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Applying the Smooth Transition Autoregressive Model for Discovering the Nonlinear Cointegration Relationship Between the Interest Rate and Inflation in Vietnam

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Abstract

Interest rates and inflation are two key macroeconomic indicators that have a direct impact on a country's economy. The Fisher hypothesis addresses the relationship between these two variables, with its core idea being that nominal interest rates and inflation have a positive long-term relationship, while real interest rates remain constant. The primary objective of this study is to explore the relationship between interest rates and inflation in Vietnam during the period from 2007 to 2023. Unlike previous studies, this research, based on Vietnam's specific context, employs the Smooth Transition Autoregressive (STAR) model. This approach allows for testing nonlinear cointegration, overcoming the limitations of traditional cointegration methods. The study identifies that interest rates and inflation exhibit long-term co-movement, adhering to a common trend. When these two variables deviate from their equilibrium position, they rapidly adjust back to equilibrium, governed by an asymmetric logarithmic transition function. The findings challenge the one-to-one relationship proposed by the Fisher hypothesis, revealing a more complex link between interest rates and inflation. Additionally, the study highlights the interactive nature of Vietnam's monetary and financial markets. It demonstrates that monetary policy tools can influence the financial market, while the long-term nominal interest rate emerges as a potential indicator of inflation. These insights provide significant implications for policymakers aiming to stabilize the economy through effective monetary and financial strategies. This research further confirms the effectiveness of nonlinear cointegration methods and the STAR model in macroeconomic analysis. The article also presents an interesting finding regarding the Fisher hypothesis in a developing country like Vietnam.

Keywords: Fisher Hypothesis, Inflation rate, Interest rate, Nonlinear Cointegration, Smooth Transition Autoregression

1. Introduction

Interest rates and inflation have a mutual impact and play an important role in the economy. To stabilize inflation and create sustainable growth for the economy, one of the crucial tools of the Central Bank is the interest rate. In addition, the interest rate is influenced by many factors including expected inflation. Studying the relationship between the interest rate and inflation has many important implications. Considering the impact of interest rate on inflation is the basis for testing the ability to forecast inflation using the interest rate. Besides, if inflation affects the interest rate, the central bank can use measures to intervene in the inflation to influence the interest rate. Therefore, analyzing the relationship between the interest rate and inflation helps examine the possibility of interaction between the monetary market, financial market, and the efficiency of these markets. From this point, policymakers can make appropriate policies, stabilize the macroeconomy, and realize socioeconomic goals.

One of the most well-known theories concerning the relationship between the interest rate and inflation is Fisher [1]. It holds that the long-term nominal interest rate is equal to the sum of the expected inflation and the ex-ante real interest rate where the ex-ante real interest rate is a constant. It indicates that the nominal interest rate and inflation have a positive relation in the long run.

The Fisher hypothesis has become one of the most influential theories in the field of economics. Although the Fisher hypothesis has been theoretically accepted by many researchers, the empirical evidence is still under investigation. While many studies have found evidence in favor of the Fisher hypothesis, some other studies found the failure of the

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Fisher hypothesis. Many methods have been employed to test the Fisher hypothesis. These include Autoregressive Distributed Lag [2], the time-varying threshold cointegration [3], the Smooth Transition Autoregressive model (STAR) [4], [5], [6]. Among them, Rapach and Weber [7] believe that the cointegration testing method has great power in testing the Fisher hypothesis. However, some authors argue that traditional cointegration methods contain many errors when testing this hypothesis, especially for countries applying inflation-targeting policies. Therefore, recently, many authors have turned to utilizing nonlinear cointegration methods such as Cushman et al. [4], Khodabakhshi et al. [5], Hepsag [6].

While the topic of testing the validity of the Fisher hypothesis has been carried out in many developed and developing countries around the world, there have been a few studies on the relationship between the interest rate and inflation in Vietnam, such as Tuan [8] and Loc [9]. The common point and also a weakness of these studies is that they only consider the relationship between these two series in the linear form and this can lead to erroneous conclusions. Currently, there have been no studies examining the nonlinear cointegration between the interest rate and inflation in Vietnam. This paper attempts to fill this gap in the literature by providing evidence on testing the Fisher hypothesis and thereby analyzing the relationship between the interest rate and inflation in Vietnam employing the nonlinear cointegration approach.

The analysis of the Fisher hypothesis in the context of Vietnam holds significant importance in both practical and academic aspects. Vietnam's economy is undergoing considerable fluctuations in inflation and interest rates amidst globalization and external shocks such as financial crises, global commodity price volatility, and the Covid-19 pandemic. Moreover, Vietnam, as a developing country, exhibits distinctive features, including deep state intervention and the absence of an inflation-targeting policy. These external and unique factors may result in a relationship between interest rates and inflation in Vietnam that differs considerably from that in more developed countries. Clarifying whether this relationship is linear or nonlinear would help Vietnamese policymakers devise flexible policies aligned with the dynamics of inflation and interest rates in Vietnam. Specifically, if the Fisher hypothesis is proven to hold true, the central bank could use the nominal interest rate as a tool to regulate inflation and maintain stable real interest rates, thereby promoting long-term investment and consumption. Furthermore, inflation in Vietnam is not solely driven by demand-pull factors but is also influenced by cost-push factors (e.g., oil prices and imported raw materials). Thus, considering nonlinear factors in the relationship between inflation and interest rates is essential. From an academic perspective, testing the Fisher hypothesis adds empirical evidence to international economic research while highlighting the unique macroeconomic characteristics of Vietnam. The article contributes to the literature in some respects. Firstly, the results in Vietnam will be a special case examining the existence of the relationship between the interest rate and inflation in a developing country in Southeast Asia without the adoption of inflation targeting. Secondly, unlike many studies in Vietnam and around the world, the article employs the nonlinear cointegration approach. This not only helps consider both the short-run and long-run equilibrium relationship between the interest rate and inflation but also helps overcome the pitfalls of the unit root test and linear cointegration test.

The rest of the paper is constructed as follows. The second section presents the literature review. The third section introduces the nonlinear cointegration method used in the article. The results are available in the fourth section before turning to the conclusions in the fifth.

2. Literature Review

The importance of the relationship between the interest rate and inflation has led to a great number of studies aimed at examining the Fisher hypothesis. Many recent studies has found empirical results that support the validity of the Fisher hypothesis, such as Dogan [10], Phiri and Mbekeni [11], Tokatlıoğlu [12].

Cointegration methods are commonly used to examine the relationship between the interest rate and inflation. Many empirical results using the cointegration method have been found. However, Gregory et al. [13] argued that if the time series contains a structural break, traditional cointegration tests tend to accept the null hypothesis of no cointegration while the actual result is different. Therefore, recent studies such as Cushman et al. [4], Khodabakhshi et al. [5], Hepsag [6] favor nonlinear cointegration methods. Cushman et al. [4] provide evidence that in the United States, during the post-war, the relationship between the interest rates and inflation was asymmetric. Using the nonlinear asymmetric

smooth transition error correction models, Hepsag [6] cannot reject the null hypothesis of no cointegration for France, Germany, Italy, Japan and the United States and finds the evidence of Fisher effect for Canada and the United Kingdom. Nusair [14] used the LSTAR model for Japan and six other Asian countries from February 1973 to April 2007 and found evidence to support the Fisher hypothesis. in Asian countries.

Some authors have found a relationship between the interest rates and inflation in the US and European countries, such as Hepsag [6], Kapetanious et al. [15]. Meanwhile, many other studies such as Dogan et al. [10], Nusair [14], Camba and Camba [16] find a relationship between the interest rate and inflation in Asian countries. Camba and Camba [16] study in the Philippines. Nusair [14] tests the Fisher hypothesis for six Asian countries and finds evidence of cointegration at the 5% significance level in Korea and at the 10% significance level in Malaysia and Singapore.

In Vietnam, there are several studies on the relationship between the interest rate and inflation including Tuan [8], Loc [9]. All of these studies employ different quantitative methods. While Tuan [8] only utilizes a simple linear regression model in which the target interest rate is regressed on inflation variable with the dataset from 2005 to 2013, Loc [9] employs the ARDL model. The studies in Vietnam have found evidence of a positive relationship between interest rates and inflation. Tuan [8] concludes that the Fisher hypothesis is valid in the short run but it is rejected in the long run. Meanwhile, Loc [9] finds that the interest rate and inflation have a positive correlation but are not one-to-one like the Fisher effect. More detail, Loc [9] also shows that the correlation between the interest rate and inflation is not one-to-one. However, in general, these studies only consider the relationship between two series of interest rates and inflation in a linear form, which can lead to erroneous conclusions. Currently, there is no research examining the nonlinear cointegration relationship between the interest rate and inflation in Vietnam.

3. Methodology

3.1. Variable Measurement

To test the Fisher hypothesis, the article makes use of the one-year government bond yield data seasonally adjusted from Reuters and consumer price index data from the International Financial Statistics database. To unify the frequency between two variables, all data in this study are monthly frequencies and cover the period from July 2007 to June 2023. The variables are introduced in table 1.

Table 1. Variables and measurement

Variables	Symbol	Data source/ Measurement
One-year government bond yield at time t	i_t	Reuters
Consumer price index at time t	CPI_t	IMF
Inflation rate at time t	π_t	$\pi_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}} \times 1200$

3.2. Methodology

If the Fisher hypothesis is valid, the interest rate and inflation have a cointegration relationship. To comprehensively examine the linear and nonlinear cointegration relationship between the interest rate and inflation, the study utilizes the Engle and Granger [17] test and the Smooth Transition Autoregression model (STAR) to select the appropriate model.

Anderson [18] argued that the traditional error correction model in linear form is inappropriate. When transaction costs of buying and selling exist and/or time series exhibit multiple transition phases due to policy changes, traditional linear cointegration tests prove to be inadequate. Real-world economic data, especially in developing countries like Vietnam, are often influenced by economic shocks, policies, and external factors, leading to the relationship between interest rates and inflation in Vietnam potentially being nonlinear. The STAR enables the examination of cointegration relationships even in the presence of nonlinearity in the data, helping to uncover hidden relationships between variables in both the short and long term and it especially suitable in contexts characterized by continuous policy transitions, as seen in Vietnam. The use of the STAR is particularly suitable in the context of studying Vietnam, where policy regimes

tend to change flexibly and continuously ("smoothly") rather than abruptly or instantaneously, as assumed in threshold regression models.

The general form of the STAR is:

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

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

If $F[\theta; u_{t-d}] = 1 - exp[-\theta(u_{t-d} - \mu)^2]$, the model (1) is called ESTAR. If $F[\theta; u_{t-d}] = \{1 + exp[-\theta(u_{t-d} - \mu)]\}^{-1}$, the model (1) is called LSTAR.

The research steps are as follows:

Conduct the unit root tests on $i_t$and π_t. The necessary condition for these variables to have a cointegration relationship is that they must be non-stationary series.

Estimate the following model and obtain the residual u_t.

$$i_t = \alpha_1 + \alpha_2 \pi_t + u_t \quad (2)$$

If there is evidence to conclude that α_2 is significant and $\alpha_2 = 1$ statistically significant then the data confirms the Fisher hypothesis.

Test the stationarity of u_t by applying the linear unit root test such as Augmented Dickey Fuller test which is formulated as:

$$\Delta u_t = \alpha + \rho u_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta u_{t-j} + \varepsilon_t \quad (3)$$

The hypotheses are $H_0: \rho = 0$ (meaning that u_t is stationary) and $H_1: \rho < 0$ (meaning that u_t is not stationary).

Test for the existence of a nonlinear cointegration relationship suggested by Teräsvirta [19]:

$$u_t = \alpha_0 + \sum_{j=1}^{p} \alpha_j u_{t-j} + \sum_{j=1}^{p} \left(\beta_{1j} u_{t-j} u_{t-d} + \beta_{2j} u_{t-j} u_{t-d}^2 + \beta_{3j} u_{t-j} u_{t-d}^3\right) + \varepsilon_t \quad (4)$$

Consider the null hypothesis $H_0: \beta_{1j} = \beta_{2j} = \beta_{3j} = 0, j = 1, \ldots, p$ and H_1: There are at least the coefficients $\beta_{1j}, \beta_{2j}, \beta_{3j}$which are different from 0. If H_0 is rejected, this is evidence to conclude that the STAR model is appropriate. H_0 can be tested using the F-test. To determine d, we can try the delays in turn. If there are many suitable delays, the value corresponding to the smallest p-value is selected.

Based on Teräsvirta and Anderson [20], the choice between the ESTAR and LSTAR models can be made by testing the following hypotheses:

$$H_{03}: \beta_{3j} = 0, j = 1, \ldots, p \quad (5)$$

$$H_{02}: \beta_{2j} = 0 \big| \beta_{3j} = 0, j = 1, .., p \quad (6)$$

$$H_{01}: \beta_{1j} = 0 \big| \beta_{2j} = \beta_{3j} = 0, j = 1, .., p \quad (7)$$

If $H_{03}$is rejected, the LSTAR model is selected. If $H_{03}$is accepted and $H_{02}$is rejected, the ESTAR model is chosen. If H_{03},$H_{02}$are accepted and $H_{01}$is rejected then the LSTAR model is selected.

Because the model (1) is in nonlinear form, we can use the nonlinear OLS method or estimate the likelihood function using the optimization procedure:

$$\ln(\mathrm{L}) = -\frac{1}{2}\ln(2\pi) - \ln(\sigma) - \frac{1}{2}\left(\frac{u_t}{\sigma}\right)^2 \quad (8)$$

The transition function is normalized by dividing the original function by $\hat{\sigma}(u_t)$if the model (1) has the form of LSTAR or by dividing the function by $\hat{\sigma}^2(u_t)$ if the model (1) has the form of ESTAR.

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To increase the reliability of the estimation and testing results, several sets of diagnostic tests were performed, including the goodness of fit of the regression function; the statistical significance of regression coefficients; autocorrelation; ARCH effect. In addition, the transition function must have a value in [0,1]. Finally, if the nonlinear model has weaker power than the linear model, the use of the STAR model needs to be reconsidered.

4. Results and Discussion

To have an overview of the volatility trend and correlation between the interest rate and inflation series, we plot these series and obtain the results in figure 1.

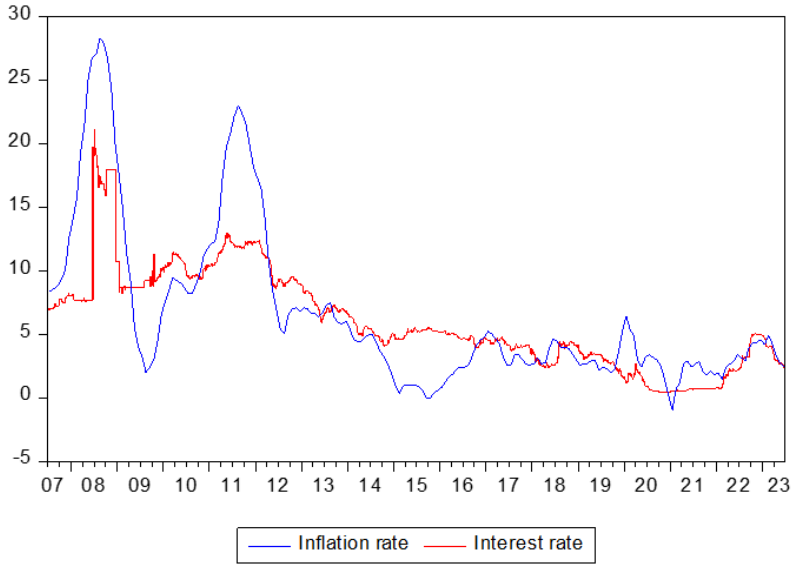

Figure 1. Graph of the time series in the period 2007 - 2023

During the research period, the interest rate and inflation fluctuated quite strongly. These time series peaked in mid-2008 and 2011 when Vietnam's economy faced many difficulties due to the impact of the world economic crisis. In 2011, the inflation rate reached 18.58% and the government bond yield also reached 12% per year. Since 2013, Vietnam's economy has gradually become more stable with many bright spots, the inflation rate has gradually decreased. The bond market has developed positively, the bond yields have tended to decrease, only about 2.5% in June 2023. A notable point is that in general, two time series of interest rate and inflation have the same volatility trend. This observation leads to speculation that the series $i_t$and $\pi_t$are positively correlated in a long-term equilibrium trend. Because there are two breaking points: 2008 and 2011, a nonlinear cointegration relationship (if any) seems more appropriate than a linear one. In addition, during the research period, the fluctuations of the interest rate and inflation were not flat but rather complex, with many large shifts, so it can be predicted that describing the balanced relationship between the interest rate and inflation with a nonlinear logarithm function is reasonable.

The unit root test results show that i_t and $\pi_t$are non-stationary in level and stationery in the first difference at the 1% significance level. Therefore, these series are both integrated of order one. The results in table 2 indicate that $\pi_t$affects positively i_t at the 1% significance level. However, when testing $H_0: \alpha_2 = 1$, the empirical evidence shows that H0 is rejected, meaning that $\pi_t$and i_t does not have a one-to-one relationship as the Fisher hypothesis referred to. We considered the issue of endogeneity as mentioned by the reviewer by examining several instrumental variables for the explanatory variable, such as lagged values, oil prices. We then conducted the Hausman test through the following steps: predicting the endogenous variable, adding the residual from the prediction step into the model. However, the results showed that the coefficient of the residual variable was not statistically significant. Therefore, we did not find evidence of endogeneity in the estimated model. We also conducted the Ramsey RESET test and obtained favorable results. This further enhances the reliability of the estimation results.

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Table 2. Estimation results of the model (2)

$i_t = \alpha_1 + \alpha_2 \pi_t + u_t$		
α_1	α_2	R2
2.374***	0.522***	0.706
(0.226)	(0.024)	

*Notes: Standard errors of coefficients are in parentheses. *** indicates significance at a 1% level of significance based on t-statistics.*

When performing the ADF test on the residual u_t, the value of the test statistic is -4.906 which is smaller than the critical value at the 1% significance level (-4.008), indicating that u_t is stationary. Thus, $\pi_t$và i_t have a cointegration relationship. However, the cointegration between $\pi_t$and $i_t$can be nonlinear. Therefore, for a comprehensive review, we continue to estimate and test the STAR model in table 3 and table 4.

Table 3. Testing the STAR model

$u_t = \alpha_0 + \alpha_1 u_{t-1} + \beta_{11} u_{t-1} u_{t-3} + \beta_{21} u_{t-1} u_{t-3}^2 + \beta_{31} u_{t-1} u_{t-3}^3 + \varepsilon_t$					
α_0	α_1	β_{11}	β_{21}	β_{31}	R2
-0.124	0.936***	0.025**	0.001	-0.0004*	0.855
(0.131)	(0.056)	(0.011)	(0.003)	(-0.0002)	

*Notes: Standard errors of coefficients are in parentheses. *, **, *** indicate significance at 10%, 5%, and 1% level of significance based on t-statistics, respectively.*

Results of testing hypothesis H0: $\beta_{31} = 0$in the model shows that H0 is rejected at the 10% significance level. In addition, the heteroskedasticity and autocorrelation test at the 1% significance level has not been found, meaning that ε_t is white noise. Thus, the LSTAR model is suitable.

Table 4. Estimate the LSTAR model

$\Delta u_t = \alpha + \rho u_{t-1} + \lambda_1 \Delta u_{t-1} + \lambda_2 \Delta u_{t-2}$ $(\alpha_0 + \rho_0 u_{t-1} + \lambda_{01} \Delta u_{t-1} + \lambda_{02} \Delta u_{t-2})(1 + exp[-\theta(u_{t-1} - \mu)]/0.86)^{-1} + \varepsilon_t$		
	Coefficient	**Standard error of coefficient**
α	-0.004	0.057
ρ	-0.081***	0.026
λ_1	0.310***	0.106
λ_2	-0.045*	0.032
α_0	-1.544**	0.646
ρ_0	-0.150**	0.076
λ_{01}	0.678***	0.206
λ_{02}	-0.902***	0.220
θ	21.534*	14.851
μ	1.365***	0.103
Breusch – Godfrey Test	1.885	
ARCH Test	0.891	
R2	0.317	

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*Notes: *, **, *** indicate significance at 10%, 5%, and 1% level of significance based on t-statistics, respectively. Δ denotes the first difference of variables.*

Estimation results of the LSTAR model show that the regression coefficients (except the intercept coefficient) are all statistically significant at traditional levels of significance. When we conducted the ARCH effect test for heteroscedasticity and the Breusch-Godfrey test for autocorrelation, the results showed that the test statistics were all smaller than the critical values at the 1%, 5%, and 10% significance levels (See table 4). This suggests that there is no evidence to reject the hypothesis of homoscedasticity and no autocorrelation. This enhances the reliability of the STAR model estimation results. Besides, the sign condition is satisfied ($\rho < 0$). So, we found that the LSTAR model is appropriate. Therefore, once again we can confirm that the variables $\pi_t$and i_t have a nonlinear cointegration relationship in the form of the LSTAR model.

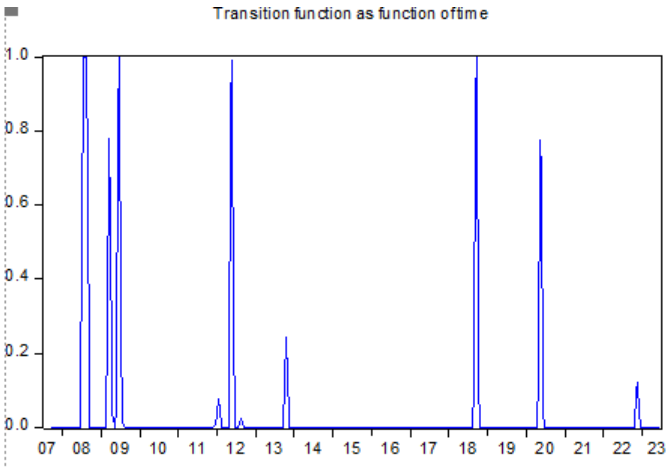

Figure 2. The plot of transition function as function off time

The plot of the LSTAR model is presented in figure 2. The LSTAR model leads to asymmetric adjustment, meaning that if the series lies above or below the equilibrium position with the same magnitude, the speed of adjustments is different, varying in the range [0,1] and in nonlinear form. The relationship between the interest rate and inflation changes most strongly when the transition function shifts from a value below 1 to 1. This happens at times when the Vietnamese economy has shocks and major changes in mid-2008, mid-2009, mid-2012, and 2018. In the context of Vietnam, the logistic function in the STAR model reflects the flexible transition between different economic regimes. For example, when the government implements tightening monetary policies during periods of high inflation (such as in 2008) or lowers interest rates during economic downturns (after the COVID-19 pandemic), the model captures these transitions. This demonstrates the flexible adjustment of monetary policy to maintain economic stability, aligning with either a balanced or imbalanced state.

Referencing figure 1, the research findings, and the practical context in Vietnam, the economy, as reflected by the series of interest rates and inflation, can be divided into five distinct phases:

(1) Phase 2007-2010: The global financial crisis (2007-2008) significantly impacted Vietnam's economy. In 2009, the central bank implemented loose monetary policies, lowering interest rates to support the economy. However, inflation remained high, reaching as much as 23% at one point. Following the crisis, interest rates sharply dropped, from over 14% in 2008 to around 8% in 2009.

(2) Phase 2011-2013: Vietnam faced high inflation during this period. To control inflation, the central bank raised interest rates to 15-17% in 2011-2012. However, inflation was not fully contained during this time.

(3) Phase 2014-2017: Vietnam's monetary policy became more flexible and stable. Inflation dropped sharply, from 6.6% in 2014 to 2.1% in 2015, and remained below 4% from 2015-2017. The central bank further reduced interest rates to 6.5% in 2016-2017.

(4) Phase 2018-2020: Amid the impacts of COVID-19, Vietnam's economy continued to grow steadily, but inflation showed a slight upward trend, increasing from about 3.5% in 2018 to 5% in 2020. The Central Bank maintained interest

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rates in the 6-7% range to foster sustainable growth and support the economy during the challenges posed by the pandemic.

(5) Phase 2021-2023: The COVID-19 pandemic deeply affected the economy. In 2020 and 2021, interest rates remained low to support businesses and the economy. However, inflation stayed stable at around 2-4% due to weakened consumer demand. By late 2022, the economy began recovering. The central bank adjusted interest rates, increasing them from 4-5% to 5.5-6% in 2023 to curb inflation as the economy rebounded strongly and consumer demand grew.

Thus, the central bank has implemented a flexible policy, transitioning very 'smoothly' between different phases. This practice aligns with the results indicating a nonlinear cointegration relationship between interest rates and inflation in the form of the LSTAR model. Furthermore, it can be noted that the central bank's interventions to ensure economic stability vary across phases, and even within a single phase. This is also consistent with the LSTAR model, as the magnitude of the error correction term differs depending on whether the variables are above or below the long-term equilibrium level.

This study provides further evidence of the cointegration relationship between interest rates and inflation in an Asian country. The result is consistent with the research of Nusair [14], Camba and Camba [16]. Additionally, Mishkin [21] argues that the Fisher hypothesis often holds in countries that implement inflation targeting policies, as such policies help reduce information costs for markets and policymakers, making the relationship between interest rates and inflation clearer and more predictable. Although Vietnam has not yet implemented inflation targeting, with strong government intervention, the relationship between interest rates and inflation is continuously and flexibly adjusted, so they are not detached from each other but move in a common equilibrium state. This study presents an interesting result about the cointegration relationship between interest rates and inflation occurring in a developing country that has not implemented inflation targeting.

5. Conclusion and Recommendation

Through estimation and testing results from the model (2), inflation has a positive impact on the long-term interest rate. However, a unit change in inflation does not result in a unit change in the interest rate. Thus, although the relationship between inflation and long-term interest rates in Vietnam is still in the same direction, it is not the same as the Fisher hypothesis.

The STAR model appears to be suitable for representing the cointegration between the interest rate and inflation in Vietnam. This result infers that the interest rate and inflation in Vietnam do not fluctuate independently but are closely linked to a common trend. Whenever they deviate from that trend, they will quickly return to a long-term equilibrium position. The transition from one stage to another takes place continuously and smoothly at a fast transition speed.

The final preferred transition function is a logistic function rather than an exponential function. This implies that when the interest rate and inflation series are in a state of disequilibrium in the long run, they will continuously adjust to return to the equilibrium position but the adjustment continuously changes. Suppose there are two cases, one case where the time series is above and one case where they are below the equilibrium position, if the deviation from the equilibrium position in these two cases has the same magnitude, then the correction error to the equilibrium position is still not the same. Thus, the adjustment to the equilibrium position depends not only on the magnitude and sign of the deviation but also on the speed of adjustment.

Unlike other studies in the world and in Vietnam, this study tests the Fisher hypothesis using a nonlinear cointegration approach and the empirical evidence confirms the effectiveness of the cointegration testing framework and the STAR model.

A special feature of this study is that examining the Fisher hypothesis occurs in the context that Vietnam has not yet implemented an inflation-targeting policy. The positive relationship between the interest rate and inflation in Vietnam is similar to the research of Loc [9] but different from Tuan [8]. However, the fluctuations of the interest rate and inflation do not correspond one by one and data do not fully confirm the Fisher hypothesis.

From the research results, the article draws some policy implications as follows:

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The period from 2007 to 2023 in Vietnam shows that the central bank has implemented monetary policies flexibly and intervened effectively in the relationship between interest rates and inflation. When inflation spiked, as in 2008, the government typically adopted tightening measures, raising interest rates to control inflation. In contrast, when the economy faced challenges, such as the post-COVID-19 period, interest rates were lowered to stimulate consumption and investment.

The nonlinear cointegration relationship between interest rates and inflation shows that these macroeconomic variables fluctuate constantly and change continuously toward a long-term equilibrium trend. Therefore, the government and the central bank need to maintain flexible monetary policies to respond to global economic fluctuations and domestic economic shocks.

The joint volatility between interest rates and inflation can directly affect capital costs and the investment environment. Thus, Vietnamese businesses need to pay attention to signals regarding monetary policy to adjust their investment strategies accordingly.

The two-way relationship between the interest rate and inflation shows that the financial market and the monetary market have an interactive relationship. The policymakers can use the tools of this market to influence each other to another market. The positive impact of inflation on long-term interest rates means that the monetary policy tools can be used to control the monetary system thereby achieving the goal of controlling inflation and affecting the financial market. Conversely, long-term nominal interest rates can become indicators of inflation. Normally, the central bank will use the short-term interest rate to control inflation. In addition, some empirical studies in Vietnam such as Tuan [8] show the impact of short-term interest rates on Vietnam's inflation. Empirical evidence in this study adds that the long-term interest rate can be used to influence the money market to control inflation. With the flexible monetary policy management and positive outcomes, especially during the difficult periods caused by the global financial crisis and the Covid-19 pandemic, the State Bank of Vietnam has earned the trust of the public. Therefore, if the central bank sets a stable long-term interest rate, it helps shape the confidence of investors, businesses, and consumers regarding future inflation levels. If inflation is expected to rise, the central bank can increase long-term interest rates to signal that monetary policy will be tightened in order to control prices and reduce inflationary pressure.

Although the interest rate and inflation vary in the same direction, they do not correspond one-to-one. Therefore, it can be said that the Fisher hypothesis is not completely valid in Vietnam. This raises suspicions that real interest rates are not constant and are affected by many other factors.

The relationship between the interest rate and inflation is not linear but nonlinear. This shows the complexity of the equilibrium relationship between these time series. Therefore, policymakers need to be very careful when using information from the interest rates to make intervention the inflation and vice versa.

The study limitations and future research: The article only considered the impact of inflation on the interest rate without paying attention to other factors such as exchange rates. The exchange rate can affect inflation and interest rates. Meanwhile, Vietnam's financial market is not fully liberalized, and the exchange rate is often managed by the government. This makes the relationship between exchange rates, interest rates, and inflation more complex, which in turn makes it difficult to clearly test the Fisher hypothesis in the short term. This limitation as well as the research method used in this study can open up many new research directions in the future. For example, additional independent variables such as exchange rates or money supply could be incorporated into the STAR model. This study utilizes the STAR model based on the nonlinearity of the error correction term, paving the way for further research on nonlinear cointegration where the nonlinearity lies within the variables themselves.

6. Declarations

6.1. Author Contributions

Conceptualization: N.T.H; Methodology: N.T.H.; Software: N.T.H.; Validation: N.T.H.; Formal Analysis: N.T.H.; Investigation: N.T.H.; Resources: N.T.H.; Data Curation: N.T.H.; Writing Original Draft Preparation: N.T.H.; Writing Review and Editing: N.T.H.; Visualization: N.T.H.; All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] I. Fisher, "The Theory of Interest, as Determined by Impatience to Spend Income and Opportunity to Invest It", Macmillan, New York, 1930.

[2] Y. S. Nadabo, "Testing the Validity of Fisher Hypothesis in Nigeria: An ARDL Cointegration Approach", *International Journal of Economics, Business and Management Research*, vol. 5, no. 10, pp. 15–27, 2021.

[3] L. Yang, "Time-varying threshold cointegration with an application to the Fisher hypothesis", *Studies in Nonlinear Dynamics & Econometrics*, vol. 26, no. 2, pp. 257–274, 2022.

[4] D. O. Cushman, G. De Vita, and E. Trachanas, E., "Is the Fisher effect asymmetric? Cointegration analysis and expectations measurement", *International Journal of Finance and Economics*, vol. 28, no. 4, pp. 3727–3748, 2023.

[5] A. Khodabakhshi, B. A. Moghaddam, B. A., and B. Bidabad, "Nonlinear impact of interest rates on price level (smooth transition autoregressive approach)", *Journal of Management and Science*, vol. 13, no. 2, pp. 5 –15, 2023.

[6] A. Hepsag (2021), "Testing for cointegration in nonlinear asymmetric smooth transition error correction models", *Communications in Statistics-Simulation and Computation*, vol. 50, no. 2, pp. 400–412, 2021.

[7] D. E. Rapach, and C. E. Weber, "Are real interest rates really nonstationary? New evidence from tests with good size and power", *Journal of Macroeconomics*, vol. 26, no. 3, pp. 409–430, 2004.

[8] N. A. Tuan, "Fisher Effect on the Interest Rate and Inflation in Vietnam", *Journal of Freign Economics*, vol. 88, no. 88, pp. 122–136, 2016.

[9] T. D. Loc, "The Relationship between the Interest Rate and Inflation in Vietnam: ARDL testing method", *Journal of Banking Science and Training*, vol. 220, no. 9, pp. 28–37, 2020.

[10] I. Dogan, E. Orun, B. Aydın and M. S. Afsal, "Non-parametric analysis of the relationship between inflation and interest rate in the context of Fisher effect for Turkish economy", *International Review of Applied Economics*, vol. 34, no. 6, pp. 758–768, 2020.

[11] A. Phiri and L. Mbekeni, "Fisher hypothesis, survey-base expectations and asymmetric adjustment: Empirical evidence from South Africa", *International Economics and Economic Policy*, vol. 18, no. 4, pp. 825 – 846, 2021.

[12] Y. Tokatlıoğlu, "The Fisher Hypothesis within the Framework of Long-Run Covariability: The Case of the United Kingdom", *Sosyoekonomi*, vol. 31, no. 57, pp. 195 – 205, 2023.

[13] A. W. Gregory, J. M. Nason, and D. G. Watt, "Testing for structural breaks in cointegrated relationships", *Journal of Econometrics*, vol. 71, no. 1-2, pp. 321–341, 1996.

[14] S. A. Nusair, "Testing for the Fisher hypothesis under regime shifts: an application to Asian countries", *International Economic Journal*, vol. 22, no. 2, pp. 273–284, 2008.

[15] G. Kapetanios, Y. Shin, and A. Snell, "Testing for a unit root in the nonlinear STAR framework", *Journal of Econometrics*, vol. 112, no. 2, pp. 359–379, 2003.

 ISSN 2723-6471

[16] A. C. Camba Jr, and A. L. Camba, "An engle-granger and Johansen cointegration approach in testing the validity of Fisher hypothesis in the Philippines", *The Journal of Asian Finance, Economics and Business*, vol. 8, no. 12, pp. 31–38, 2021.

[17] R. F. Engle, and C. W. Granger, "Co-integration and error correction: representation, estimation, and testing", *Econometrica: Journal of the Econometric Society*, vol. 55, no. 2, pp. 251–276, 1987.

[18] H. M. Anderson, "Transaction costs and nonlinear adjustment towards equilibrium in the US Treasury Bill market", *Oxford Bulletin of Economics and Statistics*, vol. 59, no. 4, pp. 465-484, 1997.

[19] T. Teräsvirta, "Testing linearity and modelling nonlinear time series", *Kybernetika*, vol. 30, no. 3, pp. 319-330, 1994.

[20] T. Teräsvirta, T., and H. M. Anderson, "Characterizing nonlinearities in business cycles using smooth transition autoregressive models", *Journal of applied econometrics*, vol. 7, no. 1, pp. 119–136, 1992.

[21] F. S. Mishkin, "The real interest rate: An empirical investigation", Carnegie-Rochester Conference Series on Public Policy, vol. 15, no. 81, pp. 151-200, North-Holland, 1981.