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THE THRESHOLD EFFECT OF THE TAIWAN STOCK MARKET ON ETF UNDER THE MONETARY POLICY

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Abstract. Taiwan's central bank produces tightening or easing effects by controlling the rediscount rate, which indirectly affects the stock market. An exchange-traded fund (ETF) is a fund that tracks the stock market index. ETF's effect on trading involves not only the trading volume brought by ETF trading but also the various ETF trading strategies and the basket trading required by ETF, which makes the trading of other stocks more active. We examine whether there is a threshold effect of Taiwan's stock market on ETF under monetary policy. The explanatory variable is the price return rate of the stock market's weighted index; the response variable is the ETF price return rate. The rediscount rate is used as a transition variable. We analyze daily data from September 28, 2011 to September 28, 2020 using a smooth-transition autoregressive model with exogenous variables (STARX). The results reveal a threshold effect between stock market of Taiwan and ETF.

Keywords: STARX, monetary policy, stock market, ETF, threshold effect.

JEL Classification: C01, C22, C58, E00, E52.

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1. Introduction

Globalization has accelerated the development of financial, economic, and technological industries, giving people more information sources for investment. Slow and stable increases in inflation can promote a resource flow effect, and increased commodity prices will also lead to a drop in purchasing power, which in turn affects capital investment in the stock market. Then, under tightened monetary policies, interest rates and stock prices will change in the reverse direction. Rising interest rates will then lead to a trend in which stock prices tend to drop (Chang et al., 2016).

The economy is the lifeline of a country, and central banks mainly manipulate economies through interest control. Changes in interest rates can then cause changes in the stock market. Interest is one of the main tools of monetary policy, and a rise or drop in interest rates will have a great influence on the flow of capital in the market (Liu, 2021). When interest rates are raised, the interest on capital borrowed from financial institutions by enterprises or investors will increase, and profits will be reduced as a result. Consequently, investors' willingness to buy stocks will be affected, and stock prices will fall. On the contrary, when interest rates are lowered, businesses' profits will not be hindered by interest, and investors will have a higher willingness to buy stocks, which will ultimately benefit stock price performance (Naik & Reddy, 2021).

A change in the rediscount rate can reduce stock market fluctuations. Passive exchange-traded funds (ETF) connected to multiple investment targets (De Rossi & Steliaros, 2022) have the important function of risk diversification for investors owing to the one-time purchase of stock targets based on different combination portfolios. Thus, ETFs are attracting increasing attention. ETFs not only bring transaction quantity to the stock market but, because of diversified transaction strategies, also make transactions in stocks more active. This generates a "synergistic effect" in which the effect of one plus one is greater than two – that is, when two or more than two substances are mixed, the effect is greater than the effect of a single substance acting independently. Therefore, ETF will have a positive effect on transactions in the entire stock market (Shieh, 2022).

The stock market and ETF are related and can achieve long-term equilibrium. If a central bank increases the deposit reserve ratio, commercial banks will have lowered excess reserves, which will reduce lending and investment. On the contrary, if the deposit reserve ratio is reduced, commercial banks will have increased excess reserves, thus expanding lending and investment (Krugman & Obstfeld, 2004). Yu (2018) and Hamm (2014) found that ETF holdings are related to stock liquidity, and there is a positive relationship between the ratios. Hong et al. (2012) and Lou and Polk (2013) highlighted ETF arbitrage via the link between the returns of their constituent stocks. With monetary easing, funds will obviously invest in the stock market, and the targets of ETF are companies with high stock market weight. Therefore, easing will lead to a rise in the stock market and an increase in the number of ETFs.

Although there is substantial research on the relationship between stock markets and ETF, certain issues remain underinvestigated. First, most of the related research focuses on performance while few studies have examined changes and trends in the stock market in terms of the threshold effect of ETF. Neglecting the threshold effect of key factors and the effect of ETF could cause ETF to be underestimated. Furthermore, most studies of ETF and stock markets have used conventional linear models to perform estimations. Thus, the results might exhibit estimation bias since linear models can neglect significant correlations between variables or because of the heterogeneity that commonly appears when the data structure has time-series characteristics. Since these time-series characteristics and heterogeneity might have nonlinear characteristics owing to asymmetrical relationships between the model's variables, conventional linear models might be unable to correctly estimate ETF and the stock market.

To address the abovementioned problems, this study establishes stock market and ETF regression models to estimate rediscount rate characteristics. To test changes in stock market of Taiwan and the threshold effect of ETF, we use a nonlinear regression analysis tool – namely, STARX. STARX has the advantage of capturing data heterogeneity and accurately describing individual and temporal effects in the model. It can also solve nonlinear and heterogeneous problems in data, and its prediction ability and identification accuracy are significantly better than those of traditional linear regression models. In addition, to determine whether the stock market will have a nonlinear effect on ETF owing to monetary policy, we use the rediscount rate as a transition variable in the model in our threshold analysis.

Stock market of Taiwan has a high turnover rate, and transactions and transfers among investors are quite frequent. When the economy is overheated, interest rate control under monetary policy can lower investors' investment willingness. Conversely, when the economy is in recession, increased capital can be put into the stock market, and this injection of capital can make the stock market more active. This can also increase ETF investment willingness. Meanwhile, under the operation of monetary policy, changes in the supply and demand of market capital affect the price of stocks and ETF. It is against this background that we investigate the Taiwan stock market's threshold effect on ETF under monetary policy.

2. Literature review

2.1. Monetary policy transmission channels and the stock market

Monetary policy is closely related to stock markets. Under monetary policy, the rediscount rate and market capital flows decrease when the economy overheats and inflation accelerates. When the economy is not good and in deflation, the rediscount rate is raised to stimulate the economy, increase the monetary supply growth rate, and attract capital to the stock market (Bissoon et al., 2016). Monetary policy is the main tool for stimulating the stock market (Wang, 2023), and increases in quantitative easing are expected to affect stock prices in anticipation of strong economic conditions ahead (Putniņš, 2022).

The relationship between monetary policy and the stock market is a hot topic in financial research. Hung (2017) noted that in a bull market, many countries will tend to raise interest rates, and this type of tight monetary policy will stimulate stock prices to drop to a fundamental level. Under a bear market, meanwhile, countries tend to lower interest rates, and such expansionary monetary policy will help raise stock prices to their fundamental level. Such decision-making processes under monetary policy can provide information about future economic performance. Goyenko and Ukhov (2009) noted that tightened monetary policy reduced stock market liquidity in the US market. Fernández-Amador et al. (2013), meanwhile, found that the European Central Bank's expansionary monetary policies led to increased stock liquidity.

Meanwhile, there is a close relationship between stock prices and monetary supply, showing a positive, one-way causal relationship. When quantitative easing monetary policy is adopted, it will stimulate investment in the market and have a positive influence on stock prices. Monetary supply has a stronger one-way influence on stock prices, and monetary policy itself is not strongly interfered with by the stock market; therefore, governments can use monetary policy to manipulate and manage the stock market (Wu et al., 2002). Studying Granger causality, Lin (2014) used three major US stock indexes (Dow Jones, Nasdaq, and the S&P 500) as sample data and found that while quantitative easing will initially have a significant positive effect, this effect will later be reduced. A negative correlation existed between interest rates and stock and bond prices, and the unexpected interest announcement was the major reason for the change in returns in the stock price index.

The rediscount rate was found to be a forecasting index for better stock market returns in Indonesia, Thailand, Malaysia, Philippines, Korea, China, and Taiwan. Regarding the forecasting capability of the monetary policy index variable for stock market returns, the long-term trends were more significant than the short-term ones, showing a mutually negative correlation (Miao, 2002).

2.2. Stock market Vs. ETF

ETF is a leading index of stock prices. ETF's effect on stock market trading activity involves not only the trading volume brought by the ETF product itself but also the various related trading strategies and the basket trading required by ETF, which makes the trading of other stocks more active. This creates a "multiplying effect," in which ETF-related trading, competition, and activity will help the stock market to a certain extent (Ben-David et al., 2018). The ETF market has grown immensely over the last decade; its total global size in 2020 was over $6 trillion (ETFGI, 2020). Huang et al. (2021) and Karmazienė and Sokolovski (2022) investigated the long-stock/short-ETF trading strategy. Glosten et al. (2021) noted that ETF activities can improve the short-term information efficiency of underlying stocks with weak information environments, and arbitrage redemptions can create related trades that can improve price discovery for underlying stocks. Agarwal et al. (2019) found that ETF carry trades increase the liquidity linkage of the underlying security.

Regarding ETF's linkages with the stock market, Nie et al. (2018) found a linear causal relationship between the US stock market and the Chinese ETF market where, in the long run, there was a bilateral nonlinear causal relationship. Yu (2018), meanwhile, found a causal relationship between the Taiwan 50 ETF and the stock market in which, as the stock price fluctuates, the company's market value also fluctuates.

Fu et al. (2022) noted an increase from US$79 billion in 2000 to US$5,268 billion in the first quarter of 2020. As of the first quarter of 2020, the number of global ETFs was 8,921. Despite global financial turmoil, $114.5 billion of capital flowed into ETFs in the first quarter of 2020. In the US, the number of ETFs increased from 95 in 2000 to 2,519 in 2020, and the assets under management reached US$3.65 trillion in the first quarter of 2020. In that study, the authors considered companies as a representative sample of foreign companies listed on the US stock market and compared US stocks. American depositary receipts (ADRs) are negotiable certificates issued by American depositary banks representing a specific number of shares of stock in a foreign company. They are denominated in US dollars and traded in US financial markets. They found that ETF ownership helped integrate a company's profit information, thereby improving the information environment of ADR companies.

Wang (2017), meanwhile, found that ETFs did not have a significant influence on stock market returns because ETFs usually have buy-high/sell-low characteristics, and their influence on stock market returns is short term. Taking Taiwan 50 ETF data covering January 1, 2012, to June 30, 2017, and using the unit-root test, vector autoregression model, causality test, and impulse response analysis, it was found that the lagged-term ETF constituent stock proportion had a significant positive relationship with the present-term ETF constituent stock proportion.

The stock market is closely related to the ETF market, but what is the exact price relationship? How do the prices change? To address such questions, we explore the threshold value of the transition variable under the dynamic relationship to fully grasp the relationship between the stock market and ETF. Next, we discuss the model for studying the relationship.

2.3. STARX

Smooth-transition autoregression (STAR) links two dynamic transition functions, allowing the explanatory variable to shift under two different situations (Chan & Tong, 1986). The value of the lagged variable creates a smooth transition process. However, the response variable and explanatory variable must be the same is limited the model. Later, Sarno et al. (2003) and Pan et al. (2011) found that, compared with traditional linear models, STARX model with exogenous variables have better forecasting ability; that is, the response and explanatory variables can be different.

Sarno et al. (2003) applied STARX model to validate the dynamic balanced correction of real money balances in the US from 1869 to 1997. The result showed that the dynamic balanced correction model was stable within the research period. Wu and Lee (2014) similarly used a dynamic STARX model to determine whether the monetary policy intervention of the People's Bank of China affected the trade balance, using the exchange rate as a transfer variable. They found that powerful intervention with the specific Ren Min Bi (RMB) exchange rate could reduce trade balance damage caused by the relative growth of income in China and fluctuations in terms of RMB exchange rate. That is, during the RMB appreciation period, powerful intervention in the RMB exchange rate could fortify China's trade balance.

Yang (2020) used STARX to verify the nonlinear correlation between stock market of Taiwan and Bitcoin prices under Taiwan's monetary policy from February 2, 2012, to August 31, 2019. It was found that the weighted stock price return of the present term had a nonlinear correlation with Bitcoin's rate of return in the present term. An uncertain effect existed between the two variables under the influence of a one-term-lagged stock market price; under two lagged terms, owing to the influence of one lagged term, the value of the two-terms-lagged investment portfolio was reduced. Yang et al. (2021) then used STARX to analyze the stock market's impact on ETF under the threshold effect of monetary policy (reserve requirements ratio) in China. The inflow of international funds to China was the highest among all Asian countries from 2008 to 2015; 72.69% of international investment inflows were to mutual funds in China from 1996 to 2015. Thus, ETF has played an important role in financial markets in China, and monetary policy had a threshold value of 8.5006 between the stock market and ETFs.

The abovementioned research reveals that there are close relationships between monetary policy, stock market, and ETF. However, no research has examined the nonlinear correlation between ETF and stock market of Taiwan under monetary policy. The present study, therefore, uses a dynamic STARX model to investigate the dynamic correlation between stock market of Taiwan and ETF under monetary policy.

3. Method

The purpose of this study is to investigate, the Taiwan stock market's threshold effect on ETF under monetary policy. Using daily data for the period September 28, 2011, to September 28, 2020, we refer to the closing price of Taiwan stock market's weighted stock price of and the closing price of ETF from Taiwan Economic Journal (TEJ) and the discount rate acquired from the central bank. TEJ was established in April 1990. With a complete database offering accurate and timely information, it provides the data needed for the fundamental analysis of stock and financial markets. TEJ is one of the most trusted financial databases in Asia. STARX and MATLAB R2010a are used for algorithmic operation. Then, this study empirically analyzes the threshold effect between stock market of Taiwan and ETF under nonlinear monetary policy.

3.1. Data

The explanatory variable is the return rate of the weighted closing price of Taiwan's stock market, $\text{SCR} = \frac{S_t - S_{t-1}}{S_{t-1}} 100\%$, where S_t represents the price of the weighted average of Taiwan's stock at time t. s_{t-1} represents the $t-1$ price of the weighted average of Taiwan's stock, and scr stands for the return rate of the price of the weighted average of Taiwan's stock. The response variable is the return rate of the ETF closing price, $\text{ECR} = \frac{E_t - E_{t-1}}{E_{t-1}} 100\%$, where E_t is the ETF price at time t. E_{t-1} is the ETF price at $t-1$ time, and ECR is the rate of return of the ETF price. These data are acquired from TEJ.

The transition variable is acquired from the rediscount rate of the central bank as controlled by the government. The rediscount rate is one of the indexes for the central bank to control inflation and deflation. Since Taiwan's central bank is devoted to maintaining the stability of commodity prices and the financial field, and to reforming the national financial system, it is considered the best reference for forecasting interest rates in the market. We use rediscount data from the central bank as the transition data. The closing price of the weighted average of the stock market and the closing price of ETF are percentage data used together with the rediscount rate. Therefore, the closing data are transformed into the return rate percentage to maintain data consistency.

3.2. Empirical model

Our empirical analysis follows the work estimation procedure using STARX in Teräsvirta (1994) and Yang (2020). First, a linear regression model, as in Formula (1). The rate of return of the ETF price is employed as the response variable, and the return rate of the price of the weighted average of Taiwan's stock is used as the explanatory variable:

$$ECR_t = \alpha_0 + \sum_{j=0}^{m} \beta_j SCR_{t-j} + \varepsilon_t, \tag{1}$$

where ECR_t is the rate of return of the ETF price of term t; SCR_{t-j} is the rate of return of the price of the weighted average of Taiwan's stock for term $t-j$, $j = 0, 1, .., m$. α_0 is the intercept, and β_j is the estimation parameter. Here, $m = 1$ is the largest lagged term of the explanatory variable, and ε_t is the error term. Hence, STRAX model can be written as

$$ECR_t = \alpha_0 + \sum_{j=0}^{m} \beta_j SCR_{t-j} + \left[\delta_0 + \sum_{j=1}^{m} \delta_j SCR_{t-j} \right] F\left(R_{t-d}, \gamma, c\right) + \varepsilon_t, \tag{2}$$

where ECR_t is the rate of return of the ETF price of the present term; R stands for the rediscount rate of the central bank; SCR_{t-j} is the rate of return of the price of the weighted average of Taiwan's stock, $j = 0, 1, .., m$. When $m = 1$, it is the largest lagged distance for explaining the change in the variable. α_0 is the intercept. β_0, β_j, and δ_0, δ_1 are the estimation parameter of different states. The form of the transition function of $F\left(R_{t-d}, \gamma, c\right)$ is different owing to its value in the interval [0,1]. The function will have function decisions of different forms, base on a series of hypothetical and test results. It is named LSTARX if the transfer function has a logical form; it is called ESTARX if the transfer function has an exponential form. Formulas (3) and (4) represent logistic functions and exponential functions respectively. R_{t-d} is the transfer function, and d is the ideal maximal lagged term, selected through the linear test process described in Formula (5). γ represents the increase or decay of the smooth parameter and describes the speed of transition among different states. Finally, c represents the threshold value of this formula. Referring to Teräsvirta and Anderson (1992) and Teräsvirta (1994), the formulas for logical and exponential transition are, separately, as below:

$$F\left(R_{t-d}\right)=\left\{1+exp\left[-\gamma\left(R_{t-d}-c\right)\right]\right\}^{-1}; \quad (3)$$

$$F\left(R_{t-d}\right)=\left\{1-exp\left[-\gamma\left(R_{t-d}-c\right)^{2}\right]\right\}. \quad (4)$$

According to McMillan (2011) in Formula (3), the transition function of $F\left(R_{t-d}, \gamma, c\right)$ can move smoothly in between its values and decide the corresponding c. When $\gamma \to 0$, Formula (2) will become a linear AR (p) model. If $\gamma \to \infty$, $F(R_{t-d})$ changes the Heaviside function, and then Formula (2) will change to TARX (p). When $R_{t-d} \le c$, $F\left(R_{t-d}\right)=0$, the coefficient representing SCR is $\left(\sum_{j}^{m}\beta_j\right)$. Suppose $F\left(R_{t-d}\right)=1$, $R_{t-d} > c$; this shows that the coefficient of SCR is $\left(\sum_{j}^{m}\beta_j+\sum_{j}^{m}\delta_j\right)$.

The exponential function permits for the systematic correspondence of parameters and allows R_{t-d} to change to c. If $\gamma \to 0$ or $\gamma \to \infty$ in Formula (4), the STARX model will become a linear model. The interval value of the rate of return distributed in the middle is different than the interval value of the larger rate of return.

In selecting the optimal lagged term d, we need to use the F test to estimate the assisted regression. This regression was proposed by Teräsvirta (1994), and it is as follows:

$$v_t=\alpha_0+\sum_{j=0}^{m}\left(\theta_{1j}\mu_{t-j}+\theta_{2j}\mu_{t-j}R_{t-d}+\theta_{3j}\mu_{t-j}R^{2}{}_{t-d}\right)+p_t,$$

$$H_0:\theta_{2j}=\theta_{3j}=0, \quad (5)$$

where v_t represents the residual of formula (1); μ_{t-j} is the explanatory variable of the linear model of formula (1); j is the lagged term, j = 0, 1, .., m; m = 1. α_0 represents the intercept; θ_{1j}, θ_{2j}, and θ_{3j} are, respectively, the estimated parameters of the assisted regression formula, wherein j = 0, 1, .., m; m = 1 is used to test the lagged term of d of this regression, and it is 0 to 1. R_{t-d} is the transfer function; for this study, we adopt the lagged term of the stock price. d is the lagged term. According to Tsay (1989), the F test can be used to find the optimal lagged term d. If H_0 is tested and refused by F, then it is estimated that the model is nonlinear – or is a STARX model – as expressed in Formula (2). Through the selection of the optimal value of the F statistical value, the lagged term d can be selected.

After confirming the form and optimal lagged term, the next step is to use a series of hypotheses proposed by Teräsvirta (1994) and applied by Wu and Lee (2014) and Yang (2020) to select the appropriate transfer function. These hypotheses are as follows:

$$H_{04}: \theta_{3j} = 0; \quad (6)$$

$$H_{03}: \theta_{2j} = 0 \mid \theta_{3i} = 0; \quad (7)$$

$$H_{02}: \theta_{1j} = 0 \mid \theta_{2j} = \theta_{3j} = 0. \quad (8)$$

If the above test result does not accept H_{04}, then we need to select LSTAR. If H_{03} is not accepted, but H_{04} is accepted, then the appropriate model is the exponential model, or ESTAR. If the result does not accept H_{02} but accepts H_{03} and H_{04} simultaneously, the LSTAR nonlinear least-squares method is used to estimate STARX model.

4. Empirical analysis

The data used in this study include Taiwan stock market weighted average return (the explanatory variable) and the rate of return of the ETF price (the response variable). We use the rediscount rate as the transition variable. The data structure includes daily data covering a total of 8848 days.

4.1. Descriptive statistics

In Table 1, the level of divergence of the rediscount rate (R) is smaller than the rate of return of the price of ETF (ECR) and Taiwan stock market weighted average return (SCR). The divergence level of SCR is the smallest. The standard deviation of ECR 0.149040 is smaller than the standard deviation of SCR, which is 0.217613. This explains that the ETF data are more centered than TAIEX data. When both are compared, SCR is significantly more stable. ECR reached its minimal value on June 27, 2014, at −0.293020 and its maximal value on August 17, 2022, at 0.398411. SCR reached its maximal value on November 30, 2012, at 0.590692 and its minimal value on August 22, 2014, at −0.462671.

4.2. Nonlinear unit-root test results

This study uses a nonlinear unit-root test to test the stability of the variables. We select the ADF test to test the existence of unit roots. The t-value range is −4.472224 to −4.808255, and the *p*-value is 0.0000 in Table 2, obviously rejecting the null hypothesis of the ADF test. This means that all variables are stationary data in this research.

Table 1. Raw data analysis

	ECR	R	SCR
Mean	9.52E-05	1.603583	9.12E-06
Maximal value	0.398411	1.875000	0.590692
Minimal value	−0.293020	1.125000	−0.462671
Standard deviation	0.149040	0.262494	0.217613

Note: The research time is September 28, 2011, to September 28, 2022. ECR is the rate of return of the price of ETF, R is the rediscount rate, and SCR is Taiwan stock market weighted average return.

Table 2. Nonlinear unit-root test results

Variable	Augmented Dickey–Fuller t-statistics	Break Date	Lag
ECR	-4.774953^{***}	07/02/2015	23
R	-4.472224^{***}	09/24/2015	0
SCR	-4.808255^{***}	07/03/2013	25
SCR_{t-1}	-4.817489^{***}	07/04/2013	25

Note: ECR is the rate of return of the price of ETF, R is the rediscount rate, SCR is Taiwan stock market weighted average return. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The sampling period is September 29, 2011, to September 28, 2022.

Figures 1, 2 and 3 illustrate daily value of dependent and explanatory variables in terms of ECR, SCR and R during the given period. Figures 1 and 2 show the break trend of ECR and SCR. Figure 1 illustrates the fluctuation of explanatory variable in case of ETF during the given period. As can be observed from Figure 1 as red arrows, the first break date happened in July 2015. On the other hand, the fulcution of SCR explanatory variable first break date happened in July 2013 as Figure 2 as red arrows. Figure 3 show the stable trend of the rediscount rate.

The breakpoint test of the Dickey–Fuller AR coefficient for each variable is significant, indicating that there is a dynamic structure transition in the structure of the sequence, and all variables will eventually be stationary with time changes, as in Figure 4. Therefore, it is appropriate to apply the dynamic STARX model in this research.

Figure 1. The rate of return of the price of ETF from September 28, 2011 to September 28, 2020

Figure 2. Taiwan stock market weighted average return from September 28, 2011 to September 28, 2020

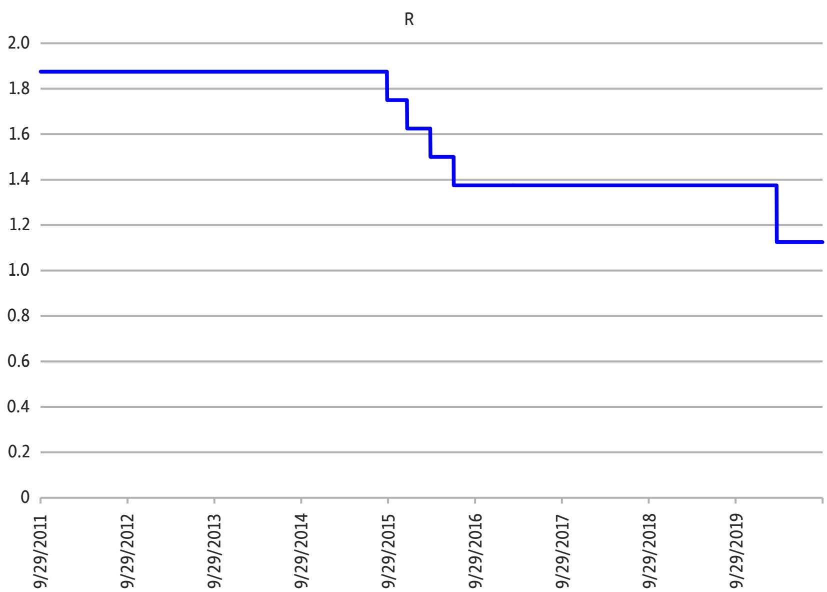

Figure 3. The rediscount rate from September 28, 2011 to September 28, 2020

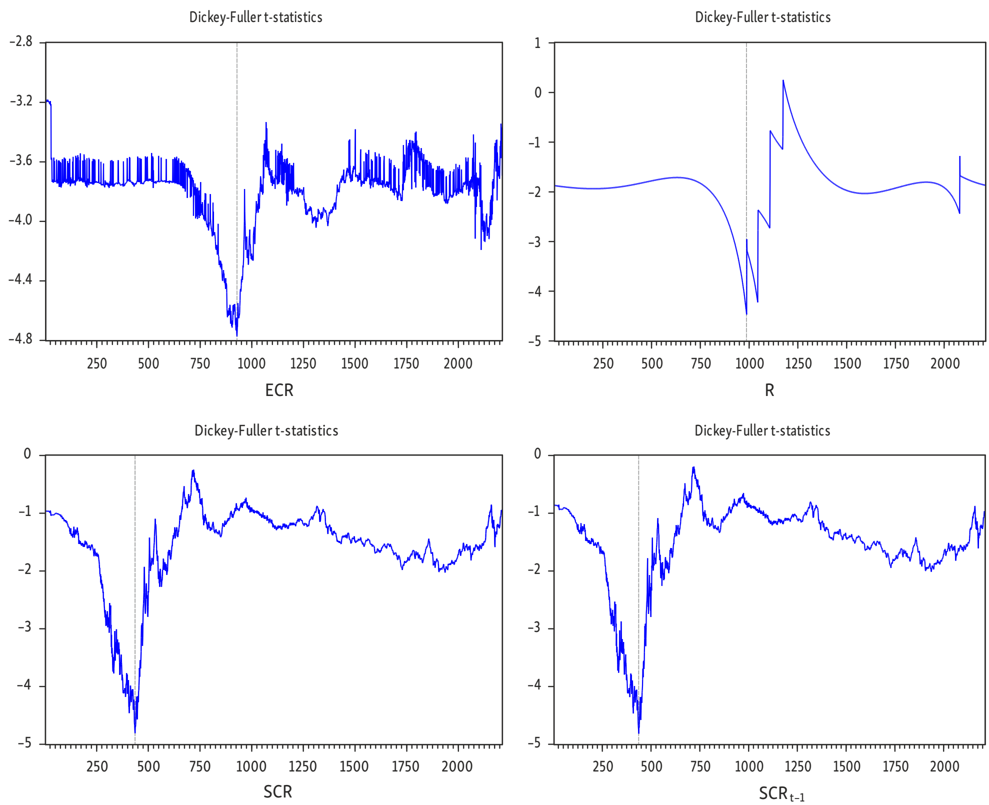

Figure 4. Breakpoint Test of the Dickey–Fuller AR Coefficient

4.3. Empirical results

Before operating the STARX model, first, built on the estimation results of stepwise regression in Formula (1), we select the explanatory variable that will have a big affect on the response variable, *ECR*. STARX model uses two important explanatory variables: *SCR*, SCR_{t-1}.

Next, this study needs to use the assisted regression in Formula (5) to confirm the optimal lagged interval *d* of conversion variable R_{t-d}. Then, this research produces the maximal F statistical quantity to refuse the optimal lagged interval of linear hypothesis H_0. Here, the selected optimal lagged interval *d* is equal to 1. The linear test results of the multiple regression model in Table 3 indicate that the optimal lag periods of each transition variable are mostly concentrated in periods 1 and 2.

Table 3. Multiple regression model linear test results

Variables	*d*	
	0	1
ECR	1.3119 (0.2856)	4.5346*(0.0095)
SCR	3.0571 (0.0912)	3.8684* (0.0059)

Note: d is the lag period of the transition variable; the value in the table is the *F* value; ( ) is the P-value; * is the optimal lag period of the transition variable that rejects the linear hypothesis.

The third step is to choose the perfect transition function. This can be done using an F-test to inspect the nested hypothesis series (Formulas (6), (7), and (8)), as proposed by Teräsvirta (1994). The test result shows that the suitable transfer function for this study is the logical transfer function, or the so-called LSTAR model. Table 4 shows the conversion function test results of the STAR model and the STARX model.

Table 4. STAR model conversion function verification results

Variables	d	$H_{04}: \theta_{3j} = 0$	$H_{03}: \theta_{2i} = 0 \mid \theta_{3i} = 0$	$H_{02}: \theta_{1i} = 0 \mid \theta_{2i} = \theta_{3i} = 0$	Model
ECR	2	0.2578 (0.6153)	0.9761 (0.3888)	6.9859* (0.0125)	LSTARX
R	0	0.1788 (0.9097)	0.1684 (0.6843)	5.0396 (0.0062)	LSTARX
SCR	2	4.0978* (0.0294)	0.6393 (0.5349)	2.4772 (0.1026)	LSTARX

Finally, estimation is conducted using the LSTARX model. Table 5 shows the results.

Table 5. The summary result of the LSTARX model

Transfer function	Coefficient	T statistical quantity
d	1	
β_0	0.0010	1.5394
β_1	0.23540	–0.4604
δ_0	0.33490	–1.7446*
δ_1	–0.0010	0.4182
g	352.3619	
c	1.7580	

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

First, we use the rediscount rate as the transition variable. The return rate of the weighted average of Taiwan's stock market in the present term affects the rate of return of the price of ETF in the present term, and the LSTARX model can be corrected as follows:

$$ECR_t = 0.0010 + 0.23540 SCR_{t-1} - 0.0010 + \left[0.33490 - 0.0010 SCR_{t-1}\right] \times F\left(R, 325.3619, 1.7580\right) + \varepsilon_t,$$

where $F\left(R, 325.3619, 1.7580\right) + \varepsilon_t$ is the transition variable, and $\tilde{a}\left(= 325.3619\right)$ is the transition speed, which is the transition speed used in different states. $c\left(= 1.7580\right)$ is the threshold value, which also explains the mean value of increase or decrease for the return rate of the closing price of ETF under different states.

As claimed by the smooth transition autoregressive model with exogenous variables model of ETF, Taiwan stock market weighted average return in the present term will affect the rate of return of the price of ETF in the present term. The rediscount rate in the present term is a transfer variable. Its threshold value is 1.7580%, and its smoothing effect is varying. The effect of the return rate of the weighted average of Taiwan's stock market on the rate of return of the price of ETF will be dependent on the level of the rediscount rate in the present term. The smoothing transition effect of the rate of return of the price of ETF is $(0.0010+0.33490)\times F(R_t;325.3619,1.7580)$. That is, the two extreme conditions displayed in the model are 0.0010 and 0.33590. Thus, along with the influence when the rediscount rate in the present term is higher than the threshold value, the rate of return of the price of ETF will be increased continuously. When the variation in the rate of return of the price of ETF is above the threshold value of the high interest rate, it will continuously arise the price of ETF. Regarding the real market, the transaction price of the stock market in the early stage will be higher when the market economy is good. Therefore, owing to the increased profit-gaining room for the investor, it will urge an increase in the price of ETF in the present term. Such a situation could lead to the blind following general investors to expand the investment percentage. This will directly or indirectly drive current ETF prices to a higher stage.

From the STARX model, we can deduce that Taiwan stock market weighted average return present term does not have a significant influence on the rate of return of the price of ETF in the present term. Rather, the rate of return of the price of ETF in the lagged one term is more significantly affected by Taiwan stock market weighted average return. Under the influence of lagging a certain stock price variable, the impact of stock price returns on ETF price returns depends on the current rediscount rate level. The current stock price conversion effect is (–0.2345 – 0.0010)* $F(R_t;$ 325.3619,1.7580), and the effect is positive. Under the influence of smooth transition variables, the periodic effect continues to increase, and the periodic effects in the two extreme cases presented by the model are 0.2345 and 0.2335 respectively. During periods of rapid economic growth, the rediscount rate is at a relatively high level. This may be due to the current return of ETF prices. Due to profit-taking in the early stock market, investment targets have turned to the ETF market with better returns. This compelling image caused ETF price returns to rise significantly, exceeding stock market returns. We can see, then, that Taiwan stock market weighted average return in the lagged onterm has a direct influence on the rate of return of the price of ETF in the present term. We use the rediscount rate as a transition variable. If the rediscount rate is lower than the threshold value of 1.7580%, when the closing price of the weighted average of Taiwan's stock market rises by 1%, then the closing price of ETF in the present term will rise 0.001%. On the contrary, when the rediscount rate is 1.7580% above the threshold value, the increase in the closing price of ETF will be 0.3359%. Thus, when the government implements monetary policy, it will change the rediscount rate, which will further affect Taiwan stock market weighted average return. Consequently, the rate of return of the price of ETF will be directly affected.

5. Conclusions

5.1. Remarks

This study adopts a STARX model and takes the rediscount rate variable as a transition variable to estimate the influence of Taiwan stock market's weighted average price of on the price of ETF. The level of the rediscount rate can be used as an index to represent whether the economy is in an expansion period or a tightening period; we therefore select it as a transition variable. Meanwhile, under linear and nonlinear models, this research examines the linear and nonlinear influence of the price of Taiwan stock market's weighted average of n the price of ETF.

Regarding the dynamic part, we can see that the marginal effect obtained from the linear part is 0.3339, which is different from the marginal effect of the nonlinear model of 0.5703. Thus, the effect estimated by the dynamic model is considerably higher than the result obtained from the linear model.

There are three main conclusions. First, the influence of the change in price in Taiwan's stock market's weighted average of on the change in the ETF price is nonlinear. It will change depending on the change in the transition variable, which varies with time at different threshold intervals. This is considerably different from results estimated using traditional linear models. Furthermore, along with the increase in the lagged terms of the variables of Taiwan's stock market, the influence on the change in ETF price will not be significant. Next, the marginal effect when delayed by one transaction day is not significant compared with the transaction of the present day. In other words, future Taiwan investors can list information about the transaction price of the stock market of the present day as a factor to consider in investment strategies. This result differs from results obtained for the China market, where the current, lagged-one, and lagged-two stock price returns affect the current ETF price return under a reserve requirements ratio threshold value of 8.5% (Yang et al., 2021).

Using the rediscount rate as the transition variable, we can see that when the monetary bureau expands capital transactions and flow in the capital market, it can stimulate the economy. Through monetary supply means, the level of the rediscount rate can be affected. If loose monetary policy is used, leading to a rise in the rediscount rate, when it rises above the threshold value, it can easily increase stock market prices. Consequently, the change in the price of ETF can be increased, capital flow in the capital market can be increased, and the economic scale can be expanded. Raising the rediscount rate to increase capital flow in the capital market could result in future prosperity. However, it could easily lead to inflation, which in turn will reduce the purchasing power of the general public. Therefore, when the monetary authority uses the rediscount rate as the transition variable, the amount of inflation the general public can assume should be considered to establish an appropriate rediscount rate interval. This can avoid a situation in which pursuing the price of ETF in the capital market could negatively affect the general public's quality of life.

Our contributions can be summarized as follows. First, this study uses a STARX model to evaluate the ETF threshold effect. This model can evaluate the effect of nonlinear and structured time-series stock data on ETFs. It also presents the smooth transition process of ETF's nonlinearity. This not only avoids the biased results that can occur when using traditional linear models but also enables accurate estimates of ETF changes. In addition, we find that monetary policy's effect on ETFs has a nonlinear structure that depends on the stock market. Our findings can help governments, business managers, and investors formulate monetary management strategies, economic policies, and investment risk diversification plans. They can also help promote economic stability, improve capital market performance, and obtain better investment returns. Finally, in terms of practical application, this study can be used to set up investment linkage software, and the data, through algorithmic operation, can be applied to currently popular investment software. Through the model's algorithmic operation system, the rate of return of stocks and ETF can be estimated without the interference of external power. When the public uses this software, it can determine an investment direction in a timely manner. For example, when a nonlinear relationship appears in the data – when the transition variable is smaller or larger than threshold value – the software will show a message to remind the investor. This can not only save the investor time on data collection but also facilitate more friendly and convenient investment judgment for the general investor.

5.2. Limitations and future research

There are not many types of ETF in Taiwan, and it cannot be divided by category or industry. Therefore, it was impossible for us to classify based on panel data. If more types of ETF are developed in the future, we recommend classifying ETF and studying the threshold values of each ETF. In addition, the spillover effects of monetary policies implemented by the central bank can be considered.

Disclosure statement

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