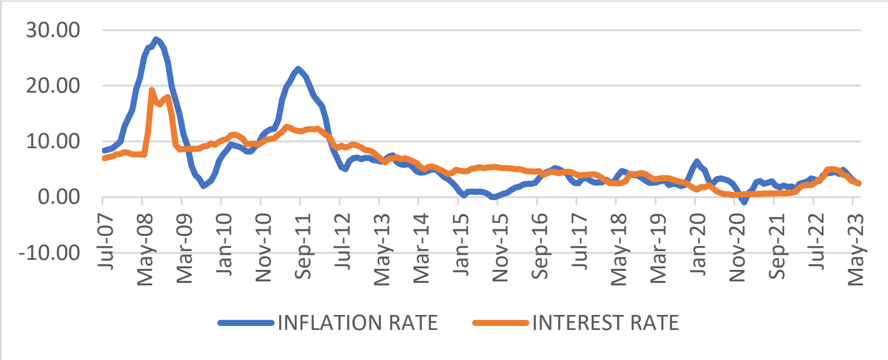
To examine the linearity and nonlinearity in the cointegration relationship, the study continues to estimate and test the ECM and STAR models. If the nonlinear model produces weaker estimation and testing results compared to the linear model, reconsideration of using the STAR model is necessary.

4. Results and discussion

4.1. Results

Figure 1 provides an overview of the trend and correlation between the interest rate and inflation time series.

FIGURE 1: **Time series plots for the period 2007-2023**



As shown on the Figure 1, there is a clear relationship between the interest rate and inflation in Vietnam. When inflation rises sharply, such as during the period from 2008 to 2011, interest rates tend to increase as well, reflecting the central bank's tightening monetary policy to control inflation. In 2008 and 2010-2011, the inflation spiked significantly, exceeding 25% at certain points, leading to a corresponding rise in interest rates to curb soaring prices. However, as the inflation gradually declined, the interest rate also followed a downward trend. From 2012 to 2023, the inflation remained relatively stable at a lower level compared to the previous period, and interest rates were also adjusted accordingly, staying low for several years. Although there were occasional fluctuations, they were not as extreme as during the financial crisis. This pattern highlights the impact of monetary policy, where higher inflation leads to increased interest rates to reduce money supply and slow down inflation, while lower inflation results in reduced interest rates to stimulate economic growth. Overall, the chart illustrates a strong relationship between inflation and interest rates in Vietnam.

TABLE 1: **The unit root test of the variables**

Variables	Level		Difference
	ADF_{CT}	ADF_{C}	
p_t	-2.9005	-2.1037	-3.7428***
i_t	-0.6227	-1.8456	-7.0189***

Notes: The values in the ADF_{CT} and ADF_{C} columns represent the test statistics of the ADF unit root test in two cases: with an intercept and trend, and with only an intercept. *** indicates the rejection of the null hypothesis of the unit root at the 1% significance level.

Source: Author's calculation.

The unit root test indicates that both series i_t and p_t are non-stationary in level but become stationary in the first difference at the 1% significance level. Therefore, these series are integrated of order one.

When regressing i_t on p_t, it finds that p_t has a positive impact on i_t at the 1% significance level. Testing the null hypothesis $H_0 : \beta_2 = 1$ leads to the rejection of H_0, indicating that p_t and i_t do not exhibit a one-to-one relationship as proposed by Fisher hypothesis.

TABLE 2: **Estimation the model (4)**

$i_t = \beta_1 + \beta_2 \pi_t + u_t$		
α_1	α_2	R^2
2.3740*** (0.2257)	0.5222*** (0.0244)	0.7062

Notes: The values in parentheses represent the standard errors of the estimated coefficients. *** indicates the rejection of the null hypothesis that the coefficients are not statistically significant at the 1% significance level.

Source: Author's calculation.

When conducting the ADF test on the residual, the test statistic (4.9064) is smaller than the critical value at the 1% significance level (-4.0084), implying that the residual u_t are stationary. This confirms that the variables p_t and i_t have a cointegrating relationship.

To test the existence of the nonlinear cointegration, we estimate và test the model (8).

TABLE 3: **Results of testing the STAR model**

$u_t = \alpha_0 + \alpha_1 u_{t-1} + \beta_{11} u_{t-1} u_{t-3} + \beta_{21} u_{t-1} u_{t-3}^2 + \beta_{31} u_{t-1} u_{t-3}^3 + \varepsilon_t$					
a_0	a_1	b_{11}	b_{21}	b_{31}	R^2
-0.1237 (0.1308)	0.9364*** (0.0558)	0.0252** (0.0112)	0.0014 (0.0025)	-0.0004* (-0.0002)	0.8554

Note: *, **, and *** indicate that the coefficients are statistically significant at the 10%, 5%, and 1% significance levels, respectively. The values in parentheses represent the standard errors of the estimated coefficients.

Source: Author's calculation.

The hypothesis test for H_0: $b_{31} = 0$ in the model shows that H_0 is rejected at the 10% significance level. Additionally, no evidence of heteroskedasticity or autocorrelation is found at the 1% significance level, meaning that e_t is white noise. Therefore, the STAR model is deemed appropriate.

The estimation results and model tests for ECM and STAR are presented in detail in Table 4 and Table 5.

TABLE 4: **Estimation of the ECM**

$\Delta u_t = \alpha + \rho u_{t-1} + \lambda_1 \Delta u_{t-1} + \lambda_2 \Delta u_{t-2} + \varepsilon_t$		
	Coefficient	Standard error
α	-0.0049	0.0568
ρ	-0.0800***	0.0276
λ_1	0.4030***	0.0693
λ_2	-0.2321***	0.0716
Breusch-Godfrey test	1.0074	
ARCH test	0.1316	
R^2	0.2012	
RSS	112.638	
SE	0.7803	

Note: ***, **, * indicate that the regression coefficients are statistically significant at the 1%, 5%, and 10% significance levels, respectively. Δ denotes the difference operator.

Source: Author's calculation.

TABLE 5: **Estimation of the LSTAR**

$\Delta u_t = \alpha + \rho u_{t-1} + \lambda_1 \Delta u_{t-1} + \lambda_2 \Delta u_{t-2} + +\varepsilon_t$ $(\alpha_0 + \rho_0 u_{t-1} + \lambda_{01} \Delta u_{t-1} + \lambda_{02} \Delta u_{t-2})\left(1 + \exp\left[-\theta(u_{t-1} - \mu)\right] / 0,86\right)^{-1}$		
	Coefficient	Standard Error
α	-0.0036	0.0573
ρ	-0.0811***	0.0264
λ_1	0.3099***	0.1060
λ_2	-0.0445*	0.0318
α_0	-1.5443**	0.6463
ρ_0	-0.1496**	0.0759
λ_{01}	0.6777***	0.2057
λ_{02}	-0.9016***	0.2202
θ	21.5340*	14.851
μ	1.3646***	0.1026
Breusch-Godfrey test	1.8846	
ARCH test	0.8914	
R^2	0.3165	
RSS	96.1668	
SE	0.7330	

Note: ***, **, * indicate that the regression coefficients are statistically significant at the 1%, 5%, and 10% significance levels, respectively. Δ denotes the difference operator.

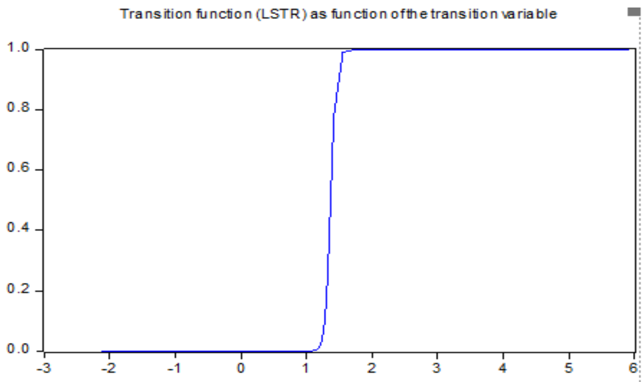
Source: Author's calculation.

When comprehensively considering criteria such as the goodness of fit of the regression function, the statistical significance of the regression coefficients, heteroscedasticity, autocorrelation, and sign conditions, it finds that both ECM and LSTAR models are appropriate.

Comparing the two models, the coefficient of determination, RSS, and the standard error of the regression function indicates that the LSTAR model performs better. Therefore, it can be concluded that the variables i_t and p_t have a cointegration relationship and are better suited to a nonlinear rather than a linear form.

According to the estimation and testing results of the LSTAR model, the variables exhibit a short-term and long-term equilibrium relationship. Whenever these variables deviate from the equilibrium position, they quickly return to equilibrium with a very high transition speed between the two periods (q). The adjustment function follows a logistic form, indicating that if the series deviates above or below the equilibrium position by the same magnitude, the adjustment speed back to equilibrium differs.

FIGURE 1: **Transition function plot in the LSTAR Model**



Source: The chart is extracted from EViews software.

Figure 2 illustrates the relationship between the logistic transition function and the transition variable. Here, we observe that approximately half of the study period has $u_{t-1} > 1.3646$, while the other half has $u_{t-1} < 1.3646$. The transition from regime 1 to regime 2 around the threshold value of 1.3646 occurs smoothly and continuously.

4.2. Discussion and implications

The estimation and testing results from model (4) show that the inflation rate has a positive impact on the long-term interest rate. However, a one-unit change in inflation does not lead to a one-unit change in interest rates. Thus, while the relationship between inflation and long-term interest rates in Vietnam remains positive, it does not entirely align with the Fisher hypothesis.

The STAR model proves to be appropriate in capturing the cointegration relationship between interest rates and inflation in Vietnam. This result implies that interest rates and inflation in Vietnam do not fluctuate independently but are closely linked in a common trend. Whenever they deviate from this trend, they quickly return to equilibrium in the long run. The transition between different phases occurs smoothly and continuously, with a high transition speed between periods.

The transition function is better represented by a logistic function rather than an exponential function. This suggests that when interest rates and inflation deviate from long-term equilibrium, they continuously adjust back to equilibrium, but the adjustment mechanism varies over time. Suppose there are two scenarios: one where the time series is above equilibrium and another where it is below equilibrium. Even if the magnitude of deviation from equilibrium is the same in both cases, the adjustment speed remains different. This indicates that the adjustment process depends not only on the magnitude and direction (i.e., whether the series is above or below equilibrium) of the deviation but also on the adjustment speed.

Unlike previous studies in both Vietnam and internationally, this research tests the Fisher hypothesis using a nonlinear cointegration approach. Empirical evidence confirms the effectiveness of the cointegration test and the STAR model in representing and analyzing the relationship between interest rates and inflation.

A distinctive aspect of this research is that it examines the Fisher hypothesis in the context of Vietnam, where inflation targeting has not yet been implemented. The findings indicate that interest rates and inflation in Vietnam exhibit a positive relationship, consistent with the study by Truong (2020) but differing from the findings of Nguyen (2016). However, the fluctuations in interest rates and inflation do not follow a one-to-one correspondence, which contradicts the theoretical basis of the Fisher hypothesis.

Based on the research findings, the study draws several policy implications.

Firstly, bidirectional relationship between the interest rate and inflation demonstrates the interaction between the financial and monetary markets. It suggests that tools from one market can be used to influence the other. The positive impact of inflation on long-term interest rates implies that monetary policy instruments - such as refinancing rates and exchange rates - can be utilized to regulate the monetary system, thereby controlling inflation and influencing the financial market. Conversely, long-term nominal interest rates could serve as an indicator for inflation. Typically, central banks use short-term interest rates to control inflation. Additionally, empirical studies in Vietnam, such as those by Nguyen and Pham (2014) and Phung *et al*. (2022) have shown that short-term interest rates have some influence on inflation. This research further provides empirical evidence that long-term interest rates can also be leveraged to influence the monetary market to manage inflation.

Secondly, the Fisher hypothesis does not fully hold in Vietnam. Although empirical evidence suggests a positive relationship between interest rates and inflation, it is not a one-to-one correspondence. This raises doubts about the assumption that the real interest rate remains constant, indicating that it may be influenced by other factors.

Thirdly, the relationship between interest rates and inflation is nonlinear, reflecting the complexity of the equilibrium dynamics between these time series. Therefore, policymakers must be extremely cautious when designing interventions and interpreting the influence of interest rates on inflation and vice versa.

5. Conclusion

This research empirically tests the validity of the Fisher hypothesis by examining the relationship between long-term interest rates and inflation in Vietnam. The findings indicate that these time series move in the same direction over both short- and long-term trends. When imbalances occur, adjustments take place continuously but follow a logistic function rather than a linear one. However, the change in interest rates relative to inflation does not exhibit a one-to-one relationship as proposed by the Fisher hypothesis. Thus, the author concludes that the Fisher hypothesis does not fully apply in Vietnam, and the relationship between interest rates and inflation is best described by a nonlinear function rather than a linear one, as previous studies have suggested. Empirical evidence supports the interconnectedness of the financial and monetary markets. However, due to the nonlinear nature of this relationship, interventions in one market to influence the other must be carefully considered.

Despite its contributions, this research has certain limitations. Factors other than inflation that may affect interest rates were not considered. This limitation, along with the research methodology used in this research, opens new avenues for future research.

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