

# A Robust Set of Indicators for the Financial Stress and Financial Stability: Taiwan's Case Studies

Chau-Jung Kuo<sup>1</sup>, Yu-Wei Li<sup>2</sup> & Li-Hua Lai<sup>3</sup>

<sup>1</sup> Department of Finance, National Sun Yat-sen University, Kaohsiung, Taiwan

<sup>2</sup> College of Finance and Banking, National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan

<sup>3</sup> Department of Risk Management & Insurance, National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan

Correspondence: Yu-Wei Li, College of Finance and Banking, National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan.

Received: December 11, 2015

Accepted: December 28, 2015

Online Published: January 18, 2016

doi:10.5430/ijfr.v7n1p172

URL: <http://dx.doi.org/10.5430/ijfr.v7n1p172>

## Abstract

This study sets up a detective system for Taiwan's financial stability with two spindles of the market-based and the bank-based, and uses "Two-state Markov regime-switching" method to capture the turning points from Taiwan's previous major financial crises through the volatility of Taiwan's financial stress index between 1997Q1 and 2014Q4. On this basis, a further study to propose the research of "a robust set of indicators for the Taiwan's financial stability" uses "noise to signal ratio" method from the candidate variables of bank-based Taiwan's financial stability, to filter out composite indicator of Taiwan's financial stability with early warning functions as a supervisory tool for financial stability, effectively to detect and alert Taiwan's financial crises. Empirical results proves, "two-state Markov regime-switching" method with the market-based Taiwan's financial stress index (FSI), it sure can rationally determine the turning points for Taiwan's previous major financial crises and successfully identify Asian financial crisis, dot-com bubble, cross-strait political-economic tensions, global financial crisis (GFC), European debt crisis, etc., especially to capture the financial crisis triggered by cross-strait political and economic tensions in 2004Q2, which completely reveals an individual characteristic of political sensitive gene in Taiwan's financial system. Moreover, a composite indicator of Taiwan's financial stability (*CITFS*) constructed by bank-based measure has a good early warning capability to detect the events of Taiwan's previous major financial crises, and provide Taiwan's financial supervisory authority some important reference to build up the financial early warning mechanism.

**Keywords:** financial stress, financial stability, two-state Markov regime-switching, noise to signal ratio

## 1. Introduction

A strong and resilient financial system is the foundation for sustainable real economy, especially for the banking sector, which provides critical services for economic agents who rely on them to conduct their daily living and business, both at a domestic and international level.

One of the main reasons the economic and financial crisis, which began in 2007 and exploded in 2008-09, became so severe was that the banking sector of many countries was not able to absorb the resulting systemic trading and credit losses due to either an excessive on and off-balance sheet leverage or an insufficient liquidity buffers. The weakness in the banking sector were rapidly transmitted to the rest of the financial system, thus the crisis was spread to a wider circle of countries around the globe because the global financial markets had lost confidence in the solvency and liquidity during the crisis periods.

In response to the deep pall cast by global financial crisis (GFC), the Federal Reserve Bank of the U.S. implemented three rounds of "quantitative easing (QE)", hoping to achieve the purpose of stimulating the job market and economic recovery by activating the financial market through the banking system with the monetary measures of trading time for space. However, these operations relatively caused the worldwide central banks to declare a "currency war", for example, Bank of Japan took the initial attack to depreciate Japanese yen a lot, and the national banks of the U.K., Europe, New Zealand, Australia, China, and other countries responded to cut down their interest

rates while Federal Reserve Bank of the U.S. announced to end QE policy of 2014. In addition, with the effect of the expansion of recent Greek debt crisis and China's stock market crash, the situation had global financial markets afraid to fall into a higher volatility risk, and the threat of the systemic risk of the source of the global financial instability seems not yet to be lifted till today.

In general, it is a time-variant formation for a wide systemic risk since the risk of disruption to financial service is caused by an impairment of all or parts of the financial system. In addition to this subject crisis of 2007-09, according to the past experiences of the significant crises, like the 1982 Latin American debt crisis and 1997-98 Asian crisis, the systemic risk was driven by economic and financial cycles over time, as well as by the degree of interconnections of financial institutions and markets. In other words, a wide systemic risk per se is a financial stress propagation process. Therefore, the works for what kinds of the tools well suited to measure this stress process, and, how to study a robust set of indicators for detecting financial crisis are very important for the financial authorities to conduct their macroprudential policy. In fact, since the 2007-09 financial crisis, new tools for measuring financial stress and monitoring crisis cycles have mushroomed in the academic literature and within policy-making circles, e.g. Alessi and Detken (2009, 2011), Borio and Drehmann (2009), Balakrishnan, Danninger, Elekdag, and Tytell (2009), International Monetary Fund [IMF] (2008, 2009, 2010a, 2010b, 2011), Basel Committee on Banking Supervision [BCBS] (2010a), and etc. Yet, even as various countries have recently studied suitable tools to set up macroprudential policy frameworks based on the related academic studies, there seems still no other academic studies for Taiwan's case. Despite not being a member of the Basel Committee on Banking Supervision (BCBS), the regulatory authorities in Taiwan have always complied with the Basel Capital Accord through all their revisions since the first Basel Accord implemented in July 1998 to the current Basel III.

In nearly 40 years from 1949 to 15 July 1987 after lifting martial law over Taiwan and experiencing the aftermath of World War II, such as the threat of further conflict, political isolation, two oil crises, and many other major challenges, Taiwan was still able to create an Economic Miracle, by the mid-1980's to be the head of the Four Asian Dragons. After martial law was lifted, Taiwan facilitated her reconstruction toward the democratic politics, but not able to prevent the threat from Mainland China during the whole process, for example, in nearly half of year of the Third Taiwan Strait Crisis between July 1995 and March 1996, Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) was dropping or declining slowly as much as 36% against the highest index before the crisis. In particular, in the recent years, facing the rise of China, Taiwan challenged more and more difficulties on economic and finance during the period of her democratic development. By the second quarter of 2015, Taiwan was ranked as the fourth with the largest foreign exchange reserves in the world and the seventeenth on per capita income in accordance with the equation of Purchasing Power Parity, ahead not only her Asian neighbors of Korea and Japan, but those of the advanced European countries like Germany, Denmark and Belgium. However, it does not imply Taiwan was already possessed with the qualification of solid financial stability. By the way, compared to the other nations, Taiwan needs more works to maintain and strengthen its financial stability because it has the "small open economy" characteristic. Two of the main reasons for this are listed as follows:

- 1) Compared with the most of the other nations, Taiwan's financial system with a special political sensitive gene is very easily impacted or interrupted by the change of the international politic reality factor.
- 2) Currently Taiwan is not a member of International Monetary Fund (IMF). Once its financial system occurred the similar situation like the catastrophe of 1997-98 Asian financial crisis, Taiwan cannot receive the support from International Financial Organization as Korea and several Southeast Asian nations do.

The backbone of Taiwan's financial system is the banking sector, and the degree of banking sector stability is embodied by the stability status of Taiwan's financial market. Therefore, the two-pronged approach is taken as our research method to study the problem of Taiwan's financial stability and to build up a financial stability detective system with market-based and bank-based axes so that it can effectively become a ring of the macro prudential policy frameworks for Taiwan's supervisory authority. This study therefore has two purposes: First, to provide a set of research methods and empirical results under the "market-based" frame to define the crisis of Taiwan's financial stress crisis effectively and objectively. Second, based on the empirical market-based results, a further study is conducted to construct a set of systems for the composite indicator of Taiwan's financial stability (*CITFS*) under the "bank-based" frame.

This paper, firstly using Markov two-state switching regime approach, studies how to identify so called "Taiwan's financial stress" elaborately extended from the version of Balakrishnan et al. (2009), and then, based on the identification of this study, tries to find out a robust set of the indicators for Taiwan's financial stability namely, a *CITFS*, which may provide for Taiwan's authorities to conduct an early warning surveillance works on its financial system. The paper, here in after, is organized as follows: Section 2 presents a literature review of the previous studies

related to the issues on the financial stress and crises. Section 3 presents the methodologies on this paper, and Section 4 shows the empirical results. Finally, Section 5 provides summary and conclusion.

## 2. Literature Review

The explosion of 2007-09 global systemic crisis did not only damage the financial system and real economy of each country but also brought financial researchers or international financial organizations a new understanding toward the thought and viewpoint of the modern financial problem (such as financial crisis and financial stability).

Before global financial crisis of 2007-09, on the study of “financial crisis” problem, IMF (1998) analyzed financial crises in the post-Bretton Woods period to be four types as 1. Currency crisis, 2. Banking crisis, 3. Foreign debt crisis and 4. Systemic financial crises. The approach described by IMF (1998) was specifically emphasized on the stylized behavior of macroeconomic variables, such as the real exchange rate, some monetary and financial market aggregates, before and after Crisis 1 and Crisis 2.

It meant the common view of financial problem at that time seemed to think that the causes of foreign debt crisis and systemic financial crises were only derived from currency crisis and banking crisis. Intensively to prevent the occurrence of Crisis 1 and Crisis 2 and to monitor the spillover effects and contagious spread caused by either one crisis on the supervisory measure of general policy, it was enough to block the explosion of overall systemic crisis. Therefore, most of the current academic literatures focused on currency crisis or banking crisis. Taking 1997-98 Asian Financial Crisis as an example, Demirgüç-Kunt and Detragiache (1998, 2000) made a definition of banking crisis as either the situation in which non-performance loans account exceeded 10% of the total assets of banking sector and the cost of bailing out a failing bank was over 2% of GDP, or a large scale of bank run in need of measures of deposits frozen or of guarantees expanded for the depositors (deposit insurance). In the other side, Kaminsky and Reinhart (1999) regarded currency crisis as either the exchange rate of a currency that has sharply fallen or foreign exchange reserves that have been substantially reduced. Persaud (2000) proposed the currency crisis was the real effective exchange rate of a domestic currency falling 10% above in three months, which was also regarded as a forex market crash.

For the study of financial stability problem, Shinasi (2004) collected a large scale of literature reviews from national central banks, financial authorities, international regulatory organizations, and even the academic literatures, and sorted out 18 different definitions from their word meanings of financial stability. In fact, the discussion to financial stability problem is the core work of the macroprudential policy implemented and executed by each of national central banks and financial authorities after Post-Global Financial Crisis Era, and its importance was stressed and declared on the page 14 of the Annual Report of Bank for International Settlements (2009): “Ensuring financial stability requires a redesign of macroeconomic as well as regulatory and supervisory policies *with an eye to mitigating systemic risks*. For macroeconomic policies, this means leaning against credit and asset price booms; for regulatory and supervisory policies, it means *adopting a macroprudential perspective*.”

Kuo (2013) further certified the discussion of financial stability problem from the institutional level to the policy measure should be examined whether the policies of national central banks and other financial authorities can be consistently and effectively applied to stabilize the operation of financial markets under the framework of the Basel III in Post-GFC era. A systematically and dynamically convergent device should be used to embody the two principles of the Annual Report of Bank for International Settlements (2009), namely, “*an eye to mitigating systemic risks*” and a “*macroprudential perspective*”.

Following the 2007-09 GFC, the studies of financial crisis in IMF (2008, 2009, 2010a, 2010b) were no longer limited to the four types of financial crisis as IMF (1998) did before, but rather to research and explore the problem of macroprudential policies as the center work for financial crisis. IMF (2011) emphasizes this point more heavily, operationalizing macroprudential policies requires the progress on a number of fronts: developing ways to monitor a risk buildup, choosing indicators to detect when risks are about to materialize, and designing and using macroprudential policy tools. Detecting both the slow buildup and the sudden materialization in systemic risk is the key to implement good macroprudential polices. Yet, establishing these robust frameworks will be a lengthy process.

To sum up the above related literature reviews, before 2007-09 GFC the discussion of financial crisis and stability problem in the literature is only limited in a single pattern study on Currency crisis, Banking crisis or Foreign debt crisis, etc. However, after the explosion of GFC, the study on financial crisis pattern is mostly based on the wide systemic crises. The studies are all emphasized how to use the measure of the macroprudential framework to secure financial stability. This paper considers the reason of this development shall be looked at the background conditions of GFC's occurrence from the viewpoint of the development of banking supervising processes. For example, before Dodd-Frank Act of 2010 was passed, the United States was under the banking supervising control of

Gramm-Leach-Bliley Act of 1999. However, due to the break-down on the firewall of Banking supervising system, designed by Glass-Steagall Act of 1933, it makes the well-known financial conglomerates, good at Wall Street banking business investment, having engaged in a large number of the essentially proprietary and speculative activities (Note 1), then resulted in an unacceptable wide systemic risk, further to damage the stability function of the integrated financial system played by the commercial banks.

In other words, this paper considers the perspective of the financial stability problem is mainly that the existed banking supervising system creates a certain degree of market activities and the abnormal situations of market activities will produce a certain degree of the financial stress propagation process. Therefore, to maintain the financial stability under the macroprudential framework must be equipped with a set of well-designed consistent standards not only to meet the demand of the individual country but to fit to the global banking supervision. This is also the implication why to set up the Basel III and to implement the macroprudential supervision.

To design a well suited macroprudential framework needs a competent methodology from which a robust set of the indicators can be efficiently used to measure financial stress propagation process. A financial stress means an episodic period when the financial system is under strain and its ability to intermediate is impaired. Specifically, this propagation process generally reveals a tendency to a large shift in asset prices, an abrupt increase in risk, a liquidity droughts and concerns about the soundness of financial system. Balakrishnan et al. (2009) employed a comprehensive financial stress index for emerging economies (EM-FSI) in which total 26 countries were included. The EM-FSI was composed of five components (i.e. banking-sector beta, stock market returns, stock market volatility, sovereign debt spreads, and exchange market pressure index), which was aggregated into an overall index to capture credit conditions in three financial market segments which are the banking sector, securities markets and exchange markets. Thus, we may view EM-FSI as a market-based indicator because it relies primarily on the market data. By following the previous studies, an episode of financial stress of Balakrishnan et al. (2009) was indifferently identified as a period when the EM-FSI for a country exceeds 1.5 standard deviations above its mean. This is the same approach typically used to identify the previous currency crises as pointed out by Laeven and Valencia (2008). According to an empirical evidence as shown by Balakrishnan et al. (2009), that the EM-FSI captured the most important episodes of financial stress experienced by emerging economies, especially in late 2008, was exceptionally high and surpassed the peaks seen during the 1997-98 Asian crisis.

In spite of performing fairly well with the benefit of hindsight as shown in the study, the approach employed by Balakrishnan et al. (2009) still has a methodological drawback needed to be elaborated. That is, the setting for a certain threshold value of FSI used to identify an episode of the financial stress which employed by Balakrishnan et al. (2009) and other previous works is an ad hoc approach. From the viewpoint of the probability theory, that any random variable exceeds 1.5 standard deviations above its mean means that the probability of the subject outcome is 6.68% if the stochastic process belongs to a Gaussian distribution. But in reality, no one knows anything about whether the stochastic process of the financial stress index is Normal or not. Our view is that the identification for any financial cycle, like business cycles, per se is an endogenous work, not exogenous, hence it is best to examine the data from a number of different perspectives. We think that no approach dominates all others but emphasize that there should be more sophisticated methodologies to identify the time point of financial stress.

Our basic view about the endogenous financial cycles is rooted from Borio and Drehmann (2009). They said that the boom sowed the seeds of the subsequent bust. Specifically, this saying used by Borio and Drehmann (2009) revealed that a dramatic unwindings (like financial stress) is difficult to predict, especially impossible for its precise timing, but the longer the financial imbalance persists, the higher the likelihood of the reversal happens. Hence, an endogenous work to forecast financial stress might firstly think what kind of the methodology can be a useful description of the financial stress propagation process generating changes in regime? And then ask that does this change in regime (like this subject crisis of 2007-09) hold permanently on the long river of time horizon?

Based on this thought as mentioned above, our methodology used to describe a permanent regime change (i.e. a turning point of the financial cycles) can be modeled with a two-state (state 1 and state 2) Markov chain in which state 1 is an absorbing state according to reducible Markov process. A simple interpretation behind such process says if the process has changed in the past, clearly it could also change again in the future, and this prospect should be taken into account in forming a forecast. Moreover, the change in regime surely should not be regarded as the outcome of a perfectly foreseeable, deterministic event. Rather, the change in regime is itself a random variable (Note 2). Summarily, the turning point of the financial cycles is a structural event that is inherent in the data-generating process. Whether the change from a certain regime to another regime or not, there is no necessary for any subjectivity, thus, an endogenous determination for the turning point of the series (e.g. financial variables) is simply on the basis of the data alone (Note 3).

### 3. Methodology

The method of this study is conducted in accordance with the following two steps.

Step 1: First to follow the EM-FSI market-based method of Balakrishnan et al. (2009) by building up a Taiwan's FSI, but different from his method on the definition of the period of financial stress crisis. The study adopts the mathematical tool of Hodrick and Prescott (1997), shortened as HP filter the following, to calculate the gap between the value of long-term Taiwan's FSI and that of cyclical volatility, then uses the method of turning points of Taiwan's FSI by endogenous work to define the timing when Taiwan faced financial stress crisis in the past.

Step 2: With the empirical results from Step 1, the study first selects a set of candidate variables of bank-based Taiwan's financial stability, and follow to employ the signal extraction method of Kaminsky and Reinhart (1999) to filter out a set of *CITFS* able to function the early warnings. The specific process of each step is described below:

#### 3.1 Step 1

##### 3.1.1 Taiwan's Financial Stress Index

Taiwan's economy is also part of emerging market economies, so to follow the method of Balakrishnan et al. (2009) to define and construct FSI<sub>t</sub> at Taiwan's period t as:

$$FSI_t = \left( \frac{BETA_t - \mu_{BETA}}{\sigma_{BETA}} \right) + \left( \frac{SMR_t - \mu_{SMR}}{\sigma_{SMR}} \right) + \left( \frac{SMV_t - \mu_{SMV}}{\sigma_{SMV}} \right) + \left( \frac{EMBI - \mu_{EMBI}}{\sigma_{EMBI}} \right) + \left( \frac{EMPI - \mu_{EMPI}}{\sigma_{EMPI}} \right) \quad (1)$$

Where:

BETA<sub>t</sub>, or systemic risk value (β) of return rate for Taiwan Financial Stock Index is defined as  $\beta_t = cov(r_t^M, r_t^B) / \sigma_t^2$ , where M = Taiwan Weighted Stock Index, B= Finance Stock Index, r = monthly return rate,  $\sigma^2$  = variance, and  $\mu_{BETA}$  and  $\sigma_{BETA}$  indicate mean and standard deviation. Respectively, BETA<sub>t</sub> value is to measure the volatility of the financial stock index against the total stock market index. The higher BETA<sub>t</sub> value signifies the relatively higher rate of return risk on financial stocks, and the greater the stress of financial crisis.

SMR<sub>t</sub>: Return rate of the stock market by computing the annual return rate of the Taiwan Weighted Stock Index, with the result to multiply -1 in response to a stock price decline, which represents the rise of the stock market pressure. Stock market crash or the long-term decline of the stock price is one of the main factors to financial crisis.

SMV<sub>t</sub>: The volatility of one-day return of the Taiwan Weighted Stock Index in the last month. Following the method of Balakrishnan et al. (2009), we employed the metric model of GARCH (1,1) to estimate the volatility of Taiwan stock market with the time-varying correlation. The higher the volatility signifies the greater financial crisis growing on Taiwan stock market.

EMBI<sub>t</sub>: The spread of ten-year T-bond yields between Taiwan and the U.S. This spread reflects the credit and liquidity risks of Taiwan's credit market against the U.S. The higher the value signifies the greater the financial stress of Taiwan's bond market.

$$EMPI_t = \frac{\Delta e_t - \mu_{\Delta e}}{\sigma_{\Delta e}} - \frac{\Delta RES_t - \mu_{\Delta RES}}{\sigma_{\Delta RES}}$$

The left is the stress index of the forex market, taking the drastic devaluation on Taiwan's forex rate and the large reduction of forex reserves to signify a rising stress. The variables  $\Delta e_t$  and  $\Delta RES_t$  represents separately the change in percentage of forex rates and forex reserves before and after the assessment month. The forex rate uses the U.S. dollar as the base, in terms of one U.S. dollars converted to some amount of N.T. dollars. While the forex rate depreciates (appreciates) and the forex reserves are reduced (increased), The high EMPI value means the rise (fall) of the forex market stress.

3.1.2 Use HP Filter to Calculate the Gaps  $\{FSIgap_t\}_t$  of Each Periodical Taiwan's FSI

$$\left\{ FSI_t^T \right\}_t^{Min} \sum_{t=1}^{t^*} \left\{ (FSI_t - FSI_t^T)^2 + \lambda [C(L)FSI_t^T]^2 \right\} \quad (2)$$

Where  $FSI_t^T$  means the long-term trend value of the Taiwan financial stress index at time  $t$ .  $C(L) \equiv (L^{-1} - 1) - (1 - L)$  stands for a second difference function of the lag operator  $L$ .  $\lambda$ , a positive number, stands for a smooth parameter. The larger the value of  $\lambda$ , the smoother the trend solution of series  $\{FSI_t^T\}_t$ . At the optimum, all the series of the  $\{FSIgap_t\}_t$  (i.e. a cyclical fluctuation of  $FSI_t$ ) can be computed from the series  $\{FSI_t - FSI_t^T\}_t$ .

### 3.1.3 Identify the Turning Point during Taiwan’s Financial Stress Crisis by Employing the Two-State Markov Regime-Switching Method

A two-state Markov regime-switching setting incorporates an unobservable state variable,  $S_t$ , and is defined as

$$S_t = \begin{cases} 2, & \text{means the financial stress in Taiwan at time } t \text{ is at a critical (crisis) point} \\ 1, & \text{otherwise} \end{cases}$$

Suppose that the probability that  $S_t$  equals some particular value,  $j$  depends on the past only through the most recently value,  $S_{t-1}$ :

$$\text{Pro}(S_t = j | S_{t-1} = i) \equiv P_{ij}, i, j = 1, 2 \tag{3}$$

That is, the transition probability  $P_{ij}$  gives the probability that state  $i$  will be followed by state  $j$ . Note that  $P_{11} + P_{12} = 1$ ,  $i, j = 1, 2$  and it is often convenient to collect that transition probabilities in a matrix with an ordered  $(2 \times 2)$  as:

$$\begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} = \begin{bmatrix} P_{11} & 1 - P_{22} \\ 1 - P_{11} & P_{22} \end{bmatrix} \tag{4}$$

The stochastic process for  $S_t$  is strictly stationary if both  $P_{11}$  and  $P_{22}$  are less than unity and do not take on the value of zero simultaneously. This is because when  $P_{11} = 1$ , once the process enters state 1, there is no possibility of ever returning to state 2. In such a case one would say that state 1 is an absorbing state and that the Markov chain is reducible.

Therein, one further cares about the probability for state variable  $S_t$  under different information sets during the sample period. Let  $\Omega_T = (FSIgap_1, FSIgap_2, \dots, FSIgap_T)$  denote all the information sets from initial time  $t=1$  until final time  $t=T$ . According to Kim (1994), the smoothed probability,  $\text{Pro}(S_t | \Omega_T)$ , which based on the information available throughout the whole sample at future date  $T$ , can be computed from  $\sum \text{Pro}(S_t = i, S_{t+1} = j | \Omega_T)$  once the filtered probabilities  $\text{Pro}(S_t | \Omega_t)$  are estimated up to date  $t$ .

## 3.2 Step 2

### 3.2.1 Selections of Candidate Variables of Taiwan’s Financial Stability Index

This study refers to CAMELS rating model which is generally used by the supervisory authorities of each country to monitor the robustness degree of banks plus “growth on the primary activities” as a considering factor, merged to be an indicator model with a set of candidate variables of CAMELS+G. The name and definition of various variables are listed as below in Table 1:

Table 1. Names and definitions of candidate variables for Taiwan’s FSI

CAMELS+G	Name	Symbol and definition
Capital adequacy	Regulatory capital to risk-weighted assets	$X_1$ : Capital/Risk-weighted assets
	Regulatory tier 1 capital to risk-weighted assets	$X_2$ : Tier 1 capital/Risk-weighted assets
	Net value ratio	$X_3$ : Net value/Asset
	Debt ratio	$X_4$ : Debt/Net value
Asset quality	Nonperforming loans to total gross loans	$X_5$ : Non-performing loans/Loans and discounts
	Coverage ratio for loan loss provision	$X_6$ : Loan loss provision/Non-performing loans
	Coverage ratio for potential asset loss	$X_7$ : Assessment potential asset loss/Reserves of bad debt

Management ability	Ratio of income before tax	$X_8$ : Income before tax/Business revenue
	Ratio of interest income to income before tax	$X_9$ : Net interest income/Income before tax
	Deposit and loan spreads	$X_{10}$ : Loan rate – deposit rate
Earnings and profitability	Return on assets	$X_{11}$ : Income before tax/Average assets
	Return on equity	$X_{12}$ : Income before tax/Average equity
Liquidity	Liquidity reserve ratio	$X_{13}$ : Liquidity reserve/NTD liabilities
	Loans to deposits ratio	$X_{14}$ : Loans/Deposits
Sensitivity to market risk	Net open position in foreign exchange to equity	$X_{15}$ : Net foreign currency position/Equity
	Ratio of foreign currency loans to total loans	$X_{16}$ : Foreign currency loans/Total loans
Sensitivity to interest rate	Ratio of rate-sensitive assets to liabilities	$X_{17}$ : Rate-sensitive assets/Rate sensitive liabilities
	Ratio of rate-sensitive gaps to equity	$X_{18}$ : Rate-sensitive gaps/Equity
Business growth	Deposit growth rate	$X_{19}$ : (Deposit balance of current season – deposit balance of last season)/Deposit balance of last season
	Loan growth rate	$X_{20}$ : (Loan balance of current season – loan balance of last season)/Loan balance of last season

### 3.2.2 Method of Decision-Making for Input Variables of Taiwan’s FSI

Following the same logic used in Step 1, we first take the HP filter to calculate the gaps between each value of the long-term trend and cyclical volatility with all candidate variables during the sampling period. After obtaining the whole gap distribution of CAMELS+G model, we then use the signal extraction method of Kaminsky and Reinhart (1999) to filter out a set of the most suitable Taiwan’s FSI based on the following criterion:

$$\left\{ \theta_i \right\}_i \left[ \frac{\beta \text{ risk}}{1 - \alpha \text{ risk}} < 1 \mid (1 - \alpha \text{ risk}) \geq C \right], i = 1, 2, \dots, 20 \tag{5}$$

Where  $\beta \text{ risk}/(1 - \alpha \text{ risk})$  stands for a noise-to-signal ratio (NTSR), herein,  $\alpha \text{ risk}$  means that no signal is issued and a crisis occurs (i.e. type 1 errors) and  $\beta \text{ risk}$  means that a signal is issued but no crisis occurs (i.e. type 2 errors) (Note 4).  $C$  denotes a probabilistic parameter used for predicting a minimum percentage of Taiwan’s financial crises. We set this parameter being 66% which follows from Borio and Drehmann (2009). And, as mentioned above, identification for the Taiwan’s financial crises are all based on the empirical results presented in the <Step 1>.  $\{\theta_i\}_i$  is a series threshold values of the HP filter gap for these candidate variables and the determination of these thresholds are purely based on the decision criterion (5). In this CAMELS+G model, the series of  $\{\theta_i\}_i$  are totally 20 candidate variables as shown by Table 1.

### 3.2.3 Construction of a Composite Indicator of Taiwan’s Financial Stability

Using the decision making process described above to select  $k$  numbers of input variables  $x_j, j=1, 2, \dots, k$ , we can define the signal function at time  $t$  as follows:

$$S_{j,t}(\theta_j) = \begin{cases} 1, & \text{if the HP filter gap of input variable } x_j \geq \theta_j, j=1, 2, \dots, k. \\ 0, & \text{otherwise} \end{cases} \tag{6}$$

A composite indicator of Taiwan’s financial stability ( $CITFS$ ) of this study is then constructed as follows:

$$CITFS_t = \frac{1}{k} \sum_{j=1}^k S_{j,t}(\theta_j) \tag{7}$$

In other words, if all input variables can satisfy the definition in Equation (6), the value of  $CITFS_t$  of Equation (7) would be 1. Otherwise, if at least one input variable meets the terms of Equation (6), it is  $CITFS_t > 0$ . Therefore, in general, the range of the value for  $CITFS_t$  is  $0 < CITFS_t \leq 1$ . Moreover, with the value of  $CITFS_t$  close to 1, it represents the selected input variables can deliver more signals, which implies more warning indicators deliver the

crisis signals. However, how to define what value of  $CITFS_t$  bigger enough to forecast a potential financial crisis in the coming year is the question needs to take the decision-making criteria as granted for its answer.

Based on the consistency considering for the decision-making criterion, we still follows the decision-making logic of Equation (5):

$$\underset{CITFS^*}{Min} \left[ \frac{\beta \text{ risk}}{1-\alpha \text{ risk}} < 1 | (1 - \alpha \text{ risk}) \geq C \right] \quad (8)$$

It is to say, if the optimal critical value of  $CITFS_t$  ( $CITFS^*$ ) can satisfy the criterion of Equation (8), we regards  $CITFS_t$  can effectively offer the early warning function to Taiwan's financial crisis.

#### 4. Empirical Results

##### 4.1. Data Sources and Description for the Events of Taiwan's Previous Major Financial Crises

The data sampling period of this study is from early 1997 to late 2014. The five variables comprised in the market-based FSI sourcing from the Taiwan Economic Journal (TEJ) are the monthly data, so the smoothing parameter with HP filter proved by FSI is set at  $\lambda=14,400$ . The twenty candidate variables of bank-based CAMELS+G sourcing from both "Condition and Performance of Domestic Banks, Quarterly Report" and "Financial Statistics Monthly" published by Central Bank of the Republic of China (Taiwan) are the seasonal data, so the smoothing parameter with HP filtering proved by CAMELS+G is set at  $\lambda=1,600$ . As to the turning point of Taiwan's financial stress defined by the smoothing probability of Markov chain, its confidence level is set at 95%.

In addition, before the analysis to the empirical results, we will give a brief description on the events of Taiwan's previous major financial crises ahead in Table 2.

Table 2. Description for the events of Taiwan's previous financial crises

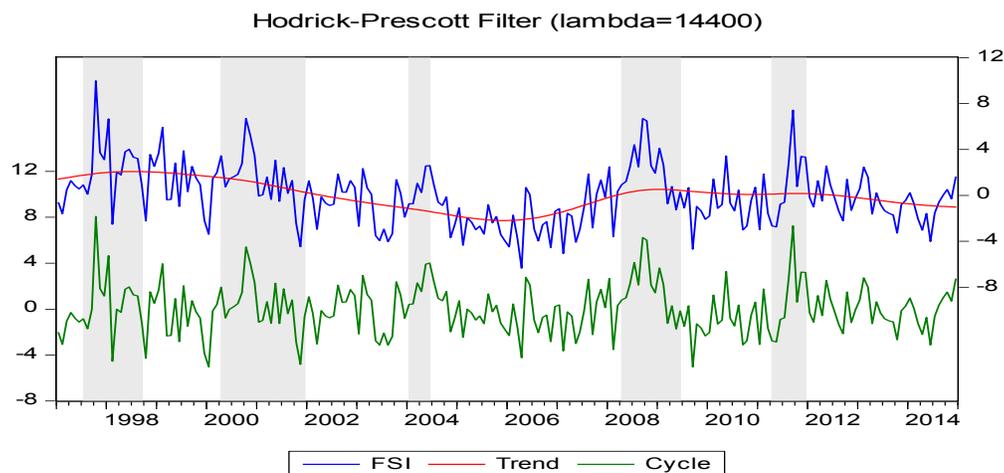
Event and approximate time	Code	Event Overview
Asian financial crisis 1997Q3~1998Q3	E <sub>1</sub>	On 2 July 1997, Central Bank of Thailand, abandoning the forex scheme pegging on US dollars but adopting the flexible exchange rate, caused the overvalued Thai baht dropping and foreign investment flowing out. The rise of interest rate and the fall of stock price caused the struggling businesses failed and the banks forced to shut down. This catastrophe, which Thailand never experienced over 10 years more, made them unable to pay back their foreign debt, and accept the support from IMF. The countries with the similar economic structure, like Indonesia, Malaysia, and the Philippines, also suffered the similar disaster. With the storm of currency depreciation spreading to Taiwan, Singapore, and Hong Kong, the damage to them is relatively smaller because these three nations have the strong robust economies. Up to the middle of November, South Korea was hit hard and fell down. The disaster then was spread to the entire Northeast Asian region.
Dot-com bubble 2000Q2~2001Q4	E <sub>2</sub>	On 13 April 2000, Dow Jones Industrial Average (DJIA) Index collapsed 6% of its market value, causing all Internet stocks crash overnight. From April 2000 to March 2001, the stock price of Yahoo fell 90% and eBay fell 78%, making many Internet companies close. The impact was spread worldwide, and caused the global falling to a deep recession and inflation during 2000-2001. 9/11 terrorist attacks of 2001 in the U.S. caused the global financial market encountered a great pressure of panic that led many nations to adopt the loose monetary policy in order to avoid falling to the recession. In Taiwan, the ratio of non-performing loans to total gross loans increased from 8.38% to 11.27% (excess 10%) in a year since 2000Q4, meeting the definition of financial crisis. See Borio and Lowe (2002) for further details.
Cross-strait political and	E <sub>3</sub>	National presidential elections were held in Taiwan on 20 March 2004, but the alleged assassination attempt on the eve of the President election to a

economic tensions 2004Q1~2004Q2	candidate made people heavily question the election result, and caused the society unrested with the stock/forex market simultaneously dropping deeply. Furthermore, as Mainland China already became Taiwan's largest export market, their economic growth or decay would affect Taiwan's stock market up or down. At the end of April 2004, Mainland China unexpectedly announced to take Macroeconomic Adjustment Policy, which made Taiwan stock market falling by 548 points in a week. Besides, the Procomp Informatics scandal, the event of asset misappropriation of a listed company, in June 2004 made the Taiwan's stock market drop 431 points in two weeks.
Global financial crisis (GFC) 2008Q2~2009Q2	E <sub>4</sub> On 14 September 2008, Lehman Brothers announced to file for bankruptcy; on that same day, Merrill Lynch declared to be bought by Bank of America, marked as preliminary notes of the global stock market collapse and led to dramatic drops in global market values on September 15 and 17, 2008. On September 16 American International Group (AIG) due to holding a lot of credit-default-swaps overdue debts, was downgraded on the credit rating and got involved in the liquidity crisis.
European debt crisis 2011Q2~2012Q2	E <sub>5</sub> The economic plight hit hard by the financial problem, appearing in eurozone members, Greece, Ireland, Portugal, Spain, Italy etc., had affected the financial situation severely in the world economy.

Source: Kuo (2013)

#### 4.2 Empirical Identification for Taiwan's Financial Stress

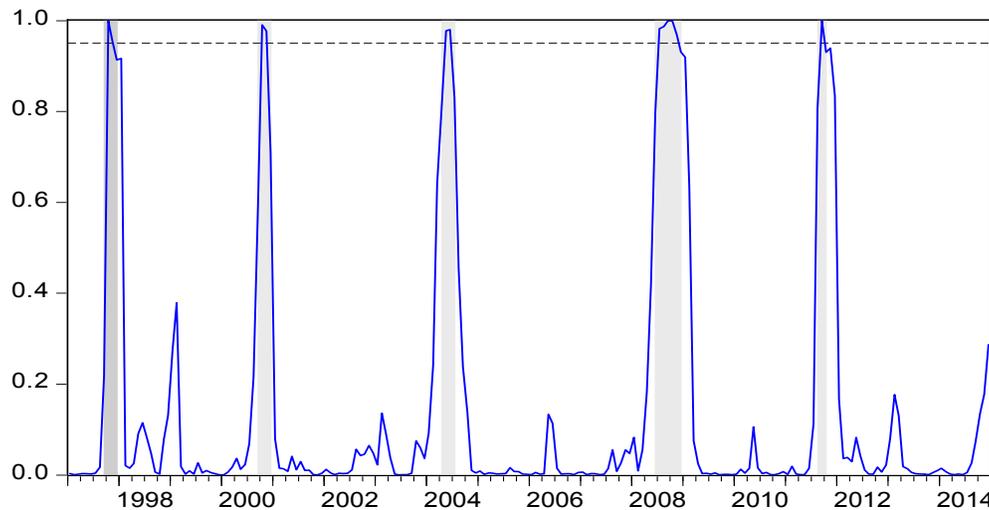
Figure 1 shows the long-term trends and cyclical volatility of Taiwan's FSI. We can observe the value of cyclical volatility against actual volatility while long-term trends of FSI appear to be stable. This shows that the FSI model built on HP filter is robust and a proper measure to observe financial stress.



Note: Shadow represents the periods of Taiwan's previous major financial crises

Figure 1. Long-term trends and cyclical volatility of Taiwan's FSI

The empirical result of Figure 2 shows the turning point analysis method of two-state Markov regime-switching fewer than 95% confidence level is able to coincide with the period of Taiwan's previous major financial crises. In particular, during the period of cross-strait tensions from 2004Q1-2004Q2, the Markov regime-switching analysis method is able to successfully capture a characteristic political sensitive factor in Taiwan's financial system on the impact of the financial markets.



Note: The curving line indicates smooth probability; the dotted line represents 95% confidence level. The shadow shows the financial crisis period identified by the smooth probability not lower than confidence level.

Figure 2. Comparison of Smooth probability chart of Taiwan's FSI variation against the period of Taiwan's previous major financial crises

Further based on Figure 2, to sort out and identify the timing of the turning point in the events of Taiwan's previous major financial crises, and the timing of warning signals issued by the empirical result of *CITFS* model, shown as Table 3.

Table 3. Timing of turning point of Markov model for Taiwan's financial crises vs. time of warning signals of *CITFS* model

Turning points with Markov model (event codes)		Warning signals with <i>CITFS</i> model
1997Q4	(E <sub>1</sub> )	1997Q1 - 1997Q3
2000Q4	(E <sub>2</sub> )	1999Q4 - 2000Q3
2004Q2	(E <sub>3</sub> )	2003Q2 - 2004Q1
2008Q3-2008Q4	(E <sub>4</sub> )	2007Q3 - 2008Q2
2011Q3	(E <sub>5</sub> )	2010Q3 - 2011Q2

Note: In the design of this warning model, the timing of warning signals issued by *CITFS* model is four quarters (i.e. last year) ahead of the crisis point identified by Markov model. However, since our sampling period of this study begins in 1997Q1, the warning signal for (E<sub>1</sub>) crisis event only appears the time of the last three quarters.

According to the values and weights percentage of variables composed in FSI as well as the deciding criteria of financial crises, five segments of Taiwan's financial crises are identified during our sampling period (1997Q1 - 2014Q4): 1997Q4, 2000Q4, 2004Q2, 2008Q3 - 2008Q4, and 2011Q3. Each value and weight of five variables included in FSI within these five segments of financial crises is shown in Table 4.

Table 4. Weight of five variables composed in FSI during financial crises

Event of Taiwan's previous major financial crisis	Event code	FSI determining crisis point	Weight of each variable to FSI (%)					FSI value	
			Beta	SMR	SMV	EMBI	EMPI		Total
Asian Financial Crisis(1997Q3~1998Q3)	E <sub>1</sub>	1997Q4	-2.14	14.58	19.63	16.20	51.73	100	9.9679
Dot-com bubble (2000Q2~2001Q4)	E <sub>2</sub>	2000Q4	-14.55	18.87	51.61	12.58	31.49	100	6.6861
Cross-strait economic and political tensions (2004Q1~2004Q2)	E <sub>3</sub>	2004Q2	23.44	35.23	38.44	-23.07	25.96	100	2.6021
GFC (2008Q2~2009Q2)	E <sub>4</sub>	2008Q3-Q4	8.77	39.87	40.38	-6.44	17.42	100	6.6794
European debt crisis (2011Q2~2012Q2)	E <sub>5</sub>	2011Q3	14.08	19.47	16.18	6.77	43.50	100	7.4181

The analysis was explained respectively as follows:

1) E<sub>1</sub>: Asian Financial Crisis (1997Q4)

On 2 July 1997, Central Bank of Thailand, abandoning the forex scheme pegging on US dollars but adopting the flexible exchange rate, caused the overvalued Thai baht dropping, and further spread the crisis to Taiwan. In 1997Q4 every Asian country was attacked by the forex opportunistic predators. To Taiwan, EMPI was the most heavily weighted variables in 1997Q4, pushing EMPI up a lot, which was also the dominating factor to make FSI rising during this period.

2) E<sub>2</sub>: Dot-com bubble (2000Q4)

On 13 April 2000, Dow Jones Industrial Average (DJIA) Index collapsed 6% of its market value, causing all Internet stocks crash overnight, and forced many website companies to shut down, then the crisis was spread to the whole world. The effects of the collapse sparked severe recession and inflation worldwide during 2000-2001. Buffeted by the global decline in share price, the Taiwan stock index appeared to fluctuate wildly, particularly in the period between October to November 2000, with the main stress from SMV and EMPI. Due to the significant increase in market volatility, it led to a rise in FSI. The most heavily weighted variable was SMV while Beta value oppositely functioned to ease financial stress.

3) E<sub>3</sub>: Cross-strait political and economic tensions (2004Q2)

National presidential elections were held in Taiwan on 20 March 2004, but the related disputes before and after the election raised the protests and political instability, dragging down the stock and currency markets, stock market down to less than 6000 points from 7000 points up lifted by the artificial effort before the election. At the same time, Mainland Chinese announced their opposition to Taiwanese independence and stated they would not welcome Taiwanese companies with strong pro-independence leanings. It led to another round of dramatic volatility in stock price. Furthermore, as China had already become Taiwan's largest export market, their economic boom and bust would affect Taiwan stock to rise and fall. By the end of April 2004 when China unexpectedly took Macroeconomic Adjustment Policy, it made Taiwan stock market falling by 548 points in a week. The Procomp Informatics scandal, the event of asset misappropriation by a listed company, in June 2004 made the Taiwan stock market drop 431 points in two weeks. The main factors of financial stress in this scenario were SMV and SMR. With the substantial increase on stock market volatility, it caused FSI rising, but reversely EMBI value would become the factor to slow down the financial stress.

4) E<sub>4</sub>: GFC (2008Q3-2008Q4)

The collapse of the U.S. subprime mortgage market in 2007 triggered heavy losses for financial institutions worldwide. By 2008Q3, the slide had evolved into a severe credit crisis. On 14 September 2008, Lehman Brothers stated to file for bankruptcy; on the same day, the sale of Merrill Lynch to Bank of America was announced. These two events marked as preliminary notes of the global stock market collapse and led to the dramatic drops in global market values on September 15 and 17, 2008. Although Taiwan suffered a loss not as huge as the U.S. did, Taiwan stock market index, impacted by a decline of global stock price due to the effect of the globalization, was also turned

out a significant volatility. The main factors to push up the financial stress were SMV and SMR, but SMV had a heavier weight.

#### 5) E<sub>5</sub>: European debt crisis (2011Q3)

Impacted by GFC, global economy was stalling, and many governments raised a higher unemployment benefit fund and bailout in order to stimulate economic recovery. However, this obviously increased government expenditure, leading to a rising national debt. By 2011, Eurozone members, such as Greece, Ireland, Portugal, Spain, and Italy, were experiencing economic and financial difficulties that had significantly impacted on global financial markets. In September 2009, investors put their investment target to U.S.D. commodities, having European debt crisis spread to Taiwan. With a surge in deposit withdrawals spreading throughout Europe and the international currency market growing more volatile, Taiwan's forex market could not avoid this disaster but have NTD depreciated. Looking at FSI's weighted values, EMPI was the main factor of financial stress in this case.

To sum up the above analysis, the events of Taiwan's previous major financial crises were all caused by international finance or the substance factors from the variables (E<sub>1</sub>, E<sub>2</sub>, E<sub>4</sub> and E<sub>5</sub>) but with the exception of E<sub>3</sub>, which was driven by cross-strait relations between Taiwan and China. This proves again the financial environmental characteristic of Taiwan is a small open economy, and her stability is highly susceptible to the impacts of any international events.

#### 4.3 Empirical Result for CITFS

In accordance with the method of filtering noise to signal ratio described in the previous chapter, the criterion for CITFS input variables were  $(1-\alpha) > 66\%$  and  $NTSR < 1$ . The empirical result reveals all twenty of CAMELS+G candidate variables except net value ratio  $X_3$  without the warning capability met the requested criteria and qualifications as input variables in CITFS model. Table 5 illustrates the empirical results and its warning capabilities of each variable.

Table 5. Empirical results and warning capabilities of input variables of CITFS

CAMELS+G	Variable code	Shock	Threshold value $\theta_i$	$\alpha$ -risk	$\beta$ -risk	NTSR	Number of financial crises in the coming year	Number of warning signals during sampling period	P (crisis/signal)
Capital adequacy	$X_1$	Negative	0.70	0.2105	0.6604	0.8365	15	50	0.3000
	$X_2$	Negative	0.53	0.2632	0.4528	0.6146	14	38	0.3684
	$X_4$	Positive	0.42	0.2632	0.5283	0.7170	14	42	0.3333
Asset quality	$X_5$	Negative	0.52	0.2105	0.4151	0.5258	15	37	0.4054
	$X_6$	Positive	0.25	0.0526	0.6792	0.7170	18	54	0.3333
	$X_7$	Negative	0.74	0.1579	0.6981	0.8290	16	53	0.3019
management capability	$X_8$	Positive	0.43	0.1053	0.4528	0.5061	17	41	0.4146
	$X_9$	Negative	0.67	0.2632	0.6415	0.8706	14	48	0.2917
	$X_{10}$	Positive	0.28	0.1579	0.6792	0.8066	16	52	0.3077
Profitability	$X_{11}$	Positive	0.63	0.3158	0.2642	0.3861	13	27	0.4815
	$X_{12}$	Positive	0.60	0.3158	0.3019	0.4412	13	29	0.4483
Liquidity	$X_{13}$	Positive	0.23	0.1579	0.7358	0.8738	16	55	0.2909
	$X_{14}$	Positive	0.45	0.3158	0.5094	0.7446	13	40	0.3250
Sensitivity to market risk	$X_{15}$	Positive	0.42	0.3158	0.5472	0.7997	13	42	0.3095
	$X_{16}$	Positive	0.35	0.1579	0.5849	0.6946	16	47	0.3404
Sensitivity to interest rate risk	$X_{17}$	Negative	0.74	0.2105	0.7170	0.9082	15	53	0.2830
	$X_{18}$	Positive	0.33	0.3158	0.6604	0.9652	13	48	0.2708
Business Growth	$X_{19}$	Negative	0.47	0.3158	0.3962	0.5791	13	34	0.3824
	$X_{20}$	Positive	0.39	0.2632	0.5660	0.7682	14	41	0.3182

Note: Positive shock means that the greater the value of this variable increases (right to the gap distribution), the more probable a financial crisis occurs. Negative shock means that the lower the value of this variable becomes (left of the gap distribution), the more probable a financial crisis occurs.

Through the calculation on signal values of nineteen input variables, we computed  $CITFS_t$  values for each period. Using the criterion of Equation (8), we further conducted a simulation to obtain the optimal critical value as  $CITFS^*=0.6842$ . Table 6 shows the simulation results and warning capabilities of  $CITFS^*$  model.

Table 6. Simulation of optimal critical value and warning capabilities of  $CITFS$

$CITFS$	$\alpha$ -risk	$\beta$ -risk	NTSR	Number of financial crises in the coming year	Number of warning signals during sampling period	P (crisis signal)
0.0526	0.0000	1.0000	1.0000	19	72	0.2639
0.1053	0.0000	1.0000	1.0000	19	72	0.2639
0.1579	0.0000	1.0000	1.0000	19	72	0.2639
0.2105	0.0000	0.9811	0.9811	19	71	0.2676
0.2632	0.0000	0.9811	0.9811	19	71	0.2676
0.3158	0.0000	0.9057	0.9057	19	67	0.2836
0.3684	0.0000	0.8679	0.8679	19	65	0.2923
0.4211	0.0000	0.7925	0.7925	19	61	0.3115
0.4737	0.0000	0.7358	0.7358	19	58	0.3276
0.5263	0.0000	0.5472	0.5472	19	48	0.3958
0.5789	0.0526	0.3208	0.3386	18	35	0.5143
0.6316	0.1579	0.1698	0.2017	16	25	0.6400
<b>0.6842</b>	<b>0.2632</b>	<b>0.0943</b>	<b>0.1280</b>	<b>14</b>	<b>19</b>	<b>0.7368</b>
0.7368	0.3684	0.0566	0.0896	12	15	0.8000
0.7895	0.5789	0.0189	0.0448	8	9	0.8889
0.8421	0.9474	0.0189	0.3585	1	2	0.5000
0.8947	1.0000	0.0000	NA	0	0	NA
0.9474	1.0000	0.0000	NA	0	0	NA
1.0000	1.0000	0.0000	NA	0	0	NA

In the end of empirical results, we took the back-testing outcomes shown in Table 7 and Figure 3 to explain the robustness of  $CITFS$ .

1)  $E_1$ : Asian Financial Crisis (1997Q4)

For three quarters (1997Q1-1997Q3) preceding the crisis,  $CITFS$  reached or exceeded threshold value (0.6842-0.8421) and generated warning signals.  $CITFS$  also reached or exceeded (0.6842) within the duration of the financial crisis (1998Q1), illustrating that  $CITFS$  is able to provide the early warning for the Asian Financial Crisis.

2)  $E_2$ : Dot-com bubble (2000Q4)

For four seasons (2003Q2-2004Q1) before dot-com bubble burst,  $CITFS$  in three quarters (2000Q1-2000Q3) exceeded threshold value (0.7895-0.8947) and generated warning signals. The only quarter in which it did not provide warning was 1999Q4. Nevertheless, this result demonstrates that  $CITFS$  was capable of providing early warning of the dot-com bubble burst.

3)  $E_3$ : Cross-strait political and economic relations (2004Q2)

For four seasons before the cross-strait tensions occurred (2003Q2-2004Q1),  $CITFS$  reached threshold value (0.6842-0.8421) respectively in three quarters of 2003Q2-2003Q3 and 2004Q1. Only in 2003Q4  $CITFS$  failed to provide the warning signal, but kept sending out warning signals (0.8947) during the cross-strait tensions (2004Q2), indicating that  $CITFS$  had a good early warning capability for the tensions of cross-strait political and economic relations.

4)  $E_4$ : GFC (2008Q3-2008Q4)

For four seasons before GFC (2007Q3-2008Q2),  $CITFS$  in three quarters (2007Q4-2008Q2) exceeded threshold value (0.7368-0.8421) although it failed to provide warning during 2007Q3. Nevertheless, the results indicate that  $CITFS$  was capable of providing early warning of the GFC.

5) E<sub>5</sub>: European debt crisis (2011Q3)

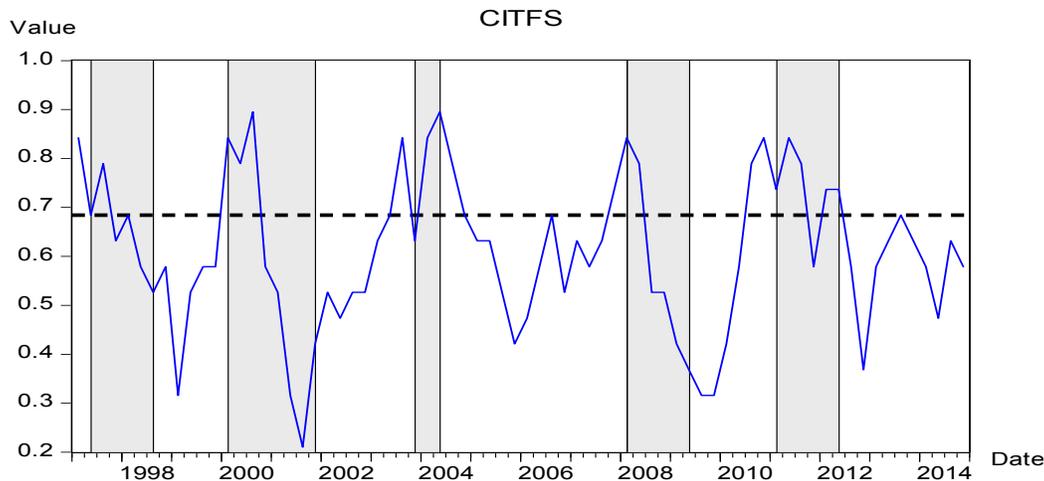
The indicator of financial stability all exceeded threshold value (0.7368-0.8421) during the four quarters preceding the European debt crisis (2010Q3-2011Q2), and continued to break threshold value (0.7368-0.7895) in crisis period(2011Q3 and 2012Q1-2012Q2). This shows *CITFS* was with a good early warning capability to the European debt crisis.

Overall, through back-testing results of a robust set of indicators for the Taiwan's financial stability, the built-up *CITFS* model within 4 seasons (E<sub>1</sub> as the last three seasons, E<sub>2</sub>-E<sub>5</sub> as the last four seasons, total nineteen seasons) before the events of Taiwan's previous major financial crises occurred is able to provide early warning signals except 1999Q4 before dot-com bubble (E<sub>2</sub>), 2003Q4 of cross-strait tensions (E<sub>3</sub>) and 2007Q3 of global financial crisis (E<sub>4</sub>) where *CITFS* failed to provide early warnings. Nevertheless, *CITFS* is shown to be reasonably effective in providing early warnings to financial crises in Taiwan.

Table 7. Analysis of *CITFS* early warning capability

Time	<i>CITFS</i>	Financial crisis?		Time	<i>CITFS</i>	Financial crisis?	
		Yes = 1,	No =0			Yes = 1,	No =0
1997Q1	0.8421	0	0	2006Q1	0.4737	0	0
1997Q2	0.6842	0	0	2006Q2	0.5789	0	0
1997Q3	0.7895	0	0	2006Q3	0.6842	0	0
1997Q4	0.6316	1(E <sub>1</sub> )	0	2006Q4	0.5263	0	0
1998Q1	0.6842	0	0	2007Q1	0.6316	0	0
1998Q2	0.5789	0	0	2007Q2	0.5789	0	0
1998Q3	0.5263	0	0	2007Q3	0.6316	0	0
1998Q4	0.5789	0	0	2007Q4	0.7368	0	0
1999Q1	0.3158	0	0	2008Q1	0.8421	0	0
1999Q2	0.5263	0	0	2008Q2	0.7895	0	0
1999Q3	0.5789	0	0	2008Q3	0.5263	1(E <sub>4</sub> )	0
1999Q4	0.5789	0	0	2008Q4	0.5263	1(E <sub>4</sub> )	0
2000Q1	0.8421	0	0	2009Q1	0.4211	0	0
2000Q2	0.7895	0	0	2009Q2	0.3684	0	0
2000Q3	0.8947	0	0	2009Q3	0.3158	0	0
2000Q4	0.5789	1(E <sub>2</sub> )	0	2009Q4	0.3158	0	0
2001Q1	0.5263	0	0	2010Q1	0.4211	0	0
2001Q2	0.3158	0	0	2010Q2	0.5789	0	0
2001Q3	0.2105	0	0	2010Q3	0.7895	0	0
2001Q4	0.4211	0	0	2010Q4	0.8421	0	0
2002Q1	0.5263	0	0	2011Q1	0.7368	0	0
2002Q2	0.4737	0	0	2011Q2	0.8421	0	0
2002Q3	0.5263	0	0	2011Q3	0.7895	1(E <sub>5</sub> )	0
2002Q4	0.5263	0	0	2011Q4	0.5789	0	0
2003Q1	0.6316	0	0	2012Q1	0.7368	0	0
2003Q2	0.6842	0	0	2012Q2	0.7368	0	0
2003Q3	0.8421	0	0	2012Q3	0.5789	0	0
2003Q4	0.6316	0	0	2012Q4	0.3684	0	0
2004Q1	0.8421	0	0	2013Q1	0.5789	0	0
2004Q2	0.8947	1(E <sub>3</sub> )	0	2013Q2	0.6316	0	0
2004Q3	0.7895	0	0	2013Q3	0.6842	0	0
2004Q4	0.6842	0	0	2013Q4	0.6316	0	0
2005Q1	0.6316	0	0	2014Q1	0.5789	0	0
2005Q2	0.6316	0	0	2014Q2	0.4737	0	0
2005Q3	0.5263	0	0	2014Q3	0.6316	0	0
2005Q4	0.4211	0	0	2014Q4	0.5789	0	0

Note: The event code in parentheses according to Markov model was able to identify the timing of financial crises in Taiwan. Further details refer to Table 3.



Note: The curve line represents *CITFS* and the dotted line represents optimal threshold value (0.6842). The shadow area represents the period of Taiwan's previous major financial crises.

Figure 3. Comparison of *CITFS* results to financial crises timeline

## 5. Conclusions and Recommendations

This study takes the method of two-state Markov regime-switching objectively to presume the volatility of Taiwan's financial stress index within 1997Q1 to 2014Q4 first and successfully to capture the timing of turning point in the events of Taiwan's previous financial crises. On this basis, a further study proposes a robust set of indicators for Taiwan's financial stability as a supervisory tool for financial stability effectively to detect and alert Taiwan's financial crises. To sum up the above empirical results, two key conclusions of this study are described as follows:

- 1) With market-based FSI put on two-state Markov regime-switching method, it is sure rationally to identify the timing of the turning point for Taiwan's previous major financial crises respectively at 1997Q1, 2000Q4, 2004Q2, 2008Q3-2008Q4, and 2011Q3 going through the events of five major financial crises as Asian Financial Crisis, dot-com bubble, cross-strait political and economic tensions, global financial crisis, European debt crisis, etc. In particular, it is able to capture the financial crisis of 2004Q2 caused by cross-strait political and economic tensions, which completely illustrates a characteristic of political sensitive gene in Taiwan's financial system. This characteristic is different from the other emerging markets where their financial supervisory authorities would take it into consideration while drafting their relative supervisory measures for the problem of financial stability.
- 2) Bank-based *CITFS* can be used as the effective device under the framework of Taiwan prudential supervision to provide an early financial warning. Overall, empirical results display that *CITFS* of this study to detect the events of Taiwan's previous major financial crises has a good early warning capability. This outcome is considerably contributed to an important support for the substantial design on Taiwan's financial early warning mechanisms.

Finally, according to the publication of BCBS in 2010, the *Guidance for National Authorities Operating the Countercyclical Capital Buffer*, it recommended that every national financial authorities do not only take "Credit-to-GDP" as an international consistent tool of common reference guide, but also study to construct the other indicators in accordance with their own national situation, then together form a more complete countercyclical capital buffer while they are implementing the buffer mechanism (scheduled to begin at 2019). Moreover, in the future once the countercyclical capital buffer mechanism is switched on; it will ask banking business to put on the additional supervisory regulation with notice period of 12 months (i.e. a year before the start date). *CITFS* model of this study with the early warning signal is also constructed on one year ahead the crisis occurred. Therefore, we recommend Taiwanese supervisory regulators to incorporate the proposed model and methodology of this study as one of the important tools in their future implementing on the countercyclical capital buffer.

## Acknowledgements

The authors thank anonymous reviewers and the editor for helpful comments. Especially thank for Gina's help.

## References

- Alessi, L., & Detken, C. (2009). Real time early warning indicators for costly asset price boom/bust cycles: A role for global liquidity. *European Central Bank Working Paper Series*, No.1039.
- Alessi, L., & Detken, C. (2011). Quasi real time early warning indicators for costly asset price boom/bust cycles: A role for global liquidity. *European Journal of Political Economy*, 27(3), 520-533.
- Balakrishnan, R., Danninger, S., Elekdag, S., & Tytell, I. (2009). The transmission of financial stress from advanced to emerging economies. *International Monetary Fund Working Paper*, WP/09/133.
- Bank for International Settlements. (2009). *Annual report*. Basel, Switzerland: Bank for International Settlements Communications.
- Basel Committee on Banking Supervision. (2010a), *Guidance for national authorities operating the countercyclical capital buffer*. Basel, Switzerland: Bank for International Settlements Communications.
- Borio, C., & Drehmann, M. (2009, March). Assessing the risk of banking crises – Revisited. *BIS Quarterly Review*, 29-46.
- Borio, C., & Lowe, P. (2002). Asset price, financial and monetary stability, exploring the nexus. *BIS Working Papers*, No. 114.
- Demirgüç-Kunt, A., & Detragiache, E. (1998). The determinants of banking crises in developing and developed countries. *IMF Staff Papers*, 45(1), 81-109.
- Demirgüç-Kunt, A., & Detragiache, E. (2000). Monitoring banking sector fragility: A multivariate logit approach. *World Bank Economic Review*, 14(2), 287-307.
- Hamilton J. D. (1989). A new approach to the economic analysis of nonstationary time series and business cycle. *Econometrica*, 57(2). 357-384.
- Hamilton, J. D. (1990). Analysis of time series subject to changes in regime. *Journal of Econometrics*, 45, 39-70. [http://dx.doi.org/10.1016/0304-4076\(90\)90093-9](http://dx.doi.org/10.1016/0304-4076(90)90093-9)
- Hamilton, J. D. (Eds). (1994). *Time series analysis*. New Jersey, NJ: Princeton University Press.
- Hodrick, R. J., & Prescott, E. C. (1997). Postwar U.S. Business Cycles: An Empirical Investigation. *Journal of Money, Credit, and Banking*, 29(1), 1-16.
- International Monetary Fund. (1998, April). Financial Crises: Characteristic and indicators of vulnerability. In World Economic and Financial Surveys (Ed.), *World economic outlook* (pp.74-97). Washington, D.C: International Monetary Fund.
- International Monetary Fund. (2008, October). Financial stress and economic downturns. In World Economic and Financial Surveys (Ed.), *World economic outlook* (pp. 131-156). Washington, D.C: International Monetary Fund.
- International Monetary Fund. (2009, April). Detecting systemic risk. In World Economic and Financial Surveys (Ed.), *Global financial stability report: Responding to the financial crisis and measuring systemic risks* (pp. 111-143). Washington, D.C: International Monetary Fund.
- International Monetary Fund. (2010a, April). Systemic risk and the redesign of financial regulation. In World Economic and Financial Surveys (Ed.), *Global financial stability report: Meeting new challenges to stability and building a safer system* (pp. 63-87). Washington, D.C: International Monetary Fund.
- International Monetary Fund. (2010b). *The IMF-FSB early warning exercise: Design and methodological toolkit*. Washington, D.C: International Monetary Fund.
- International Monetary Fund. (2011). *Macroprudential policy: An organizing framework*. Washington, D.C: International Monetary Fund.
- Kaminsky, G. L., & Reinhart, C. M. (1999). The twin crises: The causes of banking and balance-of-payments problems. *The American Economic Review*, 89(3), 473-500.
- Kim, C. J. (1994). Dynamic linear models with Markov-switching. *Journal of Econometrics*, 60, 1-22.
- Kuo, C. J. (2013). Studies on the impact of Basel III for Taiwan's monetary policies and financial stability. In Central Bank of the Republic of China (Ed.), *Technical report on the research project 101 CBC*. Taipei Central Bank of the Republic of China.

Kuo, C. J., & Lu, S. L. (2005). Taiwan’s financial holding companies: An empirical investigation based on Markov regime switching model. *Applied Economic*, 37(5), 593-605.

Laeven, L., & Valencia, F. (2008). Systemic banking crisis: A new database. *International Monetary Fund*, working paper, WP/08/224.

Persaud, A. D. (2000). Sending the herd off the cliff edge: The disturbing interaction between herding and market-sensitive risk management practices. *The Journal of Risk Finance*, 2(1), 59-65. <http://dx.doi.org/10.1108/eb022947>

Shinasi, G. J. (2004). Defining financial stability. *International Monetary Fund*, working paper.

Volcker, P. A. (2012). *Commentary on the Restrictions on Proprietary Trading by Insured Depository Institutions*, a letter for Department of the Treasury, Office of the Comptroller of the Currency, Board of Governors of the Federal Reserve System, Federal Depository Insurance Corporation, Securities and Exchange Commission and Commodity Futures Trading Commission. February 13, 2012.

**Notes**

Note 1. These well-known financial conglomerates includes Glodman Sachs, J.P.Morgan, Merrill Lynch, Lehman Brothers, Bear Stearns, Citigroup, etc. according to the attestation of Volcker (2012), Proprietary trading in any real volume is confined to a very few large, sophisticate U.S. banks: it has been reported that only six banks account for almost 93 percent of the trading revenue of all American banks.

Note 2. See Hamilton (1989, 1990 and 1994 ) for detail.

Note 3. There has been an extensive literature on Markov process applied to macroeconomic and financial variables. More details also see Kuo and Lu (2005).

Note 4. Based on the signal filtering method of Kaminsky and Reinhart (1999), (i) In a positive shock situation while the candidate variable of CAMELS+G is  $i$  and HP filter gap is higher than threshold value  $\theta_i$ , it is considered to have emitted a signal. (ii) In a negative shock situation, while the candidate variable of CAMELS+G is  $i$ , and HP filter gap is lower than threshold value  $\theta_i$ , it is also considered to have emitted a signal. By the way, other than (i) and (ii) circumstances, it is regarded no signal has been delivered. Therefore, on the null hypothesis  $H_0$ : “A potential financial crisis will occur within the next year”, the assessment of  $\alpha$  and  $\beta$  risks on the signal filtering method is to follow the classic prototype of statistical hypothesis decision. This is as follows:

Hypothesis	null hypothesis $H_0$	alternative hypothesis $H_1$
Signal display		
Signal delivered	No. of sample observations ( $n_1$ )	No. of sample observations ( $n_2$ )
No signal delivered	No. of sample observations ( $n_3$ )	No. of sample observations ( $n_4$ )

and  $\alpha$  risk =  $\frac{n_3}{n_1 + n_3}$ ,  $\beta$  risk =  $\frac{n_2}{n_2 + n_4}$