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利率政策之結構性改變：以臺灣中央銀行為例

Structure Change in Interest Rate Policy: Evidence from Taiwan

賴強立

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寫謝辭最棒的地方就是可以自由發揮，所以接下來我要放一首我最愛的歌的歌詞，KEANE, Somewhere only we know

I walked across an empty land

I knew the pathway like the back of my hand

I felt the earth beneath my feet

Sat by the river and it made me complete

Oh simple thing where have you gone

I m getting old and I need something to rely on

So tell me when you’re gonna let me in

I m getting tired and I need somewhere to begin

I came across a fallen tree

I felt the branches of it looking at me

Is this the place we used to love?

Is this the place that I've been dreaming of?

Oh simple thing where have you gone

I'm getting old and I need something to rely on

So tell me when you're gonna let me in

I'm getting tired and I need somewhere to begin

And if you have a minute why don t we go

Talk about it somewhere only we know?

This could be the end of everything

So why don't we go

Somewhere only we know?

Somewhere only we know

Oh simple thing where have you gone

I m getting old and I need something to rely on

So tell me when you're gonna let me in

I'm getting tired and I need somewhere to begin

And if you have a minute why don't we go

Talk about it somewhere only we know?

This could be the end of everything

So why don't we go

So why don't we go

This could be the end of everything

So why don't we go

Somewhere only we know?

最後我要感謝我的父母與家人讓我順利完成學業

謝謝大家

摘要

為了估計台灣央行的利率政策反應函數，這篇文章運用了文獻上廣泛應成因後果各有不同，而不同的央行總裁也帶給外界具有不同風格的解讀。因此本文導入門檻式迴歸模型，目的是要探討這些年來央行的政策是否有結構上的改變，而改變的時間點又是否可以跟現實事件做連結。本文發現統計上顯著的改變點似乎只有在 2008 年全球金融海嘯時期，央行跟隨全球央行的腳步，短短半年左右降息多次。

關鍵字: 泰勒法則、利率政策反應函數、中央銀行、門檻式迴歸

Abstract

This paper adopts a threshold autoregressive (TAR) model to capture the central bank interest rate reaction function of Taiwan. We modify the Taylor rule by using real effective exchange rate as the threshold variable. The TAR setting is able to recover the central bank's nonlinear responses when facing different exchange rate level. This paper also discusses the procedure to determine an appropriate exchange rate target, estimate a TAR model, locate the threshold effect, and perform out-of-sample forecast. This paper shows different exchange rate targets change the result. Except the era after the 2008 financial crisis, it seems that Taiwan's central bank behavior is consistent over the last decades while there were several economic crises and different chairmen.

Key Words: threshold autoregression, interest rate reaction function, central bank, nonlinear response, policy goal

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FUGURES

1. Introduction

The Central Bank of the Republic of China (CBC, Taiwan) plays a vital role on the direction of monetary policy. According to the Central Bank Act, the CBC's operational objectives include promoting financial stability, ensuring sound banking operations, maintaining the stable internal and external value of the currency, and, within the scope of the above three objectives, fostering economic development. The interpretation of the above statement is that CBC somehow has a decision sequence. For example, domestic price level and exchange rate seem to take priority over economic growth. But when we look back on Taiwan's economic development for the last two decades, we have gone through two oil crises, the Plaza Agreement, the Asian financial crisis, the dot-com bubble, the 2007~2008 global financial crisis, and several presidents of CBC. Conventional wisdom suggests CBC's reactions may be conditional on the specific events or the presidents. The following two phenomena vividly illustrate how CBC emphasizes varying targets.

First, during the 80's and 90's of the last century, when Taiwanese electronic industries skyrocketed, exporters accumulated tremendous foreign fortune. At the same time, there was only a relatively mild increase in foreign reserve (see figure 1). This phenomenon indicates that few businessmen transferred their earnings back to NTD, and the CBC did not buy in lots of foreign currencies. Perng Fai-Nan has been the chairman of the central bank since the late 1990s. Since then, foreign reserves started to surge significantly. The CBC often asserts that: "The NT dollar exchange rate is in principle determined by market forces. Nevertheless, when seasonal or irregular factors (such as massive flows of short-term capital) lead to excessive volatility and disorder movements in the exchange rate of NT dollar with adverse impacts on economic and financial stability, the CBC would step in to maintain an

orderly market." Hence, subsequent interventions in the foreign exchange market may be the cause to foreign reserve accumulation.

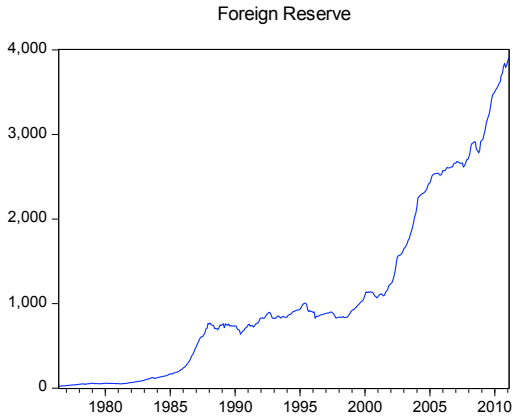


FIGURE 1.- Foreign reserve, a smooth increase at 80s & 90s

Second, before 1998, overnight interbank interest rates ranged between 5% and 8%, but since then it started to fall, tracking U.S. federal funds rates. Critics have argued that the low interest rate environment may be the cause of financial crisis in the U.S. As for Taiwan, such environment also provoked wide discussion. While some people praise the actions of the CBC, others argue that it not only triggered sharp surge in housing prices but also left little room for banks and insurance companies to arbitrage.

This paper tries to use real effective exchange rates (REER) as a threshold variable to test whether the central bank has an asymmetric feedback with respect to the change of the REER. In this paper, I intend to use an econometric model to estimate the central bank's underlying interest rate policy reaction function. According to the above discussion, when the CBC sees changes in macro data, it might react by following certain rules. The CBC might give different weight to each operational objective, and its responses might be contingent owing to the level of the

target they are concerned about. When there are such non-linearities, the Threshold Autoregressive Model (TAR) is a natural and useful tool to model the behavior of the central bank. Since Taiwan is an export-oriented country, domestic economic development is highly dependent on international trade, and hence the CBC and export companies all feel concern over the fluctuations of the exchange rate. In many statements to the public, the central bank has always stressed that exchange rate is not the only factor for companies to survive. However, policy intervention to help exporters seems an unveiled secret.

This paper is organized as follows. Section 2 reviews related literature and briefly introduces monetary policy rules and nonlinear time series models. Section 3 outlines the estimated model, providing a modified Taylor-rule with the TAR setting. Section 4 discussed TAR estimation method and nonlinearity test introduced by Hansen (1997, 2000). Section 5 describes the data. Section 6 gives estimation results, ranging from empirical result to out-of-sample forecast. Conventional OLS results are also performed to check whether TAR model is indeed more informative. Section 7 concludes.

2. Related Literature

2.1 Policy Reaction Function

The two main approaches to model central bank's policy reaction function were Taylor's rule (1993) and McCallum's rule (1987,1988). McCallum adopted a quantity rule by taking monetary base as an instrument, whereas Taylor used Federal Funds Rate (FFR) as the policy instrument. When nominal output or GDP is lower than its target value, the central bank sets a higher money growth rate or a lower interest rate. On the contrary, when there is positive output or inflation gap, monetary policies should be tighter. While McCallum considered output gap as the explanatory variable and assumed 3% steady-state annual growth rate for nominal GNP and monetary base, Taylor additionally incorporated inflation gap and assumed 2% rate for real GDP growth and inflation rate. Their simulation results both claimed that adherence to the rules specified by them could lower the inflation rate and alleviate fluctuations in output.

This paper focused on interest rate reaction function because after the spring up of financial innovation and market liberalization in the 90's, the connection between various monetary aggregates and policy targets, such as real GDP and price level, was broken. Chen and Wu (2009, 2010) stated that the year 1998 was a watershed for Taiwan's monetary policy; before 1998, the CBC seems to use money growth rule, while interest rate rule is more suitable for the post-1998 period. After 1999, there is probably an asymmetric interest rate rule about intervention in the foreign exchange market. CBC tends to curb appreciation in NTD and is more tolerant with the market when there is deprecation.

Dueker and Fischer (1996) used Markov switching model to extend McCallum's (1987) model to Switzerland. They found that exchange rate fluctuations are important policy considerations for small open economics such as Taiwan. The long-run inflation target was estimated to switch between 1% and 3%. Swiss National Bank did not seem tolerant of high inflation either.

2.2 Econometric Approaches

The TAR model, developed by Tong (1983), is a non-linear regression model to depict regime-switching phenomena depending on the values of an observable independent variable. According to Shen et al. (1995,1997), a threshold autoregressive Taylor rule is more appropriate to capture the CBC's behavior. They proposed that the interest rate reaction function of Taiwan responded differently to policy objectives when the severity of inflation differs. Policy focus was put on output growth when inflation did not cross the red line, hence they assumed that central bank's reaction to final target is lexicographic ordering, i.e. a threshold behavior. In their setup, the inflation rate is the threshold variable. The same conclusion could be applied to Taiwan and the U.S. This paper modified their specification by considering real effective exchange rate as the threshold variable. When the REER is higher than its threshold value, the CBC will react to its objectives in one way, and when the REER is below its threshold value, the CBC will react in another way.

Another non-linear specification is Markov Switching Model proposed by Hamilton (1989). In the first glance, these two approaches seem quite alike; however, in contrast to TAR model, a regime change happens with a fixed probability in Markov switching model. Presumably, it is not convincing that the transition

probabilities will be constant over a long period of time. Besides, Enders (2004), indicated, ”no attempt is made to explain the reason that regime changes occur and no attempt is made to explain the timing of such changes.” Furthermore, Perlin (2011) suggested

> *“don't try to estimate any (Markov switching) model with k > 3 (numbers of regimes) and number of explanatory variables higher than 4 ... the solution is probably a local maximum and you can't really trust the output you get ... such big number of estimated parameters is too much for a gradient descent (fmincon function).”*

Tsay (1989) simplified Tong and Lim (1980) guideline for specifying TAR model, and proposed a procedure for testing threshold nonlinearity. To be more specific, using lagged endogenous variable as the threshold variable is the so-called Self Exciting Threshold Autoregressive Model (SETAR). While Tong and Lim (1980) used Akaike information criterion to select threshold variable (or delay parameter in their paper), Tsay did this by conducting a nonlinearity test and comparing *F* statistic. The procedure was free of the prespecification of the number of regimes, and the AR order can be different among regimes.

Hansen (1997, 2000) studied the distribution theory for the TAR model, which can be applied to form confidence intervals for estimated model parameters. Hansen (1999), allowing multi-regime existence, applied SETAR strategy to study U.S. industrial production, and found SETAR (2) was more appropriate to model it. In a small-scale financial macroeconomic model, Shen (1998) estimated interest rate reaction function for Taiwan using two regimes threshold Taylor Rule model. The threshold variable comprised four crisis indexes: inflation rate, output growth rate, foreign exchange market, and capital market. Regime will change when even only

one index crosses its own threshold value. The estimation result indicated that the price stability carried significant coefficients in both regimes with an acute response in disaster regime, and that output growth and foreign exchange market were not significant.

3. Empirical Model

The equations that I want to estimate in this paper are as follow.

$$i_t = c1 + a_1 i_{t-1} + a_2 y_{t-1} + a_3 \pi_{t-1} + a_4 u_{t-1} + a_5 re_{t-1} + \varepsilon_t \text{ , } if\ re_{t-1} \le re^* \quad (1)$$

and

$$i_t = c2 + b_1 i_{t-1} + b_2 y_{t-1} + b_3 \pi_{t-1} + b_4 u_{t-1} + b_5 re_{t-1} + \varepsilon_t \text{ , } if\ re_{t-1} > re^* \quad (2)$$

The interest rate i_t is affected by its lagged term i_{t-1}, output growth y_t, inflation rate π_t, the interest rate spread between Taiwan and U.S. u_{t-1} $(i_{us} - i_{tw})$, and the lagged real effective exchange rate (REER) re_{t-1}. The two equations express that when REER re_{t-1} cross its threshold value re^*, CBC will alter its response entirely. While all coefficients will change between regimes, the homoscedasticity assumption is maintained for simplicity. In Taylor's (1993) model, Federal Funds Rate (FFR) reacts to the deviation of output and inflation to their natural rate. In this paper, I will not estimate the "natural rate " for output and inflation. The overall natural rate effects will show up in the constant term $c_1\ and\ c_2$ of the model.

In practice, discount rate is another important policy instruments that CBC utilizes. However, since discount rate is low frequency data, and will be constant unless the meeting of the Board of Governors of the CBC has declared adjustment. Albeit it has great importance, bankers and market participants pay close attention to overnight interest rate, for it represents short-term turnover interest rate. In most studies, short-term interest rates such as the Federal Funds Rate or the overnight interest rate was used as the main policy tool. This paper also follows other literature's approach.

In reality, no one knows for sure what the central bank really targets when it is setting up policies. In this paper, I want to estimate different interest rate policies facing varying levels of exchange rate. In addition to REER, I also considered other proxies for exchange rate threshold: (1) e_{t-1}, one period lagged exchange rate, (2) Δe_{t-1}, one period lagged exchange rate difference, (3) ecy_{t-1}, HP-filtered component of exchange rate.

Before the estimation, some economic intuition may help us conjecture the likely outcome. The coefficients associated with the lagged interest rate and the US-Taiwan interest rate spread, i.e. $a_1(b_1)\ and\ a_4(b_4)$, are expected to be positive in both regimes, because there is an obvious comovement between Taiwan and U.S. short-term interest rate. The higher the REER, the stronger is the NTD. Thus, a positive coefficient (a_5/b_5) means CBC accommodates with the market, i.e., a lean into the wind policy. If $a_5\ or\ b_5$ is negative, the CBC is pursuing a countercyclical policy to offset market movement. The inflation rate is supposed to have positive impact on interest rate. If inflation rate rises, generally the CBC will raise interest rate to maintain price stability. The relation between interest rate and output is more complicated. If CBC is focussing on finetuning output, interest rate goes down to stimulate output growth when output decreases. In this case, $a_2\ or\ b_2$ is positive.

4. Model Estimation

4.1 Model Specification and Estimation

Based on Hansen (1997, 2000), a two regimes TAR model takes the following form:

$$y_t = (a_0 + a_1 x_1 + \cdots + a_n x_n) I(q_t \leq r) + (b_0 + b_1 x_1 + \cdots + b_n x_n) I(q_t > r) + e_t$$

At first, the model environment needs to be defined. Let $I(\cdot)$ be the indicator function, which equals to one if the condition in the parentheses is satisfied; q_t is the threshold variable and is a known function of the data; r is the threshold value, dividing the data into two regimes; $e_t \; is \; i.i.d. N(0, \sigma^2)$, but it can be allowed to be conditionally heteroskedastic. The parameters of interest are $a_i \; and \; b_i$ $(i = 0, \cdots, n)$ and r. Once the threshold variable q_t crosses its threshold value r, the model will change to another regime with totally different coefficients. Fundamentally, this model is non-linear and discontinuous, but LS estimators can be calculated by using sequential conditional LS.

The above TAR model can be rewritten as follows:

$$y_t = x_t' a I(q_t \leq r) + x_t' b I(q_t > r) + e_t,$$

where $x_t = (1, x_1, \cdots, x_n)$;

or

$$y_t = x_t(r)' \theta + e_t,$$

where

$$\theta = (a', b')',$$

$$x_t(r) = \left(x_t' I(q_t \le r)\; x_t' I(q_t > r)\right)',$$

According to Hansen (1997, 2000), for a given value of r, the LS estimate of θ is

$$\hat{\theta}(r) = \left[\sum_{t=1}^{n} x_t(r) x_t(r)'\right]^{-1} \left[\sum_{t=1}^{n} x_t(r) y_t\right]$$

with residuals $\hat{e} = y_t - x_t(r)'\hat{\theta}(r)$, and residuals variance

$$\widehat{\sigma_n^2}(r) = \frac{1}{n}\sum_{t=1}^{n} \widehat{e_t}(r)^2$$

The LS estimate of r is the value that minimizes residuals variance

$$\hat{r} = argmin\; \hat{\sigma}_n^2(r), r \in \Gamma$$

where $\Gamma = [\underline{r}, \overline{r}]$

The upper and lower bound $[\underline{r}, \overline{r}]$ refer to data trimming to locate the likely threshold value.

4.2 Hypothesis testing

An important question is whether TAR model is statistically significant comparing to the conventional linear model. The concerned null hypothesis is that the coefficients in two regimes are all the same, H_0: a=b. According to Hansen (1997, 2000), an appropriate test statistic for the testing hypothesis is a standard F-statistic:

$$F_n = n\left[\frac{\tilde{\sigma}_n^2 - \hat{\sigma}_n^2}{\hat{\sigma}_n^2}\right],$$

where

$$\tilde{\sigma}_n^2 = \frac{1}{n}\sum_{t=1}^{n}(y_t - x_t'\tilde{a})^2$$

where $\tilde{a}$ is the estimated coefficients under the null hypothesis.

Hansen (1997, 2000) showed that the asymptotic distribution of F_n is not χ^2, because under null hypothesis, r is not identified. A bootstrap procedure could be applied to approximate the asymptotic distribution of F_n.

The entire hypothesis testing procedure is primarily based on Hansen's (1997, 2000) method, but there are other procedures, which can detect threshold effect with or without a predetermining threshold value. The following briefly discusses these tests.

1) The Chow breakpoint test, involving a single and appointed breakpoint, compares the sum of squared residuals obtained by fitting a single equation to the entire sample with the sum of squared residuals obtained when separate equations are fit to each subsample of the data.
2) The Chow forecast test estimates two models—one using the full set of data, and the other using sub-sample data. Differences between the sum of squared errors of the two estimated models can be used to check the stability of the estimated relation over the sample period.
3) The CUSUM test is based on the cumulative sum of the recursive residuals. This procedure plots the cumulative sum together with the 5% critical lines. The test finds parameter instability if the cumulative sum goes outside the area between the two critical lines.

5. Data Sources

The sample period encompasses September 1985 to August 2010 for the following reasons. First, The year 1985 was historically important to both Japan and Taiwan. During the negotiation of the Plaza Agreement, U.S. suspected Japan had manipulated the exchange rate and urged Japan to appreciate yen to alleviate their current account deficit. After the Plaza Accord, NTD appreciated from around 40 to 25 NTD/USD. Second, as indicated in figure 2, before 1980s, Taiwan had maintained a fixed exchange rate policy targeting U.S. dollars. After the 1985 Plaza Accord, Taiwan has gradually shifted its policy to a managing floating exchange rate regime.

Figure 2 plots the monthly average exchange rate from 10/1970 to 01/2011. As can be seen from the figure, the NTD exchange rate was ranging 40 before 1985, which U.S. triggered the suspicion that the CBC might have intended to undervalue Taiwan dollars. The result was a nearly 40 percent appreciation around 1985. When the Asian financial crisis broke out in 1997, the CBC let go their hold on the exchange rate, retreating from the combat against hot money brought by speculators. The Taiwan dollar depreciated from 27 to 33 in six months. Since 1998, Perng Fai-Nan has been the chairman of the central bank. Because of his immense focus on the exchange rate, so far the exchange rate has experienced relatively mild oscillation.

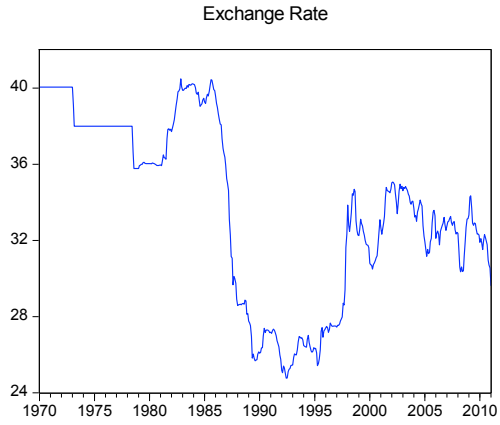


FIGURE 2- Exchange rate- October 1970~January 2011

The following are descriptions about the chosen variables. All are collected by the Taiwan Economic Journal:

1. Short − term interest rate i_t *and interest rate spread* u_t : I use overnight interbank interest rates. The original data is daily; hence I took monthly average. u_t is the interest rate gap between Taiwan and U.S. federal funds rate. As the figure 3 shows, the gap was narrowed during the 90's, but was widen for the last decade. Their long-term trends are quite alike with correlation 0.65.

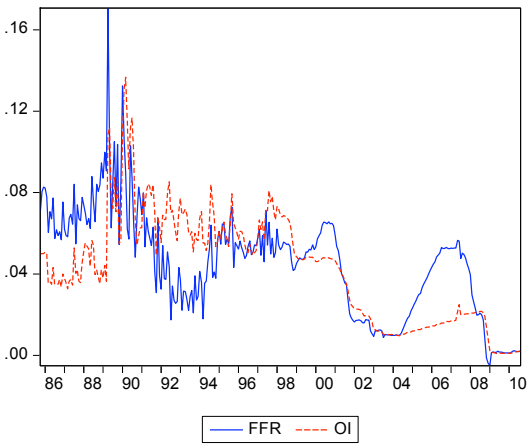


FIGURE 3- Overnight interest rate and Federal Funds Rate from 09/1985 to 08/2010

2. Output growth rate y_t: I use Industrial Production index (IPI) annual growth rate (2006=100), as a proxy for the output growth.

3. Real Effective Exchange Rate index re_t (2005=100): REER is an index used by CBC to gauge the real value of NTD. The CBC does not publish the official method to calculate REER; however, Tsaur et al.（2002）proposed a widely cited method to calculate REER. According to their paper, the data published by Taipei Foreign Exchange Market Development Foundation is highly correlated with their result, so I use the numbers from TFEMDF directly. The data starts from 01/2000. Compared with the lowest REER during the period after 2008 financial crisis, there was a plateau at 2003~2008. The REER peaked at the beginning of the last decade. (see figure 4.)

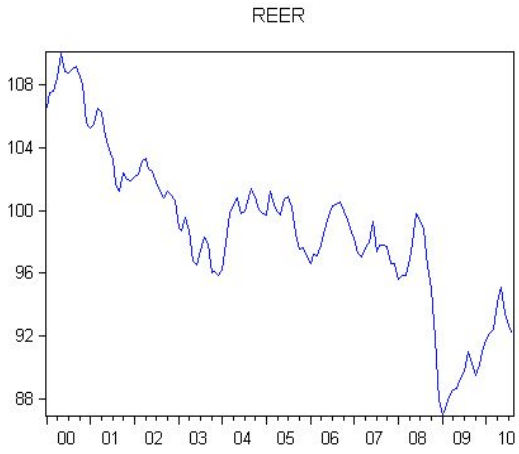


FIGURE 4- Real effective exchange rate from 200001~201009

4. Inflation rate p_t: I use Consumer Price Index (CPI) to fit commodity price level faced by common people (let 2006=100). The inflation rate is measured as the $\log(CPI_{t+1}) - \log(CPI_t)$.

The classical regression assumptions necessitate that both the dependent and independent variables sequences be stationary and that the errors have a zero mean and a finite variance. In the presence of nonstationary variables, there might be spurious regression. A spurious regression has a high R^2 and *t*-statistics that appear to be significant, but the results are without any economic meaning. So the unit root tests are performed to detect whether any variable has nonstationarity.

After taking Augmented Dickey-Fuller and Phillips-Perron unit root tests with equations including intercept and trend, I rejected the null hypothesis that all variables have a unit root in level. When there are contradictory results, I choose PP test because the test is robust with respect to unspecified autocorrelation and heteroscedasticity in the disturbance process of the test equation. The p-value of the tests results are presented below in Table 1. There are some other unit root tests that can be conducted, but they are beyond the scope of this paper[1].

Unit Root Test (with intercept and trend)		
	ADF	**PP**
e_t	0.02	0.03
i_t	0.09	0.00
π_t	0.00	0.00
u_t	0.11*	0.04
y_t	0.04	0.00
$reer_t$	0.50	0.00

Table 1 - p-value from unit root tests

- *means lags selection uses SIC criterion; others use AIC

[1] The tests of unit-root hypothesis against the alternative hypothesis of break stationary with a break in the trend can also be carried out. A break stationary series is a time series that it is nonstationary because of a break and that the series before and after the break are all stationary. Zivot and Andrews (1992) proposed a test that is capable of meeting the above requirement. Besides, the test is more suitable because it can estimate the break point without using an assigned one, i.e. the break point is endogenous.

6. Estimation Result

6.1 Estimation results, Threshold variable: re_{t-1}

First, it is necessary to discuss model performances to check model's goodness of fit before presenting estimation results.

	R-squared	SSE	AIC	SBC
OLS	0.992933	1.47	-1.52	-1,38
TAR	0.995378	1.00	-1.81	-1.54

Table 2.1- model performance between the OLS and the whole TAR model

The joint R-squared and SSE (Sum of squared errors) both improve under the TAR model structure. Further more, AIC (Akaike information criterion) and SBC (Schwartz information criterion) can be calculated as below:

$$AIC = -2(l/T) + 2(k/T)$$

$$SBC = -2\left(\frac{l}{T}\right) + (k \ln T)/T$$

where l is log likelihood value, k is the number of estimated coefficients, and T is the number of sample data

The model that has smaller criterions is better. The TAR model has lower AIC (-1.81<-1.52) and SBC (-1.54<-1.38). To inspect whether the differences are statistically significant, I conduct a likelihood ratio test. The LR statistic is

$$LR = -2(L_R - L_U) \sim \chi^2(m)$$

where L_R is the log likelihood of the constrained model (OLS), and L_U is that of the unconstrained TAR. The degree of freedom m is equal to the number of constrained parameters. LR statistic can be calculated as below:

$$LR = -2(102.5742 - 126.9692) \sim \chi^2(6)$$

which is 48.79, significant at 1% level. Those improvements and LR test suggest that TAR model is indeed useful, comparing to conventional OLS model.

After model selection, the estimation is performed using Hansen's (1997) approach. Using REER as the threshold variable, Table 2-2 exhibits both TAR & OLS estimation results for comparison purposes. Figure 5 graphs the 95% confidence interval [91.01, 98.89] for the estimated threshold value of REER. The horizontal axis in Figure 5 is the sequence of REER arranged according to quantity. The lowest likelihood ratio, i.e. the estimated threshold value, corresponds to 95.04 on 2008M10.

	Global OLS	*Regime 1* $re_{t-1} \leq 95.04$	*Regime 2* $re_{t-1} \geq 95.04$
C	-0.98**	-2.43*	-1.18*
	(0.45)	(1.27)	(0.47)
i_{t-1}	0.95**	1.35**	0.95**
	(0.02)	(0.25)	(0.01)
y_t	0.004**	-0.0013	0.006**
	(0.002)	(0.0017)	(0.002)
p_t	4.02*	-0.80	1.23
	(2.41)	(2.84)	(1.85)
u_{t-1}	0.03**	0.85**	0.03**
	(0.008)	(0.01)	(0.007)
re_{t-1}	0.01**	0.02**	0.012**
	(0.005)	(0.01)	(0.005)
Observations	127	21	106

Table 2.2 - Estimation Result, (Threshold variable: $\boldsymbol{re_{t-1}}$)

- * stands for 10% significance; ** stands for 5% significance
- standard errors are in parentheses

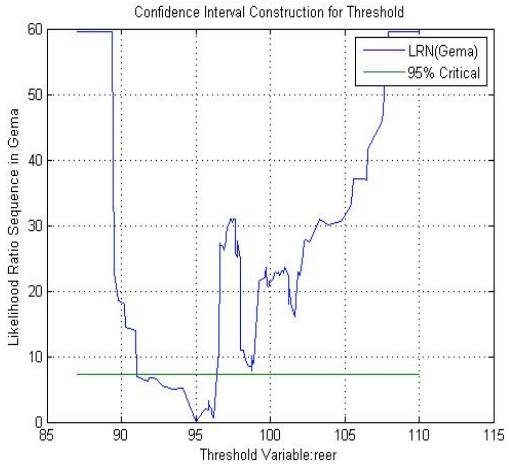


FIGURE 5. - Confidence interval and threshold value

The first column of Table 2 gives the estimated result using conventional OLS model. The OLS model indicates that overnight interest rate has strong autoregressive behavior. The coefficients of y_t *and* p_t are both positive which indicates that CBC's interest rate policy is countercyclical. The large coefficient associated with inflation, 4.02, indicates that domestic price stability is the top priority of CBC. However, comparison of the inflation coefficients between the OLS and TAR model reveals that not only the concern about inflation is lower, but the effects are not significant. Therefore, after using REER as a threshold to split sample, the explanatory power of inflation is largely diminished and absorbed by other variables. The coefficient of U.S.-Taiwan interest rate gap is significant as well, and this is consistent with common interpretation that CBC follows closely with FED's policy. The coefficient of REER is positive and significant. The positive coefficients imply that CBC intends to accommodate REER. Because during the sample period, there is a downward trend of REER, the results suggest that even if NTD is undervalued in the past decade, the CBC is not trying to increase its value. Basically the regime 2 shows little difference

from the OLS model, so my focus will be on regime 1 and the difference between regimes.

One should exercise some cautions when examining the changes of coefficients between regimes. Bases on the threshold value of 95.04, situating at 2008M10, REER data series can be separated into two horizontally and vertically divided groups. The year 2008 was the time when the financial crisis burst. On October 8 2008, the US Federal Reserve, the Bank of England, the European Central Bank, the Bank of Canada, Sveriges Riksbank, and the Swiss National Bank jointly announced reductions in policy rates by 50 basis points. Since then, the appeal to cut interest rate had been stronger, causing the coefficient of the lagged term to swell to 1.35. The epicenter was in U.S, but the ripple overwhelmed Taiwan. The co-movement of U.S.- Taiwan interest surged to 0.85, almost thirty times larger than before. Originally, the annual growth rate of IPI and CPI were at their ten-year climax, but afterward they turned to negative until the beginning of 2010. The negative sign of output -0.0013 (although insignificant) means CBC has tried to stimulate the economy by lowering interest rate. Inflation coefficient -0.8 (again, not significant) has opposite procyclical direction but it was relatively not a concern for CBC then. Inflationary pressure mitigated because of the declining energy and other commodity prices.

Discussions in section 3 state that this paper considers four exchange rate proxies in total: $re_{t-1}, e_{t-1}, \Delta e_{t-1}, and\ ecy_{t-1}$. To identify which is the likely target for CBC, it is important to test the existence of nonlinearity effect. Using the approach proposed by Hansen (2000), the following are the bootstrap p-value of the four models using different exchange rate:

	e_{t-1}	Δe_{t-1}	ecy_{t-1}	re_{t-1}
Bootstrap p-Value	0.44	0.251	0.128	0.001

Table 3. - Test of null of no threshold against alternative of threshold- allowing heteroskedastic errors (White corrected)

From table 3, the other three proxies (i.e., $e_{t-1}, \Delta e_{t-1}, and\ ecy_{t-1}$) of exchange rate fail to be threshold variables. A threshold value can still be found, but it is not statistical significant. From the first three models, it seems that CBC had not changed its behavior or policy objective order though they had undergone so many economic crises and chairpersons. But the REER model unveils an opposite story. If I use e_{t-1} as the threshold variable with a shorter data period containing a sluggish seven-year-long appreciation started from 1985 to 1992, the threshold effect happens on almost the same place compared with the whole sample result (09/1985 to 08/2010), and it has 5% significance level. I exclude this model because the cutting point cannot be supported by real world events. The same reasoning can be applied to the other two models.

6.2 Estimation Result, Threshold Variable: e_{t-1}

Table 4 shows the estimation result using e_{t-1} as the exchange rate proxy from 09/1985 to 08/2010. Although this model does not pass nonlinearity test, for comparison purpose, there are some distinctive characteristics that worth further discussions.

	Global OLS	*Regime 1* <= *27.533*	*Regime 2* > *27.533*
C	2.61**	3.1	0.47**
	(0.79)	(3.86)	(0.6)
i_{t-1}	0.92**	0.79**	0.96**
	(0.07)	(0.09)	(0.01)
y_{t-1}	-0.01	-0.031*	0.002
	(0.006)	(0.0158)	(0.003)
p_{t-1}	7	27.32*	-5.37
	(10)	(15.49)	(4.92)
u_{t-1}	0.1**	0.25**	0.03**
	(0.04)	(0.12)	(0.01)
e_{t-1}	-0.07**	-0.04	-0.013
	(0.02)	(0.14)	(0.018)
Observations	299	93	206
Sum of Squared Errors	194.38	125.77	34.16
R-squared	0.908 (adjusted)	0.58	0.95

Table 4- Estimation Result, (Threshold Variable: $\boldsymbol{e_{t-1}}$)

- * stands for 10% significance; ** stands for 5% significance
- standard errors are in parentheses

The result displays a bulge in the reaction to inflation. This manifests the credibility that CBC has always put price stability in the first place. The significance of interest rate spread again indicates that it has great explanatory power. The negative sign of lagged exchange rate seems to indicate that CBC decreases interest rate when NTD depreciates, but the non-significance, in contrast to the re_{t-1} case

(see Table 2), might be the evidence that CBC has not put much weight on the exchange rate.

6.3 robustness check and forecast

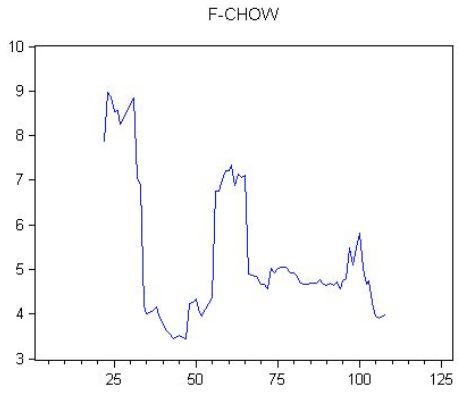
Using the approach proposed by Hansen (1997), the possible threshold value for REER is 95.04 with 95% confidence interval [91.01, 98.89] (see Figure 5). The confidence interval contains 40% of the whole sample and that gives rise to other potential choices of threshold values. I continue to run Chow tests to find other probable thresholds. All the tests listed below are performed after sorting the data according to REER.

The Chow tests results of the likely switching point, which corresponds to the highest F-statistics, are provided in table 5. Figure 6 graphs the F-statistic sequence from Chow breakpoint test. The Chow breakpoint test is not consistent with the original result 95.04 but suggest a different threshold value 95.09 locating on 2010M05, whereas the Chow forecast is. Although Chow breakpoint test proposes another turning point, it is just next to 95.04, and is too chronologically terminal to be a good switching point. Besides, from the historic importance aspect, shortly after the breakout of 2008 financial crisis, the CBC had decided to reduce required reserve ratios on NT dollar deposits with an estimated effect of injecting liquidity that is worth NT$200 billion. In addition, banks may use their holdings of certificates of deposit (CDs) and negotiable certificates of deposit (NCDs) issued by the CBC or their redeposits in the CBC to borrow collateral loans or request early withdrawal whenever needs arise. The CBC had also expanded repo operations to ensure sufficient sources of liquidity for financial institutions. The above measures indicate some major changes about CBC's monetary policy in response to escalating financial

turmoil. So the original switching point 95.04 on 2008M10 is a better choice to capture CBC's behavior.

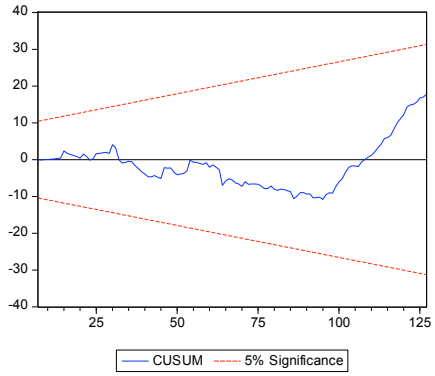
	Chow breakpoint test	Chow forecast test
No. 22-95.04	7.88 (0.00)	3.27 (0.0077)
No. 23-95.09	8.98 (0.00)	2.73 (0.0152)

Table 5- Chow test results, adjacent but contradicted



FIRURE 6. - The most likely switching point happens on No. 23

In CUSUM test, the threshold value should locate on where the solid line crosses the 5% significance boundary enclosed by the two dotted lines. In Figure 7, the solid line never reaches the 5% significance level. Thus from CUSUM test, there is no clue showing that regime change happens.



FIRUGE 7. – CUSUM test results are not significant.

In order to compare the four exchange rate proxies I have used, I compare their out-of–sample forecast performance. Although the model uses REER as the exchange rate target, according to my experiment, using TAR model instead of OLS will be more informative and increase the goodness of fit as measured by R^2. So when I conduct two-year out-of-sample forecast, I still use TAR as the underlying model. The forecast method is iterative, i.e., the dynamic forecast method, substituting the forecasted t+1 to get forecasted t+2, and repeatedly doing this for n times. For example,

To get forecasted t+1: $\hat{y}_{t+1} = constant + o.5y_t$

To get forecasted t+2: $\hat{y}_{t+2} = constant + o.5\hat{y}_{t+1}$

To get forecasted t+3: $\hat{y}_{t+3} = constant + o.5\hat{y}_{t+2}$

The sample is divided into the two regimes in advance. In this way we give each model the best chance to perform. Table 6 gives forecast outcome, and the smaller the number the better is the model. Suppose the two-year forecast sample is $= T + 1, T + 2, \ldots, T + n,$, and denote the actual and forecasted value in period as y_t and $\hat{y}_t$, respectively. The reported forecast error statistics are computed as follows:

Root Mean Square Error	$\sqrt{\frac{1}{n}\sum_{t=T+1}^{T+n}(y_t - \hat{y}_t)^2}$
Mean Absolute Error	$\frac{1}{n}\sum_{t=T+1}^{T+n}\lvert y_t - \hat{y}_t\rvert$
Mean Absolute Percentage Error	$\frac{1}{n}\sum_{t=T+1}^{T+n}\left\lvert\frac{y_t - \hat{y}_t}{y_t}\right\rvert$

	RMSE	**MAE**	**MAPE**
$\boldsymbol{e_{t-1}}$	1.13	1.07	7.95
$\boldsymbol{\Delta e_{t-1}}$	1.38	1.28	10.11
$\boldsymbol{ecy_{t-1}}$	1.03	0.98	7.54
$\boldsymbol{re_{t-1}}$	1.73	1.00	6.34
OLS	0.43	0.36	2.41

Table 6.- Comparison of model forecastablity

Table 6 gives a rather mixing result. According to RMSE and MAE, using ecy_{t-1} seems to perform well, for CBC might try to smooth the exchange rate. REER does best by using MAPE. But the OLS model outperforms them all. Note that this is just a mathematical comparison, and that statistical significance cannot be inferred from above. When the model dynamic depends on lagged variable, the estimation becomes complex. Dacco and Satchell (1999) suggested that most non-linear techniques give good in-sample outcome but are usually outperformed by random walks or random walks with drift when used for out-of-sample forecasting. The cause lies in regime misclassification that makes random walk model outperform nonlinear models.

7. Conclusions and Extensions

According to the previous discussion, a TAR model is more suitable for depicting CBC's interest rate reaction function than OLS in terms of the goodness of fit measure. But when it comes to out-of-sample forecastability, the conventional OLS model seems to outperform nonlinear ones. Using exchange rate as the threshold variable, this paper suggests that there are no statistical evidences that CBC has gone through policy regime changes with different chairperson. But when using REER as the threshold variable, the result shows that there is a structure change. During the 2008 financial crisis, CBC started significantly putting stress on cutting interest rate as the world unanimously did so. Besides, CBC seems to accommodate exchange rate movement instead of leaning against the wind. Alleviating inflation may no longer the top priority of CBC then. To be concluded, this paper indicated three important factors affecting interest rate reaction function: the interest rate lagged term, the interest rate spread with U.S., and the real effective exchange rate.

To elaborate this issue more deeply, Bai and Perron (1998) presented a comprehensive treatment of practical issues arising from the analysis of models with multiple structural changes. By the same token, the second sample splitting can be conducted within the two sub-samples using the method contributed by Hansen (1997,2000). However, in this paper, the small sample size makes the estimation cannot generate fruitful results. It is interesting to consider longer period including two oil crises and the Asian financial crisis. In case of more complex situation, the future study can drill into developing two threshold variables following Bai et al. (2009). Such studies are applicable because Taiwan had undergone the situation which combines high inflation or weak NTD with low GDP growth rate.

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